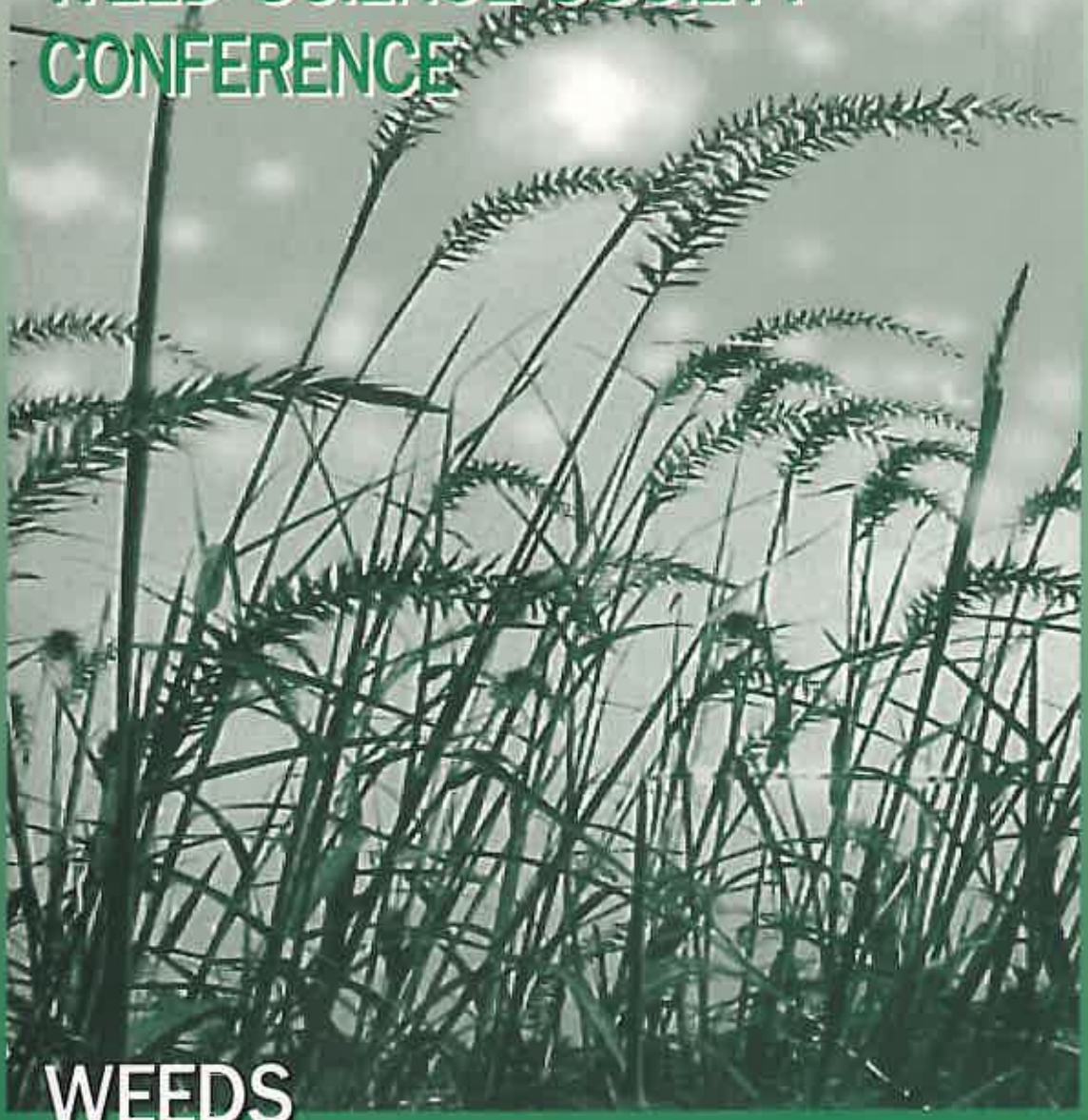
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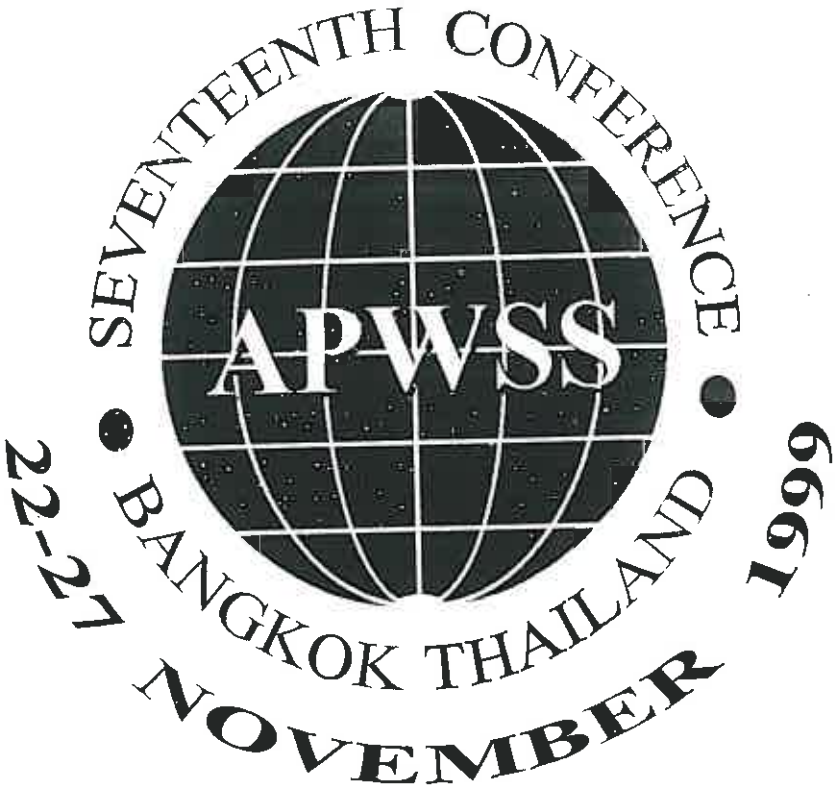
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WEEDS AND ENVIRONMENTAL IMPACT

NOVEMBER 22-27, 1999
BANGKOK, THAILAND

A.N. RAO


SEVENTEENTH CONFERENCE
APWSS
BANGKOK THAILAND
22-27 NOVEMBER 1999

A.N. RAO

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Weeds and Environmental Impact

The Seventeenth
Asian-Pacific Weed Science Society Conference

November 22-27, 1999

The Central Plaza Hotel, Bangkok, Thailand

Published by

The Organization of The 17th Asian-Pacific

Weed Science Society Conference

1999

1999 Weed Science Society of Thailand

P.O.Box 1096 Kasetsart Post office,

Bangkok 10900, Thailand

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Keynote Address

THE ETHICS OF AGRICULTURE AND WEED SCIENCE[1]

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Abstract: Agricultural scientist often believe their science is value free, as it ought to be, but neither basic nor applied agricultural science is value free; they are value laden. Agriculture's implicit values include meeting basic human needs through efficient production of abundant high quality food and fiber, achieving sustainable production systems, and increasing producer profit. What agricultural and weed scientists stand for and the validity of the ethical foundation of their convictions should be central topics for research and teaching. Ethical reflection does not imply criticism or demand change. It requires intellectual clarity and a desire to affirm who we are, what we do, and what we value. If agricultural and weed scientists do not define the values that guide their work, others will. External distortions of agriculture's values and public criticism may define the ethical position of agriculture.

Key words: agriculture, ethics, production, values, weed science

Introduction

Sometime after I began teaching, I learned that if one wants to teach an audience that is not familiar with the ways of science and is not very well educated, the best thing to do is present facts. However, if one wants to have a conversation and discuss a difficult topic with an audience that is well educated and familiar with scientific methods, the best thing to do is to tell stories. Therefore, I think it will be best if I begin with a few stories.

My first story is agricultural but comes from a non-agricultural source: the 18th century British novel - Gulliver's Travels. The King of Brobdingnag was lecturing Captain Lemuel Gulliver, the traveler in Swift's novel (Swift, 1726). The King said:

> whoever could make two ears of corn or two blades of grass to grow
> upon a spot of ground where only one grew before,
> would deserve better of mankind, and do more essential
> service to his country than the whole race of politicians put together.

The King's words express what my experience has shown to be the dominant agricultural and weed science paradigm.

My second story is about lions and gazelles. Every night the lion goes to sleep knowing that in the morning when the sun comes up, if it can't outrun the slowest gazelle, it will go hungry. Every night the gazelle goes to sleep knowing that in the morning, when the sun comes up, if it can't outrun the fastest lion, it will be eaten. The one thing the lion and the gazelle both know when they go to sleep each night is that in the morning, when the sun comes up, the had better start running (Friedman, 1999, pp. 270-271).

My final story is about the pace of life. I have noted that in Bangkok you have the same problem that many other places have. Everyone is in a hurry. If you stop to wait for the green light to cross a street you may find yourself standing alone. Everyone else is hurrying to get to work, lunch, shopping, etc. And they be speaking

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[1] Portions of this paper have appeared in Zimdahl, R. L. 1998a. Weed Sci. 43:636-639 and Zimdahl, R. L. 1998b. J. Agric. and Human Values 15:77-84.

on their cell phones as they hurry. A new book called Faster: The Acceleration of Just About Everything[2] suggests we slow down to enjoy life and ask ourselves why we are hurrying. Why are you rushing? It is a good question, especially if you don't know where you are going.

The main premise of this paper is that agricultural and weed science are deficient because their implicit values are unexamined and their operative values are purely instrumental (i.e. they are purely means to an end). Implicit values include meeting basic human needs for food, increasing food and fiber production, increasing grower profit, producing safe food, producing abundant food, and achieving sustainability. Operative values are often defined by the technology chosen to achieve production. Other values, if known, are subordinate to the primary goals of production and profit, which are uncritically assumed to be good. I suggest the primacy of these values should be debated. Production and profit dominate agricultural and weed science research and thought. They are regarded as essential to the success of any agricultural system but we have never discussed whether they ought to dominate all decisions. This is an ethical question.

Discussion

Discussion of sustainability and environmental responsibility is increasing, but agricultural scientists regard these as fundamentally scientific rather than ethical questions. Sustainability will be achieved by modifying present agricultural practice, not by changing underlying values that determine how we practice agriculture. I suggest sustainability and environmental responsibility are fundamental ethical matters. They are not just scientific questions although science is required to study them. Achieving sustainability is not a problem for most weed scientists who believe the dominant chemical technology is environmentally satisfactory, if not benign, when used correctly. Their view is that herbicides don't damage the environment or harm people: people who use them improperly do. Enduring belief in the value of production has not encouraged agricultural scientists to identify, debate, and justify the values inherent in production, efficiency, or sustainability as these terms are used in agriculture. There has been little internal debate about the role of agricultural scientists in achieving a just social order or about the changes in practice that may be required to conform to a society's goals. Therefore, in addition to discussing the unexamined values of our science, this paper has the covert objective of encouraging a conversation about the future of agricultural and weed science.

The conversation should include consideration of broadening our thoughts about productivity, efficiency, and sustainability to include basic environmental, resource, ecological, health, social and political processes, and the costs and benefits of agricultural technology (Dahlberg, 1982). Innovation in agriculture can be good, but perhaps it will be best when what agricultural scientists declare good is also judged as good by a concerned populace that finds agricultural innovations compatible with their view of what constitutes the good life, the good society, and satisfaction of human needs (Goulet, 1971). Determination of what things are good will necessarily differ among societies.

Agriculture is the most significant an widespread human environmental interaction. Therefore, public participation in decisions about the effects of agricultural technology are inevitable. Open debate about values and the governing ethic should occur in the scientific community and should precede actions that we presume will lead to achieving something most agree is good - meeting basic human needs. Industrial weed scientists who design strategies to induce changes in weed control techniques and university and public sector scientists who study and test components of these strategies, must be willing to submit their assumptions about what is good and their reasons for these assumptions to public scrutiny. As we plan our future course, we must ask what is good, who benefits, who is harmed, and what is not considered; what are the externalities[3].

Science is a descriptive, explanatory enterprise; ethics strives to establish norms or standards and prescribe what ought to be done. Ethical debate elicits reasons for what we do and ought to do. In contrast to science, ethics does not rely on an established body of factual knowledge or presuppose and rely on set of

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[2] Gleick, James. 1999. New York, NY. Pantheon Books. 324 pp.

[3] An externality is a cost that is not reflected in price, or more technically, a cost or benefit for which no market mechanism is available or which the market ignores. An externality is a cost that the decision makers do not have to bear, or a benefit they cannot capture.

fundamental scientific laws. Much of science proceeds via the scientific method aided by occasional bursts of inspiration, but most ethical analysis does not follow the same predetermined method. However, I hasten to add that there are definite answers in ethical matters. There are ethical matters that we can agree on across cultures and within a discipline.

Even casual conversation with the participants in any agricultural meeting will affirm that an important objective, what Ashby (1979) called an "emotive element", for agricultural and weed scientists is the strong desire to know that , when all is said and done, a contribution was made. We want to feel that our research contributed to agriculture. We want to feel that our work made a difference to farmers and consumers and increased food production or made food production more efficient or profitable. In agricultural research it is often through partnership with growers and farmers that the contribution is seen. Agricultural scientists have a strong and desirable, practical side. We have what Buttel (1985) called an excessively applied, insular orientation. In weed science, research is often justified because it is closely allied with the short-term needs of the agrochemical industry or commodity groups. Much of it is not research that leads to fundamental new understanding of process or problem. It is applied technology tinkering at the margin of science.

It is my perception that ethics and ethical analysis of our science are regarded with suspicion by many because it is assumed that bringing up the subject implies the need for not just change but reform. It implies to many that something is wrong and those who think they are ethical are going to prescribe what is right, what ought to be done. There is a deeper reason for suspicion of ethics. The agricultural community thinks of itself as having "an abundance, even an excess, of concern" for agriculture and society (Dundon, 1986). Agricultural scientists know their work is founded on the most ethical behavior of all: feeding the world. How can that be questioned? One suspects that those who raise ethical questions about agricultural science have never understood its purpose. It is clear that weed scientists share with other agricultural scientists a deep commitment to "persons, institutions, and ways of serving both" (Dundon., 1986). Questioning the nature or depth of that commitment by outsiders or colleagues who have lost their way is looked upon as meddling with deep-seated, essential values. Some meddlers may be regarded as crazy, but when they are colleagues they may be regarded as traitors. And the meddler who questions current practice and fails to put in place a new practice that agricultural science can add to the field's competency is subverting the fundamental responsibility and competency of the profession while bringing harm to its future (Dundon, 1986).

Ethical analysis is inherently a subversive undertaking that is likely to have the short-term effect of converting certainties into problems. Achieving ethical consensus is a meaningful, useful ideal when it enables scientists to proceed beyond analysis of values to a statement of institutional preference for particular values.

We have all learned that "science cannot make value judgments." Value judgments are, at worst, the purview of politicians and, at best, of society in general" (Rollin, 1996). Rollin (1995) suggests that when any discipline finds itself in a position where there is not value consensus, and clarification and discussion are required, "the most shrill and dramatic articulations and discussions of such issues will tend to seize the center stage." In the absence of informed expertise to counter and moderate shrill and dominating distortions, the distortions "will dominate the social mind and drive the legitimate ethical concerns out of awareness." I think this is the situation for agricultural and weed science. We have allowed the shrill voices, some internal and most external, to dominate public perception of who we are, what we do, and why we do it. Agricultural scientists who are sports fans have heard, and I suspect many believe, that the best offense is a good defense. But agricultural and weed scientists have not have an offense. They have had only a defense against external distortions of agricultural technology. I suggest our good offense must include an understanding of our ethical foundation, followed by discussion of the implicit values in our discipline and a statement of consensus on our values.

There is always a risk when members of any disciplinary community ignore or are unaware of their foundational values. In agriculture, these values include global perspectives, societal goals, ethical perspectives, and externalities. An example of an externality for weed science is the neglect of how labor saving technology affects family farms and rural community health. When members of any disciplinary community believe that their primary responsibility is to perform work that meets the standards of known boundaries – the operative paradigm, (Bella 1987), they uncritically assume that the paradigm is trustworthy. When the paradigm is biased, as it is in weed science, following it honestly may lead in the wrong direction and will not promote public trust (Bella, 1987). When this happens, trustworthy communities can be transformed into self-serving associations and education can become indoctrination (Bella, 1987). The operative paradigm for weed science has not been recorded or agreed on, and my view will not be accepted by all. Day (1978), a respected agronomist and weed scientist, argued that the only morally defensible action for agronomy and all agricultural research was the pursuit of productivity. His

argument was accepted within agriculture. It was neither discussed nor debated. It is the operative paradigm for most weed scientists. In fact, any new technology and weed science program that does not pursue production is met with at least initial suspicion (Dundon, 1982). It is the paradigm noted above and expressed by Swift (1726) in the words of the King of Brobdingnag to Lemuel Gulliver:

> Whoever could make two ears of corn or two blades of grass to grow
> upon a spot of ground where only one grew before,
> Would deserve better of mankind, and do more essential
> service to his country than the whole race of politicians put together.

Swift's lines express what my experience has shown to be the dominant agricultural and weed science paradigm, and it agrees with Day's (1978) view.

Acceptance of this paradigm by university weed scientists has placed increasing production as a high, if not the highest, value, and most regard it as prudent to employ all appropriate elements of modern technology to achieve and maintain profitable production. The dominant paradigm argues that the highest level of production or weed control that can be achieved profitably is the best level. The paradigm includes an unexpressed but fundamental assumption of the unqualified right of humans to control and dominate nature. The paradigm has the unquestioned goal of increasing production and profit. Its adherents have the ability to neglect externalities while they assume the right to dominate nature. This has raised questions in the minds of some agricultural and weed scientists and many segments of our societies about the paradigm's bias and continued value.

Those who subscribe to this ethic usually recognize that its results have not been universally applauded, but often fail to see that the lack of applause has been for good reasons. These reasons include valid objections from five perspectives (Danbom, 1997). The first perspective includes socially conscious individuals and organizations who suggest that production has been achieved at the expense of the environment and our natural resource base. Second are modern agrarians (a good example is the American author and farmer, Wendell Berry) who note the loss of family and community values and the rise of selfishness and materialism that often accompany increased production. The third perspective includes those who warn of the lack of sustainability of modern production practices. Still others warn that our abundance has been accompanied by deterioration, or at least a perception of deterioration, in food quality and healthfulness. Finally, there are those who argue that abundance has been obtained without regard for effects on small farmers, tenant farmers, and the rural and urban poor who have paid a disproportionate share of the price of abundance. Advocates of these views tend to agree that the high productivity of modern agriculture has been achieved by extensive use of technologies that often contribute to depletion of a non-renewable resource base (e.g., soil and water). They suggest that the undeniable success of modern agriculture has been achieved by combining mechanization, genetic manipulation and chemicals, and that it is dependent on a massive, unsustainable fuel subsidy.

What is right about the production ethic, and there is much right about it, is that it allows less than two million Americans to feed the rest of the population of the United States. One U. S. farmer now feeds about 130 people in the U. S. and abroad, whereas in 1960 one farmer fed only 26 people. Application of the same efficient technology developed by agricultural research has allowed other countries to reduce the percentage of their population in farming, while maintaining or increasing food production. Agricultural science correctly claims credit for its contributions to efficient labor use and increased productivity. What is wrong with exclusive emphasis on the production ethic is that it has centered on the interests and rights of some individuals while ignoring the rights and good of other living things (Comstock, 1995). It has created a system that ignores Bailey's (1915)admonition that "a good part o f agriculture is to learn how to adapt one's work to nature". Our technology has allowed us to manipulate nature to our ends. We believe we no longer have to adapt to nature.

Ethics were not part of what I was taught during my formal education. Consideration of the ethical aspects of my work has not been a regular part of my collegial or professional discourse. A dispassionate observer might conclude that weed scientists have not thought about the ethics of their science or the particular set of values that have driven its development and adoption. I have argued in this paper and elsewhere (Zimdahl, 1998a,b) that weed scientists define a good agriculture as one that optimizes yield and maximizes profit. I began to think about the values this definition of good agriculture embodies only late in my career. Examination of the basic assumptions that guided my work had not been done, and I now think it is essential. I knew I worked in an agricultural system that was driven by government programs that had the unintended effect of bestowing the greatest benefits on the largest farmers and encouraged oversupply of commodities and low prices to farmers. Many scientists are constrained by similar systems. These constraints are confounded by a production system that encouraged widespread use of agricultural chemicals and intensive mechanization that, when combined with the

effects of government programs, discouraged diversification and crop rotation while encouraging monoculture. Unintended but real side effects included farm consolidation, loss of rural communities and businesses, and much of the life and traditions that many societies value about rural life[4] (Danbom, 1997). Not all of these effects are positive, and each involves moral questions. I am compelled to acknowledge and deal with the observation that much of what is involved in modern, technologically intensive agricultural production may cause ecological deterioration and loss of biological diversity, and also may impair human health. These things never appear in conventional financial balance sheets, and we therefore gain the false impression of untroubled and unending wealth and success (Ehrlich and Ehrlich, 1996).

These observations describe a view of what modern U.S. agriculture is and, I suggest, it is not unreasonable to assume the same things are happening in many countries. The question we in agriculture need to ask is what weed science, an important part of agriculture, ought to be. If we fail to understand the importance of beginning the discussion and striving for agreement on what we ought to do and be, we will only add, as Freudenberger (1994) suggests, momentum to the pace of human and natural resource depletion.

I suggest we consider carefully what agricultural science has accomplished and what values are demonstrated by those accomplishments. We could begin by struggling with three future options (Berry, 1981; Kirschenmann, 1998). We can opt to stay on the present energy, chemical and capital intensive course without knowing how long it will be possible and knowing that each technological step often leads to what Berry (1981) calls a "ramifying series of new problems", most of which appear as externalities. Second, we can search for technological fixes such as another herbicide when resistance appears. These and similar technological fixes will adjust or modify, but probably not solve , and may worsen a problem. These solutions are similar to solving soil compaction by buying a bigger, heavier tractor that compacts soil more (Berry, 1981). Finally, Kirschenmann (1993) suggests we can consider how our science contributes to regenerative food systems that will certainly include technology but are not dependent on a series of technological fixes. They are solutions that in Berry's (1981) terms create a ramifying series of solutions. I think we should elect the third option and further suggest it means we must become part of a caring culture. A caring culture is one governed by making explicit that healthy prospects for future generations and a healthy landscape are paramount values.

Weed scientists must acknowledge and deal openly and rationally with the fact that the technology that makes our modern weed management and control system possible has shaped agriculture's development and will determine its future. The standard view in science is that technologies are neutral and that it is up to people to direct and control them toward positive ends (Dahlberg, 1989). Weed scientists must understand and deal with the dominant role of herbicides and ways in which they have created values for weed science. Modern chemical technology, unlike traditional technology, is an enterprise, not a possession, a process, not a state (Jonas, 1985). Dealing with this fact means recognizing that the technology that dominates weed science creates its own inherent objective, its own destiny. When we recognize that, then we must ask if that destiny is the right destiny. In agriculture and weed science, are we, when we get up in the morning, running in the right direction? Every new technological step, in any direction, tends to give rise to new steps and new directions (Jonas, 1985). Technology does not approach equilibrium in the process of fitting means to ends. Because technology is a process, there is no saturation point; agricultural technology can always be improved. The technological enterprise is dynamic, and as each innovation spreads quickly, it leads to new goals and ideas never before conceived (Jonas, 1985). Failure to deal with technology's inherent objectives leads to unexamined science, guided solely by a technological (often a short term) imperative, and lacking direction independent of its technology. This becomes a science that risks neglecting the questions inherent in technology: Who benefits? Who loses? Who decides? What is neglected (i.e. what is external)?

Weed scientists have been participants and frequent leaders in developing revolutionary agricultural technology. As weed science has improved production, the dominant technology's revolutionary effects on society have not been regarded as internal problems by weed scientists. For example, weed scientists are justifiably proud of their research on use of herbicides and the ensuing reduction in labor required to weed many crops. What happened to the labor displaced or how the achievement might have contributed to monocultural agriculture,

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[4] For a good explanation of the things valued see Thompson, P. 1997. Agrarian values: Their future in U. S. agriculture. Pages 17-30 *in* W. Lockeretz, ed. Visions of American Agriculture. Ames, IA. Iowa State Univ. Press.

concentration of agricultural production in fewer hands, and loss of small farms were, and remain, externalities.

We who live in free societies pride ourselves on the ability to choose goals without claiming eternal validity for them. Ethical analysis of agricultural science will not achieve absolute, eternal certainty. The desire for certainty, for values that are eternal, is akin to wanting the certainty of childhood. Value analysis includes understanding the relative validity of our conclusions. However, that relative validity yields the knowledge that we although we too must begin to run tomorrow morning and it seems that we are always compelled to run faster in our dynamic world, we will know that we are running in the right direction.

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WEED SCIENCE IN YEAR 2000S IN ASIAN-PACIFIC REGION

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Abstract: Year 2000s request us a sufficient food production to feed the growing world population without any environmental destruction. To solve such a difficult problem, weed scientists in Asian-Pacific Region must promote the following cooperative research. 1) Risk assessment and monitoring of herbicides in the ecosystem, 2) Risk assessment of genetically modified crops in the ecosystem, 3) Allelopathy as a means of sustainable weed management, 4) Mechanism and preventive measures of globalization of exotic weeds, 5) Utilization of weeds, and 6) Establishment of weed inventory center in Asian-Pacific Region.

Key words: safety assessment, genetically modified crops, exotic weeds, allelopathy, utilization

Introduction

Towards year 2000s, we are facing the fear of food shortage due to the growing world population, which is concentrated also in Asian-Pacific Region. Recent estimation showed that the area of suitable regions for the major cereal cultivation decreases 48% under conditions of double the current CO_2 concentration (Okamoto *et al.*, 1997).

To solve such difficult problems to obtain sufficient food production without any environmental destruction, the following cooperative research by weed scientists in Asian-Pacific Region is proposed.

Risk assessment and monitoring of herbicides in the ecosystem

Even more than pests or diseases, weeds are the most severe and widespread biological constraint to crop production. Chemical control using herbidies will be considered to still hold a major means of weed control in year 2000s.

Recent recommended herbicides seem to be very safe for not only humans and cattles but also the environment, when they are used properly. However, considering the increasing public fear on dioxins and other chemical compounds as endocrine disrupters (Colborn *et al.*, 1996), research for risk assessment of herbicides in the ecosystem must be strengthen by the cooperation between weed scientists and scientists in related fields. In Asian-Pacific Region where world rice production is concentrated, the research should be focused on the monitoring of herbicides in paddy fields, rivers, and ocean as an ecosystem and the effect of herbicides on non-target organisms.

Risk assessment of genetically modified crops in the ecosystem

New breeding method by genetic engineering is expected as a key technology to solve food shortage due to the growing world population in year 2000s. Many genetically modified crops (GMO) were already developed and the commercial cultication had started.

According to ISAAA report (James, 1998), global cultivated area of GMO in 1998 is 27.8 million ha, and USA occupies 74%, Argentina 15%, Canada 10% and Australia and Mexico 1%, respectively. By crops soybean occupies 52%, corn 30%, cotton 9%, canola 9%, and potato less than 1%. By trait, herbicide tolerance occupies 71%, insect resisstance 28%, combination of above both traits 1% and quality less than 1%.

Cultivation of glyphosate or glufosinate tolerant soybean, canola, etc. gave a great economical benefit to farmers by reducing the amount of herbicides and the application labor cost and has been rapidly increased (Manabe, 1999). It also gave a benefit for the prevention of soil erosion by non-tillage cultivation becoming possible easily. Such GMOs seems to be hardly introduced into most Asian countries where small-scale cultivation being practiced at present situations. However, new type of GMOs such as high yielding, stress-tolerant, etc. is under way of development and the introduction of these crops into the region is expected.

To utilize GMOs smoothly, risk assessment in the ecosystem is very important as well as the safety assessment as food. As a major importing country of agricultural products, Japan established the environment risk assessment system in 1990 based on the guidelines of Science and Technology Agency and Ministry of Agriculture, Forestry and Fisheries, and the assessment began in 1991 (Harada, 1999).

The most important point of ecological risk is the probability for weeds to acquire genes from related GMOs and to increase their range of adaptation by invading new habitats (Zimmermann, 1997). From this viewpoint, weed scientists can fulfill important roles for the environment risk assessment of GMOs. I believe that cooperative research between weed scientists and other fields of scientists make it possible to bring lots of benefits from GMOs without any biohazards in Asian-Pacific Region.

Allelopathy as a means of sustainable weed management

Molisch (1937) found the phenomenon that a chemical substance(s) emitted by a plant to an ecosystem affected the growth of other plants in the ecosystem either directly or indirectly and proposed to call it allelopathy. Since then, many scientists have been working on allelopathy and Rice (1984) reviewed the results.

Nevertheless, long before this discovery, farmers have already been aware of the fact from their experience that some plants contained weed-inhibiting substances, and have devised the weed control techniques using thse plants. Our observation revealed that 18 species are traditionally used for weed control; three are crops, three are trees and the rest are wild plants including weeds (reviewed by Harada, 1994). While the Japanese cases are those of the past, the plants are all used for weed control purposes to date in Southeast Asia and other developing countries. Weed scientists in Asian-Pacific Region should investigate further and record such farmers' wisdom before being forgotten.

Furthermore, weed scientists should promote research to search new plant species showing allelopathy and to reveal its phenomenon to utilize as a means of sustainable weed management. Cooperative work between Thai and Japanese scientists already isolated and determined the chemical structures of new allelochemics from some plant species (reviewed by Hiradate *et al.*, 1997).

Recently, Fujii (1994) found that some native varieties of rice showed allelopathic activity and the research has been continued to establish new method of weed management. I believe that the ultimate goal of weed control technology will be to breed weed-control crops introducing allelopathy-related genes into crops by genetic engineering in year 2000s.

Mechanism and preventive measures of globalization of exotic weeds

Most serious weeds are not native but exotic and naturalized species (Holm *et al.*, 1977). Many cases of dessemination of exotic weeds in Asian-Pacific Region have been reported.

Mimosa pigra L. is a leguminous weed tree originated from Central and South America. The plant grows profusely around dams and rivers and in non-arable land in Indonesia, Thailand, etc. and has been a big problem. Other areas fear the invasion of this weed. According to the record of Bogor Botanical Garden in West Java, *M. pigra* was introduced from Kew Garden in England on October 24, 1918. It maybe is the first record of transmission of this species to Indonesia (possibly to South East Asia). C.A. Backer reported in his book "Beknopte Flora Von Java, vol. V. *Mimosaceae*" published in March 1941 that the species was distributed only around Bogor in West Java. It might have thus escaped from the Botanical Garden (Harada *et al.*, 1984).

It is said that one of the leading farmers introduced *M. pigra* as a cover crop into a tobacco plantation from Indonesia to Chiang Dao and Maeten in Chiang Mai Province in the early 1960s for the first time, and thereafter the plant had been used to prevent erosion at riversides in Chiang Mai Province (Napompeth, 1982). Our observation from 1984 to 1987 showed that the distribution area of *M. pigra* expanded almost all over Thailand (Harada, 1990). This is one example of the dissemination closely related to human activities.

Besides, several plant species are known to be disseminated by humans in Asian-Pacific Region, for example, free-floating fern, *Salvinia molesta* D. S. Mitchell, introduced to Bogor Botanical Garden on December 12, 1950 from Botanical Garden of Montreal and then spread all over the area (Pane *et al.*, 1984), water hyacinth, *Eichhornia crassipes* (Mart.) Solms brought to Thailand by the Royal Family from Indonesia as an ornamental flower, and important graminous weeds of orchards and coffee plantations, *Pennisetum clandestinum* Hochst ex Chiov. and *Cynodon nlemfuensis* Vanderyst, introduced as cover crops in the highland of Northern Thailand (Harada *et al.*, 1987). These facts suggest that careful examination should be performed at the time of introduction of new plant species.

Shimizu (1998) reported that imported agricultural products, corn, millet, soybean, lupine, and canola from five countries were contaminated with viable seeds of 59 species of exotic weeds. Some of

them already invaded grasslands and upland fields all over Japan and have been a big problem. Furthermore, the invasion of some tropical and sub-tropical weeds such as *Echinochloa colonum* Link., *Cyperus esculentus* L. and *Sphenoclea zeylanica* Gaertn. were reported in temperate areas of Japan (Morita, 1991).

Thus, recent development of transportation system, further extension of world free trade of agricultural products and global warming distinctly increase the fear of biohazard by invaders, from the view point of not only the weed control in agricultural lands but also the destruction of biodiversity in an ecosystem, in year 2000s. To avoid biohazards by globalization of exotic weeds, weed scientists in Asian-Pacific Region must promote cooperative research on this subject.

Utilizatio ı of weeds

Weeds are enemies of farmers. They cover all over the agricultural fields and damage the crop production seriously. In this sense, weeds are always the targets to be controlled. On the other hand, humans in various ways have utilized weeds. Our investigation in Thailand (Harada, 1987) and in Fiji (Harada and Nagatalevu, 1989, 1990) revealed that many weed species including wild plants have been utilized by humans as foods, medicinal plants, animal feeds, housing materials, materials for handicrafts and ornaments, agricultural use, and so on. Weed scientists in Asian-Pacific Region must investigate and record those traditional cultures before being forgotten.

At the same time, weed scientists in Asian-Pacific Region must promote cooperative research for utilization of weeds in the future. Utilization as biomass for bioenergy, resources for biologically active substances and genetic resources for genetic engineering will be expected in year 2000s. Such research should focus on Asian-Pacific Region, where abundant plant resources exist.

Establishment of weed inventory center in Asian-Pacific Region

To support the cooperative research by weed scientists on the subjects mentioned above, Weed Inventory Center must be established in Asian-Pacific Region. The Center must consist of database of all weed species distributed in the region on the scientific and vernacular names, the distribution, the biological and chemical information not only for their control but also for their utilization and all the references.

The Center also needs the herbarium and viable seed bank for preserving plant materials collected at various locations in Asian-Pacific Region and at different periods. These plant materials should be supplied to weed scientists anytime upon request for research purposes.

We all must move towards realizing this proposal in year 2000s.

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Invited Papers

BEHAVIOR AND PHYTOTOXIC ACTIVITY OF HERBICIDES AND ALLELOCHEMICALS IN SOIL

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Abstract: When phytotoxic substances such as herbicides and allelochemicals penetrate into the soil environment, the behavior and phytotoxic activity in soil are dominated by the content of soil organic matter, water content, pH and other soil characteristics through the effect on adsorption, desorption, transformation and distribution in soil depending on the physicochemical properties. However, the direct relationship between the behavior and phytotoxic activity of herbicides and allelochemicals in soil has not been elucidated. Recent development of techniques for measuring the concentration in soil water indicated that the availability of herbicides and allelochemicals to plant in soil depended on the concentration in soil water but not on the amounts in total soil, suggesting that only the phytotoxic substances present in soil water are involved in the phytotoxic activity. Mechanisms inducing the phytotoxic activity in soil are discussed with particular reference to the soil factors controlling the concentration in soil water.

Key words: behavior, phytotoxic activity, herbicide, allelochemical, soil, soil water

Introduction

In many reports, information about the behavior of chemical substances in soil has been provided. However, most of them dealt with the environmental aspects and the relation to the phytotoxic activity is poorly documented. The behavior of chemical substances including herbicides and allelochemicals is controlled by the complex interactions among the substances, soil and weather, and plant growth is affected principally by the soil properties, the weather and the phytotoxic substances present in the soil. These facts indicate that the phytotoxic activity of the substances in soil are controlled by the factors affecting their behaviors such as adsorption on soil, desorption from soil, leaching with water and biochemical and abiotic transformation in different ways.

Phytotoxic activity of herbicides and allelochemicals in soil must be induced through the absorption by plant from the soil and this absorption occurs primarily with water, suggesting that the chemical substances present in soil water play an important role in the phytotoxic activity in soil (Fig.1). Factors which control the concentration in soil water include the physico-chemical properties of the

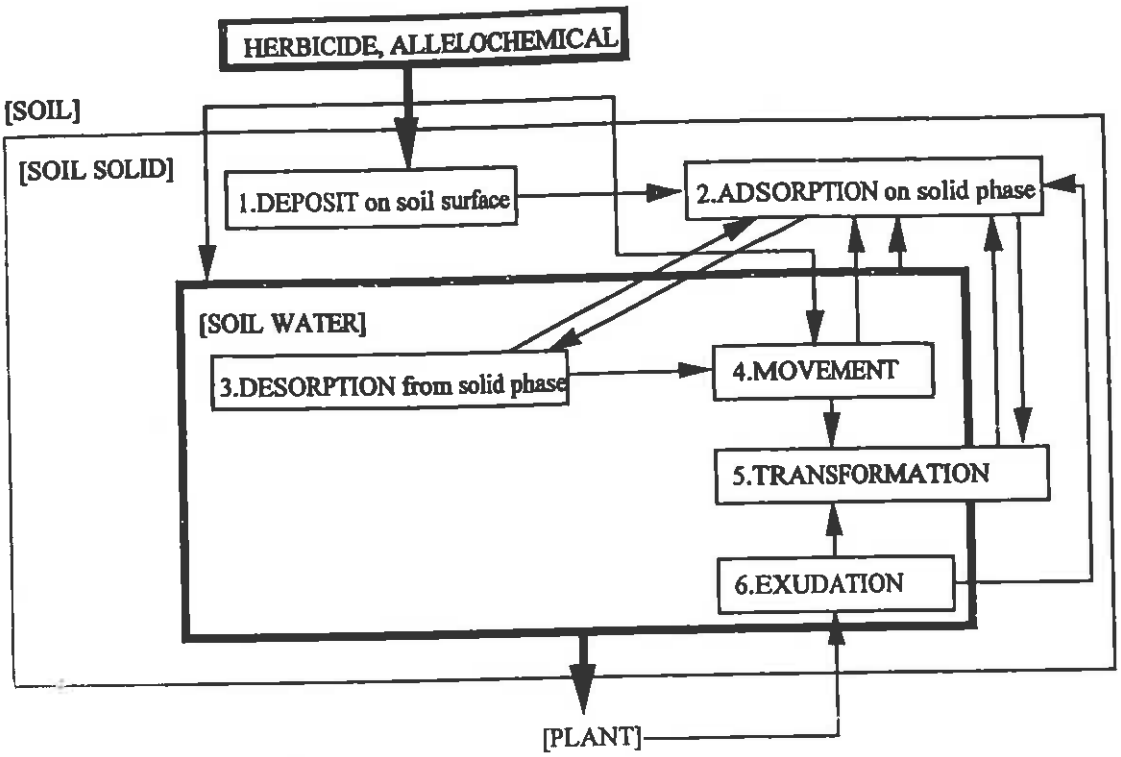


Fig.1. Schematic diagram showing mechanism of induction of the phytotoxic action of herbicides and allelochemicals in soil.

substances, the adsorptive and transformative capacities of soil. It is thus suggested that the soil factors dominate the concentration of phytotoxic substances present in soil water through the effects on their behavior in soil, resulting in the control of the phytotoxic activity.

Recent developments concerned with variability in the behavior of herbicides and allelochemicals in soil are reviewed in relation to the phytotoxic activity and discussed with particular reference to the soil factors controlling the concentration in soil water.

Behavior of Herbicides and Allelochemicals in Soil

A number of reports about herbicide behavior in soil indicated that the adsorption on soil is one of the main processes affecting the behavior in soil. In most cases, organic matter and clay play a major role in the adsorption-desorption processes depending on the properties of the substances, leading to the mobility and transformation control. It is generally observed that the adsorption of neutral chemicals mostly depends on the content of soil organic matter, whereas that of acidic or basic chemicals is remarkably influenced by the soil pH. For instance, the adsorption of mefenacet (Nakamura *et al.*) on soil increased with the increase of the soil organic matter content while the adsorption of sulfonylurea (Ukrainczyk and Ajwa, 1996) and imidazolinone (Stougaard *et al.*, 1990) herbicides increased when the soil pH decreased. Soil moisture content (Alvarez-Bendi *et al.*, 1998) and clay content (Pusino, 1992) occasionally affect the adsorption. Transformation of herbicides in soil is induced mainly by

microorganisms and also influenced by the soil characteristics. However, it is difficult to understand the role of soil factors in the transformation by the microorganisms since the microbial populations consist of a very complex system. Behavior of allelochemicals in soil is also influenced by soil factors, as reported for dehydromatricaria ester(DME), an allelochemical produced by *Solidago sltissima* L., in a similar manner to that of herbicides (Ito *et al.*, 1998). If the phytotoxic substance is irreversibly adsorbed on soil or its desorption is very slow, transformation is minimal. Limited distribution of herbicides in the top soil often leads to the formation of "herbicide treated layer", which leads to make "placement selectivity" between transplanted crop and weeds that germinated in the layer. The selectivity depends on the differences in the placement of the sensitive and absorptive parts, such as basal part of shoot and root, of the plants in soil.

Phytotoxicity of Herbicides and Alleiochemicals in Soil

It is generally recognized that phytotoxic activity of herbicides and allelochemicals in soil varies from soil to soil, suggesting that the phytotoxic activity is governed by the soil properties through the effect on the behavior in soil as reported for metribuzin(Peter and Weber, 1985). It is thus suggested that the important soil properties that affect the phytotoxic activity are the same as those that affect the behavior in soil. A number of studies have revealed that the phytotoxic activity in soil is inversely correlated with the amount of adsorption on soil and the rate of transformation by microorganisms in soil. A typical example for the former is the effect of soil pH on the behavior and the phytotoxicity of herbicides as evidenced by the fact that phytotoxic activity of chlorsulfuron increased with increasing soil pH, whereas the adsorption decreased with increasing soil pH (Mersie and Foy, 1985). As observed for L-3, 4-hydroxyphenylalanine (DOPA)(Shibuya *et al.*, 1994) and DME (Ito *et al.*, 1998), in most of allelochemicals the phytotoxic activity in soil is remarkably reduced due to the adsorption on soil and the degradation by microorganisms in soil.

Comparison of the behavior of herbicides and allelochemicals with the phytotoxic activity in soil revealed a good correlation between these parameters, as described above. However, direct interaction between plant and the substances in soil is scarcely reported.

Herbicides and Allelochemicals in Soil Water and the Phytotoxic Activity

Information about the total amount of herbicides in soil is important in environmental conservation while the concentration in soil water plays a key role in the phytotoxic activity in soil, because herbicides and allelochemicals can directly contact with plant in the soil water. Processes that control the concentration of phytotoxic substances in soil water are controlled by the properties of both soil and the substances. It is essential to distinguish between plant available and non-available amounts of phytotoxic substances present in soil for clarifying the direct interaction of the plant with the substances.

However, separation of the substances in soil water from the soil under plant-growing conditions is technically difficult. Several methods (Embalming, 1979; Gaillardon *et al.*, 1991; Gaillardon and Sabar, 1994; Green and Obien, 1969; Hance and Patterson *et al.*, 1982; Kobayashi *et al.*, 1994; Stalder and Wilfried, 1980) have been developed for the extraction of soil water from soil to determine the amount of chemicals dissolved in soil water, including soil water collection by suction under reduced pressure, pushing-out under high pressure, penetration into paper or in supernatant and in the outer tube of double tubes by centrifugation.

Phytotoxic activity of the herbicides and allelochemicals was well correlated with the concentration in soil water but not with the total amount in soil, as in the case of herbicides such as fluometuron (Patterson *et al*, 1982), linuron (Walker, 1973), thiobencarb (Lee *et al*, 1996; Yogo *et al.*, 1995), thenylchlor (Kobayashi *et al.*, 1994) and mefenacet (Kobayashi *et al.*, 1996)(Fig.2 and 3) and for DME (Ito *et al.*, 1998). In the case of clomeprop, the phytotoxic activity was induced actually by its

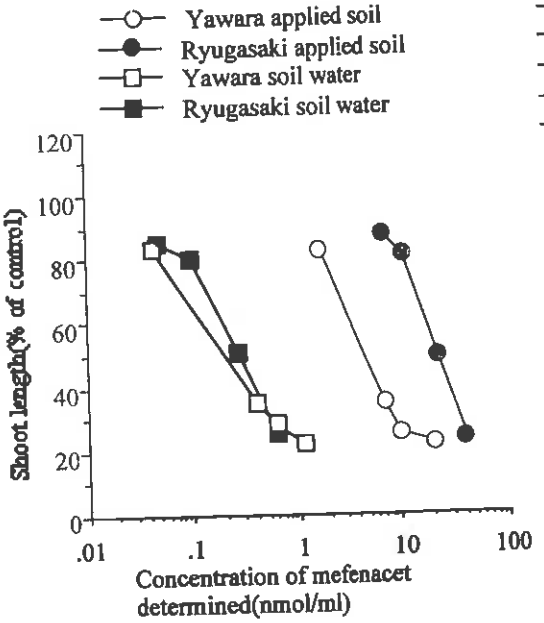


Fig.2. Relationship of rice growth to the concentration of mefenacet determined in soil water or applied soil.(Kobayashi et al.,1996)

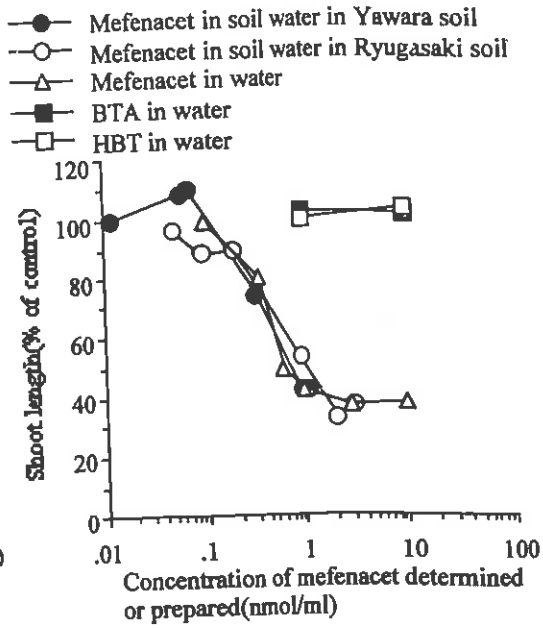


Fig.3. Gowth of rice in soil water and in distilled water containing mefenacet and the proposed metabolite at various concentrations. (Kobayashi et al.,1996)

hydrolyzed metabolite, which was a degradation product of clomeprop by soil microorganisms, in soil water separated from the soil treated with clomeprop (Kobayashi *et al.*, 1999). The relationship between the concentration in soil water and the phytotoxic activity was confirmed by the fact that the phytotoxic activity in soil water directly separated from the soil treated with the substances was similar to that in the total soil (Kobayashi *et al.*, 1994; Kobayashi *et al.*, 1996; Tongma *et al.*, 1998). These findings indicated that the phytotoxic activity of herbicides and allelochemicals in soil is substantially induced by their presence in soil water but not by the total amount in soil.

Main processes which control the concentration of chemical substances in soil water are

adsorption, desorption, movement and transformation in the soil. Of the processes, the adsorption-desorption balance is the first step and an important factor in determining the concentration in soil water. For instance, it was revealed (Kobayashi *et al.*, 1996; Onoe *et al.*, 1995) that the adsorption of thenylchlor and mefenacet on soil was controlled by the organic matter content, and that resultant higher concentration in soil water of the soil with a low organic matter content induced a greater phytotoxic activity in soil. It is thus suggested that the phytotoxic activity of herbicides and allelochemicals in soil is induced by the concentration in plant available soil water, and that the concentration in the soil water is dominated by soil factors through the effect on the behavior in soil.

Conclusions

The properties of soil are highly variable and the behavior and the phytotoxic activity of herbicides and allelochemicals in soil are different in each soil. However, there is a good correlation between the behavior and the phytotoxic activity in soil. As plants can absorb chemical substances in soil water easily, it is suggested that the concentration of herbicides and allelochemicals in soil water plays a key role in the phytotoxic activity in soil. Furthermore the concentration in soil water depends mostly upon the adsorption on soil solid and the degradation in soil. Further studies on the mechanisms inducing the phytotoxic activity of the chemical substances in soil should be carried out to provide the basic information for understanding the complexity of plant-soil-chemical substance reactions, and for the rational use of herbicides for adequate weed control under various soil conditions.

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Fulfilling needs for transgenic herbicide-resistant rice while preventing and mitigating introgression into weedy rices[1]

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Introduction

According to the FAO, rice is clearly a crop with problems (Anonymous, 1998):

(1) Rice culture has demographic problems; it has been called a greying crop, due to the increased average age of rice farmers. As more money is being earned in cities, the younger people leave. The older farmers are tired, and unless agronomic strategies change, paddies will become weedier and rice yields will drop.

(2) Rice has geographic problems; areas are being taken out of production faster than being brought into cultivation due to urban encroachment, competing crops, soil degradation and salinization, and lack of water.

(3) Rice has consumer problems; as people enter middle class in the developing world they develop a craving for tasteless white wheat bread. The expanding middle classes also want the better tasting, but lower yielding basmati or other rices instead of the high yielding types.

(4) Rice culture has agronomic problems; the yields farmers typically achieve are a small fraction of what nearby experiment stations harvest with the same varieties. Direct seeding has alleviated labor problems while exacerbating the weed problems.

Expert groups of scientists are often sent to rice areas to ascertain the insect, disease, and fertilizer constraints that prevent yields from increasing. The answer of the farmers that these entomologists, pathologists, and soil scientists quickly "discover" is that most often the major constraint to rice production is weeds. If the adverse health effects of unprotected use of insecticides are added into economic considerations, their use has negative value (Pingali and Marquez, 1996).

Weed scientists typically discuss annual and perennial weeds (Auld and Kim, 1996; Holm et al. 1997; Ampong-Nyarko and De Datta. 1991). The intensification of production, direct seeding, less rotation, shorter, high harvest index rices together have led to centennial and millennial weeds; weed problems that are pernicious and global. The greying farmers have trouble with the hand and manual (or often femanual) weeding. Some areas still use no herbicides; the weeds overcome the crop. In such areas fertilizers would nurture the weeds more than the crop, so fertilization is uneconomical. Japan is on the other side of the spectrum. They use complex "one shot" mixtures, or sequential groups of herbicide treatments. Japanese rice receives more herbicides than any other field crop in the world. Before farmer graying, rare escaping weeds in Japan were removed by hand. Now they have resistance to sulfonylurea herbicides in Japan because rare resistant individuals were not rogued, and then multiplied (Itoh et al.,

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[1] This article is slightly revised and updated from a chapter in the Proceedings of the Pest Management Council of the Philippines conference, May 4-6, 1999. Published here with the kind permission of the Weed Science Society of the Philippines and the Pest Management Council of the Philippines

1999). In the middle, we have vast areas where one or two herbicides are often used, a grass killer and sometimes a broad leaf killer. The nature and economics of farming in this vast middle realm necessitates the use of cheap generic herbicides; 2,4-D for broad leaves and either propanil, butachlor, or thiobencarb for the grasses. The latter three compounds are not rotated; each is typically solely used in a given region. Broad leaf weeds never escaped the sufficient control of 2,4-D, except in isolated instances (Gressel and Baltazar, 1996).

The Millennial Weed Problems

There are three weed groups that have become global millennial problems in rice. Biotechnologically derived, transgenic, herbicide-resistant rices may be an answer to these problems in the next century, but not as presently envisaged as single gene products. Herbicide-resistant rice can be of great benefit if used with care. No solution in agriculture has been forever; farmers always had to delay or counter evolution. More sophistication will be needed than is presently being used with transgenic rice (Table 1). There are no failsafes to prevent or mitigate the movement of the genes to weedy rices. Three herbicide resistances have been introduced into rice and are being extensively field tested, along with many other genes that might have market value. Better solutions are at hand, but will slow the time to market of herbicide-resistant rices, and their use has not been initiated.

The rice weeds that somewhat arbitrarily fit the designation as global "millennial" weeds are:

(1) *Echinochloa* spp. – always problem weeds, but are now evolving resistance to the rice herbicides used for their control;

(2) The sedges (nut and other) that were never well controlled by any herbicide chemistry and the areas infested are expanding;

(3) The red, weedy, and wild rices that were never controlled selectively in rice by herbicides (Baltazar and Janiya, 1998; Nöldin et al., 1999b). Their control is especially amenable to biotech solutions that confer selectivity. The same solutions are frightening and futile, if the crop transgenes introgress into the weedy rices and then are expressed.

Rice has books full of other weeds (Holm et al., 1977, 1997, Ampong-Nyarko and DeDatta 1991; Auld and Kim, 1996) that are less global than those designated as millennial, but are just as bothering on a local level. An open mind will allow the reader to extrapolate from the discussion of these three millennial groups to the locally-vexing problem weeds.

Presently, the best farmers can do is to delay seeding rice until after the weedy rices have germinated and have been controlled with non-resistant graminicides, or go back to transplanted rice, which has far fewer weed problems. This shortens the season, reducing the yield. Red rice is often controlled by delayed planting of rice till after red rice is controlled by a non residual, non-selective herbicide, or by rotating rice with other crops and instituting strong control measures to reduce the seedbank (e.g. Forner, 1995; Askew et al. 1998). Italian farmers have had to resort to ancient herbicides such as dalapon to control red rice before delayed planting of rice (A. Ferrero, pers comm.). All these cases are amenable to the biotechnological solution of generating transgenic herbicide-resistant rice. Insert a gene into rice conferring resistance to a broad spectrum herbicide (Table 1), and you can even kill closely-related grasses, including conspecific red, weedy, and other wild rices. One can even

choose bacterial genes for inexpensive old herbicides such as dalapon, modify them for plant codon usage, and transform them into grains (Gressel et al. 1997). Such genes have the advantage that it is harder (but not impossible) for the weeds to mimic bacteria than plants in evolving resistance. The confounding problem is the possibility of these transgenes for herbicide resistance and other traits (Table 1) may introgress into weedy rices, rendering them more fit, as discussed below.

The Echinochloa spp. are major weeds wherever rice is grown, but *E. crus-galli* is hardly limited to rice (Holm et al., 1977). It is truly global from temperate to tropics in a wide variety of crops. The *Echinochloa* spp. were major targets for graminicide development and they were excellently controlled for a very long duration. The excellent control was the key to resistance problems. If there is excellent kill through all weed germination flushes, the only survivors are individuals that are totally resistant to huge herbicide doses, i.e. the selection pressure for evolution is immense. Propanil was excellent throughout the Americas and in Europe until resistance evolved (Gressel and Baltazar 1996). Resistance to photosystem II inhibiting herbicides such as propanil is not uncommon, but propanil resistance in *Echinochloa* was not at this target site in the chloroplasts. Propanil resistance was but another case of weed mimicry of crops. Weeds have evolved morphologies and phenologies similar to crops for the past millennia. As the year 2000 arrives, the millennial weeds have become more sophisticated and have begun to evolve biochemical mimicries. Two *Echinochloa* spp. evolved elevated levels of the same acylamidase enzyme system that rice uses to detoxify the herbicide (Leah et al., 1994; Carey et al., 1997). Biotechnology via herbicide-resistant crops would overcome this problem, but this particular case is also amenable to chemical solutions. Various phosphorus graminicides (e.g. anilofos, piperophos) (Caseley et al., 1996; Norsworthy et al., 1999) or the insecticide carbaryl (Daou and Tolbert, 1999) mixed with propanil prevent *Echinochloa* from degrading propanil, but do not prevent rice from detoxifying it. These are classic cases of synergy.

Butachlor and thiobencarb are widely used in Asia for *Echinochloa* control. Resistance to the chloroacetamide and thiocarbamate groups to which they belong was thought to be nigh impossible and improbable (respectively) (Gressel and Baltazar, 1996). It was a triple surprise when reports of resistance started emanating from China (Huang and Gressel, 1997) because: (1) resistance evolved to these herbicides; (2) there was cross resistance among them. Where butachlor was solely used, the weeds were cross resistant to thiobencarb, and vice versa; (3) of the extent of resistance – it was claimed that there were 2 million hectares of butachlor/thiobencarb resistant *Echinochloa*. Few thought that China was producing and using so much of these herbicides for so long to get this extent of resistance.

The sedges. Sedge control never was that good with herbicides. The newer cropping systems for rice favored sedges. The excellent control of grass weeds such as *Echinochloa* left an ecological vacuum, which nature abhors. The only good chemical way to kill sedges is with systemic herbicides that will penetrate to the storage organs of these pests. There are genes available to confer resistance to a few systemically-translocated herbicides that kill sedges.

The weedy rices have also filled a vacuum (Holm et al., 1997; Baltazar and Janiya, 1998; Noldin et al., 1999a). Their genetic, morphological, and phenological similarities to domestic rice have always kept them as camp followers. Some of the conspecific red rice and other *O. sativa* types (Table 2) can be considered as progenitors to,

or as feral forms of domestic rice. There are other *Oryza* spp. that have weedy characters, as well as wild species that are not competitive at present in agroecosystems (Vaughan, 1994). The various weedy rices shatter most of their seeds before cultivated rice is harvested, so the farmer loses rice yield while filling the seedbank with weeds (Baltazar and Janiya, 1998). Still, enough weed seed is left in the harvested crop to sow farmers' fields with this problem.

Another feral aspect is the prolonged dormancy of red and weedy rices. Their seed germinates over a number of years, resulting in a prolonged problem. Without these two qualities, the weedy rices would almost be domestic rice. The weedy rice species have become greater problems since farmers became more reliant on chemical means to control other weeds in rice. It should be no surprise that the domestic and weedy rices are generally naturally resistant to the same herbicides (Noldin et al., 1999b). This is a general problem in agriculture; there is rarely selectivity among closely-related species.

The easiest way to obtain selectivity among closely related species is to engineer resistance into the crop, and it has already been shown that red rice is easily controlled by glufosinate in transgenic rice bearing the *bar* gene conferring resistance to this herbicide (Oard et al., 1996). Glufosinate was less effective after flooding in controlling hybrid rice in transgenic glufosinate resistant rice (Sankula et al., 1997b).

Herbicide use in rice facilitated weed control in low stature, high harvest index rices, allowing fewer farmers to harvest far more rice. Herbicides also facilitated the ecological and evolutionary changes that are just beginning to appear that tell us that chemical answers are not forever. Confucius was claimed to have said: "people who never change direction will end up where they are heading". The chemical path has been rosy, but the thorns are growing larger. One changed direction is to transgenic herbicide-resistant rices. We must be careful not to step into abysses with them. We could also turn backwards to the labor- intensive, herbicide-free, back breaking, transplanted and hand weeded rice. Well meaning, city-living greens think this a great idea, but they have never waded into a paddy nor wielded a hoe for more than a few minutes. Photographs of rice workers appear so romantic, pastoral, and tranquil, but do not capture the ooze, the smell, the insects, nor the strain and tiredness of weeding paddy.

The examples above suggest that there are many needs for transgenic herbicide-resistant rice. Additionally, rice varietal name recognition is considered a key reason for slow acceptance of new rice varieties (Nakaganra et al., 1997). Genetic engineering of single traits does not substantially change the variety, (except in the particular engineered trait), which is a distinct advantage. Maize and soybeans did not have any major uncontrollable weed problems, yet transgenic herbicide-resistant maize and soybeans quickly covered a large proportion of the US growing area. The reason for rapid adoption was a marginally-increased cost effectiveness, and a slightly better ease of use. So why are there transgenic herbicide resistant maize, cotton, and soybeans, but not rice where the needs are most dire? There are many political and socio-economic reasons but we will only consider the constraining biological one: maize, cotton, and soybeans have no close, interbreeding, weedy relatives where they are cultivated; rice does have these weedy relations.

The fear of introgression.

A U.S. newspaper headlined "The major danger posed by genetic engineering may come from sex with weeds" suggesting to many readers that they put their potted plants outside at night for their personal safety. That writer had trouble expressing the concept that some crops (such as rice) could pollinate weeds, and some transgenic traits could introgress into related weeds. Other headline writers coined the term "superweeds" (Kling, 1996), that would soon inherit the earth. The idea was that weeds that introgressed herbicide, insect, disease, and/or stress resistances, or modified starches or oils from crops would become dominant and predominate. You do not sell newspapers or get research grants saying that these weeds might be slightly better competitors, requiring minor modification of farming strategies, something farmers continually have had to do with every new technology.

The situation was not made clearer by scientists who redid experiments that were done decades ago showing that you could cross many crops with wild relatives, including those in related genera. The "modernists" made the crosses using transgene markers, breeders did these long ago with standard markers. The press and protagonists rarely reported that the crosses typically required hand pollination (without competing species-specific pollen), that often it was necessary to "rescue" embryos by cultivating in tissue culture medium, and that most progeny were sterile or their progeny were runts. Because a few genes could successfully make it past the barriers between very closely related species, generalizations were made to all crops and all weeds, ignoring centuries of information on genetic barriers.

Still, there are the cases where there are very closely related, easily introgressing crops and weeds; the outstanding cases being cultivated and wild sorghums, barleys and rices. In these cases caution is required and failsafe mechanisms should be considered. Many rice farmers say: "give us transgenic herbicide-resistant rice to control red rice. After red rice becomes resistant, we'll use a different transgenic herbicide-resistant rice". This assumed that problems would not ensue for five years or more, and that there are an unlimited number of genes available to generate additional transgenic herbicide-resistant rices. Resistance may appear faster than predicted by industry, and there are not that many good genes for resistance available when the first ones are lost to resistant weedy rices.

It is best to first evaluate the magnitude of the risks on a regional level based on the indigenous weed problems, and then make some hard decisions. Previously introgression was treated like the weather; discuss, complain, and argue about it, but do nothing about it. The hard decisions are not whether to allow or ban transgenic rice but whether to allow transgenics as single gene products, or whether to require failsafes or mitigation, as will be described later.

Risk evaluation

The wild rices are already resistant to rice herbicides, so it is highly unlikely that they could become much more weedy than at present, except that it would be nice to keep them controlled when transgenics are used, and not have them back for a while. The implications and reservations about such introgressions were recently discussed (Cohen et al., 1999). The magnitude of risk of introgression is a function of which weedy rice species grow in or near cultivated rice, and their present weediness. As long as the weedy rice is controlled by the herbicide, the potential to hybridize is low; dead plants do not breed. There was less than 1% red rice survival following herbicide treatment in an experiment using glufosinate-resistant transgenic rice mixed with weedy red rice. The competition

with rice further reduced red rice seed set on the remaining plants, and none of the progeny were resistant (Zhang et al., 1999). The problems of introgression ensue with unsprayed border weeds, or during seasons when the herbicide is not used, as well as when the few remaining red rice plants pollinate rice yielding partially feral F_1 hybrids. There is no logical risk of introgression beyond *Oryza* spp. (as some proponents of horizontal (intergeneric and beyond) gene transfers claim. If this possibility existed, the native rice genes for herbicide resistances would have moved long ago to other grass species. Thus, this theoretical but hardly plausible risk will not be discussed further.

Rice genera and species have pollen infertility and progeny sterility barriers that prevent natural introgression, and the analogous genome sets are defined by the ease of crossing (Table 2). Useful genes have been introduced from many of these wild species Vaughan, 1994) (see bold in Table 2), although embryo rescue was required (Brar and Khush, 1997). The extent of the rare homeologous pairing between AA domestic rice with non AA weedy species was very weak, suggesting strong genetic exclusion barriers. There was considerable ease in fixing the traits in backcrosses in the few cases where homeologous pairing occurred, and RFLP mapping suggested that the homeologous recombination was of very small pieces of chromosomes (Brar and Khush, 1997). Thus, in areas where all weedy rices do not have AA genomes the risks of introgression are far reduced, and should be studied case by case. Much is known about introgression of genes from non AA rices to domestic rice, as this has been the vehicle to introgress useful genes to rice (Zeller 1998; Xiao et al. 1998). Less is known about introgression of domestic rice genes into non AA rices, although there is information about movement of domestic rice genes to con-specific red rice, including movement of transgenes. It is possible that many studies on the possibility of introgression with wild rice species must be repeated, as the wild rices are often misidentified. A RAPD analysis showed that 10-20% of IRRI accessions labeled *O. meridionalis, O. glumaepatula* were misidentified and that there might even be mistakes in the *O. nivara* and *O. rufipogon* groups (Martin et al., 1997). Within the AA genome types there are infertility barriers, but they are overcome in the field with time. Natural hybrids between domestic rice and *O. rufipogon* are often found in areas where they co-habitate (Majumder et al., 1997). A few of the hybrids withstand the selection pressure and remain as superior competitors.

Many viable F_1 crosses and a few viable backcrosses have been obtained between domestic rice and *O. minuta* (BBCC), but embryo rescue was required at both the F_1 and BC_1 (to rice) stages (Mariam et al., 1996). Genetic traits were thus transferred to domestic rice, as analyzed by disease resistance (Mariam et al., 1996) and with DNA probes (Aswidinnoor et al., 1995). Kaushal and Ravi (1998) report >10% success obtaining intergenome hybrid F_1 seed (BBCC, CCDD genomes), but only by embryo rescue, and all progeny were sterile. Still, Brar and Khush (1997) were able to stably introgress genes from CC, EE, FF, GG (but not HHJJ) into domestic rice via limited homoleogous pairing. For the purpose of risk analysis, it is better to evaluate what has happened in the field, not what breeders can do in the lab. Many weedy *O. sativa* populations were probed by RAPD analysis, and found to have either introgressed domestic specific sequences or were possibly older domestic types that became feral (Suh et al., 1997). Similar studies must be performed in non-AA weedy rices.

Another question that can be asked is whether the weedy species are likely to evolve resistance more quickly by mutation than they would introgress the gene. For example, if the herbicide is one of the acetolactate synthase inhibitors, most species have a 10^{-6} frequency of resistant individuals. If the only wild rice species is *O. officinalis*, which has a CC genome, with an extremely low likelihood of introgression from AA genome rice (Table

2), then introgression will probably not lead to resistance before naturally occurring resistant mutants become large populations. The rate of field introgression in some AA weedy rices is very low due to partial compatibility problems, different flowering times, predominant self pollination, as well as fertility and fitness problems. Here too it can be asked, which will occur faster, introgression or mutated populations. Introgression might be faster for herbicides where rice has a very low mutation frequency for resistance, and/or where mutants in the herbicide target are highly unfit, as with glufosinate and glyphosate (but not the imidazolinones). Within the AA genome rices in the *O. sativa* complex the risk of introgression is probably too great for release, despite the incompatibilities (Naredo et al., 1997).

Risk analyses are best performed using decision trees that require answering a series of fixed questions (Gressel and Rotteveel 1999); this can considerably lessen bias factors in decision making. As there are ways to mitigate the positive effects of having herbicide resistance introgress into weeds, it would be wise to allow single gene transgenics only where the risk is exceedingly low (i.e. where no AA genome rices are present as weeds).

Two types of strategies are described below to prevent introgression of transgenes from rice to wild rices. One utilizes genetic placement of the transgenes in ways that prevent introgression, the other links mitigating (TM) genes to the gene of choice to render weeds less fit.

Gene Placement Failsafes.

Two failsafes exist to prevent gene flow, not yet widely used, that would not require TM constructs:

Hybrids. A simple failsafe can be used in hybrid rice, which is claimed to cover half the ricelands of China. If a dominant transgene for herbicide resistance is placed in the male sterile line, there will be no possibility of introgression in crop-production areas, if this line produces no viable pollen. Care will have to be taken in the seed production areas where the male sterile line is restored. Such areas must be kept free of related weedy rices, a typical precaution generally practiced before the advent of transgenics.

Plastome or chondriome placement. If the transgene for herbicide resistance is placed on the mitochondrial or plastid genomes, as has been done with glyphosate resistance in tobacco (Daniell et al., 1998) there should be little possibility of gene flow, due to maternal inheritance of these genomes in rice. Species that are often claimed to have no paternal inheritance often have about 0.1% pollen transfer of traits. Large scale experiments should be performed in rice to ascertain the level of paternal transfer of traits, and evaluating if it sufficiently low to justify using this strategy. The level of paternal inheritance of chloroplast and mitochondrial genome inherited traits in rice is not known (D. S. Brar, pers. comm.)

Transgenetic Mitigation (TM) Traits

The concept (Fig. 1) of using genetic engineering to mitigate selective advantages of introgressed transgenes in weedy species (Gressel, 1999) is based on three premises:

(1) Tandem constructs of genes act as tight linkage groups, and gene segregation, or loss, is rare.

(2) There are traits that are either neutral or positive for domestic rice that could be deleterious to weedy or wild rices. Xiong et al. (1999) have mapped 19 domestic rice traits that confer "domestication", traits not expressed in a weedy AA rice. The seven qualitative traits mapped to one locus.

(3) Because weedy rices are strongly competitive amongst themselves, and have a large seed output, even mildly-deleterious traits are lost from populations.

Thus, if the herbicide resistance gene engineered into a crop is flanked by transgenic mitigation (TM) genes in a tandem construct, the overall effect would be deleterious after introgression into weeds. Even if one of the TM genes disappears, the other flanking TM gene will still provide mitigation. If domestic rice already possesses the TM trait, a different TM gene coding that trait should be used to prevent co-suppression.

TM traits utilizing differences between rice and weedy rices are summarized below.

Seed dormancy

Red and weedy rice seeds typically have secondary dormancy, with seeds from one harvest germinating throughout the following seasons and years (Khan, 1997). This evolutionary risk-spreading strategy maximizes fitness while reducing losses due to sib competition (Hyatt and Evans, 1998). Staggered secondary dormancy prevented all weeds from being controlled by a single agronomic treatment or by predators, disease, or pests. Rare mutants in the rice progenitors lacking secondary dormancy were domesticated, as the loss of secondary dormancy allows uniform germination and harvest, as seen when comparing rice with its weedy progenitors and relatives (Ling-Hwa and Morishima, 1997). Dormancy in rice is quantitatively inherited with dormancy being dominant (review by Foley and Fennimore 1998). A single gene controls the predominant, hull-imposed dormancy. Some cultivars have too strong dormancy (Foley and Fennimore, 1998) and thus anti-dormancy genes would be useful for the crop. Transgenically abolishing secondary dormancy is thus positive or neutral to domestic rice, but deleterious to the weedy rices.

Seed ripening and shattering. Weed seeds mature over a period of time and most ripe seeds "shatter" to the ground, insuring replenishment of the soil seed bank. Domestic rice has been selected for non-shattering (Price et al., 1996). Uniform ripening and anti-shattering genes are deleterious to weeds, neutral for rice (which ripens uniformly and does not easily shatter) (Ling-Hwa and Morishima, 1997). Rice contaminated with low levels of weed seeds must be cleaned, or used for feeding or processing. Only weed-free "certified" seed should be sown. This would eliminate weedy seed if transgenes were to introgress as the non-shattering weedy rice seeds would be harvested with the rice crop, but not resown.

Dwarfing. Dwarfing has been especially valuable in generating "green revolution" rice based on increasing the harvest index, the ratio of grain to straw. Previously, rice had long been selected for increased height to outgrow weeds, limiting the photosynthate available for grain. Weed evolution continued apace, giving rise to taller weedy rices. Selective herbicides allowed for genetic dwarfing of rice. The lowering of height, precluding lodging of tall plants, increased yield, especially after fertilizer use (which previously promoted lodging), brought self sufficiency to many countries.

Genetically-engineered height reduction is available, using genes relating to hormone production (Azpiroz et al., 1998; Schaller, et al., 1998), or recognition (Peng et al., 1999) as well as with shade avoidance (Robson et al., 1996). The response to shading is stem elongation, which is advantageous for competing with other species, but not in a weed-free crop stand where only siblings compete. Dwarfing is disadvantageous for weeds that cannot overgrow the crop.

Overcoming the advantages of resistance in weeds

Herbicide resistance would confer an advantage to weedy rices; it would keep them alive when the herbicide is used. Will TM traits actually mitigate that advantage? Weedy rices are competitive with their own and other species as well as with rice. Weedy rices typically produce hundreds of seeds that compete to replace a single plant; the selection for high competitive fitness is intense. Any marginally-advantageous transgene introgressing into a weed will proliferate and spread through a population (Thill and Mallory Smith 1997). Conversely, the disadvantage of TM traits can balance against the advantage of the primary trait, and if a resistant individual appears, the TM trait will render it non-competitive with its sibs. This relationship must be measured when the herbicide resistance trait is needed (when the herbicide is used) against when the herbicide is absent. When the herbicide is not present, the herbicide resistant transgenic trait can diminish in the population as shown with one herbicide resistance gene that had been thought to be neutral (Bergelson et al., 1996). When the primary gene has a strong advantage (e.g. for herbicide resistance), there may be a need for herbicide or crop rotation so that the TM genes can effect mitigation, if introgression occurs.

The likelihood of TM genes segregating away. The likelihood of the TM and the herbicide resistance traits segregating from each other is about the same as for the TM trait being inactivated by a mutation. If the frequency of mutation or crossing over of tightly linked traits represents an unacceptably high risk, two flanking TM genes could be used. The frequency of loss of two genes TM can be predicted as $<10^{-12}$. Each TM trait should work in a balance with the primary trait. Where the primary gene provides too strong an advantage to a weed, or when crop rotations are problematic, as in paddy rice, it might be necessary to have more than one TM trait in a construct.

TM genes deleterious to cultivated rice

In a more complex strategy, TM genes can be used that are deleterious to the rice crop, but only in cases where homeologous recombination is required, i.e. where the weedy rices are non AA. In such a gene scenario the TM construct causing prostrate growth and high shooting could be used (Zhu et al., 1995). The first progeny then would be worthless prostrate, heavily-tillered rice. One then would further transform the rice with a repressor for this TM gene and then map the transgenes and use those where the repressor did not integrate to the same chromosome as the TM gene. A modified virescent 1 (V-1) gene from rice (Kusumi et al., 1997), which causes severe chlorosis, with a suitable specific repressor on a different chromosome might also be a suitable pair. A weed introgressing the TM trait would be likely to do so without the repressor, and the derepressed TM trait would do its deleterious duty. This solution would also be useful for AABBDD hexaploid wheats and BBCC oilseed rape where both the TM trait and the repressor are not on chromosome sets that are homologous with that of related weeds.

What TM genes are available for transformation?

Some potential genes for TM traits exist only as named heritable traits, others are mapped to positions on chromosomes, and a few are characterized as sequenced genes. Thus, not all TM traits are immediately available for insertion in tandem constructs. As TM genes have been given a value, they might be rapidly sought, especially with the availability of transposon tagging for fishing. Enough genes are presently available to test the TM concept.

An interim solution to the paucity of genes is to select transformants that have the primary gene inserted to a point in close linkage with a TM trait. Many of these TM traits are already mapped in major crops, such as dormancy in rice (Wan et al., 1997; Lin et al., 1998). The closer the linkage distance, the less the likelihood of segregation. Rice has a few known mapped chromosomal blocks of such "domesticated" genes as has been demonstrated in crosses with *O. rufipogon* (Xiong et al., 1999). When technologies are available for site-specific insertion of genes into chromosomes, the primary genes could be targeted close to such natural TM genes.

Secondary dormancy. While the genetics of secondary dormancy have been described, it is not clear which genes actually control it (Khan, 1997). The lack of dormancy is dominant in important weeds (Foley and Fennemore, 1998). This would be positive in related domestic species, but would convert the wild weed into a less fit weed. *Arabidopsis*, the typical source for genes, has already been sufficiently domesticated that it is unlike cruciferous weeds; the lab strains no longer have strong secondary dormancy (Van der Schaar et al., 1997). An *Arabidopsis* mutant that is insensitive to the senescence hormone abscisic acid lacks secondary dormancy (Steber et al., 1998). Perhaps a way to find more genes is to use the genetic differences between wild *Arabidopsis* strains and the lab strains presently used, as is being done in other instances (Aukerman et al., 1997).

Much has been published on the physiology of secondary dormancy and how its causes vary among species (Khan, 1997). It can be due to impervious seed coats or inhibitors in the seed. Clearly more basic mechanistic research must be performed with rice and wild rices before the "abolish secondary dormancy" TM genes are isolated. Anti ABA chemicals break secondary dormancy in barley embryos (Wang et al. 1998a), so there is reason to believe that genes in the pathway, correctly engineered, would do the same in rice. Propionic acid breaks dormancy in rice (Footitt et al., 1995) suggesting that introducing genes to produce this metabolite in seeds would act as anti-dormancy genes.

Shattering. Seed shattering is lessened when there is uniform ripening. The hormonology of the abscission zone controls whether shattering will occur and possibly cytokinin overproduction will delay shattering. Sorghum QTLs control shattering (Paterson et al., 1995). As with secondary dormancy, no sequenced genes are available. When anti-shattering is used as a trait, the use of certified, or weed-free seed is imperative for replanting. Surviving intermediate (hybrid) *O. sativa* x *O. rufipogon* types often lack shattering, and when they remain, further hybridization occurs (Majumder et al. 1997).

Stature limitation.

Dwarfing is desirable in grain crops, increasing harvest index by having less stem and more seed. Many genes are known that could control height.

Gibberellins. Preventing the biosyntheses of gibberellin hormones reduces height. The genetic relationships between some dwarfing genes and gibberellin biosyntheses have been elucidated (Webb et al., 1998). The chemical dwarfing agents that are commercially used to dwarf wheat and prevent lodging inhibit gibberellin biosynthesis. The enzymes and genes controlling various steps in gibberellin biosyntheses are also known. Copalyl diphosphate synthase, *ent*-kaurene synthase, and *ent*-kaurene oxidase are responsible for early stages in the biosynthesis of all gibberellins (Smith et al., 1998; Hedden and Kamiya, 1997; Lange, 1998; Helliwell et al., 1998). *Arabidopsis* mutations in these genes are dwarfed, with dwarfing reversible by gibberellin treatment. Over-expression of a gene coding for *ent*-kaurene synthase, causing co-suppression mimicked the mutant phenotype. Some of these genes

have been isolated (Kusaba et al., 1998). Suppressive overexpression of the rice homeobox gene OSH1 controlling GA20 oxidase dwarfed tobacco (Kusaba et al., 1998), so there is reason to believe it would do the same in rice. It has also been possible to dwarf rice by introducing a gene construct that prevents recognition of gibberellic acid (Peng et al., 1999).

Brassinosteroids. These hormones cause stem elongation in many species, and their absence results in dwarf plants. A specific 22 □-hydroxylase cytochrome P450 controls steps in brassinosteroid biosynthesis (Choe et al., 1998), and plants missing the enzyme are dwarfed. Additionally, co-suppressive overexpression of a sterol C24-methyl transferase in the pathway also causes dwarfing (Schaller et al., 1998).

Antidwarfing. For deep water rice, one could envisage putting a dwarfing gene in the TM construct and a repressor on a different chromosome. If the gene introgressed (without suppressor) to a weedy rice, its growth rate will be reduced, further preventing competition due to the known slower growth rate (Maesako et al., 1995).

Shade avoidance. Various forms of the pigment phytochrome interact, detecting whether a plant is shaded, leading to stem elongation (Aukerman et al., 1997; Devlin et al., 1998; Smith et al., 1997; Torii et al., 1998). The engineering of suppressive overexpression constructs of one of these phytochromes led to plants that did not elongate when shaded (Robson et al., 1996). Much of the gene isolation has been from rice, yet the suppressive overexpression was active in dwarfing tobacco (Robson et al., 1996). Rice phytochrome genes are continuously being isolated (Emmler et al., 1995; 1996; Emmler and Schäfer, 1997). Oat phytochrome was also active in dwarfing rice (Clough et al., 1995).

Regulatory considerations

One of the greatest advantages of transgenic herbicide-resistant rice is that closely related weedy rices can be controlled. Crosses between transgenic glufosinate resistant domestic rice and red rice yielded resistant F_1 and F_2 offspring (Sankula et al., 1998). The progeny had greater shattering and dormancy (Lindscombe et al., 1998), insuring that they would be fixed in the population. This increase in weediness was expected, yet would have been prevented if TM traits had been added in tandem constructs. Thus, one wonders at the desire to rapidly bring such varieties to "non-regulated" status, and to release glufosinate-resistant transgenic rice varieties (Van Wert, 1998), as is presently under consideration by US regulatory authorities (Anonymous, 1999). There is also already widespread field testing of transgenic glyphosate and imidazolinone resistant varieties, as well as rices bearing other traits.

Should there be a regulatory-mandated delay in allowing the use of single primary genes, without failsafes or TM genes in situations where there is a strong risk of introgression? Should such decisions on delay be voluntary? My view is to paraphrase of a sign about playing of radios in the Edinburgh zoo: "Considerate biotechnologists will not release primary genes without failsafes; others may not" in high risk cases.

Acknowledgements

The invitation of the Weed Science Society of the Philippines to prepare and present this paper and the opportunity they provided to learn more about rice is deeply appreciated. Discussions with many weed and rice specialists, especially Drs. Aurora Baltazar, Alan Watson and Darshan S. Brar were of utmost importance. The

author's research on evaluating introgression of traits from transgenic crops to weeds is supported by an EU INCO grant. The author is the Gilbert de Botton professor of plant sciences.

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Table 1. Genes field tested in transgenic rice in the U.S.A. (excluding markers)

Type of gene Gene	*Type of gene* Gene
Herbicide resistance	*Pharmaceuticals*
glufosinate	Aminoglycoside 3'-adenyltransferase
imidazolinone	Antithrombin
glyphosate	Serum albumin
Pathogen resistance	Antitrypsin
chitinase + [glucanase]	
hygromycin resistance	*Seed characters*
receptor kinase	pea & rice storage proteins
Insect Resistance	starch synthase
Cry1A (a) Lepidopteran	
CryIIIA – Coleopteran	

Source: Compiled from "Environmental releases in the U.S.A. (http://www.nbiap.vt.edu/cfdocs/fieldtests1.cfm)

Table 2. Asian species belonging to the genus *Oryza*

Species[1]	Number of chromosomes[2]	Genome[2]	Weediness[3]
Section Oryzae			
[*O. sativa* complex]			
O. sativa L	24	AA	Cultivated
O. sativa **L (red strains)**	**24**	**AA**	**Major weedy**
O. nivara Sharma et Shastry	24	AA	
O. rufipogon Griff.	**24**	**AA**	**Major weedy**
O. longistaminata A. Chev. et Roehr.	**24**	**A^LA^L**	
[*O. officinalis* complex]			
O. officinalis Wall. ex Watt	**24**	**CC**	**Major weedy**
O. minuta Presl. et Presl.	**48**	**BBCC**	
O. eichingeri Peter	24	CC	
O. rhizomatis Vaughan	24	CC	
O. malampuzhaensis		BBCC	
Section Granulatae			
[*O. meyeriana* complex]			
O. meyeriana Baill.	24	GG	
O. granulata Nees et Arn. ex Watt	**24**	**GG**	
Section Ridleyanae			
[*O. ridleyi* complex]			
O. ridleyi Hook.f.	**48**	**HHJJ**	
O. longiglumis Jansen	48	HHJJ	

[1]Species in **bold** have been used to introgress genes in to domestic rice (Brar and Khush, 1997), suggesting that transgenes could be introgressed in the reverse direction.
[2]Compiled from Morishima, 1984; Vaughan, 1994; Aggarwal et al., 1997; Khush, 1997; Kaushal and Ravi,1998.
[3] Compiled from Holm et al. (1997).

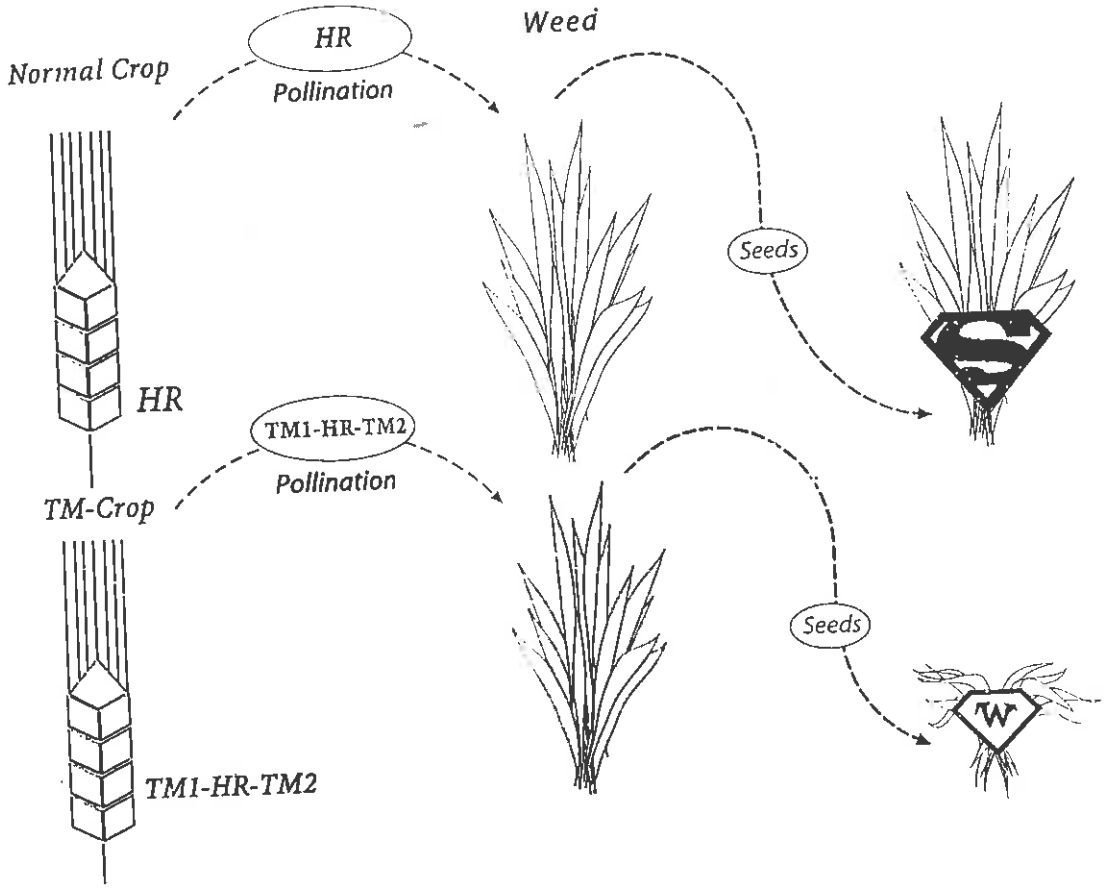


Figure 1. Comparison of current and TM technology. In the current technology, on the rare occasions that transgenic rice pollen (e.g. conferring herbicide resistance, insect resistance, etc.) reaches and fertilizes a live, rice weed, there can be some offspring bearing the trait, the proverbial 'superweed'. In the TM technology, the gene conferring the desired trait) is flanked in a tandem construct by TM (transgenetic mitigator) genes that are positive or neutral to rice, but deleterious to the weedy rice spp. Fertilization of related weedy rices with such pollen will give rise to offspring that are herbicide resistant, but are also non-competitive wimps.

HERBICIDE MODES OF ACTION, RECENT PROGRESS AND NEW CHALLENGES

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Abstract: By physiological and biochemical approaches, the fifteen or so molecular target sites of commercial herbicides have been identified. In the herbicide discovery in the last decade, two target sites, namely protoporphyrinogen oxidase (Protox) and acetolactate synthase (ALS) are dominating the mode of action of new herbicides. Recent studies further suggest several new possible target sites e.g. geranylgeranyl diphosphate synthase, glutamate dehydrogenase and auxin transport. Novel modes of action of herbicide offer additional tools to combat the evolution of resistance to currently available herbicides and alternatives to herbicides to which resistance has already evolved. Identification of new target sites also enables modification of crop resistance to herbicides through recombinant techniques. Therefore, considerable effort is now going into discovery of new molecular sites. To shorten the time scale for herbicide discovery, incorporation of the high throughput screening (HTS) strategies has been attempted. Selectivity of new herbicidal molecules has also become increasingly important in recent years. Although absorption, translocation of herbicides and sensitivity at target sites are involved in the selectivity mechanism in some cases, the selectivity of the majority of herbicide groups is defined by differential metabolism between plant species. The studies of the selectivity mechanisms for currently used and some of those under development show that metabolism by glutathione transferases (GSTs) and cytochrome P450 monooxygenases (P450s) account for the selectivity. Investigation on these herbicide-detoxifying enzymes may lead to discovery of novel herbicides.

Key words: herbicide modes of action, herbicide target sites, high throughput screening, glutathione transferases, cytochrome P450 monooxygenases

Introduction

In the past 50 years starting with the introduction of 2, 4-D, agrochemical industries have successfully introduced a wide array of selective herbicides. Herbicides are important components of agricultural production systems in Asian countries and the present weed management in major crops mostly depend on selective herbicides. By the repeated use of herbicides with the same mode of action, however, herbicide-resistant weeds have evolved. Development of herbicide resistance within existing weed populations and shifts in weed populations due to herbicide use and cultural practices have provided important stimulus to the search for new herbicides. Novel modes of action of herbicide offer additional tools to combat the evolution of resistance to currently available herbicides and alternatives to herbicides to which resistance has already evolved. Herbicidal compounds in the future should be more effective at lower rates, less toxic to other organisms, controllable resistant weeds, and less prone to cause environmental problems. This short paper briefly review recent trends in new herbicide mode of action and selectivity, and summarize some of attempts in herbicide discovery.

Established herbicide target sites and recent progress

Herbicide discover research has been primarily based on traditional random screening for phytotoxicity and crop selectivity at the whole-plant level. Random screening of compounds has resulted in the discovery of many herbicidal compounds with diverse mode of action. Interestingly, the herbicides found by random screening are known to act through blocking a relatively limited number of biochemical processes of plants irrespective of their diverse chemical structures. To date, only the fifteen or so molecular target sites have been identified for commercial herbicides (Table 1) and mode of action of the majority of them have been well-defined. In the herbicide discovery in the last decade, two target sites, namely protoporphyrinogen oxidase (Protox) and acetolactate synthase (ALS) are dominating the mode of action of new herbicides. The investigation of the sulfonylurea group is the major factor contributing to the number of new ALS inhibitors, whereas the susceptibility of Protox to a variety of chemical classes of chemicals led to discovery of many new herbicides. Remarkable achievement in the mode of action

Table 1. The molecular modes of action of herbicides

Physiological site	Molecular target	Herbicide family	Representative herbicide
Photosynthesis			
Electron transport(PSII)	D1 protein	Triazines	atrazine, simazine, prometryne
		Triazinones	metribuzin
		Uracils	lenacil, terbacil
		Ureas	diuron , linuron, chlortoluron
		Amides	propanil
Electron transport (PSI)	Electron diversion from photosystem I	Bipiridyliums	paraquat, diquat
Pigment synthesis			
Tetrapyrrole synthesis	Protoporphyrinogen oxidase	Diphenyl ethers	acifluorfen, fomesafen, lactofen
		N-phenylphthalimides	flumiclorac
		Oxadiazoles	oxadaizon
		Triazolinones	sulfentrazone
		Triazolopyridinones	azafenidin
Carotenoids synthesis	Phytoene desaturase	Pyridazinones	norflurazon
		Nicotineanilide	diflufenican
		Others	fluridone
Plastoquinone synthesis	4-Hydroxyphenyl-pyruvate dioxygenase	Triketones	sulcotrione
		Isoxazoles	isoxaflutole
		Pyrazole	pyrazolate, pyrazoxyfen
Amino acid synthesis			
Aromatic amino acids	EPSP synthase	Glycines	glyphosate, sulfosate
Branched chain amino acids	Acetolactate synthase	Sulfonylureas	chlorsulfuron, besulfuron-methyl
		Imidazolinones	imazapyr, imazaquin
		Triazolopyrimidines	flumetsuram
		Primidinylthiobenzoates	pyrithiobac, bispyribac
Nitrogen assimilation	Phosphinic acids	Glutamine synthetase	glufosinate
Lipid synthesis			
Fatty acid synthesis	Acetyl-CoA carboxylase	Aryloxyphenoxypropionates	diclofop, fluazifop
		Cyclohexanediones	clethodim, sethoxydim
Fatty acid elongation	Unknown	Thiocarbamates	EPTC, molinate, thiobencarb
Cell division			
Mitosis disruption (microtubule assembly)	β-Tubulin	Dinitroanilines	benefin, oryzalin, trifluralin
		Phosphoric amides	amiprophos-methyl, butamiphos
		Pyridazines	dithiopyr
Mitosis disruption (microtubule organizing center)		Carbamates	chloropropham, propham
Unknown	Unknown	Chloroacetamides	alachlor, butachlor, pretilachlor
		Acetamides	diphenamid
		Oxyacetamides	mefenacet
		Tetrazolinones	fentrazamide
Cell wall formation			
Cell wall synthesis	Cellulose synthase	Niriles	dicrobenil
	Cellulose synthase?	Benzamide	isoxaben
Vitamin synthesis			
folate synthesis	dihydropteroate synthase	Carbamates	asulam
Auxinic action			
Synthetic auxins	(same site with IAA)	Phenoxys	2,4-D, MCPA, clomeprop
		Benzoic acids	dicamba
		Carboxylic acids	clopyralid, pycloram, trichlopyr
		Quinoline carboxylic acid	quinclorac, quinmerac
		Others	benazolin-ethyl
Membrane function			
membrane disruption	(uncoupling)	Dinitrophenols	dinoseb

studies in the last decade was identification of 4-hydroxyphenylpyruvate dioxygenase (4-HPPD) as a new target site (Ellis et al., 1995).

Novel herbicide target sites and high throughput screening

Recently, several new possible target sites for novel herbicides have been reported (Table 2). Some of these new targets are in the metabolic pathways that were not previously targets of herbicides. These findings indicate that the discovery of new target sites which are different with currently available herbicides is highly practicable. These chemicals also provide plant scientists with new tools with which to explore the physiological, biochemical, and molecular dimensions of plant systems. Identification of new target sites also enables modification of crop resistance to herbicides through recombinant techniques. However, we still do not know enough about the properties of vulnerable target sites in plants. Theoretically, all genes in plants are potential targets. The challenge is to identify if any of plant genes possesses the the characteristics necessary to cause phytotoxic effects.

To shorten the time scale for herbicide discovery, the current trend in discovering new active compounds is the incorporation of high throughout screening (HTS) strategies in the processes. Because the ability to test large numbers of compounds quickly and efficiently can provide a competitive advantage, HTS systems both *in vivo* and *in vitro* have become a key tool in many agrochemical industries (Major, 1998). HTS systems are subject to economic constraints and must have short analysis times per samples. In recent years, major efforts have been undertaken in miniaturization, parallelization, and automation of screening technologies, as well as in the development of new homogeneous assays and the integration of highly sensitive and rapid detection devices. To achieve the necessary productivity, effective integration of compound supply, assay operation and data management is essential. The next step in the HTS is to identify more targets and develop simple assay systems for a larger number of targets.

Table 2. New possible target sites of novel herbicides.

Target enzyme (or Site)	Metabolic Pathway	Chemicals	Reference
Dethiobiotin synthetase	Vitamin (biotin) synthesis	7,8-diamino-pelargonic acid	Rendina et al. (1999)
Geranylgeranyl diphosphate synthase	Terpenoid synthesis	bisphosphonates	Oberhauser et al. (1998)
Anthranilate synthase	Aromatic synthesis	6-methyl anthranilate	Siehl et al. (1997)
Imidazoleglycerolphosphate dehydratase	Histidine synthesis	triazole phosphonates	Ohta et al. (1997) Cox et al. (1997)
Auxin transport (efflux)		semicarbazone	Subramanian et al. (1997)
Lycopene β-cyclase	Carotenoids synthesis	2-(4-methylphenoxy-triethylamine	Schnurr et al. (1998)
Glutamate dehydrogenase	NH4+ assimilation	glyphosate, maleic hydrazide	Osuji et al. (1997)

Importance of glutathione transferases and cytochrome P450 monooxygenases in herbicide selectivity

Selectivity of new herbicidal molecules has also become increasingly important in recent years. Although absorption, translocation of herbicides and sensitivity at target sites are involved in the selectivity mechanism in some cases, the selectivity based upon differential herbicide metabolism by tolerant crops compared with susceptible weeds is the basis for the majority of herbicide groups. At present, differential metabolism is the most important mechanism of the selectivity and will remain important to new herbicide discovery. In the herbicide metabolism in plants, glutathione transferases (GSTs) and cytochrome P450 monooxygenases (P450s) are the most significant enzyme systems.

GSTs are mostly cytosolic enzymes which catalyze nucleophilic substitution reactions between GSH and electrophillic compounds. The specificity of GSTs for herbicides is relatively low, GSTs having a wide and overlapping ability to bind chemicals of diverse structures and physical chemical properties. GSTs in crops are important in detoxifying major classes herbicides, including chloro-*s*-triazines, chloroacetanilides, sulfoxide derivatives of thiocarbamates, diphenyl ethers and several aryloxyphenoxy-propionate and sulfonylurea herbicides. Therefore, glutathione conjugation mediated by GSTs has a crucial role in the selectivity of these herbicides. The first plant GSTs to be studied intensively was isolated from *Sorghum*. It was shown that the enzyme is responsible for the tolerance of the plant to the herbicide atrazine. Because of their importance in herbicide tolerance, many more GSTs have now been isolated and characterized. Furthermore, metabolism-based assay system to measure the reactivity of herbicidal compounds with glutathione (GSH) has been developed, and structure-activity and structure-reactivity relationship has been explored (Clarke et al., 1998).

Table 3. P450s-dependent metabolism of herbicides.

Herbicide family	Herbicide	Plant	Reference
Aryloxyphenoxypropionate	diclofop	wheat	Zimmerlin and Durst (1992) Frear et al. (1991) Zimmerlin and Durst (1990) McFadden et al (1989) McFadden et al. (1990)
Benzothiadiazole	bentazon	maize soybean sorghum	Leah et al. (1991) Burton and Maness (1992) Moreland and Corbin (1991)
Substituted urea	linuron	rice, sorghum, maize wheat	Haack and Balke (1994) Frear (1995) Frear et al. (1991) Moreland et al. (1993)
	chlortoluron	maize maize wheat	Fonne-Pfister and Kreuz (1990) Mougin et al. (1990) Barret (1995)
Sulfonylurea	chlorimuron	maize	Polge and Barret (1995) Barret (1995)
	nicosulfuron primisulfuron	maize maize	Moreland et al. (1993) Fonne-Pfister et al. (1990)
Triazolopyrimidine	flumetsuram	barley, maize, wheat	Frear et al. (1993)

P450 enzymes are membrane (endoplasmic reticulum)-bound heme-thiolate containing oxidases. In higher plants, the enzymes perform an exceptionally wide range of functions, including the biosynthes is of primary metabolites necessary for normal growth and development, the biosynthesis of secondary products, and the catabolism of xenobiotics. Despite their importance, progress in assigning enzymatic function to individual P450 gene products has been slow. P450s also play an important role in the oxidative metabolism of herbicides. P450-dependent oxidation of herbicides in plant microsomes has been reported with many herbicides in major crops (Table 3). Although a wide variety of the metabolic reactions can be catalyzed by P450s, reactions with herbicides most often involve aromatic or alkyl hydroxylations and *O*, *N*-dealkylations. The importance of the P450s to the herbicide tolerance was emphasized by finding that inhibition of the activity by organophosphate insecticides resulted in crop injury. Current genome analysis suggests that *Arabidopsis thaliana* has more than 200 P450 genes. Some of the P450 genes have now been isolated from different sources, expressed in yeast and supplied for searching new inhibitors (Schalk et al., 1997).

Given the importance of GSTs and P450s in the herbicides metabolism and selectivity, it is apparent that a greater knowledge of these enzyme systems will increase our understanding of how the selective metabolism is achieved. Accumulated knowledge may help develop new selective herbicides.

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ON ECOLOGICAL ISSUES IN THE DEVELOPMENT OF SUSTAINABLE WEED MANAGEMENT

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Abstract: Ecological studies underpin the evaluation of new and improved methods of weed management. This paper selectively comments on the respective roles of studies of theoretical population dynamics, mechanisms of crop-weed interactions, description of multi-species interactions and environmental impact analysis for sustainable weed management. It is argued that all four topics need to be studied to ensure quantitative mechanistic understanding for the design of rational integrated weed management strategies.

Key words: population dynamics, integrated weed management, competition.

Introduction

In 1997, Blacklow concluded that the assertion that weed management systems were sustainable[1] had an equivocal answer for both low and high technology based agricultural systems. Whilst debate over agricultural sustainability, both in definition and assessment, is not new (Dahlberg, 1998), it has been cast into sharper focus with the advent and increasing use of transgenic crops (James, 1998). Meanwhile there have been increasing calls for reduced reliance on chemical weed control and improved integration of control technologies that maximize the contribution of cultural practices in weed management (Jackson, 1997).

The concept of integrated weed management[2] (IWM) is not new (Buchanan, 1976) but research towards its application is much more recent. In part, this is because factors such as the evolution of herbicide resistance (Powles and Holtum, 1994), environmental concerns over chemical residues in agricultural produce and the environment (Crosby, 1996) and the occurrence of intransigent weeds have not always been considered to be significant factors contributing to a lack of sustainability. Indeed acceptance that technologies for weed management will inevitably improve has been a *sine qua non* (Ghersa *et al.*, 1994) and is seen by many as reaching a new apogee with biotechnological development of herbicide resistant crops. Hence the need to develop integrated weed management practices is posited to be of lessening relevance. Such an assertion however ignores the context-specific nature of weed management and the breadth of the original definition of IWM (Buchanan, 1976). For example, Akobundo (1997) points out that weed management strategies for low input systems and in lesser developed countries should primarily be aimed at minimizing the enormous variation seen within individual crop production systems by improving use of existing technologies. Conversely in a high input system using a herbicide resistant crop, much less concern is being placed on production *per se* and more on the perceived and actual risks of using transgenic plants, for both food products and environmental impacts. As Blacklow (1997) concluded, societies must assess the appropriateness of particular technologies for weed control because of legitimate concerns over environmental quality and resource use. Moreover, the fallacy of assuming that rapid transference of 'high-input packaged' solutions will easily solve agricultural problems of lesser developed countries is well established (Richards, 1985). As the global community increasingly questions how necessary increases in food production may be achieved in high to low input systems, central to the evaluative process is an understanding of a) the dynamics of weed-crop interactions under management and b) off-site impacts of weed control on the environment. Both raise questions which, whilst different, are fundamentally ecological.

The ultimate arbiter in the choice of a weed management system at the farm level is economics, with the goal of profit maximization, but 'profit' for farmers in low-input systems and in developing countries is rarely equated solely to monetary terms. In these cases, weed management systems with the greatest potential for maintaining productivity will also provide ground cover, livestock food, and return

[1] *Sensu* the ability to maintain crop yield indefinitely in the face of weed interference using present agricultural activities and lifestyles (following Blacklow, 1997).

[2] Integrated weed management is the deliberate selection, integration and implementation of effective weed control measures with due consideration of economic, ecological and sociological consequences (Buchanan, 1976).

organic matter to contribute to soil fertility (Akobundo, 1997). In high-input systems, the inability to achieve *total* weed control to date and diminishing marginal rates of return with imperfect technologies excludes using eradication as an achievable general farm policy (Auld and Tisdell 1987). This leaves control of weeds to 'acceptable' levels as the sole alternative. The manner in which it is achieved is important. Weed management in combination with agronomy is a strong agent of inter-specific and inter-genotypic selection resulting in weed species shifts and herbicide resistance evolution respectively (Mortimer and Hill, 1999). Reduced environmental quality due to control practices is another concern. The design of sustainable weed management systems therefore needs to be underpinned by sound ecological and evolutionary theory (Cousens and Mortimer, 1995; Jordan and Jannink, 1997).

Ecological contributions to the design of integrated weed management

Integrated weed management combines direct weed control interventions (e.g. hand weeding, herbicides) with indirect ones arising from agronomic practices designed to achieve a high yielding crop (e.g. cultivar, time of sowing, seeding rate, nutrient management etc.). Assessment of the contribution of any one weed management component involves comparative analysis of its effect on yield loss and weed population growth rate on the one hand, and the environmental impact of its use on the other. If component practices in IWM are to be considered sustainable, arguably they must be evaluated in relation to criteria illustrated in Table 1.

Table 1. Questions in an appraisal of components of an integrated weed management program.

Does the component significantly contribute to

- arresting the development of weed abundance (biomass) to reduce weed interference with crop yield?
- prohibiting succession / species substitution in the composition of the weed flora?
- preventing change in genetic structure of the target species?
- achieving weed management in an environmentally acceptable manner?
- improving farmer income and overall pest management at the farm level?
- adopting socially acceptable practices that are appropriate to 'end-user' communities?

At first sight, advocacy of such a reductionist approach is questionable for a number of reasons. Among these are: a) disentangling interactions amongst management factors is an immense experimental task, b) for many crops the causes of between and within seasonal variation in both the size of a weed population and associated yield loss remain poorly understood; and c) off-site impacts of control practices have rarely been fully evaluated. However, crop agronomy broadly defines the habitat in which a weed species will tend to persist and the farmer's choice of available control options usually comprises a set, prescribed by socio-economic circumstances and the cropping system itself. Cousens and Mortimer (1995) therefore argued that it was the role of the weed scientist to test innovations within farm weed management systems rather than to expect to initiate wholesale changes in farming systems. In this respect, ecological and evolutionary analyses provide conceptual and analytical tools for the evaluation of IWM, the design of decision support systems for weed management, and for regulatory oversight and policy making. In this paper we briefly illustrate these at four levels: theoretical population dynamics, crop weed interactions, multi-species responses and environmental impact analysis.

Single species population dynamics

To some, theoretical studies in weed management often appear to have little practical relevance to weed control. Yet an understanding of the dynamics of weed populations experiencing control is essential if weed management practices are to be rational (bio-economic) and decision support systems strategically sound. Theoretical studies concentrate upon single species analyses because of the analytical complexities in modeling multiple species interactions. Population modeling approaches have been reviewed recently by Kropff and Bastiaans (1997) and debate continues over the utility of thresholds and the incorporation of control functions. Wallinga and Oijen (1997) showed that decision making based upon a discrete choice of threshold (e.g., spray if 'x' weeds/m^2 are present) applied in successive seasons generated quasi-periodic or 'chaotic' weed population dynamics. In other words, if weed control is only exerted when a threshold is exceeded in any given season, then future sizes of the weed population are bounded above and below the threshold but oscillate within these bounds in an aperiodic (unpredictable) manner. Two conclusions follow. Firstly, when this analysis is applied to grass weed populations, where

the dynamics are reasonably well known (e.g., *Avena fatua* L.) and control is implemented at a fixed threshold (e.g., 4 plants/m^2), fluctuation in densities in the range of 1 to 12 plants are predicted. Such variation will in turn be reflected in significant yield losses in most cereal crops given the sharp decline in yield that is a common response to an increasing grass weed infestation. The same conclusion applies when an economic optimum threshold is applied. Secondly, the frequency of weed control in the long term is independent of the threshold, and aperiodic dynamics generate uncertainty about the frequency and costs of future control. The important managerial conclusion is that, whilst economic thresholds are of use for cost-effective weed control on a single season basis, the underlying concept of economic thresholds does not provide a basis for rational use of weed control measures in the long term.

Theoretical analysis of the impact of a single weed control intervention can also be revealing (e.g., a post-emergence herbicide for the long-term control of a major (noxious) weed). Wallinga (1998) defined the critical kill rate as the lowest kill rate that prevented weed population increase and linked this, through the dose response relationship, to a critical dose of a post-emergence herbicide required in a single application to achieve this kill. Subsequent bio-economic analysis, using a discrete generation population model in a case study, showed that the rational long-term herbicide use (dose averaged over many years that maximised profit) was primarily determined by two factors: herbicide efficacy and critical kill rate. Of much lesser importance were the planning horizon for weed control, the response of crop yield to weed density, and crop and herbicide prices. Interestingly the analysis highlighted that weed interference with crop growth (*sensu* crop tolerance, Jordan, 1993) had little effect on rational long-term herbicide use, whereas crop interference with weed population growth (weed suppression), reduced the critical kill rate (by lowering overall weed population growth rate) and thus influenced herbicide use.

Both of these ecological modeling approaches illustrate the manner in which generalities can be drawn about the sustainability of weed management practices. Pandey and Medd (1991) have developed them further in relation to risk aversion and stochastic population processes. Whilst open to criticism over implicit assumptions, theoretical analyses of this type contribute to priority setting of research objectives for weed management.

Crop-weed interactions

The goal of IWM within a single cropping season is to adapt management practices to increase the suppressive ability of crops and to decrease that of weeds, which involves cultural as well as chemical factors. Interspecific competition is inherently a dynamic process. Despite this, most of the voluminous amount of research on interspecific competition has not focused on understanding these mechanistic responses. For example, common objectives have been to quantify crop yield losses to weeds or to measure critical weed-free periods. Such studies have resulted in empirical descriptions of yield loss-weed density relationships (e.g. Lindquist *et al.*, 1999) and of time density equivalents (Berti *et al.*, 1995) that are characteristically trial-dependent and often have low predictive power. Beyond identifying weed emergence time as a key factor in competitive outcomes, empirical studies have added little to our mechanistic understanding of seasonal variation in competitive outcomes or the role of management practices in manipulating competition. For some (perhaps many) crop systems it is arguable whether the relevant competitive processes have been identified yet (e.g., Gibson et al., 1999).

Mathematical simulation models of crop-weed interactions (e.g., Kropff and van Laar, 1993) have been developed to address some of these limitations. These models vary in the degree of mechanistic description, and hence robustness and ability to untangle complex interactions. They also vary in the extent to which calibration (e.g. site, cultivar, weed species) is necessary, reflecting the trend to date to develop general crop models and apply them to many areas of agricultural production. Recent attempts to develop more mechanistic and management-oriented models (e.g. Caton *et al*, 1999ab), however, confirm that lack of understanding of crop-weed interactions and dependence on semi-empirical models continue to limit model usefulness for IWM analyses.

These issues are illustrated well using recent research on increasing crop competitive ability (e.g., Callaway, 1992; Jordan, 1993; Pester *et al.*, 1999). For practical purposes in breeding, selectable, non-aggregated growth traits, such as specific leaf area rather than leaf area index, need to be identified. Varietal field trials often reveal differences in competitiveness (Callaway, 1992) but are less successful at identifying the operative traits because those vary with crop, cultural practices, and weed densities (Pester *et al.*, 1999). Moreover, two simulation analyses of competitiveness in rice, the only examples to our knowledge, have indicated that models are not yet mechanistic enough to produce robust results (Bastiaans *et al.*, 1997; Caton *et al.*, 1999c). Thus, identifying released cultivars that are more competitive for use in weed management seems feasible at present but breeding programs for crop competitiveness are not yet possible. Overall, then, it seems clear that identification of important crop-weed interactive

processes has been good but researchers do not yet fully understand those processes or utilize their potential to contribute to weed management programs. Both of these will require more ecological, mechanistic approaches.

Multi-species interactions

Well-known responses to weed management are changes in weed community composition (weed species shifts) and the selection of species well adapted to particular crops and cropping systems. Weed species shifts are often most dramatic when there is a major change in crop establishment method (e.g. transplanted to direct seeded rice, deep ploughing to minimum tillage in cereals) and in response to serial use of a chemical class of herbicides. Understanding the factors that drive weed species shifts is important since a sustainable weed management system will prohibit weed species replacement. Rotation (e.g. crops, or herbicide class) or amalgamation of weed control tactics is the primary underlying management method. More often than not however, changes in tactics occur when farmers note that a new weed community or species has become damaging; they are not always planned proactively within a long term management system. Accurately predicting weed community responses to changes in weed management and cropping systems requires not only knowledge of individual species biology and ecology and but also of fitness components in species assemblages, particularly those for seedling recruitment, plant survival and fecundity. Empirical field studies are only the first step in seeking correlations of relative weed abundance with management practices. Multivariate ecological analysis techniques are also well suited to initial description of community changes and hypothesis generation with regard to potential mechanisms determining change in species abundance. Thereafter, studies isolating relevant system characteristics or management factors can be done (e.g., Légère and Samson, 1999).

A further case can be made for detailed ecological studies of individual weed species in selected cases. In well-developed weed management systems, especially those using herbicides, weed communities are often reduced to a dozen or fewer abundant species. Control of these intransigent weeds requires action(s) beyond the normal practices that control most weeds, without risking the level of control already achieved. For these species more detailed ecological studies may identify weaknesses (i.e., "Achilles' heels") in their life histories that could be exploited in management. Certainly this approach has led to 1) an understanding of the reasons why *Lolium rigidum* L. has become a particularly noxious weed in Australia in its evolution of resistance to herbicides, and 2) the implementation of novel control strategies (Cousens and Mortimer, 1995).

Environmental impact

Agricultural production has traditionally depended upon the management of resource inputs (e.g. pesticides, fertilizers) which selectively maximize plant growth. These perturbations to the cropped environment may lead to unwanted and diverse off-site effects. Therefore a need exists to develop methodologies for regulatory oversight that incorporate rational and objective decision making. Moreover, assessing risks and benefits of weed management strategies increasingly involves ethical considerations. Cost-benefit analysis of trade-offs between high productivity and environmental quality are often complex and ultimately involve a value judgement by policy makers on behalf of society. Monitoring herbicide usage and studying the metabolic decomposition and fates of herbicides are essential since the costs of a change in policy to ensure environmental protection may be very large. For example, Hill *et al.* (1997) point out that over US$600,000 was expended in cost share assistance alone to implement water recovery systems in Californian rice production to eliminate molinate and thiobencarb pollution of drinking water. In rice farming in Asia, the intimacy of rice and fish farming, and the multiple uses of water place evaluation of the role of herbicides in a particular ecosystem and human heath context. Predicting the ecological effects of herbicides however extends beyond conventional eco-toxicological testing. Pratt *et al.* (1997) point out that individual laboratory bioassays provide limited insight into biological interactions that are important in sustaining ecosystems, then illustrate experimental approaches and methodologies through microcosm analysis. In particular they highlighted the technical importance of considering the effects of low levels of herbicides on ecosystem functioning, especially in aquatic systems.

Ten years ago Tiedje *et al.* (1989) outlined in considerable detail the ecological considerations and recommendations for the planned introduction of genetically modified organisms. More recently Gressel and Rotteveel (1999) proposed using decision trees to rank the relative importance of ecological and evolutionary concerns to aid risk assessment for herbicide resistant transgenic plants. It is now clear that early arguments about the extent to which gene flow between transgenic introductions and wild relatives may occur are of lesser importance (Squire *et al.*, 1999) than considerations of the safeguards or

mitigatory steps that need to be in place anticipating that the engineered trait will escape. Safeguards may be regulatory but biological security is clearly preferable. In addition to genetic sterility barriers, or as alternatives, Gressel (1999) proposed transgenic mitigation traits that are transferred as linked genes to confer reduced fitness in the recipient wild relative. Others (e.g., Seefeldt *et al.* 1999) point to the use of cultural practices to limit the spread of hybrids, such as crop competitiveness and fallow management. Both instances point to the need to understand the ecology of both volunteer crops and weeds to fully understand the potential environmental impacts of transgene outcrossing.

Concluding remarks

Table 1 contains a broader set of issues than can be fully discussed in this paper and we have only chosen to highlight a specific set of issues and ignored others. However it is clear that in all of the topics discussed, ecological approaches are the basis for evaluating and improving both existing and emerging weed control options. The assumption that herbicide resistant crops may simplify the practice of weed control changes the focus of research interest from existing problematic weeds, to assessment of those weeds that may become problematic. Here ecological and evolutionary responses to herbicides may become particularly important (Gardner *et al.*, 1999). However crop and weed responses to farming practices are still often quantitatively unknown, in spite of their relevance for the design of IWM (e.g., water depth effects on direct-seeded rice and weeds). Focusing on factors determining weed recruitment and early season growth phases when weeds are most susceptible to suppression, and on the patch dynamics (e.g., Latore *et al*, 1998) and phenotypic plasticity (Bradshaw, 1965) of weeds surviving control remain particularly important.

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SOME ASPECTS OF TROPICAL WEED SEED BANKS : DETERMINATION, DYNAMICS AND DEPLETION

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Abstract: The literature concerning seed banks is enormous and expanding rapidly, however the information that is available on tropical weed seed banks is limited. The recent movement away from traditional transplanted rice to directly seeded rice has highlighted the need for a better understanding of tropical weed seed banks. The aspects of tropical weed seed banks covered by this paper range from new research findings on size and composition, through estimation of weed seed longevity, to the stimulation of germination in buried weed seeds. Information is also presented on the methods for seed bank analysis and species identification, dormancy and dormancy cycles and how certain farming practices can affect tropical weed seed bank size and composition.

Keywords: seed banks, dormancy, germination, viability, longevity.

Introduction

In just about all plant habitats where angiosperms grow there is a reserve of dormant seeds in the soil. This is referred to as the soil seed bank. The existence of seed banks has been recognised for several hundred years and the classical study of Beal and that of Duval indicate that certain weed seeds can persist in such banks for up to 100 years (Baskin and Baskin, 1998).

Thompson *et al.,* (1998) have described two transient and two persistent seed bank types. In the first form of persistent seed bank, many seeds germinate soon after shedding, but a small proportion of viable seeds remain ungerminated. In the second form of persistent seed bank, only a small portion of seeds germinate immediately after dispersal and a large reserve of viable seeds are retained. In the transient seed banks, viable seeds germinate in the season of production at times when conditions allow. Other forms of seed bank have now been recognised including, pseudo-persistent, seasonal transient, and delayed transient. Potentially, more soil seed bank strategies exist in the tropics than in the temperate zones of the world because reproduction can occur throughout the year (Baskin and Baskin, 1998). The seed banks of any tropical community will consist of a mixture of transient and persistent species, however, the vast majority of tropical annual weed species will have persistent seed banks.

There are relatively large numbers of publications that report studies on temperate weed seed banks in the scientific literature. This is in contrast to the situation for tropical weed seed banks, which get less coverage. In the last 10 years cultural practices on many tropical farms, particularly in rice growing regions, have changed. Now many rice crops are directly seeded and the technique of transplantation is less often the method of choice. Direct seeding of rice, relying on less aggressive tillage and a greater use of herbicides, has lead to an increase in annual weed problems as well as a change in the spectrum of annual weeds present. Management of these new weed problems of rice and other tropical weeds in other situations is dependent upon knowledge of soil seed banks, their size and dynamics.

This paper places emphasis on tropical weed seed banks of disturbed locations. It examines some of the conditions or treatments involved in their creation, their dynamics and how they can be manipulated (Figure 1).

Seed Bank Formation and its Determination

Seed production and incorporation

The production of annual weed seeds, whether from plants growing in tropical or temperate parts of the world, can be exceedingly large. For example, tropical weeds of disturbed areas can produce in the order of 15,000 seeds per plant for *Parthenium hysterophorus* in central Queensland (Navie *et al.*, 1997) or 415,800 seeds per m^2 for *Amaranthus retroflexus* (Baskin and Baskin, 1998) in California. These sorts of numbers are similar to weeds of the same families growing in the temperate parts of the world. However, little is known concerning how much of this seed on tropical plants finds its way into the soil (Figure 1).

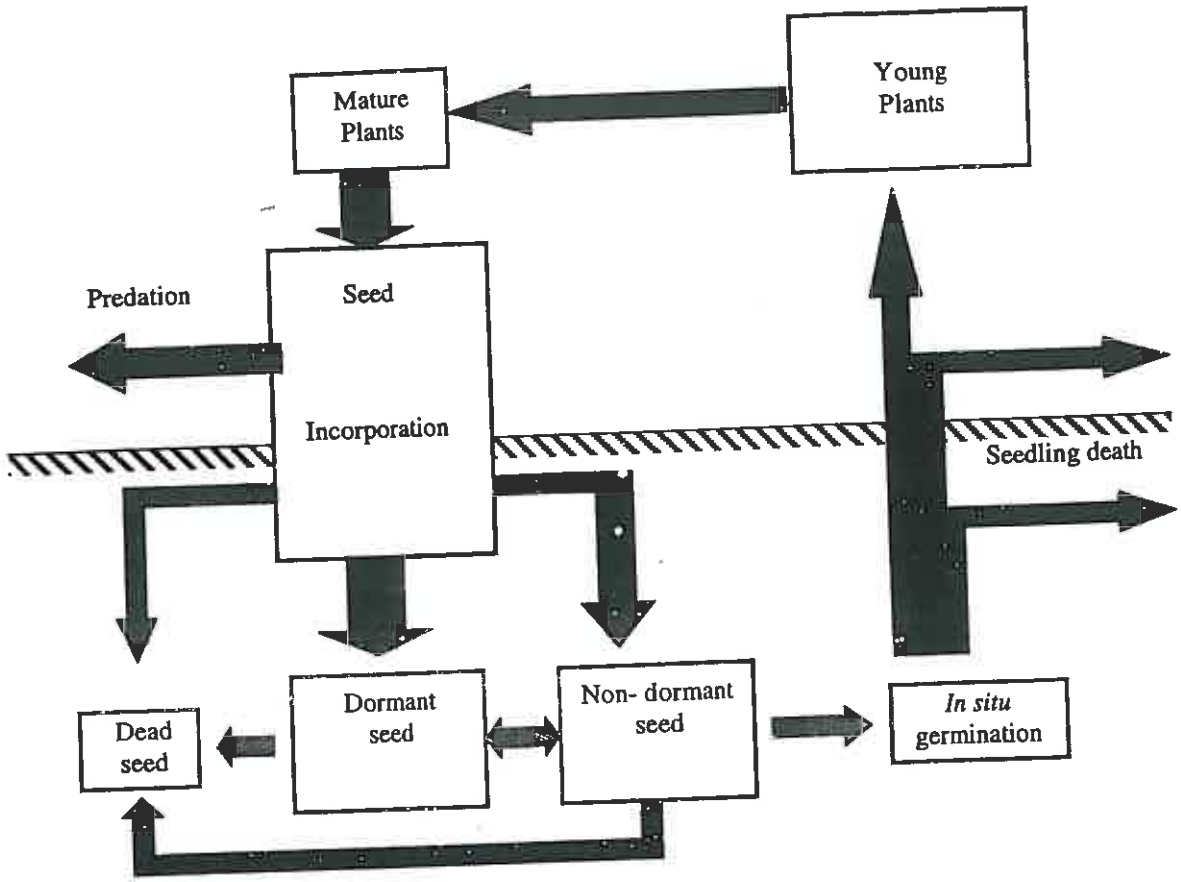


Figure 1 The changes that a seed bank can undergo after burial in a tropical soil. Information is required on each of the driving processes (black arrows) before a full understanding of the soil seed bank dynamics can be obtained.

How tropical weed seeds become incorporated into the soil is not well known (Figure 1). In farming sites plowing will bury many seeds. Animals such as rodents, ants or beetles can bury surface-lying seeds up to 8cm deep, while larger animals dig holes or create spaces on the soil surface. In addition seeds might find their way into soil spaces and be further buried by biotic or abiotic factors. In some tropical regions, earthworms overturn enormous amounts of soil by burrowing and cast activity. Other climate features, such as rain or wind, may force small seeds into course-textured soil and bury them.

Seed bank analysis

In studying soil seed banks two basic methods are commonly used. In both cases samples of soil are removed from the study site then, the numbers of seeds of each species, in each sample determined by either a) separating the seeds from the soil and counting them or b) allowing them to germinate from the soil samples and counting the seedlings. Various methods of washing, floatation or air blowing have been developed to rapidly separate seeds from soil samples. After isolation is complete, the identification and viability estimation takes place. Allowing seeds to germinate in the soil (method b) eliminates some of these problems particularly that of determining whether a seed is viable or not. In one further technique sieves have been used to concentrate seeds, then seedlings are counted when the concentrated soil is placed in the glasshouse for germination to take place. When the seed extraction method (method a) was compared to the seedling emergence method on an arable subtropical soil growing soybean, the seedling emergence method proved to be the best for accurately estimating weed seed composition. However, there was no difference in the two methods in determining seed bank density (Barberi *et al.*, 1998b).

Frequently, data collected on the size of soil seed banks has large standard deviations, and one reason for this is that seeds are not evenly distributed (horizontally or vertically) in the soil. Seed banks of most species are aggregated or clustered and these aggregations have an irregular distribution. Therefore, sufficient samples have to be collected to avoid this potential sampling variation. Precision of seed number estimates may be improved by taking many small samples rather than a few big ones. In a temperate location, 15-20 sampling locations were required to determine the number of species present (Gross, 1990) while the minimum amount of soil needed in each sample to detect a single species was estimated to be approximately 100g (Forcella, 1992).

To get a clear picture of the seasonal changes in a given soil seed bank, samples should be taken at a number of times through out the season. Only on a very few occasions has this been done for tropical regions (e g. Navie *et al.*, 1997; Table 1). Such regular sampling is necessary if an understanding of the dynamics of the seed bank throughout a single season is to be obtained.

Species identification

When the technique of seed extraction is used to determine seed bank size and composition, seed identification becomes a major problem, as the distinction of similar species is not possible using morphological characters alone. In addition, many seeds present in the seed bank will have lost some of their diagnostic features. Seed DNA fingerprinting, using PCR-based markers, is being used for the identification of similar seed types (Joel *et al.*, 1998; Shrestra *et al.*, 1999). These studies are looking for unique molecular markers for a particular tropical weed. In the study of Shrestra *et al.*, (1999) a range of *Sporobolus* (Giant ratstail grasses) species are being identified using a PCR/RAPD technique applied to DNA extracted from seed. The aim is to clone and sequence unique markers, then to develop long primers that can be used as the diagnostic probes (known as SCARs). So far specific markers are being identified for *S. pyrimidalis, S. africanus, S. natalensis, S. fertilis* and *S. jacquemonti.*

Size and Composition

Density

As a very rough guide to the size of various seed bank sizes Fenner (1995) suggests the following figures are representative of arable sites (20-40,000), grassland (5-20,000), temperate forests (1-10,000), tropical forests (100-1,000) and subarctic forests (10-100 per m^2). In addition, Thompson (1992) suggested that the densities of buried seed declines with increasing altitude, latitude and succession age. He further states that smaller numbers of seed will occur in tropical and in arctic/alpine habitats than in temperate habitats and that larger numbers will be found in disturbed than in non disturbed habitats. Skoglund (1992) in support of these views concluded that tropical seed banks are generally smaller than those in temperate locations, although tropical seed banks can still have up to 10,000 seeds m^{-2}.

The size of tropical seed banks is also going to be controlled by a number of other abiotic and abiotic factors (Figure 1). For example Navie *et al.* (1996) found the seed bank size in a semi-arid grass and woodland to depend on the distance from water, and many studies have shown that the soil and standing vegetation type will have some influence on the size of the seed bank under that community. Regional differences in soil fertility, drainage, disturbance regimes and seasons also cause predictable changes in seed bank size. In a detailed study Navie *et al.*, (1997; Table 1) discovered densities of 8,376 and 7,487 seeds per m^2 in autumn and spring respectively, in a disturbed tropical seed bank. Of these, 90% were weeds with *Parthenium hysterophorus* making up over 80% of these.

Composition and richness

Information on the plant families found in temperate and tropical seed banks has been compiled by Baskin and Baskin (1998). A total of 155 families were listed as having species that produce seed that can be found in the persistent seed bank. Seventy-one of these are represented by 2 or more species. The Asteraceae (131), Brassicacea (46), Cypreraceae (83), Fabaceae (65), Poaceae (157), Polygonaceae (32), Rosaceae (51), and Scrophularaceae (35) each had 32 or more species. Very little is known concerning composition and richness in tropical seed banks. In one study Navie (unpublished data) has shown seed banks in central Queensland to be species rich, particularly in the autumn after good summer rains and at sites with plenty of soil moisture (Table 2).

Table 1 Size and temporal variation in the germinable soil seed bank of a tropical rangeland in central Queensland in 1995/96. Seed densities in each row followed by the same letter are not significantly different ($p > 0.05$). Adapted from Navie *et al.*, 1997 with permission.

Species	Life history	Seeds m^{-2}	
		Autumn	Spring
Weeds			
Amaranthus spinosus	A/F	104 a	373 b
Parthenium hysterophorus	A/F	5245	4414
Trianthema portulacastrum	A/F	20	36
Verbena bonariensis	P/F	78	10
Other minor species		23	30
Natives			
Catotis cuneata	A/F	79	14
Cyperus sp.	A/G	18	0
Einadia polygonoides	P/F	14	3
Euphorbia sp.	A/F	205 a	47 b
Sida sp.	P/W	3	21
Tribulus terrestris	A/F	0 a	74 b
Wahlenbergia sp.	A/F	0	17
Other minor species		12	16
Poaceae		1918	2011
Unidentified		624	453
Total		8376	7487

Aggregation

For many species, seed are shed close to the parent plant, and as a consequence this leads to a departure from randomness in their distribution. Soil seed bank aggregations may also be modified by farm machinery and occurs at different scales between sites (Grundy, 1997). Studies show that where there is little soil disturbance, patches exist over greater distances than when disturbance is high. Such aggregations lead to difficulties in undertaking seed bank size, composition and richness studies. There are no indications that aggregations in tropical seed banks are any different to those seen in temperate seed banks, however little research has been undertaken on this topic.

Seed Bank Dynamics

Dormancy and dormancy cycles

Extensive surveys of tropical species show germination of fresh seeds under suitable conditions to be the most common response (Garwood, 1989). However in some vegetation types, particularly those with many annual weeds growing on disturbed lands, dormancy is common (Figure 1). If weeds are to persist in the soil seed bank for several years, viability must not only be maintained but germination must be also be avoided. They do that by having dormancy. Reviews of the form of dormancy in seeds are numerous. The mechanisms that exist in tropical plants range from hard or impermeable seed coats to physiological dormancy in the embryo (Adkins and Bellairs, 1999). Often seeds have more than one mechanism.

Table 2 Species richness (number of species present) and diversity (Shannon-Weiner Index) of the seed banks of two tropical rangeland sites in central Queensland, 1996. Site 1 was a disturbed rangeland while site 2 was similar but closer to a creek. Means in the same column group followed by different letters are significantly different ($p > 0.05$). Adapted from unpublished results of Navie, 1999)

	Site richness	Mean sample richness	Site diversity	Mean sample diversity
Site 1				
Autumn	16	3.1 b	4.9	0.4 a
Spring	11	2.1 a	3.5	0.3 a
Site 2				
Autumn	28	10.4 c	0.8	0.8 b
Spring	12	2.9 a	0.1	0.2 a

Seeds in the soil seed bank may also undergo annual cycles in their level of dormancy. The first clear evidence that such events occurred in buried seeds was reported in 1968 and there are now many instances of annual dormancy cycles in seeds of annual plants in temperate soils (Garwood 1989). Physiological responses of the seed to seasonal variables, such as temperature or soil moisture change, may be responsible for these changes in dormancy level. Such changes will keep the seeds synchronized with changes in the suitability of the environment for germination and seedling establishment.

Little is known about dormancy cycles in tropical seed banks. One study undertaken in Nigeria showed dormancy to cycle seasonally in 5 species, to change permanently in 2 but to remain constant in 6 others (Marks and Nwachuku 1986). Physical changes in the soil environment, particularly those involving moisture were thought to be involved in some of these cases.

Seed viability and longevity

Various methods have been devised to estimate whether soil extracted seeds are alive and how long the seed has been in the soil. One way to obtain information on the longevity of seeds in the soil is to collect soil samples at regular intervals (yearly) in areas where all plants have been removed and their re-established prevented. Another way to determine seed longevity is to sow seeds, and sample the soil over a period of time to see how many are still alive.

The longevity of a seed will be determined by inherent characters (such as viability, dormancy) and environmental conditions such as soil type, climate change (triggers for germination) as well as consumption rate by predators and pathogens (Figure 1). Longevity in temperate soils has been shown to range from only a few weeks to several *(Abutilon theophrastri)* or many (*Ulex europaeus*) years (Baskin and Baskin, 1998). Some tropical species are also known to have longevity including *Parthenium hysterophorus* (half life of >6 years; Navie *et al.*, 1998; Table 3) and *Acacia cyclops* (36 years; Holmes, 1988). In Zimbabwe after 5 years of burial 10% of seed from several weedy agricultural herbs were still alive (Garwood, 1989) whereas in Nigeria at a depth of 5cm, after 1.2 years, 50% of seed from 5 weedy agricultural herbs were still alive.

Seed loss

Seed death can be through natural causes as the seed ages or alternatively the seed is destroyed or consumed (Figure 1). The activities of soil organisms, including those that predate or eat seeds, fungi and bacteria that attack seeds, are major pathways for destruction. The microorganisms often involved are those that breakdown cellulose and polysaccharides. However in the case of fungi, fungicide treatments of buried *Mimosa pigra* seed indicate that in this case fungi were not responsible for large seed losses (Lonsdale, 1993). Other agents that cause seed death include fire in fire prone habitats and flooding. It has been argued these types of seed loss are more important to tropical than temperate weed seed banks. In the tropics rodents may remove up to 99% of seed of buried *Cordia elaeagnoides* (Garwood, 1989), a relatively large seeded species. Fires can kill some seeds but some seeds are unaffected or even stimulated to germinate by high temperatures and/or smoke.

Table 3 Duration of burial and the subsequent fate of *Parthenium hysterophorus* seeds measured as either germinable, not germinable or not recovered . Modified from Navie *et al.*, 1998 with permission.

Period of burial (months)	Germinable (%)[1]	Not germinable (%)	Not recovered (%)
2	93	7	0
4	84	14	2
6	91	8	1
12	79	9	12
24	74	9	17

[1] At a constant rate of decrease the half-life of buried of seed was calculated to be > 6 years.

External Effects

Cultivation and fallow

Size and structure of weed seed banks depends, in part, on the management system applied to that land. For example, in a sub-tropical system four management options (conventional, organic, reduced input and strip cultivation) were applied to continuously cropped maize. After application, the total weed seed density was largest (100,761 seed per m^2) under an organic system and smallest under the conventional system (27,601). The differences in seed bank size among the maize management systems depended mainly upon the efficacy of the applied weed control methods (Barberi *et al.*, 1998a,c). In contrast, differences in the abundance of some major species seemed mostly dependent on the tillage system used. Diversity being higher in systems based on conservation tillage than those based on plowing.

Selected forms of cultivation can therefore be used to reduce the size of the weed seed bank, not only because they reduce seed input but, because they stimulate weed seed germination. Perhaps the most popular technique for reducing weed seed bank size has been some form of fallowing (Cavers and Benoit, 1989) combined with cultivation. Cultivation has been shown to be a potent stimulator of seed germination from the seed bank (Table 4). Cultivation stimulated a 10 fold greater number of seedlings than was possible from several different depths of planting (Taylor, unpublished data). Plowing as a form of cultivation moves the majority of seeds from the surface to 15cm-deep layer. Subsequent plowing can move seeds upwards and downwards. Plowing buries about 80% of surface-sown seeds, but retains *ca.* 38% of them towards the surface in a subsequent operation.

Herbicides

Weed seed banks can be reduced by the persistent use of herbicides in temperate regions, but the bank can be rapidly replenished if control is less than perfect. Atrazine used in maize monoculture reduced the weed seed bank by 98% after 6 years of application. Nevertheless 3 years after it was discontinued, the seed bank had rebounded to half of its original density (Cavers and Benoit, 1998). Herbicides will also change the weed seed bank spectrum. More recently temperate cereal growing has adopted a late season herbicide application to the crops at the time of maturation in an attempt to kill any weed seeds that may still be present. This herbicide treatment, known as crop topping, is able to reduce the number of viable weed seed going into the seed bank that season. It is unknown if such techniques are being used in tropical crops.

Dormancy manipulation

It has been suggested that better control of certain weeds of disturbed sites could be achieved if the soil seed bank could be manipulated in such a way that their seeds were either made to germinate or were induced to die (Figure 1). In attempts to stimulate seeds to germinate from the soil seed bank numerous chemicals (e.g. nitrate, thiourea, ethephon, azide, peroxide) have been applied to the soil seed bank.

Table 4 The influence of burial depth or cultivation on the emergence of paradoxa grass (*Phalaris paradoxa*) seedlings from the soil seed bank. Adapted from unpublished data of Taylor, 1999.

Time of year	Number of seedlings emerging from various soil depths or following cultivation				
	0	5	10	15	Cultivation
Autumn	26	31	7	9	216
Winter	1	4	13	4	10
Spring	4	17	12	5	18
Summer	1	0	1	1	1

However, for various reasons most of these treatments have failed to increase the rate of seed depletion (Carmona and Murdoch, 1998). Plant growth regulars such as gibberellic acid show the most promise and stimulate seed germination but field applications would be uneconomic. Applying 1-(3-chlorophthalimido) cyclohexane carboxide (AC-94377), which has gibberellin-like properties, to soils has, however, been effective (Peters and West 1991) and ethylene gas has been shown to have an application in stimulating *Striga asiatica* seed to germinate from the seed bank (Egley, 1986).

More recently a cheaper, more effective seed stimulant has been studied (Brown and Van Staden, 1997). Plant-derived smoke has been shown to stimulate the germination of a number of tropical species including some weed species (Table 5). In another study a series of soil seed bank studies were conducted to determine the effect of smoke on the soil seed bank samples collected from 5 arable and 1 rangeland site near Brisbane, Australia. The soils were treated with aerosol smoke produced from burning native species vegetation. The germination of 3 introduced weed species (*Melinis minutiflora, Panicum maximum and Verbena officianalis*) were strongly stimulated while the rate of germination was stimulated for 2 further species (*Cyperus gracilis* and *C. polystachus*) (Adkins *et al.*, 1999).

Conclusions

The study of tropical weed seed banks at disturbed sites is poorly reported in the scientific literature. Recent changes in tropical farming systems and the broad adoption of the practice of directly seeding rice, has highlighted the need for further information on the basic biology and ecology of tropical weed seed banks. Generally, the production of tropical weed seed is high, however little is known on how this seed finds its way to the soil and how it becomes dispersed and incorporated. The techniques used for tropical seed bank analysis are the same as those used for temperate seed banks. The technique of following seedling emergence is simplest to apply and avoids the problem of identifying which seeds are viable and which seeds are dead. It also helps in species identification as seedlings, and then plants, are easier to identify than seed that has been extracted from soil. However, new DNA-based techniques are becoming available to help identify soil-stored seed if necessary

Sampling technique and sample size should be accurately determined for each study. Tropical seed banks are often smaller than temperate seed banks but still can be as large as 10,000 seed per m^2. They are often exceedingly species rich particularly following the wet season. Most tropical seed banks have member species that have dormancy. Some species undergo dormancy cycling while others remain deeply dormant. The longevity of seeds in tropical soils is poorly studied but is generally thought to be less than seen in temperate seed banks. Very little is known concerning predation pathways and pathogens attack on tropical seed. Like temperate soil seed banks, cultivation can stimulate tropical seed to germinate and therefore reduce the seed bank size. Herbicides can reduce seed bank size, but only while they are actively applied. The future reduction of seed bank size by chemical manipulation is a possibility and the use of soil applied smoke solution holds some hope.

Table 5 The stimulation of germination of a number of tropical and temperate species by plan-derived smoke solution

Species	Type[1]	Germination (%)[2]		Reference
		Control	Smoke	
Temperate				
Veronica persica	A/W	23	100	Adkins *et al.*, 1999
Malva negelecta	A/W	28	73	
Avena fatua	A/W	30	100	
Paparer rhoeas	A/W	3	40	
Galium aparine	A/W	5	26	
Fallopia convulvulus	A/W	15	24	
Stellaria media	A/W	0	4	
Tropical				
Sorghum halepense	A/W	2	31	Adkins *et al.*, 1999
Parthenium hysterophorus	R/W	98	35	Navie *et al.*, 1998
Anigozanthos manglesii	N	6	32	Dixon *et al.*, 1995
Actinostrobus acuminatus	N	19	85	

[1] A = arable, W = weed, P = pasture, R = rangeland, N = native
[2] Germination produced in distilled water or the most effective concentration of smoke solution tried.

The following are suggested as topics worthy of future study for tropical weed seed banks 1) the physiological basis of seed longevity in tropical soils, 2) the role of tropical weed seed banks in ecosystem dynamics, 3) the relationship between seed rain, seed bank size and standing vegetation composition, 4) the physiological basis of seed dormancy bin tropical soils, 5) seed germination stimulation and 6) information on the dynamics and functioning of the seed bank.

Acknowledges

The author would like to thank Sheldon Navie and Ian Taylor for helpful discussions on seed bank issues and for the use of data produced during their doctorate studies at the University of Queensland and Andrea Adkins for preparing this manuscript.

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Oral Presentation

1. Weed Biology

A SURVEY OF WEEDS IN RAINFED RICE-ONION CROPPING SYSTEMS IN CENTRAL LUZON, PHILIPPINES

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Abstract: The major weeds infesting rainfed rice-onion systems were identified in 13 farms in three villages in San Jose, Nueva Ecija, Philippines, the Asian site of the Integrated Pest Management-Collaborative Research Support Program (IPM-CRSP). The kind and density of weed species were determined using the quadrat sampling method from 1994 to 1997 wet and dry seasons. About 20 weed species each were observed in the rice (*Oryza sativa* L.) and onion (*Allium cepa* L.) crops with three species in each crop emerging as most dominant. These were *Ludwigia* spp, *Cyperus rotundus*, and *Echinochloa* spp. in rice and *Cyperus rotundus*, *Cleome viscosa* and *Trianthema portulacastrum* in onion. Two of the villages had more species and more kinds of weeds than the third village. A carry-over of dominant weeds across crops occurred distinctly in all the three villages. Certain upland species normally occurring only during the onion crop are increasing in populations in lowland rice, apparently caused by insufficient flooding during the rice rotation and enhanced by the alternate wet-dry annual rotation pattern. Over time, this could result in dominant species shifts in rainfed rice-vegetable cropping systems not only in the Asian site but also in other rainfed areas in the country with similar cropping patterns and weed populations.

Keywords: dominant weeds, crop rotation, rainfed lowland rice, onion

Introduction

One-half of the 3.2 million ha rice-growing areas in the Philippines is rainfed due to inadequate irrigation facilities. Among these is the IPM-CRSP Asian site, located in the town of San Jose in the province of Nueva Ecija, about 160 km northeast of Manila. The wet season with about 350 mm rainfall per month is from June to September and the dry season with about 30 mm rainfall per month is from November to April. May and October are transition periods between the wet and dry seasons with a 150 mm average rainfall. Farmers grow lowland rice in rotation with upland crops (vegetables) in a pattern that coincides with the annual rainfall distribution. Rice is grown in the wet season and one or two crops of vegetables in the dry season with fallow periods in between seasons. In most of the farms during the dry season, onion is the main or sole crop and string beans, eggplant, pepper and similar vegetables are secondary crops.

In determining integrated management strategies against weeds infesting multi-crop systems, the first step is to identify the major problem weeds that compete with and reduce yields of the component crops. In general, previous surveys focused on weed flora based on a single crop. With two to three crops a year, weed dominance is the result of the cropping pattern and its associated cultural practices, rather than a simple case of crop-weed competition and succession (Harwood and Bantilan 1974). In rainfed rice-based cropping systems in San Jose fields are usually dry to saturated during the vegetable growing period and are submerged in about 5 cm water during the rice growing period. Semi-aquatic or aquatic weeds grow with lowland rice during the wet season and terrestrial weeds grow with vegetables during the dry season. Consequently, different weeds occupy the same physical location at various times of the year depending on soil moisture levels. To our knowledge, there has been no field survey to determine the weed flora in rainfed rice-onion systems or to compare the dominant weeds in multi-crop systems with mono-crop systems.

This study was conducted to determine the kind and density of weeds growing in rice-onion crops rotated in an annual cycle in rainfed areas in San Jose, Nueva Ecija. The implication of the weed flora on subsequent management practices in multi-crop systems as compared with mono-crop systems is discussed.

Materials and Methods

Weed surveys were conducted in 13 farmers' fields in three villages in the Asian site, in the town of San Jose, province of Nueva Ecija, Philippines. The villages were Abar 1st, Santo Tomas and Palestina. The sampling sites consisted of four fields each for Abar 1st and Santo Tomas and five fields for Palestina. For Abar 1st and Santo Tomas, sampling was done from September to October 1994 (late wet season, rice), then from December 1994 to March 1995 (dry season, onion), and from June to October 1995 (wet season, rice). For Palestina, sampling was done from June to October 1996 (wet season, rice) and from December 1996 to March 1997 (dry season, onion).

The kinds of weed species and their densities were determined by the quadrat sampling method. Weeds from a 1m x 1m quadrat were hand-pulled from the soil, with the roots intact. Each sample was identified and counted by species. The counted samples were placed in paper bags, oven-dried at 70°C for 72 hr, and dry weights were recorded. In each field, sampling was done three times at various periods during the season: early season (30-45 days after planting), mid-season (60-70 days after planting), and late season (7 days before harvest). At each sampling time in each field, three quadrats were laid out at random. Thus, in each crop (rice and onion), a total of 36 quadrats each were sampled for Abar 1st and Santo Tomas. In Palestina, a total of 45 quadrats were sampled for each crop (rice and onion). Weed dominance was expressed as the summed dominance ratio (SDR) of relative density (RD) and relative dry weight (RDW).

Results and Discussion

Abar 1st

Twenty weed species were observed in lowland rice (Fig. 1a). More than half (52%) were broadleaf weeds (7 species), 31% were grasses (8 species) and 16% were sedges (5 species). The most dominant species (SDR of 9 or higher), in decreasing order, were *Ludwigia* spp. (*L. octovalvis* and *L. perennis*), *Echinochloa* spp. (*E. glabrescens* and *E. crusgalli*), *Monochoria vaginalis*, *Sphenochlea zeylanica*, *Ischaemum rugosum*, and *Cyperus rotundus*. Three other species, *Oryza sativa*, (red rice), *Cyperus iria*, and *Eclipta prostrata* were also prominent although not as dominant as the first six species.

In onion, there were 17 weed species (Fig. 1b). About 75% were broadleaf weeds (11 species), 17% were grasses (5 species), and 8% consisted of *Cyperus rotundus*, the only sedge present. The most dominant species (SDR of 5 or higher), were *Cleome viscosa, Phyllanthus amarus, Cyperus rotundus, Cassia tora, Trianthema portulacastrum* and *Echinochloa colona.*

Santo Tomas

Eighteen weed species were identified in rice in Santo Tomas (Fig. 1c). About 35% were grasses (8 species), 35% were broadleaf weeds (5 species), and 30% were sedges (5 species). Six of these species (SDR of 6 or higher) were most dominant: *Ludwigia* spp., *Echinochloa* spp., *Cyperus rotundus, C. difformis, Trianthema portulacastrum*, and *Ischaemum rugosum.*

Thirteen weed species were observed in onions (Fig. 1d). Almost 60% consisted of *Cyperus rotundus*, the only sedge species present. Eight species of broadleaf weeds consisted 22% while four species of grasses consisted 20%. The most dominant, (SDR of 3 or higher), were *C. rotundus, Cleome viscosa, Oryza sativa, Trianthema portulacastrum*, and *Echinochloa colona.*

Palestina

Of 14 species observed in rice, 44% were sedges (5 species), 36% were broadleaf weeds (5 species), and 20% were grasses (4 species) in Palestina (Fig. 1e). The most dominant species (SDR of 6 or higher) were *Cyperus rotundus, Ludwigia* spp., *Echinochloa colona, Cyperus iria*, and *Sphenoclea zeylanica.*

In onion, there were 13 weed species (Fig. 1f). The sedges (3 species) consisted 38%; the grasses (4 species), 34% and the broadleaf weeds (6 species), 27%. The most dominant (SDR of 7 or higher) were *Cyperus rotundus, Trianthema portulacastrum, Echinochloa colona, Eleusine indica* and *O. sativa* (volunteer rice).

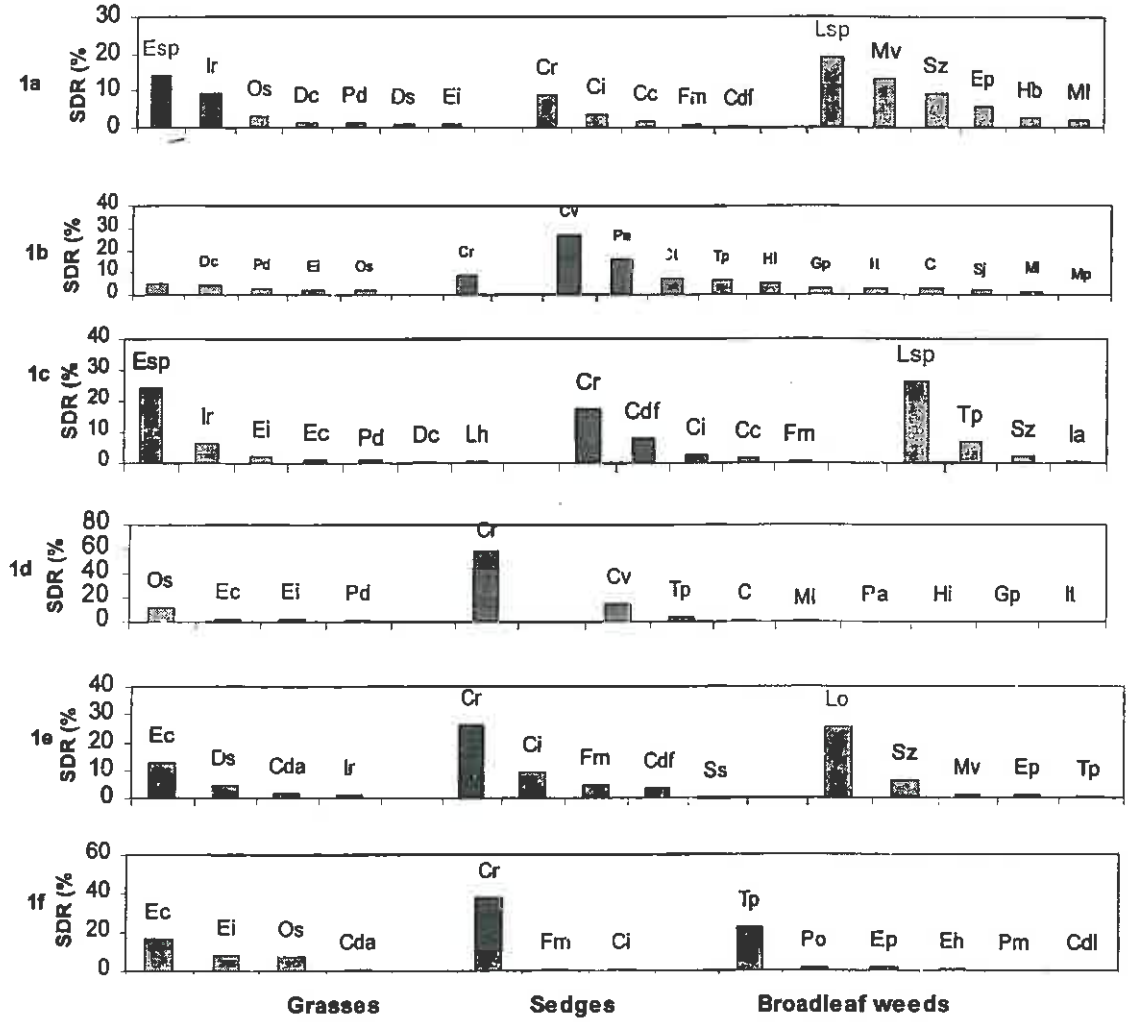


Fig. 1. Summed dominance ratio of weeds in rice (1a) and onion (1b) in Abar 1st, rice (1c), and onion (1d) in Santo Tomas, and rice (1e) and onion (1f) in Palestina from 1994 to 1997 wet and dry seasons.

Legend, Fig. 1. Rice weeds: Grasses: Esp=*Echinochloa crusgali* and *E. glabrescens*; Ir=*Ischaemum rugosum;* Ec=*Echinochloa colona*; Ds=*Digitaria setigera*; Os=*Oryza sativa* (red rice); Ei=*Eleusine indica;* Pd=*Paspalum distichum*; Dc=*Digitaria ciliaris*; Cda=*Cynodon dactylon*; Lh=*Leersia hexandra*; **Sedges**: Cr=*Cyperus rotundus*; Ci=*Cyperus iria*;Cdf=*Cyperus difformis*; Fm=*Fimbristylis miliacea*; Cc=*Cyperus compressus*; Ss=*Scirpus supinos*; *Broadleaf weeds*: Lsp=*Ludwigia octovalvis* and *L. perennis*; Sz = *Sphenoclea zeylanica*; Mv=*Monochoria vaginalis*; Tp=*Trianthema portulacastrum*;Ep=*Eclipta prostrata*; Hb=*Hedyotis biflora*; Ml=*Macroptilium lathyroides*; Ia=*Ipomoea aquatica*; *Onion weeds*: **Grasses**: Ec=*Echinochloa colona*; Dc=*Digitaria ciliaris*; Ei=*Eleusine indica*; Pd=*Paspalum distichum*; Os=*Oryza sativa* (volunteer rice); Cda=*Cynodon dactylon*; **Sedges:** Cr=*Cyperus rotundus*; Fm=*Fimbristylis miliacea*; Ci=*Cyperus iria*; **Braodleaf weeds**: Cv=*Cleome viscosa*; Tp=*Trianthema portulacastrum*; Pa=*Phyllanthus amarus*; Ml=*Macroptilium lathyroides*; It=*Ipomoea triloba*; Ct=*Cassia tora*; Hi = *Heliotropium indicum*; Csp=*Crotolaria* sp.; Sj=*Stachytarpeta jamaicensis*; Mp=*Mimosa pudica*; Gp=*Galinsoga parviflora*; Pm=*Panicum maximum*; Eh=*Euphorbia hirta*; Ep=*Eclipta prostrata*; Po=*Portulaca oleracea*; Cdi=*Commelina diffusa.*

In the three villages, a total of 26 weed species were observed in rice: 9 broadleaf weeds (41%), 11 grasses (29%) and 6 sedges (30%). In onion, 24 weed species were observed: 15 broadleaf weeds (41%), 6 grasses (24%) and 3 sedges (35%).

Although 13 to 20 weed species were growing with each crop, only three, with SDRs of 10 or greater, were most dominant. Averaged across the three villages, the three most dominant species were *Ludwigia* spp., *Cyperus rotundus,* and *Echinochloa* spp. in rice and *Cyperus rotundus, Cleome viscosa* and *Trianthema portulacastrum* in onion (Fig. 1). Our results agree with those of previous surveys who also reported that of more than 10 species found in a crop field, only three or four species usually pose major problems (Moody and Drost, 1983).

The kind and number of weed species varied with the villages. Abar 1st had the most number of species (20 in rice and 17 in onion), followed by Santo Tomas, and Palestina had the least number of species (Fig. 1). More broadleaf weeds were observed in Abar 1st and Santo Tomas, than in Palestina, particularly in the onion crop. Most of the weeds found in Abar 1st and Santo Tomas, including its two most dominant weeds, *Cleome viscosa* in onion and *Echinochloa glabrescens* in rice, were not found in Palestina.

Although the kind of weeds varied among the villages, in all villages a carry-over of dominant weeds occurred distinctly across the cropping seasons. Broadleaf weeds, the dominant weeds during the rice season in Abar 1st, were also the dominant weeds during the onion season. In Santo Tomas and Palestina, sedges were the dominant weeds in both rice and onion crops. Carry-over of dominant weeds was particularly evident in Palestina, where *Cyperus rotundus* and *Echinochloa colona* were dominant in both rice and onion crops and only the broadleaf weeds differed in each crop.

Most of the dominant weeds in rice identified in our survey are the same aquatic weeds dominating lowland rice in Nueva Ecija 10 years ago (Pablico and Moody 1985; 1986). But six dominant species in onions are now appearing in increasing populations in lowland rice. These are *Cyperus rotundus, Echinochloa colona, Eleusine indica, Digitaria* spp., *Eclipta prostrata* and *Trianthema portulacastrum*. These weeds were not reported to occur, or were observed only occasionally, in lowland rice in surveys conducted in the 1980s (Pablico and Moody 1985; 1986).

In integrated weed management, crop rotation is among several agroecological practices used as an indirect method of suppressing weed growth. Since particular weeds grow with particular crops, growing the same crop in the same piece of land repeatedly in monocrop systems inevitably results in weed population build up. Rotating crops with completely contrasting growth habits or cultural requirements breaks the weed cycle and prevents build up of any one weed species. In practising the traditional rice-onion rotation scheme to fit the annual rainfall distribution pattern, farmers in rainfed areas in San Jose were thus also effectively keeping weed populations in check and preventing build-up of weeds in either crop.

However, Plucknett and others (1977) had indicated that even with crop rotation, weed build up problems similar to those that occur in monoculture may result if the same cropping pattern and the same weed control practices were done repeatedly over the years. When the study of weed control in multiple cropping systems was initiated 20 years ago, Plucknett and others (1977) was then aware of the fact that weed control in multi-crop systems is different from that in mono-crop systems. He emphasized the need for constant monitoring of crop and weed management practices and weed growth mechanisms that could lead to weed species build up or dominant species shifts because of the highly dynamic nature of weeds. Today, 20 years and numerous rice-onion cycles later, our survey in San Jose has confirmed Plucknett's (1977) observations. In the rainfed fields of San Jose, inadequate flooding depths during the lowland crop (rice) growing alternately with an upland crop (onion) in a regular annual cycle over the years is causing an increase in populations of upland weeds in lowland rice. Because of insufficient irrigation, low floodwater levels (< 10 cm) during periods of scarce rainfall encourages germination and growth of dryland weeds in rice. Holm and others (1977) observed that saturated soil conditions during periods of scarce rainfall or inadequate irrigation after the rice has been transplanted encouraged germination and growth of *C. rotundus* in lowland rice. It is also possible that certain weed seeds and propagules subjected to alternately flooded and saturated soils in the course of the rice-onion rotation have acquired adaptation mechanisms to enable them to germinate and grow in both upland and lowland conditions.

Repeated regularly in annual pattern, this rotation system could select for species that could grow in both soil moisture regimes. Over time, this could affect the composition of the weed flora and result in dominant species shifts in rainfed rice-vegetable rotation systems. This is already being exemplified by the increasing dominance of *C. rotundus* in both rice and onion crops in Palestina and in Santo Tomas.

Of the upland weeds that are now growing in lowland rice, the most dominant is *Cyperus rotundus*. Ten to 20 years ago, *C. rotundus* was the dominant weed only in upland rice (De Datta 1974) and other upland crops, particularly vegetables (Paller and others 1979; Moody, 1992). It was not observed, or at best, was only a minor weed in lowland rice (Pablico and Moody 1985; 1986; Carbonell and Moody 1983). In 1979, Carbonell and Moody (1983) reported that only two farms in Nueva Ecija regarded *C. rotundus* as important in rainfed rice. In this survey, it ranked second most dominant weed in rainfed lowland rice in three villages in San Jose. In a span of more than 10 yr in these areas, its densities had increased from occasional (Pablico and Moody 1985; 1986) to 1-3 plants/m^2 throughout the season in Santo Tomas and Abar 1st and 4-8 plants/m^2 throughout the season in Palestina (data not shown). In Palestina, where it was the most dominant weed in lowland rice, *C. rotundus* density peaked at 15 plants/m^2 at early season, apparently before the fields were handweeded. Consisting of an average of 60% of the total sedge population in all three villages, it had outranked *C. iria,, C. difformis,* and *Fimbristylis miliacea*, the dominant sedges in lowland irrigated rice 10 yr ago (Pablico and Moody, 1985; 1986).

The increasing dominance of upland weeds, in particular *Cyperus rotundus*, in the rice rotation means increased infestations in the onion crop because its presence in rice provides a continued supply of propagules in the onion crop. In our survey, a direct relationship between the density of *C. rotundus* in both rice and onion crops supports this observation. In Abar 1st, where the density of *C. rotundus* in rice was low (1 plant/m^2) its density in onion was also low (1-2 plants/m^2). In Santo Tomas, where the density of *C. rotundus* in rice was about 2 plants/m^2, its density in onion also increased to 9-14 plants/m^2. In Palestina, where the highest density of *C. rotundus* (4-8 plants/m^2) was observed in rice, its density in onion was also highest (19-20 plants/m^2) (data not shown).

In terms of weed management, higher populations of *Cyperus rotundus* in onion implies greater problems because no selective control measures other than handweeding are available against *C. rotundus* when it grows with vegetables. All the currently available selective herbicides for vegetables are not effective against this weed. Those that can control it are not selective to vegetables. For this reason, its presence in rice may provide an alternative management strategy because it opens up the possibility of applying control measures in the rice crop which are not possible during the onion crop due to selectivity problems.

Our survey of weeds in rainfed rice-onion systems show that, in addition to the major weeds infesting each crop, certain weed species are growing in both crops due to factors related to water management. The appearance of weeds in both crops implies greater infestation. However, it also provides an opportunity to apply weed management practices based on a multi-crop, multi-season approach, a strategy which has been suggested since the initiation of multiple cropping studies in 1970s (Harwood and Bantilan 1974; Shetty 1986). To this date, most existing weed management practices in the Philippines are still largely based on a single-crop, single-season approach, in spite of the fact that about one-half of the cultivated areas are rainfed with rice-based multi-crop rotation systems.

Acknowledgements:

This project was supported by IPM-CRSP (Collaborative Research Support Program) funded by USAID Global Bureau Grant No. LAG 4196-G-00-3053-00, with Virginia Tech as lead institution and Philippine Rice Research Institute, University of the Philippines Los Baños, and International Rice Research Institute as collaborating institutions.

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COMPETITIVE ABILITY OF SPRING WHEAT AS INFLUENCED BY RELATIVE TIME OF WEED EMERGENCE

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Abstract: A field experiment was conducted with four spring wheat (*Triticum aestivum*) varieties (Alexandria, Tonic, Canon and Baldus) at Aberdeen, UK during May to October 1997 to study the effect of the relative time of weed emergence on the competitive ability of wheat varieties. Wheat was raised in pure stands and in mixture with fat hen (*Chenopodium album* L.) sown in three different times e.g. 15 days before the wheat, the same time as wheat and 15 days after wheat. Monocultures of wheat and that of fat hen at the three emergence times were also maintained. Results revealed that loss of biomass and grain yield of wheat due to fat hen competition was higher and significant when fat hen emerged 15 days earlier or with the crop, but fat hen emerging 15 days after crop establishment did not lead to any crop loss. Wheat varieties were less competitive when fat hen started competition 15 days earlier but the crop had higher competitiveness when fat hen was raised with the crop or 15 days after. Light interception was related to crop competitiveness. The variety Alexandria was the highest competitive and Baldus was the least. Plant height, leaf area and shoot biomass of wheat were positively related, and plant height and shoot biomass of fat hen were negatively correlated to crop competitiveness.

Key words: Competitive ability, Relative time of weed emergence, Wheat cultivars, Fat hen

Introduction

The competitive ability of crop species is closely related to the neighbouring weed plants and is mainly influenced by seed size, environmental conditions and relative time of emergence (O'Donovan, 1992; Spitters *et al.* 1989). In crop fields, weeds usually emerge in successive flushes different from crop emergence and this may influence the competition e.g. O'Donovan *et al.*, (1985). This study was carried out to investigate the effect of relative time of fat hen emergence on the competitive ability of spring wheat varieties.

Materials and Methods

Four cultivars of spring wheat (Alexandria, Tonic, Canon and Baldus) were grown in pure stands and in mixtures with fat hen raised at different times relative to wheat in fields at Aberdeen in May to September 1997. Fat hen was raised at either 15 days before, same time as, or 15 days after wheat with a target density of 400 plants/m^2. Weed monocultures at 3 emergence times were also raised. The land was fertilized with N, P, K at the rate of 100, 50, 50 kg/ha. Wheat was sown in rows 16cm apart on 23 May to raise 300 plants/m^2. Fat hen seeds were broadcast on the surface before or after wheat sowing or in plots without wheat. Plots (1.3 x 1.3m) were arranged in three randomised blocks. Samples of 8 plants of each species were taken on 1 July, 17 July, 3 August and 18 August. In the laboratory, leaf area was measured and plant height, number of tillers (in case of wheat) and total dry matter per plant were recorded. Two central rows of 1 meter length were harvested on 15 October at full maturity. Grain yield of wheat and seed yield of fat hen were recorded. Seed shedding of fat hen was assessed by trapping seeds fortnightly in seed rain traps. Light reflectance (Infrared/Red) ratio of different wheat varieties was recorded on 25 June, 6 July, 16 July and 27 July. The aggressivity of wheat varieties was calculated as the difference between relative shoot yields of wheat and the

weed (McGilchrist and Trenbath, 1971). Since the weed density differed significantly between weed emergence treatments, covariance analysis was done for all statistical analysis to avoid confounding emergence time with weed density (Mead *et al.* 1993). Correlations between crop aggressivity and plant characters were studied at different harvests.

Results and Discussion

The grain yield of wheat was significantly reduced by the early-emerged fat hen compared to late-emerged plants (Table 1). Two weeks early-emerged fat hen led 1.3 times less yield than the yield when fat hen emerged with the crop. Again about 1.2 times less yield was produced when fat hen emerged with the crop compared to fat hen emerged two weeks after the crop. More or less similar effects of weed emergence times was observed on the dry matter accumulation of wheat varieties. This showed the strong effect of relative weed emergence time (Fig. 1). The crop produced greater yield in mixture than its monoculture when fat hen emerged 15 days after wheat. The reason for increase of grain yield with late-emerged fat hen than its monoculture is not clear. However, Joenje and Kropff (1987) noticed similar increase of sugar beet production (biomass and sugar) with late-emerged fat hen in comparison to the weed-free crop.
The relative time of fat hen emergence was also an important variable affecting fat hen biomass and seed production (Table 1, Fig. 1). Fat hen plants which emerged 15 days after the wheat produced much less biomass and fewer seeds which substantiates the poor competitive ability of late-emerged fat hen with spring wheat. Ferrero (1993) in Italy observed that when fat hen emerged 20 days after sugar beet had a pre-harvest biomass 48% lower than the weed that emerged at the same time as the crop. The possible explanation for this might be the earlier emerging species produced larger root systems and above-ground shoots than late emerging species, thus achieved a competitive advantage (Blackshaw, 1993; Hakansson, 1997) (Table 2).
Among the wheat varieties the highest yield was from Alexandria and lowest with Baldus. The ranking of the varieties in terms of fat hen seed production was in opposite direction. Here it is obvious that by selecting Alexandria as a spring wheat cultivar, the growers can reduce seed return of fat hen to the soil by about 50% in comparison to Baldus. Similar varietal ranking in respect of grain yield, fat hen seed production or aggressivity values was also noticed by Karim *et al.* (1997)
Light interception by the crop was associated with crop competitiveness. The highest reflectance occurred when the fat hen emerged with the crop or 15 days earlier. Among the varieties, Alexandria had the highest reflectance ratio and Baldus the least. The positive correlation between crop aggressivity and IR/R ratio (R^2 = 0.10, df=142) in mixture with fat hen, suggests that varietal competitiveness was strongly related to the ability to shade associated weeds. Although these relationships may relate to total vegetation, wheat was always taller than fat hen which indicates that reflectance ratios may well have been more related to wheat flag leaves at the top of the canopy.
Crop aggressivity was positively correlated to plant height, number of tillers, leaf area, shoot biomass and grain yield of wheat varieties in mixture with fat hen at different harvests (Table 4). It was negatively correlated to % loss of wheat dry matter (R^2 = 0.64 df=142) and % loss of wheat grain yield (R^2 = 0.15, df =142). In case of fat hen, plant height, leaf area and shoot dry matter were negatively correlated to crop aggressivity at different harvests (Table 4). Percent loss of weed dry matter was positively correlated to crop aggressivity (R^2 = 0.53 df = 142).

Conclusion: Growers of spring wheat need to be most concerned about fat hen infestations emerging before or with the crop, but that fat hen emerging two weeks after the crop under Scottish conditions or elsewhere may not lower wheat yields. Shallow planting of wheat with adequate soil moisture should ensure rapid crop emergence with little effect of the weed on the crop yield as well as reduced weed biomass and seed production. In areas where fat hen is a problem, growers should select competitive varieties (like Alexandria) which may be taller and leafy varieties.

Acknowledgements: The authors are grateful to the Islamic Development Bank, Saudi Arabia for providing with the IDB Merit Fellowship to the senior author during this study.

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Table 1. Grain yield (g/m^2) of wheat varieties, and seed yield (g/m^2) of fat hen under different varieties as affected by relative time of fat hen emergence

Weed emergence time	No crop	Wheat variety				Mean	LSD (5%)
		Alexandria	Tonic	Canon	Baldus		
a. *Grain yield*							
15 days earlier	---	204.9	277.9	181.5	129.3	198.38	NS
With the crop	---	345.2	220.8	249.0	175.9	247.72	NS
15 days after	---	350.5	232.2	421.9	128.4	283.24	123.26
Mean	---	300.2	243.6	284.1	144.5	243.1	84.23
LSD (5%)						72.95	
b. *Fat hen*							
15 days earlier	122.8	63.3	74.4	100.7	83.7	80.5	NS
With the crop	105.3	20.4	26.3	34.8	46.3	32.0	NS
15 days after	124.8	0.70	0.70	1.5	1.4	1.1	NS
Mean	117.6	28.1	33.8	45.7	43.8	37.8	NS
LSD (5%)						23.81	

Table 2. Aggressivity of wheat varieties as affected by relative time of fat hen emergence

Weed emergence time	Wheat variety				Mean	LSD (5%)
	Alexandria	Tonic	Canon	Baldus		
15 days earlier	0.35	0.41	0.21	0.01	0.25	
With the crop	0.73	0.55	0.54	0.36	0.55	
15 days after	0.73	0.84	0.82	0.64	0.76	
Mean	0.60	0.60	0.52	0.34	0.52	0.12
LSD (5%)					0.14	

Table 3. Infrared/Red reflectance ratio of wheat varieties as affected by relative time of fat hen emergence

Weed emergence time	Wheat variety				Mean	LSD (5%)
	Alexandria	Tonic	Canon	Baldus		
15 days earlier	6.2	4.9	4.9	4.8	5.2	1.21
With the crop	6.6	5.5	5.5	5.1	5.7	0.86
15 days after	4.7	5.1	4.8	4.6	4.8	NS
Mean	5.8	5.2	5.1	4.8	5.2	0.63
LSD (5%)					0.55	

Table 4. The values of R^2 of fitted curves of crop aggressivity against plant characters of wheat and fat hen at different harvests.

Piant characters	Harvests				
	1st	2nd	3rd	4th	Final
Wheat:					
Plant height	0.20	0.14	0.37	0.25	
Tillers/plant	0.02	0.03	0.12	0.21	
Leaf area/plant	0.04	0.34	0.26	0.37	
Total dry matter	0.12	0.48	0.59	0.68	
Grain yield	---	---	---	---	0.11
Fat hen:					
Plant height	0.10	0.11	0.33	0.61	
Leaf area/plant	0.02	0.18	0.41	0.44	
Total dry matter	>0.01	0.48	0.51	0.61	

Correlation coefficient (r) > 0.330 is significant at P = 0.05 and > 0.424 is significant at P = 0.01 with df = 34

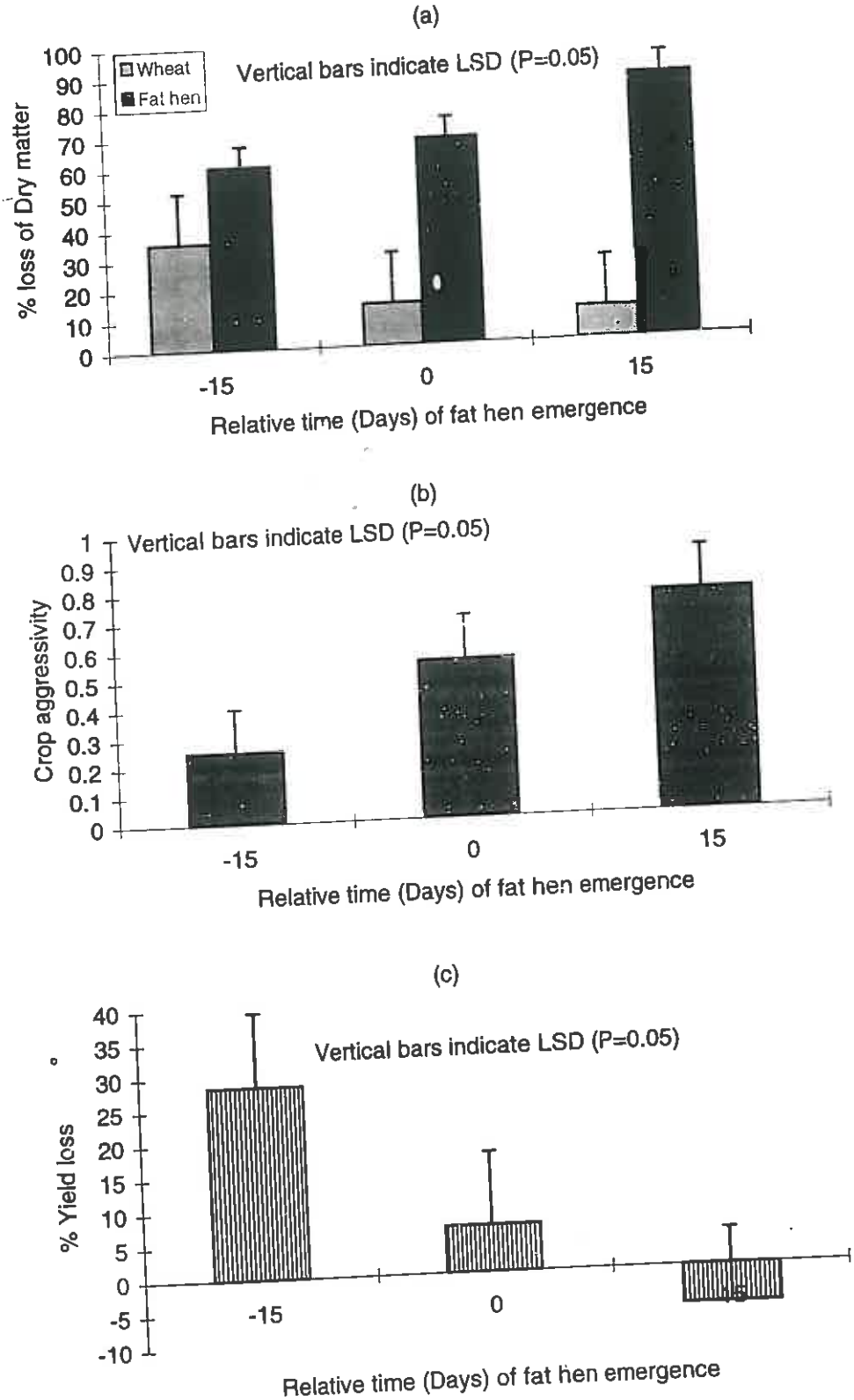


Fig. 1. Pattern of % loss of wheat and fat hen dry matter (a), of crop aggressivity (b), and % loss of wheat grain yield (c) under different weed emergence times. Data are adjusted for difference in weed density in weed emergence times.

DEVELOPMENT OF AN COMPETITIVE ENZYME-LINKED IMMUNOSORBENT ASSAY FOR BUTAMIFOS

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Abstract: Butamifos is organophosphate widely used as selective non-systemic herbicide. It is effective against annual and especially graminaceous weeds in beans, lawns, rices and vegetables. Enzyme-linked immunosorbent assay (ELISA) is recognized as a rapid, sensitive and inexpensive analytical method comparing with conventional instrumental method. A competitive ELISA was developed for quantitative detection of butamifos in water. Conjugate of butamifos derivative with proteins were prepared by attachment at the *sec*-butyl carbon of butamifos. Monoclonal antibody against butamifos was produced using this conjugate as immunogen. The obtained monoclonal antibody showed excellent specificity indicating negligible cross reactivity with its analogues and its oxon compound. Using this antibody, an ELISA for specific detection of butamifos in field water was developed. The effective range of detection of this assay was 1 to 100ppb. To study possible matrix interference from field water, analysis of spiked water samples from golf links was performed. The recovery was quantitative down to 2.5ppb showing sufficiently high sensitivity for field water analysis whereas regulated level is under 40ppb. Correlation between this assay and GC-MS analysis was also examined among various butamifos spike level in the range from 2.5 to 80ppb. Linear regression analysis yielded a correlation coefficient of 0.996 with an intercept at +2.2ppb and a slope of 0.943 showing good agreement between this ELISA and GC-MS method. Our newly developed ELISA is very promising analytical tool for sensitive and accurate determination of butamifos in environmental water.

Key words: butamifos, immunoassay, ELISA, golf links, water analysis

Introduction

Butamifos is organophosphate widely used as selective non-systemic herbicide. It is effective against annual and especially graminaceous weeds in beans, lawns, rices and vegetables. Recently importance of monitoring residual levels is increasing because of its widespread use in golf links. Residues of butamifos may be present in air, soil, surface water and ground water. In Japan, butamifos concentration in effluents from golf links is regulated under 0.04ppm by goverment. It is also regulated under 0.004ppm in ground water, 0.05ppm in rices, 0.1ppm in fruits, 0.05ppm in vegetables. Residual analysis of

butamifos are generally performed by GC-NPD or GC-MS. However, these methods present some limitations derived from the facts that they require sophisticated equipment, time-consuming cleanup steps and derivatization steps.

Enzyme-linked immunosorbent assay (ELISA) is based on the interaction of an analyte with an antibody that recognizes it with high affinity and specificity. ELISA is considered as a rapid, sensitive and inexpensive analytical method comparing with conventional instrumental method. Recent progress in immunochemistry made monoclonal antibody as a convenient tool. Using this monoclonal antibody technology, we developed a competitive ELISA for specific and quantitative detection of butamifos in water.

Materials and Methods

Preparation of immunogen

Structures of butamifos and its hapten used in this study are shown in Fig.1. The hapten was prepared by introduction of alkyl chain spacer and ending in a carboxylic acid at the *sec*-butyl carbon of butamifos. Conjugates of this hapten with proteins were prepared by acid anhydrous method using tri-n-butylamine and isobutylchloroformate as coupling reagents.

Production of monoclonal antibody to butamifos

Female Balb/c mice were immunaized with 100 μg of KLH-conjugate in PBS and Freund's complete adjuvant. Boosters were carried out on days14 and 28 using Freund's incomplete adjuvant. Serum titers were determined with competitive indirect ELISA using BSA-hapten conjugate as a plate-coating antigen. Two mice that have presented high titer were chosen for hybridoma production. Fusion of P3U1 myeloma cells with splenocytes from immunized mice was done by electrofusion method. Screening of hybridoma was performed by competitive indirect ELISA in which BSA-conjugate was used as a plate-coating antigen.

ELISA

Polystyrene plates were coated overnight at 4℃ with obtained antibody. Block Ace™ was used as blocking reagent. Water samples were 10 fold diluted by PBS containing 10% methanol. 50microliter of a diluted sample and a same amount of hapten-peroxidase conjugate was applied to the each well of coated plate after washed with PBS containing 0.05% Tween20. The plate was incubated 1 hour at room temperature followed by washing three times. *o*-Phenylenediamine was added for color developing and 2M sulfuric acid was used as stopping reagent. The absorbance at 490nm was recorded for determination of remained peroxidase activities.

GC-MS analysis

GC-MS analysis was performed according to Japanese government official method. In brief, water sample was applied to GL-Pak PLS2™ column and eluted with dichloromethane. The eluate was dehydrated by anhydrous sodium sulfate and concentrated under nitrogen flow. The concentrate was redissolved in acetone and applied to GC-MS equipment.

Water spiked study

Effluent was collected from a golf links in Shizuoka prefecture, Japan. One thousands volume of standard methanol solution was spiked into the effluent in various concentrations. The spiked samples were divided into two parts and one was provided for ELISA and the other for GC-MS analysis.

Results and Discussion

Characterization of monoclonal antibody

Cross reactivity of obtained monoclonal antibody was evaluated by performing competitive direct ELISA using several compounds as competitors, and the obtained IC50 values were used to calculate cross reactivities. As shown in Table.1 our monoclonal antibody expressed excellent specificity indicating negligible cross reactivity with its analogues and its oxon compound. A standard curve for authentic butamifos calibrators was constructed and its IC50 was 5ppb (Figure 2). As shown in Figure 2, the sensitivity of this ELISA exceeded both government regulatory levels, 40ppb in golf links and 4ppb in water source.

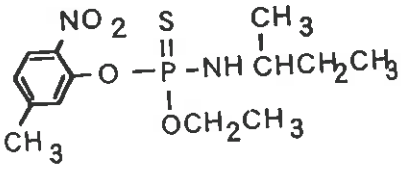
Recoveries for water spiked studies

Spiking matrix samples with several amounts of analyte is common practice to evaluate reliability of analytical method. Water samples from golf links were spiked at six concentrations and provided for ELISA after dilution with PBS including 10% methanol (Table 2). The IC50 of the standard curve used in this study was 15ppb and the effective range of detection was 1 to 100ppb. GC-MS analysis was also carried out at the same time to compare the performance of these two methods. The recovery for both methods were quantitative down to 2.5ppb showing sufficient sensitivity for golf links water analysis whereas regulatory level is below 40ppb. However, coefficients of variation (C.V.) of GC-MS was smaller than of ELISA. A correlation of both methods was illustrated in Figure 3. Linear regression analysis yielded a correlation coefficient of 0.996 with an intercept at +2.2ppb and a slope of 0.943 showing good agreement with GC-MS method. Our newly developed ELISA is considered to be very promising analytical tool for sensitive and accurate determination of butamifos in water in the environment.

Acknowledgements:

The authors are grateful to Drs. H. Abe and T. Ohishi of Eco-Pro Research Inc. for the GC-MS analysis and Dr. Y. Yuasa of Environmental Immuno-Chemical Technology Co., Ltd. for his encouragement and helpful discussins.

a



b

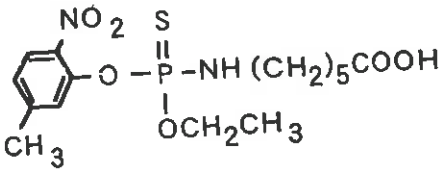
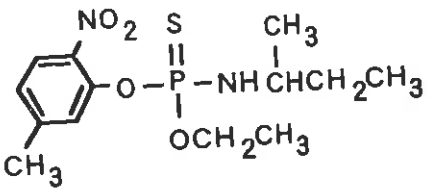
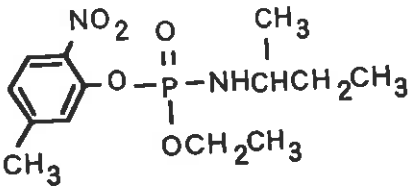
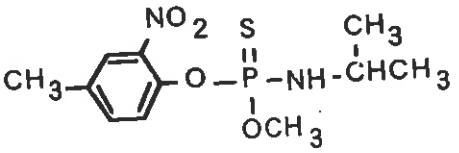
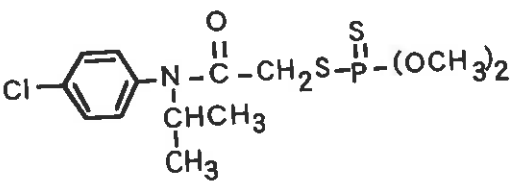


Figure 1. Structures of butamifos(a) and its hapten(b)

Table 1. Cross reactivity of obtained monoclonal antibody

compound	chemical structure	IC_{50}(ng/ml)	Cross(%)
butamifos		5.0	100
butamifos oxon		>1000	<0.5
amiprophos-methyl		>1000	<0.5
anilofos		>1000	<0.5

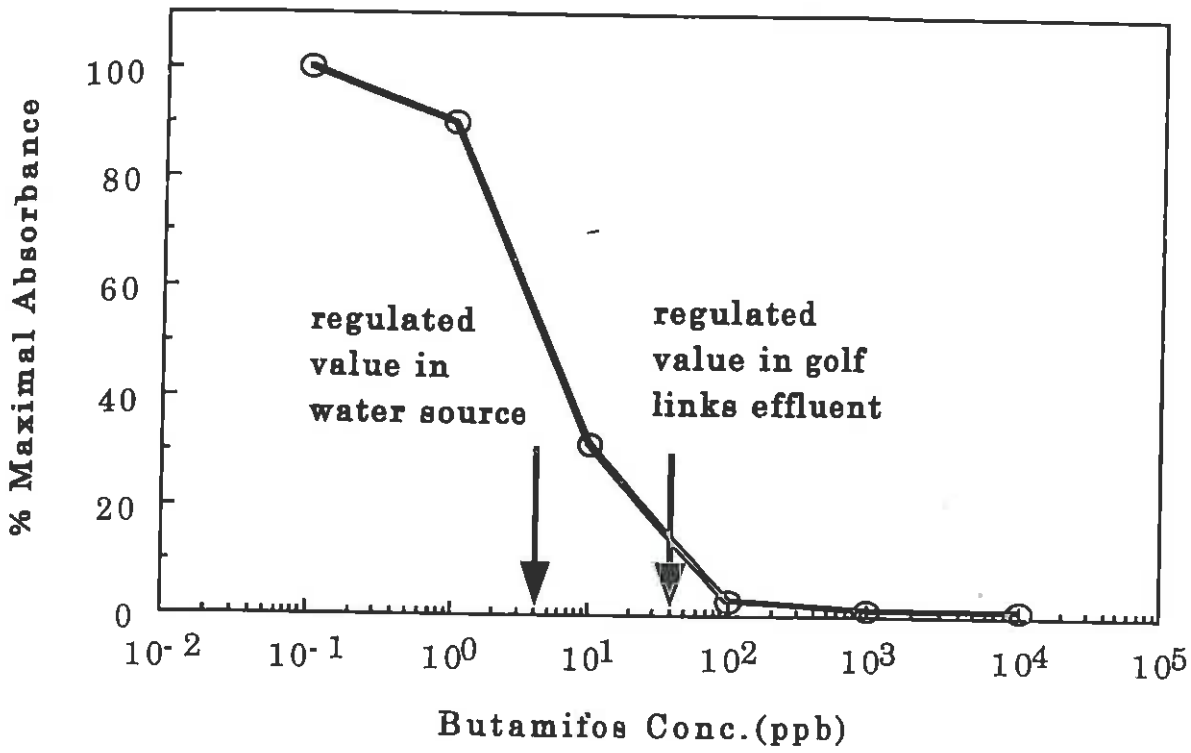


Figure 2. Standard curve of Butamifos

Table 2. Recoveries for water spiked studies

spiked level (ppb)	ELISA recovered (n=3)	ELISA recovery (%)	ELISA C.V. (%)	GC-MS recovered (n=3)	GC-MS recovery (%)	GC-MS C.V. (%)
2.5	2.7	109.3	12.1	2.6	103.6	3.8
5.0	4.2	84.7	24.5	5.2	103.5	1.7
10.0	10.3	102.7	3.7	11.0	110.0	6.2
20.0	18.2	91.0	1.3	23.9	119.5	1.4
40.0	37.2	92.9	2.3	38.1	95.3	1.2
80.0	80.0	100.0	0.0	76.5	95.7	1.7

* regulated value in golf links : 40ppb

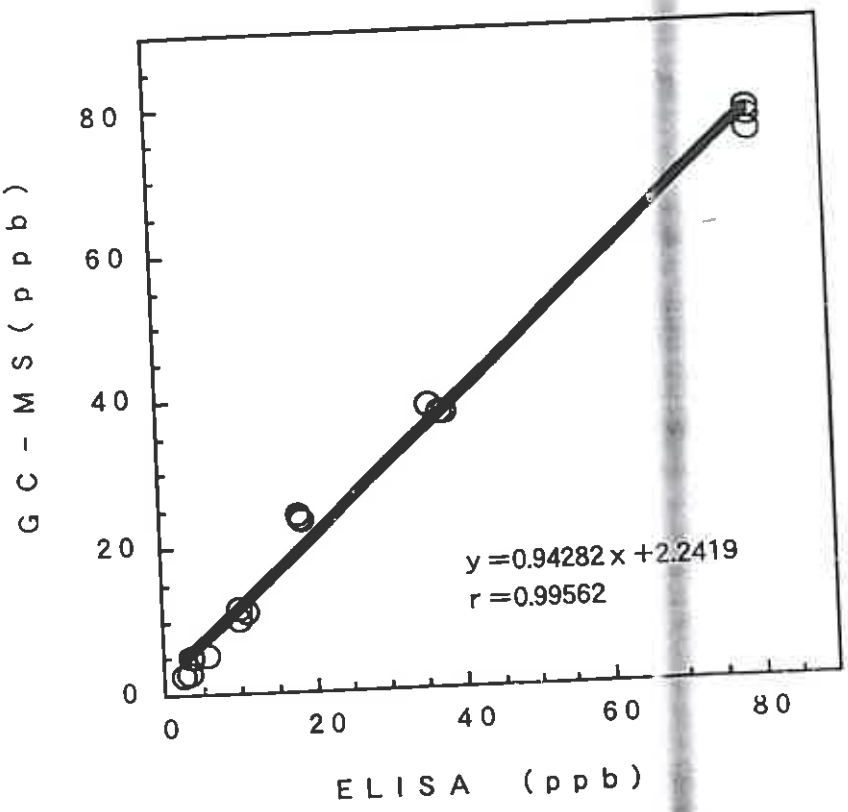


Figure 3. Correlation between butamifos water sample concentrations determined by ELISA and GC-MS method

EFFECTS OF DELAYING STARTER FERTILIZER APPLICATION ON RICE (*oryza sativa* L.) - BARNYARDGRASS (*Echinochloa crus-galli* (L.) Beauv.) COMPETITION

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Abstract: Field experiments were conducted in the low country dry zone of Sri Lanka to study the effect of delaying starter fertilizer application on rice-barnyardgrass (BYG) competition. Rice cultivar BG 350 was transplanted with a moderate density (10 plants of BYG m^{-2}) or no BYG competition and with the starter fertilizer application delayed for 0, 7 or 14 days after planting. Delay of fertilizer application reduced the yield in rice monocultures, but in rice-BYG mixtures the delay of fertilizer application increased the grain yield. The interaction effect of starter fertilizer application time and BYG had significant effects on rice plant dry weight, tiller number, plant height, leaf area, panicle number and grain yield. With normal planting densities of rice, the delay of starter fertilizer application for 14 days reduced the crop loss by BYG competition by 6.64 and 22.99% during the Maha (wet) and Yala (dry) seasons, respectively.

Key words: Starter fertilizer, weed density, Barnyardgrass, *Echinochloa crus-galli* (L.) Beauv

Introduction

Numerous weed species have infested rice (*Oryza sativa* L.) cultivation throughout the world.. Under lowland irrigated conditions usually weeds compete with rice to obtain mineral nutrients and for light. The intensity of rice yield loss by weed competition varies with the soil fertility, time of weed infestation, planting method, the weed flora and the rice variety used (De Datta *et al.*, 1969).

Usually weeds absorb large amounts of mineral nutrients at a faster rate than crops, as they have well developed root systems that derive a greater benefit from applied fertilizer (Zimdahl, 1980). Many studies have proved the importance of below ground competition between crops and weeds for mineral nutrient absorption (Perera *et al.* 1992; Johri *et al.*, 1991; Exley and Snaydon, 1992). In a study of wheat (*Triticum aestivum* L.) and blackgrass (*Alopecurus myosuroides* Huds.) competition, Exley and Snaydon (1992) concluded that root competition for nutrient absorption was higher than the above ground competition for light. In another study on rice-barnyard grass competition, Perera *et al.*, (1992) recorded below ground competition for nutrients was more important than the above ground competition for light. Most of the presently growing improved cultivars of rice have slow initial growth, while weeds in rice have a rapid initial growth resulting in their absorption of much of the nutrients applied at the time of planting or seeding of rice.

Effects of mineral nutrition on plant growth and yield are usually explained in terms of the functions of nutrient elements in plant metabolism (Marschner 1986). However these mineral nutrients may also have indirect relationships on plant growth and yield by changing responses of other components like weeds associated with crops. Many researchers have recorded stimulation of weed growth with application of inorganic fertilizers just before seeding or planting a rice crop (Bleasdade, 1960; Adiar *et al.*, 1962; Kleinnig and Noble 1968; Smith 1983). This stimulation of weed growth is an additive effect of relatively low competition effects of the rice seedlings and high rate of nutrient absorption by weeds. Under high nitrogen and phosphorous fertilizer levels the growth of rice was much more affected by weeds than those growing with low levels of nitrogen and phosphorous (Ampong-Nyarko and De Datta, 1992 ; Kleing and Nobel,

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1968). Therefore the level of soil nutrient availability at early growth stages is an important factor determining the outcome of rice-weed competition.

In many rice growing situations availability of fertilizer is limited or a costly input and therefore the maximization of fertilizer use efficiency by rice is important. In most growing situations nitrogen is the first growth limiting nutrient for rice. The efficiency of absorption or percentage of nitrogen recovery varies to a great extent depending on soil properties, timing and method of application and crop management practices (Yoshida, 1983). In the tropics recovery of applied nitrogen varies from 30-50 percent. (Prasad and De Datta, 1979). The percent of applied nitrogen recovery tends to be high with split applications and also when the nitrogen is top dressed at later stages of growth (Prasad and De Datta, 1979). Therefore delaying starter fertilizer application until roots of transplanted or direct seeded rice get established in the soil may increase the fertilizer use efficiency and it may increase the competitive ability of rice by reducing the stimulation of the growth of weeds. This would be a useful agronomic practice with poor weed control, if the net yield of rice under delayed fertilizer application is higher than for a rice crop that received fertilizer at the time of planting. The objective of this study was to evaluate the effects of delayed starter fertilizer application on rice plant growth and yield under moderate weedy situations.

Materials and Methods

Field experiment were conducted during 1993/94 Maha (wet) and 1994 Yala (dry) cultivation seasons at the Regional Agricultural Research Center, Aralaganwila, Sri Lanka under lowland, irrigated conditions. The soil type at the experimental site was sandy old alluvial (p^H 6.5 and organic matter 1.8% , nitrogen 163 ppm, phosphorous 52 ppm, potassium 180 ppm). Plot size used was 4 x 3 m, each separated by a 30 cm bund. Rice (cultivar BG 350; 3.5-month age class) seedlings which were raised in a wet bed nursery were transplanted manually with either 10 x 10 cm (high density) or 15 x 15 cm (normal density) spacing with 3 seedlings per hill. Barnyardgrass (*Echinochloa crus-galli* (L) Beauv.) a troublesome weed in rice was used as the weed in this experiment. Seedlings of barnyard grass (BYG) were raised in a separate nursery and transplanted uniformly in relevant plots just after planting of rice with a density of 10 plants m^{-2}, keeping one seedling per hill. This density of barnyard grass resembles a moderate level of weed infestation (Smith 1983) which is similar to the weed pressure in many rice farms.

The experimental design used was a split-split plot with four replications, with the planting density of rice as main plots, barnyard grass density (0 or 10 plants m^{-2}) in sub plots and the starter fertilizer application time (0, 7 or 14 days after planting) in sub-sub plots. All weeds other than planted barnyard grass were removed by manual weeding at 2-week intervals during the first two months after planting. All plots received the recommended level of rice fertilizer mixture for the low country dry zone (Department of Agriculture, Sri Lanka, 1991). The total amount of fertilizer (N 100, P_2O_5 25, K_2O 25 Kg ha^{-1}) is recommended to be applied with N 25, P_2O_5 25 and K_2O 25 Kg ha^{-1} as starter fertilizer (at planting) and 25 and 50 N Kg ha^{-1} as top dressings at 3 and 7 weeks after planting. In this study the starter fertilizer application time was delayed 0, 7 or 14 days as needed for relevant treatments.

Soil samples were taken just before starter fertilizer application to determine N and P levels in each plot. Leaf samples of rice and barnyard grass were also taken just before starter fertilizer application and one week after to determine plant N and P contents. Plant height measurements, tiller number, plant dry weight and panicle number were measured at 3, 5, 7, 9 and 11 weeks after planting (WAP) in both rice and barnyard grass. Leaf area measurements of rice and barnyard grass were taken at 5 and 8 WAP using a leaf area meter (Delta-T area measuring device, Model AM 82, Cambridge, England). Relative growth rate (RGR) of rice and BYG were calculated from the collected plant dry weight data .Rice grain yields were obtained from a 6 m^2 harvesting area and measured at 14% moisture level. Analysis of variance was performed using the general linear models procedure (SAS Institute Inc., 1991) to study the effects of treatments on rice and BYG performances.

Results and Discussion

Effects of treatments on rice and BYG growth

A retarded plant growth was observed in rice monocultures which received a delayed starter fertilizer application compared to the rice monoculture received normal starter fertilizer application. But in the presence of barnyardgrass, delayed fertilizer application increased the growth of rice plants compared to the growth of rice plants in the rice-BYG mixture fertilized at the time of planting. Statistical analysis of the collected data on rice plant growth revealed that the interaction of basal fertilizer application time and BYG had significantly affected the rice plant dry weight, tiller number, plant height, leaf area, panicle number and grain yield in both cultivation seasons (Table 1 and 2). The planting density of rice also had significantly affected plant dry weight, tiller number and leaf area of rice and the plant dry weight, tiller number and panicle number of BYG (data not shown).

Table 1. Effect of the delay of starter fertilizer application on rice plant growth and yield (1993/94 Maha).

Treatment	Height at maturity	Tiller number at maturity	Plant dry weight at maturity	Leat area (8 WAP)	Panicle number	Grain yield
	– cm —	– no. plant^{-1} –	– g plant^{-1} –	— cm^2 —	– no. plant^{-1} –	– Kg ha^{-1} -
S1W0B1	87.63 a	13.00 b	16.31 a	300.25 b	5.35 a	6200 a
S1W0B2	85.55 a	11.00 ab	14.72 a	391.25 b	5.33 ab	6145 a
S1W0B3	86.06 a	11.00 ab	13.66 b	401.75 b	6.20 a	6111 a
S1W1B1	91.00 ab	9.25 ab	11.34 b	438.25 b	5.25 b	4713 b
S1W1B2	91.63 ab	9.75 ab	13.01 b	356.50 b	5.63 ab	4715 b
S1W1B3	93.44 b	10.13 ab	13.28 b	530.00 a	5.90 ab	5049 b
S2W0B1	87.48 a	9.38 bd	8.86 bc	301.00 b	3.30 bc	6523 a
S2W0B2	84.75 a	7.70 a	8.41 bc	275.50 bc	3.23 c	6308 a
S2W0B3	87.06 a	7.74 a	8.08 bc	302.50 bc	4.00 b	6154 a
S2W1B1	83.45 a	7.10 a	9.23 bc	279.25 bc	3.35 bc	5279 b
S2W1B2	82.50 b	8.13 a	7.64 c	272.75 bc	3.30 bc	5562 b
S2W1B3	85.44 a	8.76 a	8.32 bc	269.50 c	3.68 bc	5923 a

S1 and S2- Planting density of rice (15 x 15 and 10 x 10 cm respectively) W0 and W1 - weed free and 10 barnyardgrass m^{-2}. B1, B2 and B3- starter fertilizer application at 0, 7 and 14 days after planting. WAP - weeks after planting. In a column, means followed by the same letter are not significantly different at the 5% probability level of Duncan's multiple range test.

Calculated values of relative growth rate (RGR) of rice were significantly higher in normal rice density than the high density rice. Though a reduced growth of rice was observed with the early application of starter fertilizer in the rice-BYG mixture, no statistically significant differences in RGR values were recorded in rice among fertilizer application times. But the delay of starter fertilizer application had significantly reduced the RGR of barnyardgrass throughout the growing period in the Maha season and during the early growth phase in the Yala season (data not shown). RGR values of BYG exhibited a high degree of variability, making the interpretation of results difficult.

A covariate analysis was done for soil and plant analysis data since these were measured in different growth stages. Soil analysis for total N revealed a reduced availability of N with the delay of starter fertilizer application. Similarly, leaf N analysis of samples collected at the time of fertilizer application revealed that both rice and barnyardgrass had lower N content than normal when the starter fertilizer was delayed. Generally this effect was more pronounced the greater the delay. Leaf N analysis of rice plant samples taken at one week after starter fertilizer application were not statistically significantly different from samples collected from the plots which were fertilized at the time of planting, but barnyardgrass leaves had significantly lower N when the starter fertilizer was delayed. Therefore this information suggests that at low

nitrogen availability, rice is less affected than barnyardgrass in the competition process for nitrogen. As cited by Marschner (1990), Klemm (1966) had found increased root growth in cereals with low nitrogen supply during early growth. Therefore the increased root growth of rice due to the delay of fertilizer application may have increased the ability of rice to absorb late applications of nitrogen. Plant analysis data for phosphorous did not show statistically significant effects from the delayed fertilizer application. Soil phosphorous contents at the time of starter fertilizer application time also were not different from the initial levels.

Table 2. Effect of the delay of starter fertilizer application on rice plant growth and yield (1994 Yala season).

Treatment	Height at maturity	Tiller # at maturity	Plant dry weight at maturity	Leaf area (8 WAP)	Panicle number	Grain yield
	– cm –	– no.plant^{-1} –	– g plant^{-1} –	– cm^2 –	– no.plant^{-1} –	– Kg ha^{-1} -
S1W0B1	89.31 a	10.56 a	22.25 a	366.25 a	8.40 a	7960 b
S1W0B2	81.06 b	8.44 b	20.19 a	296.50 a	7.30 b	6885 b
S1W0B3	83.13 bc	8.06 b	16.48 b	265.50 a	7.97 b	6300 bc
S1W1B1	83.06 b	7.13 b	13.23 b	295.25 a	7.10 b	4740 d
S1W1B2	85.56 a	7.11 b	13.81 b	327.50 a	7.45 b	5110 c
S2W1B3	90.56 a	9.03 b	17.10 b	380.75 a	8.45 a	5200 c
S2W0B1	87.13 ac	6.63 bc	10.85 b	272.25 a	7.78 b	8905 a
S2W0B2	84.75 ac	5.69 bc	9.17 bc	190.50 bc	5.05 bc	7127 b
S2W0B3	80.25 bc	5.06 bc	8.11 bc	176.50 bc	5.13 bc	7960 b
S2W1B1	76.06 b	4.06 c	8.05 c	149.25 c	4.65 c	5860 bc
S2W1B2	76.13 b	4.88 c	8.70 bc	149.00 c	4.95 c	6298 c
S2W1B3	79.38 b	6.25 bc	10.50 b	230.75 b	5.30 bc	6580 bc

S1 and S2- Planting density of rice (15 x 15 and 10 x 10 cm respectively). W0 and W1 - weed free and 10 barnyardgrass m^{-2}. B1, B2 and B3 - starter fertilizer application at 0, 7 and 14 days after planting. WAP - weeks after planting. In a column, means followed by the same letter are not significantly different at the 5% probability level of Duncan's multiple range test.

Effects of treatments on rice grain yield

The planting density of rice had significant effects on rice grain yield during the Maha season but during the Yala season it was not significant. When the starter fertilizer application was delayed for 14 days both densities of rice monocultures showed significant yield reductions during the Maha season. Though a similar trend was observed in the Yala season it was not significantly different (Table 3).

Interestingly, an increase in rice plant growth and grain yield was observed in the rice-BYG mixture with the delay of starter fertilizer application. There were increases in the yield of rice in rice-BYG mixtures in both of the tested rice densities, but only the high density planting of rice recorded statistically significant effects. The increased rice grain yield with a 14-day delay was 12.20 % and 12.29% in the Maha and Yala seasons, respectively (Table 3).

The percent rice yield loss by barnyard grass competition at each fertilizer application time was calculated from the yield difference between the rice crop grown under weed free and weedy conditions for each fertilizer application time (Table 4). These values clearly showed that the delay of starter fertilizer application had reduced the magnitude of rice yield loss by competition from barnyardgrass. Generally, the percent yield loss in the high density planting of rice was relatively less than that in the normal planting density of rice. The reduction of competitive effects of BYG with the delay of starter fertilizer application had improved the performance of rice, resulting in increased growth and yield.

Application of the starter fertilizer at planting under weedy situations seems to stimulate the growth of BYG and its resulting increased competition with rice to acquire resources, ultimately reducing rice yield. When fertilizer application was delayed both rice and BYG had reduced nutrient availability. Under this low fertility condition the relative competitive ability of BYG seems to be reduced, resulting in a reduced effect on rice plant growth. Similarly, delayed application of starter fertilizer may increase the fertilizer use

Table 3. Effect of the delay of starter fertilizer application on rice grain yield.

Starter fertilizer application time	S1W0		S1W1		S2W0		S2W1	
	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala
— DAP —				Kg ha^{-1}				
0	6200 a	7960 a	4713 a	4740 a	6523 a	8905 a	5279 a	5860 a
7	6145 a (-0.90)	6885 a (-13.5)	4715 a (0.04)	5100 a (7.59)	6308 a (-3.30)	7128 b (-19.96)	5562 ab (5.37)	6298 ab (7.47)
14	6111 a (-1.44)	6300 b (-20.9)	5049 a (7.14)	5200 a (9.70)	6154 a (-5.50)	7960 b (-10.61)	5923 b (12.2)	6580 b (12.29)

S1 and S2- Planting density of rice (15 x 15 and 10 x 10 cm respectively). W0 and W1 - weed free and 10 barnyardgrass m^{-2}. DAP - days after planting. Rice yield loss/gain by the delay of fertilizer application as a percent of its "no delay" treatment is given in the parenthesis. In a column, means followed by the same letter are not significantly different at the 5% probability level of Duncan's multiple range test.

Table 4. Percent yield loss of rice by barnyardgrass competition at each fertilizer application time.

Basal fertilizer application time	S1W1		S2W1	
	Maha	Yala	Maha	Yala
— DAP —		Percent		
0	24.00 ab	40.45 b	19.07 c	34.19 b
7	33.00 b	25.93 a	11.82 b	11.64 a
14	17.36 a	17.46 a	3.76 a	17.34 a

S1 and S2- Planting density of rice (15 x 15 and 10 x 10 cm respectively). W1 - 10 barnyardgrass m^{-2}. DAP - days after planting. In a column, means followed by the same letter are not significantly different at the 5% probability level of Duncan's multiple range test.

efficiency of rice as the roots of rice can be better established in the soil by the time of fertilizer application. Similar growth responses of rice and BYG were recorded by Kleinig and Noble (1968) in an experiment on the effect of different levels of nitrogen and phosphorus on BYG competition with rice. Under conditions of high N and high P, BYG competition reduced rice grain yield more than under low N and low P conditions. The intensity of yield reduction by BYG was greater for additions of nitrogen than for the addition of P fertilizer in that experiment.

Delaying fertilizer application for 2 weeks resulted in more yield reduction than a delay of one week (Table 3), but the 2-week delay had less yield loss from weed competition (Table 4). When considering the total yield loss in Table 5, the 2-week delay resulted in the least total yield loss as compared to a delay of 0 or 7 days. Therefore delaying the starter fertilizer application for two-weeks seems to be a good alternative agronomic practice to reduce the magnitude of rice yield reduction by weed competition.

Table 5. Total yield loss by the delay of fertilizer and barnyardgrass competition at each fertilizer application time.

Basal fertilizer application time	S1W1		S2W1	
	Maha	Yala	Maha	Yala
– DAP –	Percent			
0	24.00 a	40.45 c	19.07 b	34.19 c
7	33.04 b	33.52 b	17.19 ab	19.11 b
14	24.50 a	27.16 a	15.96 a	29.63 a

S1 and S2- Planting density of rice (15 x 15 and 10 x 10 cm respectively). W1 - 10 barnyardgrass m^{-2}. DAP - days after planting. In a column, means followed by the same letter are not significantly different at the 5% probability level of Duncan's multiple range test.

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INFESTATION AND IDENTIFICATION OF PERENNIAL GRAMINEOUS WEEDS IN PADDY FIELDS OF JAPAN

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Abstract : Several perennial species of Geamineae have become problem weeds in paddy fields in Japan in recent years. There is misunderstanding on these weeds among farmers because *Paspalum distichum* and *Leersia oryzoides* have been known well only as perennial grass occurring in paddy fields of southern and northern Japan, respectively since the 1970's. *L.japonica, L.sayanuka, Agrostis stolonifera, Glyceria declauperta, G.ischyroneura, G.acutiflora, Cynodon dactylon* and *Isachne globosa* are determined also as perennial Gramineous weeds in paddy fields of Japan. Keys for correct identification using the morphological characteristics of leaf blade and sheath are presented. Direct sowing rice cultivation was considered as a factor affecting the severe infestation of perennial Gramineous weeds through a survey in paddy fields in Chiba Prefecture of Japan.

Key Words: Gramineous weeds, paddy field, perennial weed, identification, Japan.

Introduction

Perennial Gramineous weeds are troublesome especially in the fields for cereal crops including rice because their control with herbicides is generally difficult. Recent years, their infestation in the paddy fields has become a problem. However, the problem species seems to be different place by place while same common name is used occasionally for the weeds in several cases. Investigation on the identification and distribution of perennial Gramineous weeds growing in paddy fields in Japan was conducted in order to obtain correct information of their infestation and to establish the effective methods for their management.

Materials and Methods

Examination of perennial Gramineous weeds in paddy fields

Correct species were identified in the paddy fields of several prefectures in the central Japan, according to the information on the severe infestation of perennial Gramineous weeds. The samples of perennial Gramineous weeds collected in the paddy fields throughout of Japan were identified.

Keys for identification of perennial Gramineous weeds without panicles

Ten species and one variety of perennial Gramineous weeds collected in the paddy fields were cultivated in the cement pot of 75l under submerged condition at National Agriculture Research Center, Tsukuba, Ibaraki to compere the morphological characteristics of leaf blade and sheath.

Analysis on infestation of perennial Gramineous weeds in paddy fields of Chiba Prefecture

In the paddy fields on the end of October, 1996, just after harvested, the degree of infestation was measured for each perennial species by observing re-grown plants along a levee and a diagonal line of every 45 paddy of field, in Yachiyo, Chiba Prefecture of central Japan, where several cultivation styles were practised. Degree of infestation was determined as a: no infestation, b: present along levee, c: present in field, d: abundant in field.

Response to cyhalofop-butyl in several species

Five segments of culm with two nodes of *Leersia japonica*, *Paspalum distihcum*, and *Agrostis stolonifera* were plated in 3.8 litter pot filled with clay loam and 0.14g of N, P_2O_5 and K, on the end of May, 1997, with three replications. At 3.1-4.9 leaf stage and 4.8-6.6 leaf stage of re-grown shoot under submerged condition, cyhalofop-butyl (EW emulsifiable concentrate) was applied by 30ml ai/ha. Effect of herbicides was measured at 33 and 37 days after each treatment, respectively.

Results and Discussion

Examination of perennial Gramineous weeds in paddy fields

There were many cases of misunderstanding on the identification of perennial Gramineous weeds growing in the paddy fields in the farmers and officers of agriculture extension (Table 1). In these cases, perennial Gramineous weeds were recognized commonly as *Paspalum distichum* or *Leersia oryzoides*. There is a tendency that perennial Gramineous weeds are incorrectly identified as above two species without any accurate observation because they have been known well as the representative perennial grasses in the paddy fields since the 1970's (Miyahara 1987). By examining the samples of perennial Gramineous weeds collected from paddy fields of Japan, following species were detected in addition to *Paspalum distihcum* L., including *P.distichum* L. var. *indutum* Shinners and *Leersia oryzoides* Sw.. *Leersia japonica* Makino, *Leersia sayanuka* Ohwi, *Agrostis stlonifera* L., *Glyceria depauperta* Ohwi, *Glyceria ischyroneura* Steud., *Glyceria acutiflora* Torr., *Cynodon dactylon* Pers. and *Isachne globosa* O.Kuntze

Table 1. Examples of recognition of perennial Gramineous weeds in paddy fields of central Japan

Location and field	season	considered as	correct identification
A Pref. farmers corporation	July 1994	*Paspalum distichum*	*Leersia japonica*
C Pref. Agr. Exp. Stn.	July 1995	*Paspalum distichum*	*Paspalum distichum*
			Agrostis stolonifera
S Pref. herbicide evaluation	July 1996	*Paspalum distichum*	*Leersia japonica*
			Agrostis stolonifera
N Pref. Agr. Exp. Stn.	Aug. 1996	*Paspalum distichum*	*Leersia oryzoides*
N Pref. farmers fields	Aug. 1997	*Leersia oryzoides*	*Leersia sayanuka*
C Pref. farmers corporation	July 1995	*Paspalum distichum*	*Leersia japonica*
			Leersia sayanuka
			Agrostis stolonifera
			Glyceria depauperta
			Paspalum distichum

Keys for identification of perennial Gramineous weeds without panicles

Through the observation of leaf blade and leaf sheath of 11 samples of perennial Gramineous weeds cultivated at Tsukuba, keys for identification were prepared as shown in Table 2. During the early growing season of transplanted rice when herbicides would be applied, it is difficult to obtain the panicles which is essential for correct identification of Gramineae plants. Therefore, the keys with morphological characteristics will be useful in actual paddy fields to prevent misidentification of perennial Gramineous weeds. A desk pad type sheet with the keys and coloured photographs of each species was made in order to distribute the correct information on the perennial Gramineous weeds into the farmers and agricultural technicians.

Analysis on infestation of perennial Gramineous weeds in paddy fields of Chiba Prefecture

Leersia japonica, *L. sayanuka* and *Agrostis stolonifera* were determined by the keys shown in Table 2, in the sueveyed area. Percentage of severely infested paddy field by *L. japonica* was greater in the dry sown cultivation than in the transplanted field while the infestation of *L. sayanuka* and *A. stlonifera* was not conspicuous in the direct sown paddy fields (Fig. 1). Severe infestation of *L. japonica* in dry sown paddy fields might be caused by lack of puddling which would prevent re-growth from segments of culms or rhizomes in perennial Gramineous weeds.

Table 2. Keys for perennial Gramineous weeds based on morphology of leaf blade and sheath, growing in paddy fields of Japan

a: leaf blade emerges in rolled
- aa: leaf sheath glabrous and smooth, glabrous plant, ligule membranous, obvious ---------- *Agrostis stolonifera* L.
- ab: leaf sheath remarkably scabrous
  - aba: ligule obvious ---------- *Leersia japonica* Makino
  - abb: ligule not obvious
    - abba: base of leaf blade pale green ---------- *Leersia oryzoides* Sw.
    - abbb: base of leaf blade reddish brown ---------- Leersia sayanuka Ohwi
- ac: leaf sheath pilose
  - aca: ligule membranous, obvious ---------- *Isachne globosa* O.Kuntze
  - acb: ligule truncate, inconspicuous
    - acba: hair on sheath dispersed ---------- *Paspalum distichum* L.
    - acbb: hair on sheath dense ---------- *P.distichum* L. var. *indutum* Shinners

b: leaf blade emerges in folded
- ba: leaf sheath closed, leaf blade slightly leather-like ---------- *Glyceria ischyroneura* Steud.
- bb: leaf sheath closed except for upper part, leaf blade papery, slightly greyish green, ligule membranous
  - bba: leaf blade around 3mm width, longer than ligule ---------- *Glyceria depauperta* Ohwi
  - bbb: leaf blade around 5mm width, shorter than ligule ---------- Glyceria acutiflora Torr.
- bc: leaf sheath open, white hair dispersed at blade base and sheath collar ---------- *Cynodon dactylon* Pers.

Modified partially from Morita *et al.* (1998b)

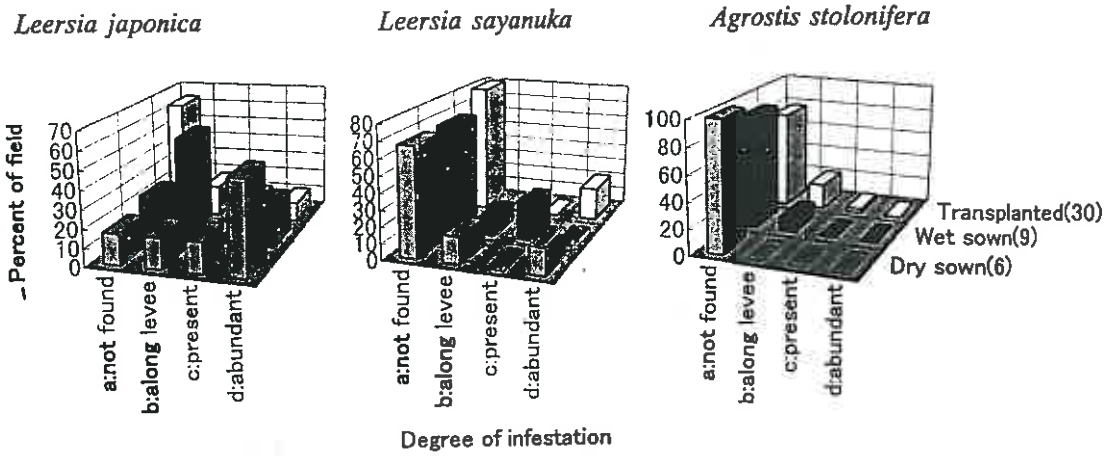


Fig. 1. Degree of infestation of *Leersia japonica*, *L. sayanuka* and *Agrostis stolonifera* in different style of rice cultivation in paddy fields of Yachiyo, Chiba Prefecture.
Modified from Morita *et al.* (1998b) and Morita (1999).
Measured after harvest of rice in 1996.

Response to cyhalofop-butyl in several species

Cyhalofop-butyl controlled around 90% and 60% of plants and reduced the dry weight of plants to about 4% of control in both application times for *Paspalum distihcum*. *A. stolonifera* was also susceptible to cyhalofop-butyl in both stages of regrowth. However, this herbicide could not control *L. japonica* in both application times (Table 3). The result was surported by the reports that *L. oryzoides* was tolerant and *A. alba was* susceptible to cyhalofop-butyl (Ito *et al.*, 1998) and that cyhalofop-butyl could control *P. distihcum* effectively at 15-20cm of culm length (Sudo and Iwai, 1996). The correct identification is essential to apply cyhalofop-butyl to control *P.*

distihcum because this species can not be distinguished frequently from other perennial Gramineous weeds as shown in Table 1.

Table 3. Response to cyhalofop-butyl (30%, EW) at different stages of re-growth in *Leersia japonica, Paspalum distichum* and *Agrostis stolonifera*

Application time	3.1-4.9 leaf stage		
Species	*L. japonica*	*P. distichum*	*A.sotlonifera*
No. of plants (/pot)	4.7 ± 0.5 (94)	1.0 ± 0.0 (22)	1.7 ± 0.5 (34)
Longest culm (cm)	93.5 ± 0.5 (88)	10.9 ± 2.2 (12)	22.4 ± 12.4 (50)
No. of culms (/plant)	11.1 ± 1.4 (93)	1.0 ± 0.0 (5)	2.5 ± 1.54 (26)
Dry weight (g/plant)	2.1 ± 0.3 (94)	0.2 ± 0.1 (3)	0.06 ± 0.04 (15)
Dry weight /pot (%)	(88)	(1)	(5)

Application time	4.8-6.6 leaf stage		
Species	*L. japonica*	*P. distichum*	*A.stolonifera*
No. of plants (/pot)	5.0 ± 0.0 (100)	1.7 ± 0.5 (38)	3.0 ± 1.6 (60)
Longest culm (cm)	100.5 ± 7.4 (94)	10.7 ± 2.8 (12)	26.0 ± 10.9 (58)
No. of culms (/plant)	13.0 ± 0.4 (109)	1.2 ± 0.2 (6)	3.3 ± 2.5 (34)
Dry weight (g/plant)	2.4 ± 0.2 (108)	0.3 ± 0.2 (5)	0.08 ± 0.08 (20)
Dry weight /pot (%)	(108)	(2)	(12)

Modified from Morita *et al.* (1998a)

Figure shows average ± S.D. of 3 replication and it in parenthesis shows percentage to control.

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PHYTOTOXIC ACTIVITY OF MEXICAN SUNFLOWER (*Tithonia diversifolia*) IN SOIL AND ITS ALLELOPATHIC POTENTIAL

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Abstract: A series of experiments were conducted to determine the phytotoxic activity of Mexican sunflower in soil and to evaluate its allelopathic potential under natural field conditions. The soil from the pots previously planted with Mexican sunflower for 6 months, water extract from air-dried Mexican sunflower leaves at the concentration of 10-20 mg dry matter equivalent/ml applied in soil, Mexican sunflower leaf powder incorporated in soil at the ratio of 10-20 mg/g dry soil and water leachate of Mexican sunflower leaves obtained by water spray applied to soil significantly inhibited shoot and root growth of test plant seedlings. The soils collected from the areas growing Mexican sunflower for 5 years in Thailand, contained plant growth inhibitory substance(s) in amount sufficient to inhibit seedling growth of the tested plants

Key words: Mexican sunflower, *Tithonia diversifolia*, phytotoxic activity, allelopathy.

Introduction

Mexican sunflower is a perennial plant of the family Asteraceae that originated in Mexico and Central America (Dutta *et al.* 1993). The plant was introduced to many country in Asia, Africa, South America and Australia and has become a dominant plant in some regions where it is present (Zungsontiporn and Harada, 1995; Ayeni *et al.*, 1997a; Ayeni *et al.* 1997b). This suggested that the plant has a strong competitive ability and possible allelopathic activity to other plant species. Mexican sunflower was reported to contain sesquiterpene lactones, i.e., tagitinin A, tagitinin C, and a flavone, hispidulin (Baruah *et al.*, 1979; Schusler *et al.*, 1992; Dutta *et al.*, 1993). These compounds could inhibit seed germination and seedling growth of the test plants in petridish bioassays (Baruah *et al.*, 1994). Although the substances isolated from Mexican sunflower are known plant growth inhibitors, the phytotoxic effects of its water extract, water leachate and residues in soil have not been examined. This study was conducted to determine the phytotoxic activity of Mexican sunflower in soil and to evaluate the allelopathic potential of Mexican sunflower under natural field conditions.

Materials and Methods

Plant Material and extraction

Fully expanded leaves of 6 month-old Mexican sunflower grown in the greenhouse on a Kannondai soil [light color andosol, total carbon 3.5%, total nitrogen 0.2%, cation exchange capacity 21.0 me/100g, clay content 22.3%, maximum water holding capacity (MWHC) 69.8% of dry soil], were harvested, air dried, ground, and kept in glass bottles at – 20 C until used. The water extract was prepared at a concentration of 20 mg dry matter equivalent/ ml (Tongma *et al.*, 1997). Six plant species, radish, rice, sorghum, crabgrass, rice flatsedge, and slender amaranth, were used as the bioassay plants

Germination and growth of seedlings in soil previously planted with Mexican sunflower

Plastic pots containing 2.8 Kg of air-dried Kannondai soil were planted with one Mexican sunflower seedling (4-leaf stage) each. Soil from the pots where Mexican sunflower was grown for 6 months was air-dried at room temperature. Forty grams of dry soil was put into petri dishes. Twenty-eight ml of distilled water was added to reach MWHC. Bioassay was carried out using 50 seeds of radish, rice and sorghum or 100 seeds of crabgrass, rice flatsedge and slender amaranth. Incubation was done in the dark at 25 for 7 days (except radish and sorghum for only 4 days). Soils from the non-planted pots were used as control treatments. Seed germination percentages were recorded, and the shoot and root length of seedlings were measured. A similar bioassay experiment was conducted by using soil-water separated from planted soil. Soils from the pots planted with Mexican sunflower for 6 months were centrifuged to separate the soil-water from the soil (Kobayashi *et al.*, 1994). Five millilitres of soil-water was used to moisten a sheet of filter paper in petri dishes and bioassay was carried out following the same procedures described above. Soil-water separated from the non-planted pots served as the control.

Seedling growth as affected by Mexican sunflower extract applied to soil

Ten grams of air-dried, sieved Kannondai soil was put into small glass bottles (4 cm in diameter and 8 cm in height) and moistened with 7 ml of the leaf water extract at the concentrations of 5, 10, 15 and 20 mg DME/ml. Five uniformly germinated seeds of the test plants were separately grown at 2 mm depth from the soil surface. The bottles were covered with translucent plastic caps and placed in a growth chamber at 25/20 C 12/12 h day/night period for 4 days. Shoot and root length of the test plants were recorded.

Seedling growth as affected by Mexican sunflower leaf residue mixed into soil

Mexican sunflower leaves or peat moss powder were mixed with air-dried, sieved Kannondai soil at the ratios of 10 and 20 mg/g dry soil. Ten grams of the mixed and non-mixed soil was put into glass bottles and moistened with 7 ml distilled water. Five uniformly germinated rice seeds each having a 1 mm coleoptile were planted and placed in the growth chamber for 4 days. Shoot and root length of the rice seedlings were measured.

Residual phytotoxic activity of Mexican sunflower leaf water extract and leaf residue in soil

To compare the phytotoxic activity of Mexican sunflower extract and leaf residue at different periods after treatment to soil, 10 g of Kannondai soil was treated with 7 ml of water extract from Mexican sunflower leaves at the rate being equivalent to the amount of Mexican sunflower leaf powder 10, 14 and 20 mg/g dry soil. The treated soils were incubated in the dark at 25 for 0, 7, 14, 21, 28, 35, 42, 56 and 70 days. Similar treatments were conducted to investigate the residual phytotoxic activity of Mexican sunflower leaf residue at different periods after incorporation into soil. Mexican sunflower leaf powder was mixed with air-dried Kannondai soil at the ratios of 10, 14 and 20 mg/g dry soil. Ten grams of soil mixed with the leaf powder was put into the bottle, moistened with distilled water and incubated. At the end of the incubation period, 5 germinated rice seeds were planted in each bottle and placed in the growth chamber for 4 days. Shoot and root length of rice seedlings were measured and compared. Soil-water from the incubated soils were separated. Seven milliliters of soil-water was applied into 20 g of sea sand in the glass bottles and bioassayed with germinated rice seeds in a growth chamber for 4 days (Tongma *et al.*, 1998)

Phytotoxic activity of Mexican sunflower leaf leachates

The green and senescent leaves were separately spread on a stainless screen at the rates of 50, 100, 150, 200, 250 and 300 g/m^2. The screen was placed over a collecting plastic box (215 mm x 150 mm x 50 mm) containing 330 g of air-dried sieved Kannondai soil. The leaves were gently hand-sprayed with 200 ml of distilled water, being equivalent to a 6 mm rainfall. The leached water passing through the screen was allowed to gravitationally drip onto the soil in the box for 30 min. Soil moisture content in each box was adjusted to MWHC with distilled water by sub-irrigation (Tongma *et al.*, 1999). Thirty uniformly germinated rice seeds, having 1 mm coleoptile were planted in each box and allowed to grow in a growth chamber for 4 days. Shoot and root length of the rice seedlings were measured and compared to the seedlings grown in the control soil.

To determine the effect of the amount of rainfall on the phytotoxicity of Mexican sunflower leaf leachate, 6.67 grams of air-dried green or senescent leaves placed on the screen was sprayed with 50,100,150, 200 and 250 ml of distilled water, the amounts being equivalent to 1.5, 3.0, 4.5, 6.0 and 7.5 mm of rainfall, respectively. After the leachates had completely dripped into the soil boxes, soil moisture content in each box was adjusted to MWHC. The treated soils were bioassayed with germinated rice seeds as described above. Shoot and root length of the rice seedlings were measured and compared to the seedlings in the control soil.

Germination and growth of seedlings in soil collected from Mexican sunflower field

The site chosen was the area where Mexican sunflower plants have been grown for 5 years in Lampang, northern of Thailand. Soil samples were taken (0-10 cm depth) sieved and air dried at room temperature for 24 h. The phytotoxic activity of soil from beneath Mexican sunflower plants on seed germination and seedling growth of the test plant species were examined in petri dish and glass bottles as described above. Soil from the same area, without Mexican sunflower plants, served as the control soil.

All experiments were carried out twice with four replications each time. The data were combined and presented as the pooled mean values.

Results and Discussion

Germination and growth of seedlings in soil previously planted with Mexican sunflower

Seed germination of all test plant species grown in Mexican sunflower planted soil and non-planted soil were similar. Shoot growth of radish, sorghum, crabgrass and slender amaranth were significantly reduced in soil previously planted with Mexican sunflower. Root growth of radish, rice, sorghum and slender amaranth were markedly reduced. This indicated that the soil planted with Mexican sunflower contains some growth inhibitory substance(s) in amounts sufficient to suppress shoot and root growth of the seedlings in the early stage, although these amounts have no inhibitory effect on seed germination. The phytotoxic activity differed among the test plant species.

Shoot growth of most test plants was inhibited by soil-water separated from soil previously planted with Mexican sunflower. Root growth of all test plants was inhibited. Plant responses observed in this experiment were generally similar to the results of the bioassay using previously planted soil. This suggested that the growth inhibition observed in the soil previously planted with Mexican sunflower was induced by the compound(s) present in the soil-water.

Seedling growth as affected by Mexican sunflower extract applied to soil

Shoot and root growth of radish, rice, sorghum, rice flatsedge and slender amaranth were inhibited in the soil treated with water extract from Mexican sunflower leaves. Shoot and root growth of all test plants decreased with increasing concentration of the extract. Sorghum shoot growth was the most sensitive to the extract, followed by radish, rice and slender amaranth. Root growth of radish, sorghum and rice were more susceptible to Mexican sunflower water extract than those of crabgrass, rice flatsedge and slender amaranth. The result showed that the phytotoxic activity of Mexican sunflower extract was present in the soil and the degree of inhibition was dependent on the plant species.

Seedling growth as affected by Mexican sunflower leaf residue mixed into soil

The effects of Mexican sunflower leaf and peat moss residue incorporated into soil on the growth of radish, rice, sorghum, crabgrass, rice flatsedge and slender amaranth seedlings were examined. Peat moss powder at 10 or 20 mg/g dry soil did not inhibit shoot and root growth of test plant seedlings, whereas Mexican sunflower leaf powder at 10 and 20 mg/g dry soil caused a reduction. This demonstrates that the inhibitory effect of Mexican sunflower is induced by phytotoxic substances released from the leaf residue in soil.

Residual phytotoxic activity of Mexican sunflower leaf water extract and leaf residue in soil

The residual phytotoxic activity of Mexican sunflower leaf water extract and leaf powder applied into soil was investigated at various periods of incubation. Shoot and root growth of rice seedlings in soil applied with Mexican sunflower leaf water extract and mixed with the leaf powder were remarkably inhibited in the first 4 weeks of incubation (Fig.1). However, the phytotoxicity decreased with the incubation period elapsed. The reduction of phytotoxicity of water extract was greater than that of the leaf powder residue. This was probably due to the continuous release of phytotoxic compound(s) from the leaf residue into soil during the incubation period, while no phytotoxic substance was additionally released in the water extract treatment. The result showed that the phytotoxic compound(s) from the extract and leaf powder were maintained in the soil for at least 4 weeks and the performance period of phytotoxic activity was dependent on the amount of water extract or leaf powder application.

Shoot and root growth of rice seedlings in sea sand treated with soil-water from the soil applied with the extracts and in the soil mixed with the leaf powder, were inhibited to a similar extent as those grown directly in the treated soils. This finding suggested that the phytotoxic activity of Mexican sunflower extract and leaf residue in soil was depended on the concentration of phytotoxic compounds in soil-water and influenced by soil factors such as soil adsorption and microbial degradation with time.

Phytotoxic activity of Mexican sunflower leaf leachates

Both green and senescent leaf leachates inhibited rice root growth. The green leaf leachate showed a slightly higher inhibitory effect than the senescent leaf leachate. Rice root growth decreased with increasing amounts of leaves. Shoot growth of the rice seedlings was also inhibited but the degree of inhibition on shoot growth was less than on root growth. This result indicated that the phytotoxic compound(s) contained in both green and senescent leaves of Mexican sunflower could be eluted by water spraying.

The response of rice seedlings to water leachate obtained from various spray volumes differed. Spraying water at the rate of 50 ml onto 6.67 grams of green Mexican sunflower leaves showed a slight inhibitory effect on shoot and root growth. The highest phytotoxicity of leachate was found at the spray volume of 150 ml. The inhibitory activity on rice seedling growth declined in larger spray volumes. The similar pattern of rice response was found in the senescent leaf leachate treatments.

Water sprayed at the rates of 50, 100, 150, 200, and 250 ml on the 215 mm x 150 mm screen are equivalent to 1.5, 3.0, 4.5, 6.0 and 7.5 mm of rainfall, respectively. The water leachates obtained from these spray volumes showed phytotoxic activity on seedling growth, suggesting that phytotoxic substance (s) in both green and senescent leaves could easily be washed out by rain water, and that they require a sufficient amount of water to dissolve and be released into the environment. However, too much leaching water may lead to dilution of the phytotoxic compound(s) after the washing out.

Germination and growth of seedlings in soil collected from Mexican sunflower field

Seed germination, shoot growth and root growth of radish, rice, sorghum, crabgrass, rice flatsedge and slender amaranth in soil from the field planting with Mexican sunflower for 5 years were inhibited compared to those in the soil from the area non-planting with Mexican sunflower (Table 1). Soil samples collected from the areas, with and without Mexican sunflower, did not differ in soil texture, pH and organic matter content. This result suggested that soil planting with Mexican sunflower for 5 years, under natural conditions in northern Thailand, contains phytotoxic substance(s) in amounts sufficient to suppress germination and seedling growth of other plant species.

Under field conditions, during 5 months of rainy season in Mexican sunflower infested areas in the northern part of Thailand, it was found that this plant is able to produce green and senescent leaves that are about 80-300 and 25-150 grams in dry weight per m^2, respectively. The range depended on age, plant density and soil fertility. The average rainfall was 950 mm with 32 rainy days in the season. This amount of rainfall is estimated to be sufficient to leach the phytotoxic compounds from the plant and its residues into in a concentration sufficient to inhibit growth of other plant species. It can be assumed that the phytotoxic compounds are continually accumulated in the soil, brought about by sufficient amounts of rainfall and the biomass of Mexican sunflower and by exudation from the roots.

Baruah *et al.*, 1994 reported that tagitinin A, tagitinin C and hispidulin, which were isolated from Mexican sunflower leaves, reduced seed germination and seedling growth of radish, cucumber and onion but the phytotoxic activity of these compounds in soil have not been examined yet. In the present study, soil previously planted with Mexican sunflower, leaf powder incorporated in soil, water extract and water leachate from Mexican sunflower leaves applied to soil and soils collected from the areas growing Mexican sunflower for 5 years showed inhibitory activity on growth of the test plant seedlings. These findings suggest the allelopathic potential of Mexican sunflower under natural field conditions.

In this study, no attempts were made to isolate and determine the quantities of the phytotoxic compound(s) contained in the Mexican sunflower plant and in soil, but it is believed that allelopathic activity of Mexican sunflower in soil is induced by the combined action of water soluble and /or non-water soluble phytotoxic substances released from the plant such as tagitinins and hispidulin in soil-water.

Understanding on allelopathy of Mexican sunflower may be valuable in weed control management in the upland areas of northern Thailand. For this purpose, Mexican sunflower might be suitable in both non-cropping and cropping areas. In non-cropping areas, particularly in rangeland and deforested areas, Mexican sunflower can be grown as the cover plant to prevent soil erosion and reduce weed infestation prior to the land being reforested. In non-cropping areas, Mexican sunflower might be used as a green manure plant. It can be mulched on the soil or incorporated into the soil for weed control and for improving soil fertility in some selected crops that tolerate to the phytotoxic compound(s) contained in this plant. Proper management of Mexican sunflower residue in the cropping areas may help to improve upland crop production in the future. More intensive investigations in Mexican sunflower growing areas are required before suggesting the appropriate management of this plant and the suitable cropping system in these areas.

Acknowledgements:

We thank the Forest Industry Organization of Thailand for providing the Mexican sunflower seeds and very valuable data.

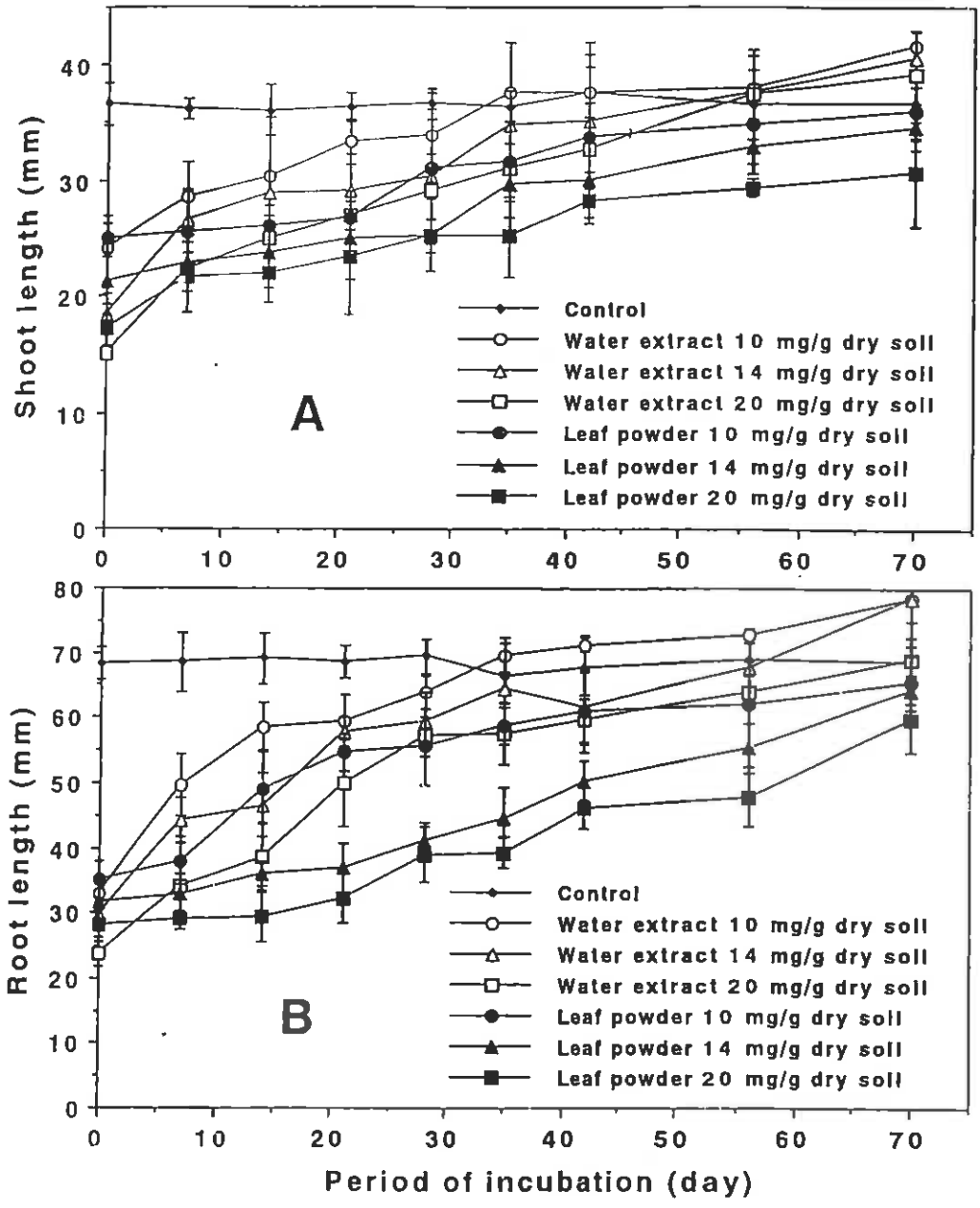


Fig. 1 Shoot growth (A) and root growth (B) of rice seedlings in soil applied with water extract from Mexican sunflower leaves and mixed with Mexican sunflower leaf powder at different period of incubation.

Table 1. Seed germination and seedling growth of test plant species in soil collected from fields planting and non-planting with Mexican sunflower.

	Seed germination		Shoot length		Root length	
Plant species	Planting soil	Non-planting soil	Planting soil	Non-planting soil	Planting soil	Non-planting soil
	%		mm			
Radish	85*	97	45*	58	40*	62
Rice	82*	96	23*	29	51*	82
Sorghum	81*	94	37*	76	42*	76
Crabgrass	69*	87	28*	35	7 *	10
Rice flatsedge	71*	83	15*	20	7 *	11
Slender amaranth	54*	69	14*	18	5 *	10

Seed germination, shoot length and root length of test planted were recorded 7 DAP, except for radish and sorghum (4 DAP). An asterisk (*) represents means in planting soil and non-planting soil that are significantly different according to paired t test at $P< 0.05$.

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PLANT CHARACTERISTICS ASSOCIATED WITH RICE (*Oryza sativa* L.) - BARNYARDGRASS (*Echinocloa crus-galli* L. Beauv.) COMPETITION

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ABSTRACT: Five cultivars of rice possessing high, medium and low levels of weed competitive morphological traits (based on the INTERCOM model sensitivity analysis) were evaluated for their performances and competitive ability against barnyardgrass (BYG) under lowland irrigated conditions in the low country dry zone of Sri Lanka. Each cultivar of rice was planted with 0, 3, 9, 27 and 81 plants m^{-2} of BYG to determine cultivar differences in competitive ability. Significant variations were observed in cultivar performances and also in the suppression of the weed. Growth and yield of cultivars PPL and BG 94-2 were least affected by BYG competition while cultivars BG 1611 and BG 350 were most affected by BYG competition. Rice leaf area, plant height and plant dry weight data taken at 4 weeks after planting (WAP) were negatively correlated with BYG dry weight at maturity (Leaf area $r = -.40^{*}$ to $-.62^{**}$, plant height $r = -.39^{*}$ to $-.61^{**}$ and plant dry weight $r = -.41^{*}$ to $-.78^{**}$). At high BYG densities rice plant height at maturity was positively correlated with the grain yield.

Key words. Barnyardgrass, *Echinochloa crus-galli* (L.), Simulation, INTERCOM model

Introduction

Most of the modern cultivars of rice (*Oryza sativa* L.) with improved plant type have been developed with a reduced ability to compete with weeds and poorer adaptation to weedy situations (Moody, 1979). Therefore farmers spend much time and money for weed control to obtain good yields. During the last 30 years, coincident with the "green revolution", farmers have applied increasing quantities of herbicides, gradually replacing traditional cultural and mechanical weed control practices. The use of herbicides however has not eliminated weed problems in agriculture (Firbank and Watkinson, 1986). Economic and environmental costs associated with the use of herbicides and increasing incidence of weed resistance to herbicides have made apparent the need of environmentally sound alternative weed management practices.

Weed competitive cultivars of several crop species have produced promising yields under low weed management levels (Ford *et al.*, 1990; Jennings and Herrera, 1968; Garrity *et al.*, 1992). Cultivars of rice vary in their ability to compete with weeds. Most of the modern high yielding rice cultivars are generally less competitive against weeds than traditional cultivars. Many authors have mentioned plant height as highly correlated with weed competitive ability of rice (Jennings and Jesus, 1968; Jennings and Herrera, 1968;; Garrity *et al.*, 1992). Tillering capacity is reported to be correlated with competitive ability in some studies (Jennings and Aquino, 1968) while in others it is concluded that tillering is not important (IRRI, 1977). Similarly, some researchers have concluded that the leaf area index (LAI) has no relation to yield reduction due to weeds (IRRI, 1977) yet in another study early LAI appeared to be an important factor in weed competitive ability (Jennings and Aquino, 1968). Jennings and Jesus (1968) and Jennings and Aquino (1968) indicated that cultivars with long lax leaves are more competitive than those with short, erect leaves. According to Jennings *et al.*, (1979) plants with early vegetative vigor are desirable if such vigor does not carry through to excessive growth and mutual shading after panicle initiation. According to Perera *et al.* (1992) root competition for obtaining mineral nutrients is more important than above ground competition for

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light. Therefore different strong weed competitors of rice probably have diffe[rent] combinations of morphological characters while maintaining the same morphological advantage.

Little research has been done to develop varietal screening procedures [for] plant selection that consider the crop's ability to compete with weeds. New crop cultivars have been se[lected] under weed-free conditions or without any specific regard to their ability to compete with weeds, resul[ting] in cultivars that are less competitive against weeds than traditional cultivars.

Objectives of this research were to identify the important morphological trai[ts] responsible for weed competitive ability of rice and study the possibility of using crop-weed competitio[n] simulation models to predict the weed competitive ability of rice cultivars.

Materials and Methods

Field experiments of various barnyardgrass densities with rice cultivars were [con]ducted on a sandy old alluvial soil (p^H 6.5, organic matter 1.8%) at Regional Agricultural Research Ce[nt]er, Aralaganwila, Sri Lanka during the 1993/94 Maha (wet) and 1994 Yala (dry) cultivation seasons. The c[rop] - weed competition simulation model, INTERCOM (Kropff and Van Laar, 1992) was used to select cu[ltivars] of rice for field experiments. Yield responses of rice cultivars to quantitative changes in morphologica[l characteristics such as plant height, tiller number, relative growth rate, leaf area and root dry weight were [pre]dicted by a sensitivity analysis.

Based on results of the sensitivity analysis (Table 1), cultivars of rice with[high, medium and low combinations of these morphological traits were selected from available variety catal[og] records at the Central Rice Breeding Station, Batalagoda, Sri Lanka. These selected rice cultivars were te[sted] in field experiments to identify the important traits and validate the model predictions. A general descripti[on] of morphological and yield characteristics of the selected rice cultivars for field experiments is listed in Tab[le].

During the 1993/94 Maha season four cultivars, and during the 1994 dry [sea]son five cultivars, of rice (3.5 month age class) were evaluated in field experiments. A split-split plot wit[h] three replications was used during 1993/94 Maha season in which rice density (15x10 or 15x15 cm) formed main plots, barnyardgrass density (0, 3, 9, 27 or 81 plants m^{-2}) was the variable in sub plots and [the] cultivars (BG 1611, BW 267-3, BG 350 and a traditional cultivar PPL (Pachcha-perumal) in sub-sub plo[ts]. During the 1994 dry season a split plot design was used as only one density of rice was tested. Another cu[ltivar] of rice (BG 94-2) which possesses a good combination of competitive morphological traits was added t[o] the experiment during the 1994 Yala season.

Table 1. Sensitivity of rice yield loss to a 20% increase in the value of each morpholo[gical parameter.]

Parameter	Sensitivity [Value]
Seedling height	2.83
Leaf area of seedlings	4.05
Relative growth rate of leaf area	6.69
plant height at maturity	2.85
Leaf area at maturity	2.73
Tiller number at maturity/ plant density	4.06
Initial root dry weight	0.001

Experiments were conducted under lowland irrigated conditions. Seedlin[gs] of rice cultivars and BYG were raised in separate wet-bed nurseries and planted at the specified densities [whe]n they were 18 days old. The crop received the recommended rice fertilizer mixture for the low countr[y] zone of Sri Lanka. Hand weeding was practiced at two-week intervals for 8 weeks to remove all volun[teer] weeds. Plant height, tiller number, dry weight and leaf area were measured in both species throughou[t] the growing season. A growth analysis was done to calculate relative growth rate of leaf area (RGR_{LA}) and [leaf] area index (LAI) of rice at different stages of growth. Rice grain yields were measured at the 14% moistu[re] level.

Table 2. Morphological characteristics of the tested rice cultivars collected from variety catalog records and an observation experiment (1993/94 Maha season).

Cultivar	Plant height		Tillers	Leaf characteristics				Yield
	3 WAP	Maturity		3 WAP		Maturity		
				length	width	length	width	
	cm		no./plant	cm				
BG 1611	38.5	104.8	11.3	24.7	0.59	40.8	1.3	High
BW 267-3	39.2	114.1	16.9	25.4	0.64	45.3	1.2	High
BG 350	34.3	85.1	12.0	21.2	0.68	31.6	1.3	High
PPL	51.3	124.3	11.6	28.9	0.68	47.1	1.0	Low
BG 94-2	41.1	118.6	10.2	26.2	0.62	46.2	1.2	High

* Average of 10 leaves. WAP= Weeks after planting.

RESULTS AND DISCUSSION

Model Predictions

According to the results of the sensitivity analysis, simulated rice yield loss was highly sensitive to relative growth rate of leaf area (RGR_{LA}), leaf area of seedlings, seedling height and number of plants/unit area at maturity (tillering capacity and/or planting density). Other morphological outputs such as leaf area at maturity and initial root dry weight were less sensitive to quantitative increases of these morphological traits (Table 1).

Weed competition

During its seedling stage, BYG grew faster and was taller than rice cultivars. It also had higher plant dry weights than rice during early seedling stages. But at maturity the average dry weight of BYG was less than that of rice cultivars (Tables 3 and 4). Similarly, increased BYG density also had significant negative effects on the per plant BYG dry weight. Competitive effects of BYG on rice increased with the increase of the BYG density. It significantly reduced the rice plant dry weight, tiller number, leaf area and the grain yield (Tables 3 and 4). Similarly significant differences were observed among rice cultivars in terms of the dry weight of BYG at crop maturity. Even though it was not statistically significant during the Maha season, BYG dry weights in rice cultivars BG 94-2 and PPL were consistently lower than other cultivars and these were least affected by the BYG competition, suggesting the presence of a good combination of competitive traits in these two rice cultivars. The cultivar BG 350 had high weed dry weights during both seasons across all weed densities and also suffered from weed competition more than any other cultivar. Significant differences were also observed among the tested two rice densities in terms of the BYG dry weight during 1993/94 Maha season. There were not significant interactions between cultivar x rice density, but the rice density x weed density interaction was highly significant for rice plant dry weight, yield and many other growth parameters.

Rice yields

In general, the grain yield of cultivars of rice declined as the density of BYG increased. There were significant differences ($p=0.01$) in rice grain yield among the tested BYG densities and rice cultivars (Table 4). The cultivar by BYG density interaction was highly significant for rice grain yield and panicle number per plant during both growing seasons. During both cultivation seasons, grain yields of cultivar BG 1611, BG 350 and BW 267-3 declined more sharply with the increase of BYG density. Cultivar BG 94-2 had an intermediate slope while the cultivar PPL had the lowest rate of yield decline with increased BYG density. This suggests the existence of some weed competitive traits in these two cultivars.

Table 3. Plant height, dry matter, tiller number and leaf area of rice as affected by rice cultivar and barnyardgrass (BYG) density at 4 WAP.

Treatment	Plant height (cm)		Dry matter ($g.hill^{-1}$)		Tiller number ($\#.hill^{-1}$)		Leaf area ($cm^2 hill^{-1}$)	
	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala
Cultivar:								
BG 1611	40.23	32.45	4.68	4.75	6.35	7.74	224.23	169.60
BW 267-3	43.57	39.65	5.01	5.10	4.90	7.31	226.67	234.60
BG 350	35.95	33.17	3.90	4.39	5.97	7.09	193.33	182.93
PPL	51.01	47 66	5.82	5.82	4.40	7.38	270.97	266.87
BG 94-2	-	49.54	-	5.75	-	7.01	-	256.00
LSD (0.05)	1.69	1.68	0.59	0.44	0.49	0.47	56.61	27.53
BYG density:								
0 (no. m^{-2})	42.86	40.71	5.94	6.40	6.16	8.69	232.67	251.53
3	42.99	40.67	5.68	5.61	6.00	8.09	270.67	249.93
9	42.36	39.98	5.90	5.09	5.42	6.81	207.54	236.13
27	41.82	40.39	6.00	4.17	4.80	6.56	231.75	180.33
81	43.43	40.73	6.01	4.54	4.64	6.37	201.38	191.87
LSD (0.05)	3.00	1.89	0.86	1.01	0.68	0.47	142.36	28.15
Rice spacing:								
15x15 cm	43.17	-	4.24	-	5.89	-	254.60	-
15x10 cm	42.21		3.97		5.22		203.00	
LSD (0.05)	1.69		0.42		0.38		53.31	

WAP- weeks after planting

Important morphological traits

The cultivar PPL was the tallest at the time of transplanting and during early seedling phase. The cultivar BG 94-2 was the tallest at maturity and grew taller rapidly during late vegetative phase. (Table 3 and 4). Average height of rice cultivars at 4 WAP had a strong negative correlation with the BYG dry weight (Table 5). This suggests that increased rice plant height tends to reduce BYG dry weight. BW 267-3, the high yielding rice cultivar with intermediate plant height, also was associated with relatively low weed dry weights as compared with short stature cultivars BG 350 and BG 1611, indicating the importance of the seedling plant height on weed competitive ability.

Cultivar PPL and BG 94-2 possessed long, wide, droopy leaves resulting in a high leaf area during early growth. Correlation analysis results revealed that the leaf areas at 4 WAP also have a high negative correlation with final dry weight of BYG (Table 5). High values of leaf area were observed in cultivars PPL, BG 94-2 and also in BW 267-3 at the 4 WAP sampling. These cultivars also had relatively less grain yield losses than BG 350 and BG 1611. Therefore in addition to the relatively great seedling height, these high values of seedling leaf area also may have contributed to their better performances under weed competition. Leaf area at maturity was not significantly correlated with weed dry weight (Table 5).

Calculated values of RGR_{LA} during the first month after transplanting (seedling stage) was highest in cultivar PPL. Cultivars BG 94-2 and BW 267-3 ranked second and third while the cultivar BG 350 had the slowest RGR_{LA}. This trend was similar during both cultivation seasons. During late growing season other cultivars had faster leaf area increases than cultivar PPL (Data not shown). Calculated LAI values for rice cultivars (for 15x10 cm plant density) were highest in the cultivar PPL throughout the growing period during Maha season. During Yala season the cultivar PPL had the highest LAI during seedling stage but the cultivar BG 94-2 had the highest LAI at maturity .

Tillering capacity of rice was high in cultivars BG 1611 and BG 350 (Table 4), but in general these

cultivars suffered more from BYG competition than the other cultivars of rice. There were only small negative correlation between rice tiller number and BYG dry weights in tested rice cultivars during both seasons in most of the competitive situations (Table 5). Therefore tillering capacity of rice was not important for weed competitive ability in this experiment.

Interestingly, grain yields from the rice under high weed densities were positively correlated with the rice plant height in this experiment. But in low weed densities it was negatively correlated. This clearly suggests that under situations of high weed pressure the morphological trait plant height had significantly increased the rice grain yield, probably by increasing weed competitive ability. In the absence of weed pressure crop plant height is not correlated with yield. Under high weed densities similar trends were observed in other traits such as leaf area and dry weight of rice seedlings This information suggests that under high weed infestations rice plant height is the most important morphological trait determining weed competitive ability but other morphological traits such as high leaf area and growth rate of seedlings also have strong relationships with increased weed competitive ability.

Although the effect was not statistically significant, the cultivar BW 267-3 was a better competitor against BYG than cultivars BG 1611 and BG 350 in terms of grain yield production under weedy situations (Table 4). This performance may be a cumulative effect of relatively tall seedlings, high leaf area and good root growth in this cultivar.

Table 4. Plant height, dry matter, tiller number and leaf area of rice as affected by rice cultivar and barnyardgrass (BYG) density at maturity.

Treatment	Plant height (cm)		Dry matter ($g.hill^{-1}$)		Tiller number ($\#.hill^{-1}$)		Leaf area ($cm^2 hill^{-1}$)		Grain yield ($Kg.ha^{-1}$)	
	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala
Cultivar:										
BG 1611	89.41	89.40	9.03	11.06	6.20	6.40	519.97	398.80	4386.0	4461.1
BW 267-3	103.62	103.68	8.90	11.22	5.07	6.65	475.67	489.27	4229.4	4472.7
BG 350	73.89	89.57	7.64	10.38	6.92	5.71	523.45	369.20	3465.9	4349.0
PPL	109.16	104.01	11.48	13.76	5.50	6.20	406.43	462.33	2523.9	3158.3
BG 94-2	-	120.06	-	13.44	-	5.37	-	520.93	-	4267.6
LSD (0.05)	4.27	8.71	0.99	1.19	0.69	0.70	61.17	43.98	254.5	305.8
BYG density:										
0 ($no. m^{-2}$)	94.60	100.94	12.17	15.53	6.82	6.80	468.88	554.20	5697.3	5930.8
3	94.47	100.26	10.93	12.37	6.36	6.33	519.67	520.20	5023.6	5643.8
9	94.27	98.40	9.52	10.51	6.43	6.23	445.46	435.73	3678.5	4550.2
27	94.23	98.19	7.00	10.08	5.39	5.42	472.25	360.80	2275.6	2777.1
81	94.42	105.21	6.69	11.37	4.60	5.55	437.88	369.60	1581.4	1805.7
LSD (0.05)	10.30	7.85	1.79	1.73	1.10	0.61	148.74	118.39	702.9	619.0
Rice spacing:										
15x15 cm	94.89	-	9.81	-	6.52	-	496.98		3540.1	-
15x10 cm	93.15		8.71		5.33		440.67	-	3762.5	
LSD (0.05)	3.41		1.04		0.49		54.48		306.2	

Both of the tall cultivars PPL and BG 94-2, were susceptible to lodging. Therefore in the process of screening of rice cultivars for competitive ability, the use of plant height trait has limitations. Cultivars with tall seedlings and a slow late height growth, leading to an intermediate plant height at maturity, is desirable. For weed competitive ability it is also important to have a good combination of other competitive traits such as high seedling leaf area, rapid seedling growth and a good root growth. The high yielding cultivar BW 267-3 possesses these characters to a certain extent.

Information gathered in these experiments revealed that the morphological traits and other related rate-parameters which were highly sensitive in determining crop yield in the INTERCOM simulation model

are important for weed competitive ability of rice. It also suggests the possibility of using crop-weed competition simulation models to predict the weed competitive ability of rice cultivars. Since screening of new rice cultivars is done under weed free conditions these simulation models can be used to test cultivar performances under "on-farm" conditions where the crop has weed competition. Therefore the use of crop-weed competition models could be a useful tool to analyze weed competitive ability and yield loss of new cultivars developed by rice breeders.

Table 5. Correlation coefficients (r) for final dry weight of barnyardgrass (BYG) and some rice plant characters under different BYG densities.

Season	BYG density	Plant dry weight		Plant height		Tiller number		Leaf area	
		4 WAP	MT	4WAP	MT	4 WAP	MT	4 WAP	MT
	no. m^{-2}	Correlation coefficient (r)							
93/94 Maha (n=24)	3	.17	-.08	-.39	-.13	-.04	-.04	-.47*	-.34
	9	-.15	-.11	-.44*	-.34	-.06	-.81*	-.58*	-.40*
	27	-.78**	-.22	-.47*	-.37	-.04	-.22	-.62**	-.22
	81	-.78**	-.18	-.54*	-.39*	-.41	-.01	-.58*	-.29
94 Yala (n=15)	3	-.16	-.17	-.27	-.39*	-.19	-.15	-.43*	-.31
	9	-.40*	-.52*	-.36*	-.61**	-.35*	-.36	-.39	-.38
	27	-.41*	-.27	-.59**	-.50**	-.26	-.41	-.41*	-.42
	81	-.47*	-.42	-.49**	-.26	-.10	-.25	-.47*	-.39

WAP- Weeks after planting, MT- At maturity.
*, ** - Statistically significant at 5% and 1% probability level respectively.

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The Spatio-Temporal Pattern Of Distribution of Weedy Rice Accessions In Sungei Burong Rice Granary Of Tanjong Karang, Selangor

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Weedy rices *(Oryza sativa* L.), first detected in 1988 in the Tanjung Karang granary, are an important new scourge in the Malaysian rice fields. Since then, weedy rices have spread to the granaries of Trengganu, Kedah, Perlis, Seberang Prai and of late in Kelantan. Weedy rices inflicted extensive yield losses as high as 90% (Azmi,1999). Weedy rices, otherwise known locally as *padi angin* displayed weedy traits of easy shattering and several morphological variations in the plant architecture, leaf colour and grain chacteristics. Samplings on the infestation of weedy rices were conducted for five seasons in 1995 - 1997 to assess the spatio-temporal patterns of distribution based on selected quantitatve indices and the indices of dispersion. About 25 accessions of weedy rices had been identified in the 28 farm blocks (identified as Farm Blocks A, B, C.....L) of Sungai Burong rice growing area covering an area of 3220 hectares. Invariably, Farm Blocks H, F, S, Q and L showed high infestation with the Summed dominance Ratio values ranging from 5.52 (Block L) to 18.82 (Blocks H). The majority of weedy rice accessions in Sungei Burong were those possessing horizontal flag leaves and of the tall types. These accessions had distinct and varied morphological structure, heterogenous in nature with closed panicles bearing awned or awnless grains. Short-awned accessions were present only in two farm blocks. The spatial and temporal pattern analyses of weedy rices of Sungai Burong showed clumped distribution over the five-season period. The extent of clumping , however, varied according to seasons and farm blocks.

Keywords: Weedy Rices, Padi Angin, Spatial analyses, Spatio-temporal, Oryza sativa complex.

INTRODUCTION.

Weedy rices or otherwise known locally as *padi angin,* have caused alarm to the padi farmers of the rice granary areas of Barat Laut, Selangor. Sungei Burong, one of the granary areas of Barat Laut Selangor covering an area of 3220.5 hectares are heavily infested with weedy rices. The undesirable traits of weedy rice in easy-grain shattering can cause yield reduction and yield loss as high as 50% (Azmi,1999). Prior to 1988 the padi farmers had problems with grassy weeds but to date the weedy rices problem had created awareness amongst them. The weedy rices menace started on 168 hectares padi land and has now steadily increased to > 90% of the total area of Sungei Burong. Weedy rices have established themselves in the granary for the past ten years and they shatter their seeds at the slightest touch by the wind hence the name *padi* (rice) and angin (wind) in the Malay language.They are very heterogenous with dominant morphological and ecological characteristics. The number of panicles varies from one to ten panicles and have high competitive ability *vis-`a-vis* the commercial cultivars of the rice fields (Watanabe *et al,* 1996). Other characters of of weedy rices include distinct differences in panicle length, longer culm length with the top six or seven internodes differences in grain width / length ratio and the degree in their shattering ability.Weedy rices are of several plant types showing non-uniform heading times even within the individual plant of the same clump.They have light green leaves and could be identified as early as ten days (Azmi,M 1996). In terms of the tillering productions the accessions display low tillering production when raised in green house as compared to those planted in the rice fields possibly due to the varying degrees of the competition prevailing.

Sungei Burong weedy rices mimic the cultivated varieties of MR 84 and MR 185 depending on the localities. Field observations and the RAPD studies have provided information on the origin of weedy rices (Azmi,1999; Vaughan *et al*, 1999). Quantitative indices of the weedy rice accessions and their indices of dispersion had been closely looked into for over five seasons starting in the offseason 1995. We believed such information would be useful in formulating strategies for weedy rices integrated management in the fields. This paper enlisted the dominant weedy rice accessions based on selected quantitative indices and discussed their spatio-temporal pattern of distribution under dry - and wet seeded rice cultures in the Sungai Burong granary of Selangor, Malaysia based on the survey data of 1995-1997.

MATERIALS AND METHODS.

Field surveys were conducted for five seasons beginning in II/95 until II/97 in the farm blocks D,E,F,H,I,J,L,S and Q of Sungai Burong (Fig.1). About 25% of the total rice farm blocks were randomly sampled and the same blocks were taken for the five consecutive seasons Random samples were taken from each block using quadrat of 50cm x 50cm method (Kim and Moody 1983). Four quadrats were randomly taken at each site . The distance between each quadrat depended upon the size and shape of each block. Surveys were conducted at 90 days after seeding when weedy rices could be censored and quantified by means of distinct characteristics such as plant heights, lengths of flag leaves, awn or awnless, panicles types,grain colour and the numbers of plants.The taxonomical aspects in this study followed the nomenclature of Tateoka,(1963b). The dominance of a particular accession within the community was denoted by its importance value *(IV)* index and the data could be computated following methods of Kim and Moody (1983). Importance value and the summed dominance ratio were used to compare the dominance stature of weedy rices in each planting season.Thus the dominance curves were constructed by plotting the IV of weedy rices against each individual accession in the decreasing order of importance (fig 2).

Comparisons among weedy rice accessions in the different growing seasons based on Simpson diversity index of similarity were also made (Krebs,1978).The mean *(m)* and variances (v) values of each accession per quadrat were calculated. Three indices of dispersion were calculated, *viz: variance-to-mean ratio(vmr), the Lloyd's mean crowding (m*) and Lloyd's patchiness(Ip)* (Lloyd's 1967). *The variance-to-*mean ratio was tested for deviation from unity. Values significantly >1 indicated aggregated spatial patterns. Lloyd's mean crowding and patchiness values for each accession were calcuted using the formulae below:-

$$m^* = \Sigma xi(xi-1)$$

$$Ip = m^* / m.$$

Where Q = numbers of quadrats
X_i = numbers of plants in the i th quadrat.

The values of Ip were tested for deviation from unity. In a random distribution, the mean density and mean crowding are equal to each other.Computation of the Simpson index *(s)* values (Kim and Moody 1983) was as follows:-

$$S = \Sigma (y/N)^2$$

where y = importance value
N = sum of the importance values for all accessions in the sample.

The bigger the *s* value the closer the similarity of the accessions in all the seasons when the surveys were conducted . Conversely a smaller s value would reflect the divergence in accessions similarity.

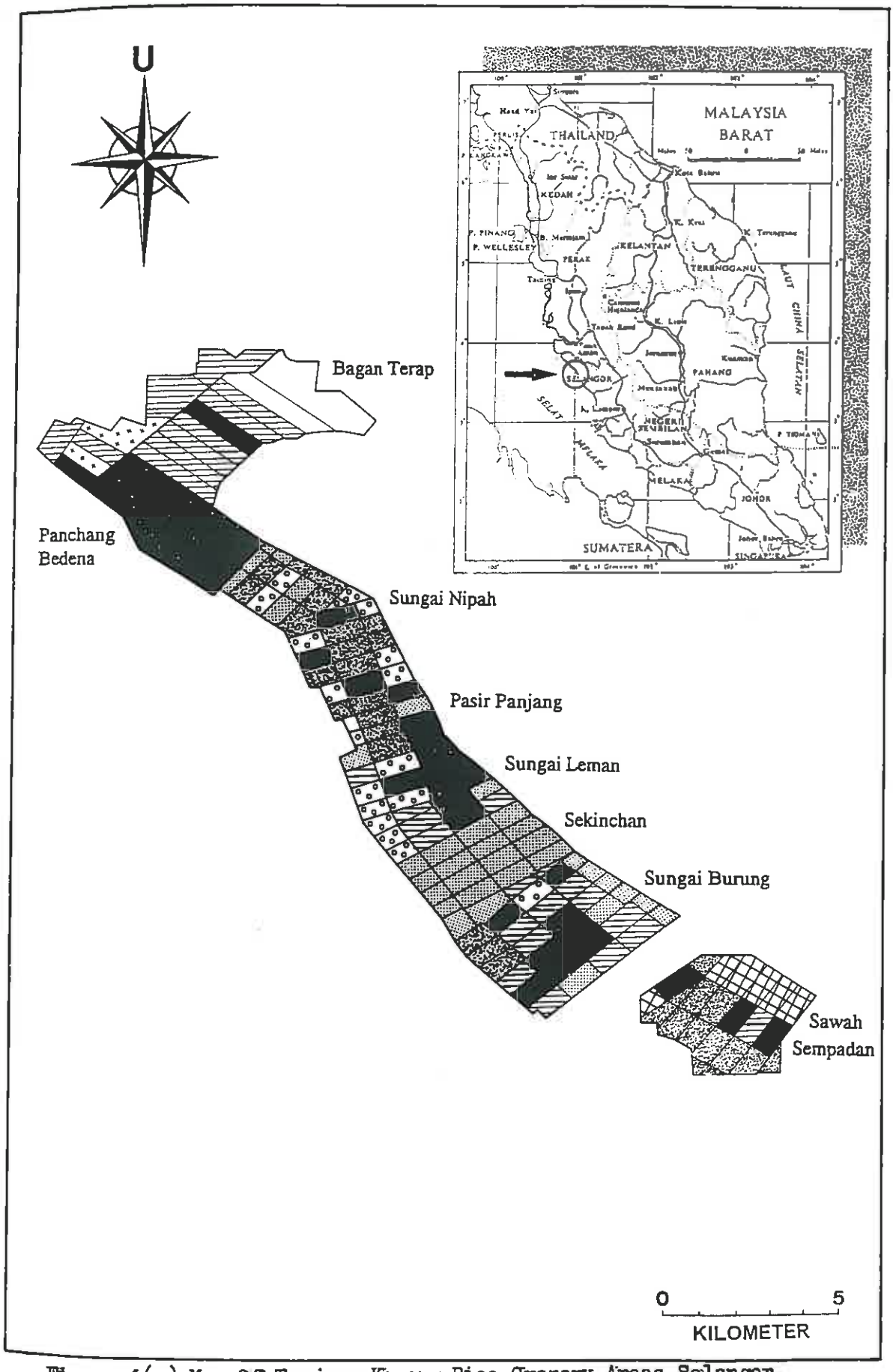


Figure 1(a) Map Of Tanjung Karang Rice Granary Areas, Selangor.

Further calculations and tests were made to assess the evenness of the weedy rice accessions in their distribution pattern, based on the *Evenness Index(E)* and these were shown below:- as shown below:-

$$E = N2\text{-}1 / N1\text{-}1$$

where $N2$= number of very abundant species ;

$N1$= number of abundant species.

RESULTS AND DISCUSSION

A mixed population of the accessions of weedy rices with various morphological characters in the majority of the farm blocks was registered in the planting seasons of 1995-1997.Weedy rice accessions of the tall plant type and horizontal flag leaves with long awned pigmented grains outgrown those accessions of the tall plant type with semi-erect flag leaves with yellow straw-coloured grains and the cultivated varieties of MR 84 and MR 185. Their heterogeneity and distinct plant structures of weedy rice accessions remained the dominant features in the rice fields of Tanjung Karang. Twenty-five weedy rice accessions(arbitrarily named as PA_1, PA_2, PA_3,.....PA_{25}) were identified surveys had identified twenty five weedy rice accessions and of these fourteen were detected in 1995, six in 1996 and five in 1997. More accessions prevailed in the offseasons 1996 and 1997 with repeated occurrences of PA 18, PA 19, PA 28, PA 33, PA 34 and PA 36. Such situations occur probably due to the water management and the cultural technique. A total of 144 samples were collected from the farm blocks per season. Infestations were high in blocks F,H,L,S,Q with the importance values ranging from PA_{19} (25.22) to PA_{22} (183.7) in descending orders of PA 22 > PA 27 > PA 29 > PA 25 > PA 21 in seasons II/95. The quantitative scores gave only the estimates of the plant numbers over a unit area.The dominant accessions in seasons I/96 were PA 31,PA 37 and PA 36 whilst in the off season of II/96 PA 28 > PA 21 >PA 20> PA 31 > PA 30. The importance values ranged from 1.69 to 22.03. The descending orders of weedy rice accessions in the main season of I/97 were PA 41 > PA 43 > PA 38 > PA 42 > PA 40 > PA 39 based on the quantitative indices scores of 27.5 to 63.34.The off season of II/97 illustrated the importance values ranging from 13.4 to 54.92 with the descending orders of PA 36 > PA 34> PA 33 > PA 35 (table 1.)

Table 1:The Quantitative Indices Scores Of Weedy Rice Accessions In Tanjong Karang Selangor 1995 - 1997.

Weedy Rice Accessions	Relative Density	Relative Frequency	Relative Abundance	Importance Value	Summed Dominance Ratio.
	Seasons II/95				
PA_{18}	5.5	25	2.5	33	11
PA_{19}	0.22	22	25	25.22	8.41
PA_{20}	21.12	25	4.0	50.12	16.71
PA_{21}	30.91	25	4.25	60.16	20.05
PA_{22}	87.67	80	16	183.67	61.22
PA_{23}	12.33	20	2.25	34.58	11.53
PA_{24}	19	25	0.12	44.21	14.74
PA_{25}	12.50	50	6.25	68.75	22.92
PA_{26}	11	25	2.75	38.75	12.92

PA_{27}	16	50	8	74	24.97
PA_{28}	10	37.5	3.6	53.1	17.7
PA_{29}	16	37.5	8	76.4	25.5
PA_{30}	17.5	68.8	11.3	97.5	32.5
PA_{31}	22	25	16.5	63.5	21.2
	Season I / 96				1.6
PA_{32}	3.17	0.13	1.5	4.80	1.6
PA_{33}	2.65	0.13	1.25	4.03	1.34
PA_{34}	1.06	0.13	0.5	1.7	0.6
PA_{35}	2.1	0.13	1	3.3	1.1
PA_{36}	2.8	12.5	0.8	16.1	5.4
PA_{37}	4.7	12.5	1.3	18.4	1.3
	Season II / 96				
PA_{18}	0.65	12.5	0.5	1.69	6.14
PA_{19}	0.98	12.5	1	3.25	1.08
PA_{20}	2.29	12.5	0.75	16.05	5.35
PA_{21}	2.9	12.5	1.25	18.42	6.14
PA_{28}	10.2	0.32	5.75	22.03	3.12
PA_{29}	2.02	6.32	1.5	9.84	3.28
PA_{30}	3.3	6.32	1.75	11,36	3.79
PA_{31}	3.58	6.32	1.75	11.65	4.06
PA_{32}	1.67	0.13	1.5	3.8	1.27
PA_{35}	2.23	0.13	2	4.04	1.45
	Season I / 97				
PA_{36}	21	33.3	7	61.3	20.43
PA_{37}	2	16.67	0.5	27.5	9.4
PA_{38}	12	16.67	2	30.67	10.2
PA_{39}	40	16.67	6.67	63.34	21.1
PA_{40}	25	16.67	4.2	45.87	15.29
PA_{18}	1	25	35	26.25	8.75
PA_{41}	6	50	3	59	19.67
PA_{42}	4	50	2	56	18.67
	Season II / 97				
PA_{33}	5.79	29.17	5.25	40.22	13.4
PA_{34}	5.74	21.2	5.79	32.86	10.95
PA_{35}	4.13	18.4	4.25	26.8	9.04
PA_{36}	9.14	29.94	4.8	41.2	13.3
PA_{37}	6.0	6	12.5	24.5	8.2
PA_{38}	20	25	5	50	16.67

Table 2. Estimation Of Density (D) Mean (m),variance (v),Variance / Mean Ratio (vmr) Lloyd's Mean crowding(m*), Simpson Index Of Similarity, (S) and Evenness Index,Of Weedy Rices In The Rice fields Of Sungai Burong, Selangor.

Weedy Rice Accessions	D	m	v	vmr	m*	Ip	S	E
			Season	I / 95				
PA_{18}	10	10	0	0	90	9	0.4	0.2

PA 19	12	12	0	0	132	11	1	0.2
PA 20	16	16	0	0	240	15	0.5	0.3
PA 21	17	17	0	0	272	16	0.5	0.3
PA 22	64	64	0	0	4032	63	0.7	0.9
PA 23	9	9	0	0	72	8	0.4	0.1
PA 24	15	15	0	0	210	14	0.5	0.3
PA 25	39	13	26	338	1482	114	3.7	0.4
PA 26	26	8.7	17.3	2.0	200	23	0.6	0.2
PA 27	21	21	0	0	420	20	0.5	0.6
PA 28	76	19	57	3	1296	68.21	0.5	0.4
PA 29	2	2	0	0	2	1	1	0.03
PA 30	2	2	0	0	2	1	0.13	0.01
PA 31	25	12.5	12.5	312	24.96	0.01	1.0	1
PA 32	40	40	0	0	1560	39	0.06	0.12
			Season	I/96				
PA 33	5	2.65	2.4	6.4	20	7.5	0.11	0.07
PA 34	4	1.06	0.1	0.12	2	1.89	0.17	0.42
PA 35	7	2.12	0.64	1.36	10	4.7	0.29	0.34
PA 36	8	2.8	1.8	5.04	11	3.9	0.02	0.4
PA 37	15	4.67	10.33	48.24	210	45	0.5	0.6
			Season	II / 96				
PA 18	2	2	0	0	1	1	0.13	0.09
PA 19	20	10	10	1	380	38	0.2	0.1
PA 20	2	2	0	0	1	0.5	0.5	0.3
PA 21	3	3	0	0	6	3	0.54	0.53
PA 28	21	21	0	0	420	20	0.5	0.5
PA 29	10	10	0	0	90	9	0.3	0.1
PA 30	5	5	0	0	20	4	0.1	0.2
PA 31	3	3	0	0	6	2	0.1	0.2
PA 32	9	9	0	0	81	9	0.6	0.4
PA 35	16	16	0	0	240	15	1.0	0.6
			Season	I /97				
PA 36	1	1	0	0	1	1	0.04	0
PA 37	27	13.5	13.5	1	422	31.3	0.96	0.96
PA 38	8	4	4	1	64	22.7	0.15	0.13
PA 39	2	2	0	0	2	1	0.04	0.02
PA 40	12	12	0	0	132	11	0.22	0.2
PA 18	40	40	0	0	1560	312	0.3	0.3
PA 41	25	25	0	0	600	24	0.17	0.16
PA 42	8	4	4	1	54	14	0.05	0.01
PA 43	42	21	21	1	890	42.4	0.3	0.3
PA 38	34.5	17.3	17.3	1	656	36.9	0.2	0.2
		Season	II / 97					
PA 33	14.2	8.15	6.05	0.75	141.8	12.36	0.2	0.9
PA 34	17	16.64	5.36	5.36	208.29	11	0.3	0.3
PA 35	7	7	0	0	42	6	0.1	0.1
PA 36	14	5	0	0	20	4	0.2	0.2
PA 37	6	6	0	0	30	5	0.1	0.3
PA 38	3	3	0	0	18	6	0.05	0.1

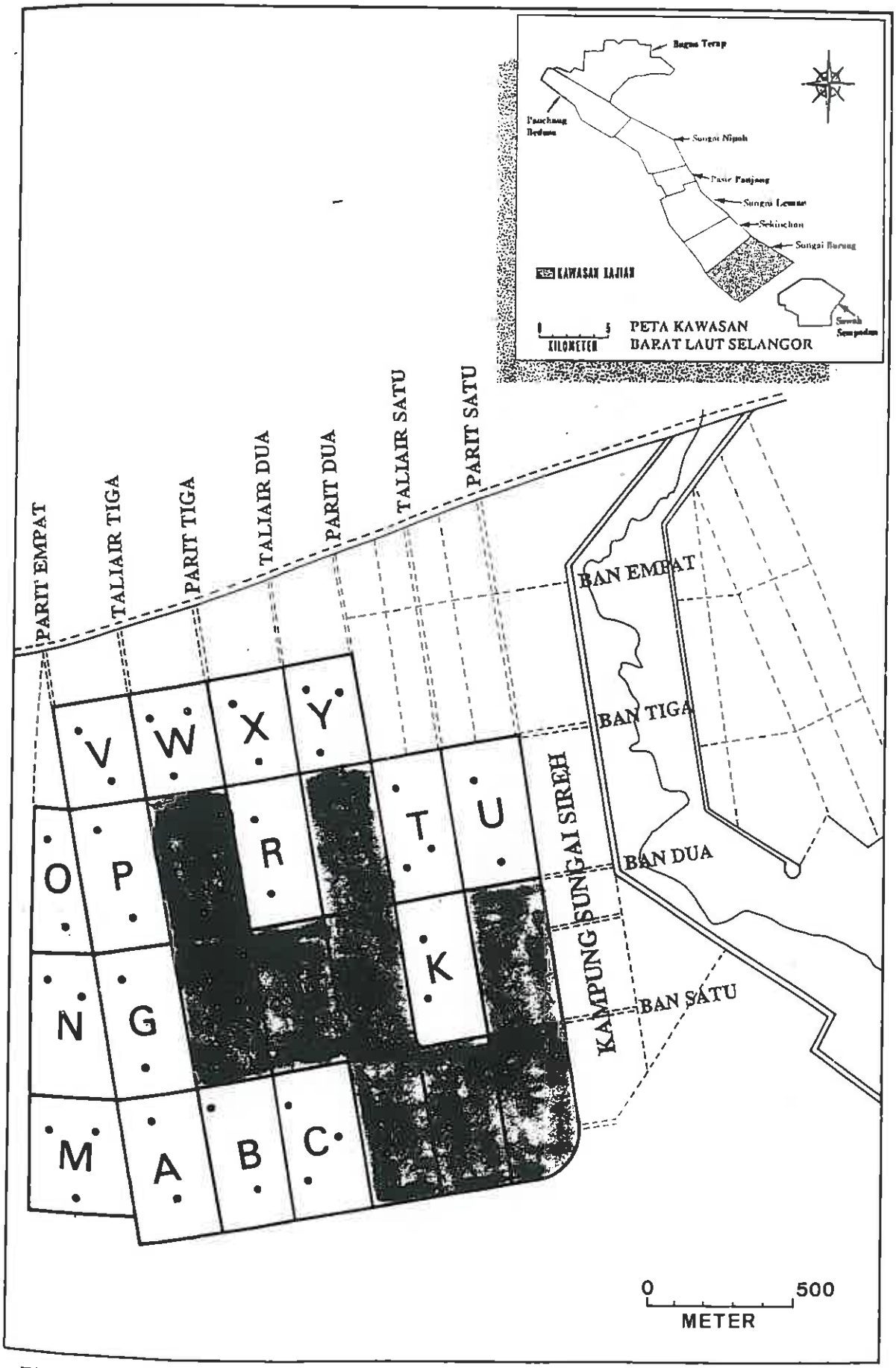


Figure 1 (b). Sampling Sites Of Sungai Burong ,Tg .Karang,Selangor.

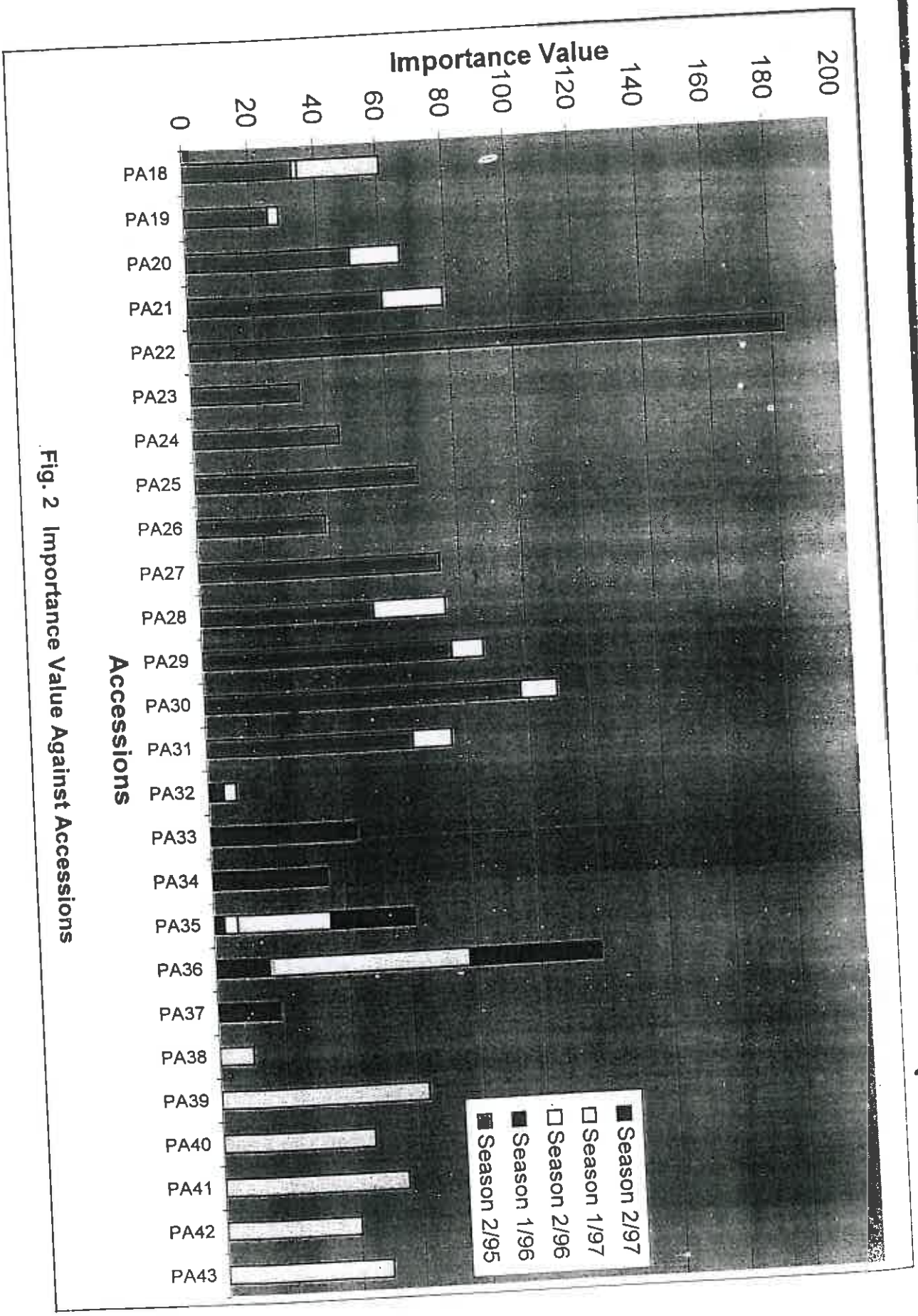


Fig. 2 Importance Value Against Accessions

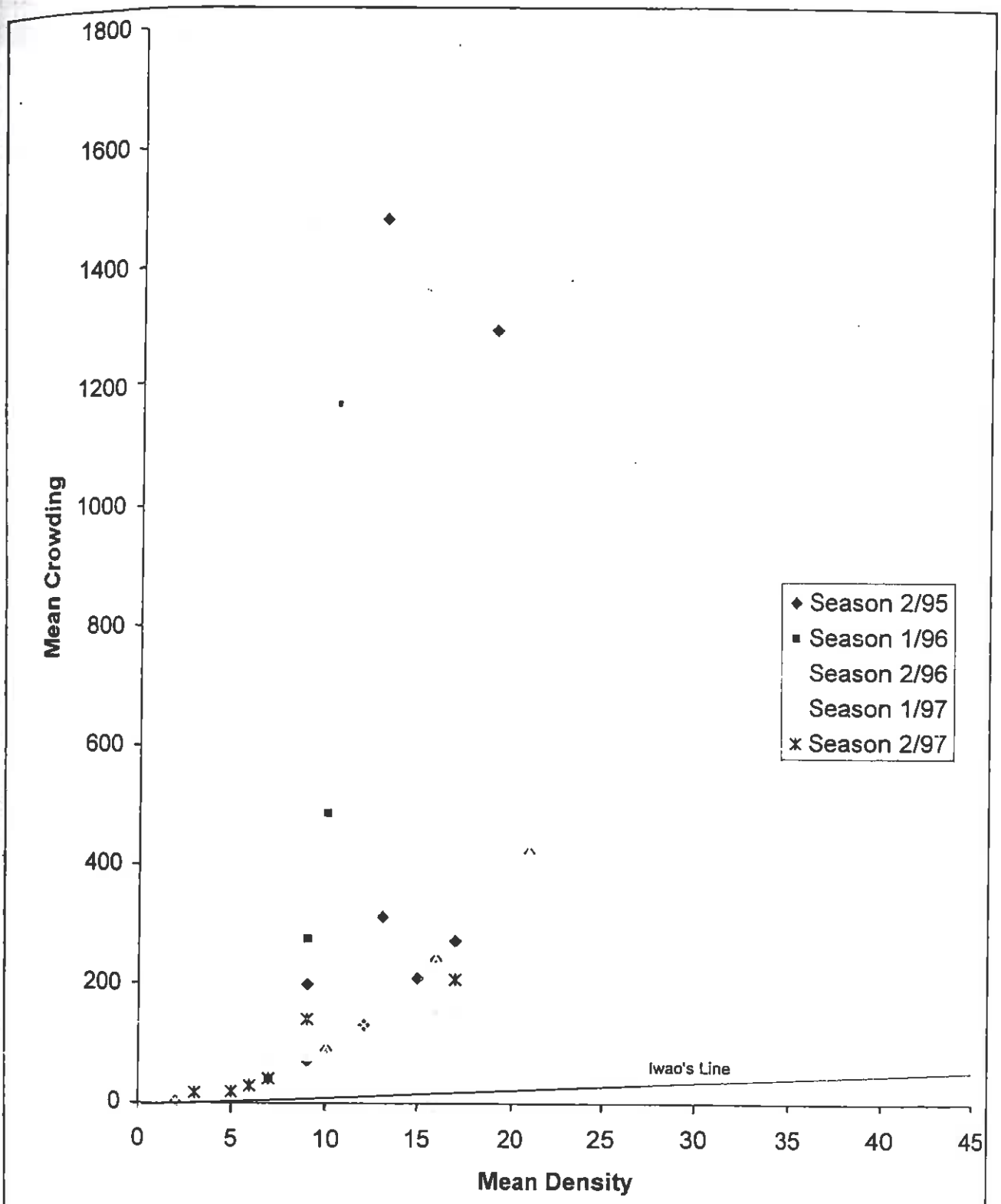


Plate 3: Mean Crowding Against Mean Density of Weedy Rice Accessions in Sungai Burong 1995-1997

A discontinuos pattern of emergence was observed in most of the weedy rice accessions from survey data of 1995,1996 and 1997. The spatial distribution pattern of the accessions were further tested for their indices of dispersion by means of variance-to-means ratio, Lloyd's mean crowding and patchiness values (table 2 and figure 2) while the diversity of accessions were based on their Simpson's index of similarity values. Accessions 18, 19 and 34 occurred in the planting seasons of 1995-1997.The quantitative indices of the accessions were quite high ranging from PA19 (25.22) to PA (183.67). The most dominant weedy rice accession was PA22 and this was found in abundance in farm block D followed by accession PA30, PA29, PA21, PA27, PA 28 through accession PA19 (Fig 2). Their Lloyd's patchiness values from >1except for accessions PA29 and PA30 which had *Ip* values of 1.Such values g.eater than 1 displayed clumped pattern of distribution and the occurrences were not repetitive throughout three years (Fig.2) seasons. The quantitative indices of the accessions were quite high ranging from 25.22 to 183.67. The most dominant weedy rices were accessions 22 which were found abundant in block D followed by accessions 30, 29, 21,27,28 till accession 19 (fig. 2) Their Lloyd's patchiness ranged from values greater than 1 except accession 29 and accession 30 which had Ip values of 1.Such values greater than 1 displayed clumped pattern of distribution and the occurrences were not repetitive throughout the three years (figure 2.). Marked differences were registered in the nature and the extent of clumping of weedy rice accessions, hence the trend of the distribution pattern.These were fortified by the values of the of Lloyd's patchiness of weedy rices in the 1996 survey which were as low as 1 to as high as 114 whilst the 1997's survey displayed a clumped pattern of distribution with Lloyd's patchiness of a minimum of 12 to as high as 392. Consequently there were marked differences amongst the accessions in their dispersions and these, arguably indicated irregularity in their growth habits. They were sensitive to micro-environmental irregularities and differences. Under stress condition some accessions produce longer stolons and weedy traits.The irregularities in the occurrences of weedy rices in Sungai Burong probably were attributed to the following factors, *viz* .(a) land preparation technique; (b) types of rice culture being practised, namely the wet-secded and dry-seeded rice cultures; ©tcrossing among the prevailing weedy rice accessions, (d) breakdown of genes and (e) occurrences of natural mutation among accessions.

The information generated by this study is only one of the pre-requisites to develop long-term stragies of weedy rice management in Malaysia. More studies should be conducted on the seed and seedling dynamics of different weedy rice accessions under different agronomic and cultural practices before a proper control protocol could be formulated and tested for field application.Weedy rices population in the Malaysian rice fields are very diverse and heterogenous. These coupled with seed abundance in the soils posed a serious problem to effective management of the scourges. A holistic control strategy should be a better alternative to combat the weedy rice menace in Malaysia.

ACKNOWLEDGEMENT

The authors would like to thank all the staffs of Weed Section Crop Protection and Quarantine Branch, and all the staffs of the Crop Protection Unit Sungai Burong, Tanjung Karang for carrying out the surveys.

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WEED MORPHOLOGY EFFECTS ON COMPETITIVENESS FOR LIGHT IN DIRECT-SEEDED RICE

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Abstract: A rice-weed model for direct-seeded systems, DSRICE1, was used to analyze the effects of weed shoot morphology on competitiveness for light in rice (*Oryza sativa* L. cv. M-202). The effects of vertical leaf area distributions, leaf angle, and height were tested for hypothetical but typical weed morphologies. Leaf area distributions were described as leaf area per unit volume (LAV; $m^2\ m^{-3}$). Empirically-based LAV shapes were skewed to the bottom (two types shown by broadleaf and grass weeds) or conical (sedge weeds). These differed in the fraction of leaf area in the top half of the plant (F_{top}). Leaf angles vary from erectophile to planophile, and are described in the model as leaf light extinction coefficients (k_{leaf}). Maximum weed heights were $0.5H$, $1H$, and $1.25H$, where H is maximum rice height. Except seed size, other weed growth parameters were identical to those of rice, which limited differences to the morphological traits being tested. Competitiveness was evaluated using rice yield ($g\ m^{-2}$) at maturity. Clear patterns were evident in the model results. Weeds with conical leaf distributions and short weeds were not competitive, regardless of other traits. For weeds with bottom-skewed LAVs competitiveness was positively related to both height and LAV skewness. Finally, interference was greater by more planophile weeds (higher k_{leaf}) than more erectophile weeds (lower k_{leaf}). The results confirmed that competitiveness for light was improved by being taller, having more planophile leaves, and having a more skewed vertical leaf area distribution. More importantly, interactions between traits determined competitiveness. For example, tall weeds were about as competitive as weeds with average height if the taller leaves were more erect (higher k_{leaf}). Similarly, the competitiveness of a weed with planophile leaves was reduced if it had a less skewed leaf area distribution. Thus, all three morphological traits were significant determinants of weed competitiveness for light.

Key words: rice-weed model, competitive ability, leaf area distribution, height, leaf angle

Introduction

It is well established that weed species vary in their competitive effects on rice (*Oryza sativa* L.) (e.g., Smith, 1988). Although morphology obviously differs between weed species, the quantitative effects of this variation on rice-weed competition has not been described. Weeds are often broadly grouped into grasses, sedges, and broadleaves in a crude morphological classification. These morphological "types" refer to characteristic features such as monocot or dicot leaves, tillering ability, and stem shape. Despite their familiarity, these general plant descriptions are usually not quantitatively useful and may not describe actual differences. For example, rice (cv. M-103, a semi-dwarf, japonica type) and redstem (*Ammannia* spp.)—a grass and a broadleaf weed, respectively—have almost equivalent vertical leaf area distributions for much of the cropping season in California (Caton *et al.*, 1999c; Caton *et al.*, 1998b, *unpublished*). Notably, the morphology of rice and some important weeds has been studied recently in more detail (Breen, 1995; Caton *et al.*, 1997; Caton *et al.*, 1998ab, *unpublished*; Yamasue *et al.*, 1997).

Our objective was to examine how morphological traits affect weed competitiveness for light in direct-seeded rice. Variations were quantitatively described for three important morphological traits: vertical leaf area distributions, leaf angles (light extinction coefficient), and maximum plant heights. Competition for light between rice and hypothetical weeds with all possible combinations of these morphological traits but no other differences was simulated for standard conditions of temperate direct-seeded rice in California. Competitiveness of the hypothetical weeds was evaluated by comparing rice yields at maturity.

Models are useful for mechanistic analyses because they specify and quantify important interactions, and allow the effects of plant growth traits or system factors (such as water depth in rice) on those interactions to be analyzed more directly and in more detail than can usually be done by empirical methods. The model used was DSRICE1, which simulates rice and weed growth and competition for light in direct-seeded systems (Caton *et al.*, 1999a). DSRICE1 has been validated for monoculture growth (Caton *et al.*, 1999b) and for competition for light with two weeds, redstem (*Ammannia* spp.) and early watergrass

(*Echinochloa oryzoides* (Ard.) Fritsch.) (Caton *et al.*, 1999c).

Materials and Methods

Model

DSRICE1 was developed to analyze integrated weed management strategies in direct-seeded rice systems (Caton *et al.*, 1999a), and it has a strong management and system orientation. For example, DSRICE1 explicitly simulates growth from seeds, dynamic growth from flooding (weeds) or seeding (rice), and the effect of water depth on light capture by submerged plants. It runs on a daily time step, uses daily maximum and minimum temperatures and solar radiation as input, and requires management specifications for flood and seed dates, water depth and turbidity (extinction coefficient), cultivar, weed species, and weed density. This version simulates direct competition for light, based on the vertical distributions of live and dead shoot material (leaves and stems) and associated light extinction coefficients. In validation tests DSRICE1 simulated rice growth in monoculture well, including water depth effects on early-season growth (Caton *et al.*, 1999b). It also simulated competition with redstem and watergrass well (Caton *et al.*, 1999c) but did not accurately predict watergrass growth and interference in fields that had been drained early in the season (rice-redstem interactions were unaffected). Thus, DSRICE1 accurately predicts rice competition in continuously-flooded fields with two very different weed species.

Specification of weed morphological traits

In this study it was not our intent to replicate real rice-weed interactions but to assess the effects of traits over their likely ranges. The effects of three morphological traits on rice-weed competition for light were analyzed. These traits were plant height, leaf angle, and vertical leaf area distribution. It is well-established that height affects weed competitive ability (e.g., Caton *et al.*, 1997). The maximum height of cv. M-202 is about 0.95 m (Caton *et al.*, 1999a), and three relative weed heights were used here: $1H$ ("average"), $1.25H$ ("tall"), and $0.5H$ ("short"), where H is rice plant height. These values are arbitrary but consistent with common rice weeds.

Leaf angle specifies the orientation of leaves to incoming radiation and therefore strongly affects light capture (Loomis and Williams, 1969). Leaf angles are expressed mathematically as the leaf light extinction coefficient (k_{leaf}), and vary from erectophile (nearer to 0) to planophile (nearer to 1). Leaf angle is not the only factor that determines k_{leaf} but is probably the most important (Loomis and Williams, 1969). In this study k_{leaf} values of 0.2, 0.4, 0.6, and 0.8 were tested, which represent reported ranges. For rice and watergrass, k_{leaf} varies from 0.4 to 0.6 over the season (Kropff and Lotz, 1993). Caton *et al.* (1999c) used $k_{leaf} = 0.8$ for redstem, and we believe $k_{leaf} = 0.2$ describes the very erect, narrow foliage of ricefield bulrush (*Scirpus mucronatus* L.) (Caton *et al.*, 1998b, *unpublished*).

Vertical leaf area distributions can be described as leaf area per unit volume of canopy (LAV; $m^2 m^{-3}$). LAVs strongly affect rice-weed competition (Caton *et al.*, 1999c) but have only recently been measured in direct-seeded rice. Caton *et al.* (1998b, *unpublished*) found that rice and watergrass LAVs were skewed to the bottom, and that ricefield bulrush LAV was conical. Fractions of total area in the top half of the plant (F_{top}) for rice and watergrass LAV were both about 0.70. Those of ricefield bulrush were lower, varying from 0.25 to 0.35 over the season. Yamasue *et al.* (1997) found very similar results for rice and late watergrass (*E. phyllopogon* (Stapf.) Koss) in a transplanted system. Broadleaf weeds also have bottom-skewed LAVs, such as those of redstem (Caton *et al.*, 1999c) and California arrowhead (*Sagittaria montevidensis* Cham. & Schlecht.) (Breen, 1995). F_{top} for redstem and arrowhead were 0.69 and 0.90, respectively. Based on these empirical studies, the effects of three LAVs were tested: bottom-skewed with $F_{top} = 0.90$ and 0.70, and conical with $F_{top} = 0.35$ (Fig. 1).

Simulation specifications

While it was important for the tested values of the morphological traits to be realistic, it was also critical to minimize all other differences between the hypothetical weeds studied. Hence, except for the morphological traits tested, all other weed growth parameters were identical, and for simplicity were equal to those of rice (see Caton *et al.*, 1999a).

Analyses reflected environmental conditions and cultural practices for temperate rice production in the Sacramento Valley, California. Standard long-term data for daily maximum and minimum temperatures (30-year) and solar radiation (15-year) were used (http://www.ucipm.ucdavis.edu). Rice (cv. M-202) density was 250 plants m^{-2} and weed density was 50 plants m^{-2}. Flooding occurred on 15 May, and seeding was three days later, giving weeds a two-day advantage (see Caton *et al.*, 1999c). Water depths were 0.1 m until 60

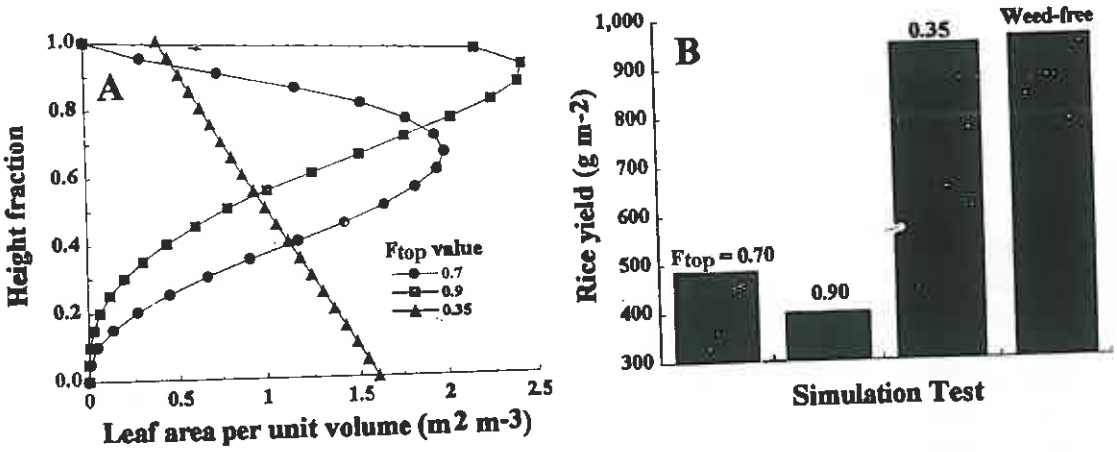


Fig. 1. (A) Vertical leaf area distributions of weeds used in rice-weed competition simulations, and (B) their effects on competition for light. Simulated rice yield (140 days after seeding) as affected by competition with weeds having the distributions in (a) and for weed-free rice. Data are presented for tall weeds with $k_{leaf} = 0.6$.

days after seeding (DAS), and 0.2 m thereafter, and the light extinction coefficient of water was 3.0 (Caton *et al.*, 1999a). The effects of weed morphology on simulated rice yields at 140 DAS were evaluated below.

Results and Discussion

Four clear patterns in the results were: 1) weeds with a conical distribution were never competitive (Fig. 1b), regardless of height or k_{leaf} value (not shown); 2) competitiveness was positively related to height (Fig. 2a), so short weeds were not very competitive, regardless of LAV or k_{leaf} value; 3) for the bottom-skewed LAVs, $F_{top} = 0.90$ was more competitive than $F_{top} = 0.70$ (Figs. 1b and 2a); and 4) increasing k_{leaf} (more planophile leaf angles) increased weed competition, especially for tall weeds (Fig. 2b). For example, weeds with average heights and $k_{leaf} = 0.6$ reduced rice yields by only 5%, while tall weeds with the same k_{leaf} caused a 15% reduction.

It was easily concluded from this that weed competitiveness for light was improved by being taller, having a more bottom-skewed vertical leaf area distribution (greater F_{top}), and having more planophile leaves (higher k_{leaf}). Or, intuitively, weed morphologies that place a larger amount of more planophile leaf area above rice, shade the crop more. More importantly, weed competitiveness for light was determined by interactions between morphological factors. For example, tall weeds were not as competitive if they had a conical LAV or erect leaves (low k_{leaf}). Likewise, simulations indicated that a weed with planophile leaves (e.g., $k_{leaf} = 0.8$) was not competitive if it had a conical LAV or was short. Therefore, results clearly indicated that competiveness for light of weeds was due to a combination of morphological traits.

These results have implications for the potential competitiveness of some rice weeds. For example, short weeds and weeds with conical leaf area distributions were non-competitive regardless of leaf angle. Available evidence tends to support the hypothesis that short weeds are not very competitive in some field situations (Breen, 1995; Gibson *et al.*, *in review*) (c.f., Smith, 1988), and at least for *S. montevidensis*, probably do not even need to be controlled (Gibson *et al.*, 1998, *in review*). Less is known about competition from weeds with conical LAVs, but it seems reasonable to assume that they will be non-competitive unless that disadvantage is overcome by some other means. Examples of some possibilities are that other physiological growth traits (e.g., photosynthetic rates) or high densities resulting from high reproductive rates enable greater growth per m^2 and thus more interference with rice growth. Another possibility is that such weeds affect rice through mechanisms for which DSRICE1 does not account, such as nutrient competition or light-mediated photomorphogenesis (see Breen, 1995). Such inferences can only be settled with much-needed data on rice-weed competition, particularly with sedges (which seem most likely to show conical leaf area distributions). Still, based on competition for light, weeds that are short or have conical LAVs clearly have a severe growth disadvantage in rice.

This information also provides a crude means of evaluating potential interference from weeds in field

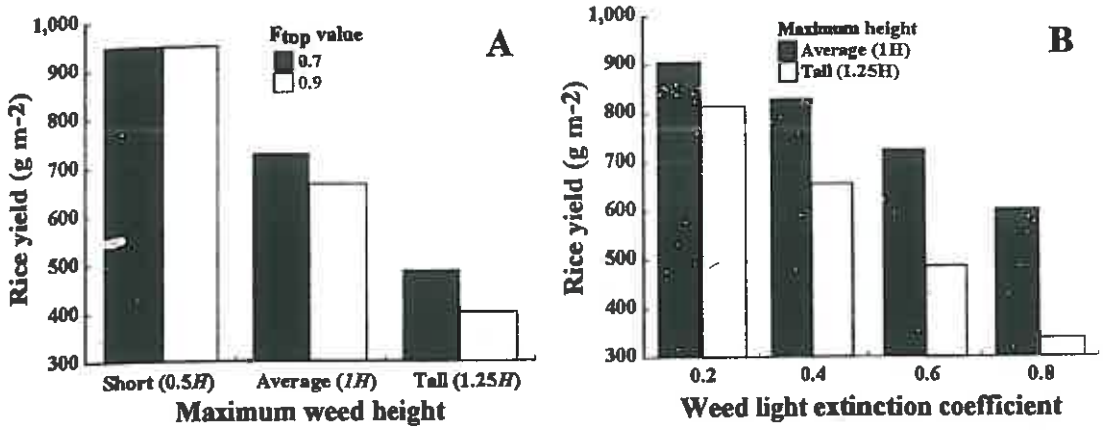


Fig. 2. Results of simulated weed reduction of rice yield (140 DAS). A) Effect of weed maximum height. Data presented for weeds with bottom-skewed LAVs and leaf light extinction coefficient (k_{leaf}) = 0.6. B) Effect of weed k_{leaf}. Data presented for weeds with skewed LAV with F_{top} = 0.70.

situations. An obvious example of this is that many rice growers and weed scientists assume that taller weeds are more competitive. Evaluating the competitiveness of weeds based on their LAVs would be difficult because few weed LAVs have been described and may be difficult to evaluate visually, but leaf angles are easily observed. Therefore, all else being equal, weeds displaying more planophile (or more droopy) leaves would be rated higher than weeds with more erect leaves. Similarly, it might be possible to use these ideas to improve weed monitoring for making control decisions. Exact use of this information would depend on the objectives, but ratings might be increased or decreased relative to the height and leaf display of the weeds observed.

Morphology is not the only determinant of weed competitiveness, and morphological traits other than those studied here may also be important. Other physiological traits, in particular, probably contribute significantly to determining the impact of a weed on rice. Moreover, a whole suite of ecological traits determine the fitness of a weed for a given cropping system, and these may or not affect competitiveness. Approaches that help us understand how all these traits combine to explain crop-weed interactions will be most useful for designing more successful, better integrated, and more sustainable weed management programs.

To conclude that placing leaves higher in the canopy and decreasing leaf angles increases weed or plant competitiveness for light in general may seem too obvious. We argue, however, that this model analysis quantified and confirmed what 'conventional wisdom' had only suggested. Science depends on hypothesis testing and the model provided an efficient means to do what would perhaps be impossible in an empirical study because of the difficulty in designing appropriate treatments and controls (e.g., manipulating LAV). Also, identifying the most competitive variations in traits was simpler and more intuitive than demonstrating that the interactions between traits was ultimately critical to competitiveness. The latter probably required the use of a model. As more weeds are studied in detail, DSRICE1 or other models like it will be critical analytical tools for evaluating the small but important differences in leaf area distributions, heights, and leaf angles that will probably be found.

Finally, morphological analyses of crop plants (Loomis and Williams, 1969), similar to this study, were critical for understanding crop production prior to the Green Revolution. The principles discovered then are now considered the 'conventional wisdom' about the effects of crop plant morphology on light interception and biomass accumulation. Perhaps ecologists studying crop-weed interactions have only recently recognized that measuring and evaluating the effects of plant morphological traits (and others) on competition could form a substantive and lasting part of our understanding about crop-weed interactions.

Acknowledgements:

This research was supported by a grant from USAID designed to increase collaboration between

scientists at U.S. universities and those at international agricultural centers (CGIAR).

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2. Weed Ecology

A PRELIMINARY STUDY AND SURVEY ON GRAMINEAE OF THAILAND

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A preliminary study on Gramineae of Thailand was conducted by collecting specimens in various localities at different altitudes from sea level to the highest summit (2,565 m.) in Thailand. This was supplemented with reference and herbarium specimens search from major botanical libraries and herbaria, i.e. Herbarium, Royal Forest Department (BKF); Herbarium, Department of Agriculture (BK); Herbarium, Queen Sirikit Botanic Garden (QBG); Herbarium, The New York Botanical Garden (NY); Herbarium, The Smithsonian Institution (SI); Herbarium, The Royal Botanic Garden, Kew (K) and Herbarium of Aarhus University (AAU).

Classification rank is arranged follow Clayton and Renvoize system of 1986. The number of taxa in Gramineae are 132 genera and 505 species (Bamboo is excluded). The family is one of the most diverse groups, which includes important plants for food, medicine, ornamental, landscape, decoration and especially for soil and water conservation: i.e. Rice (*Oryza sativa*), Sugarcane (*Saccharum officinarum*), Maize (*Zea mays*), Job's tear (*Coix lacryma-jobi*); Buffalo grass (*Brachiaria mutica*); Vetiver (*Vetiveria zizanioides*); Malaysian grass (*Axonopus compressus*); Manila grass (*Zoyzia matrella*) etc. Beside, grassland is also an important ecosystem for various kinds of insects and animals. Lalang (*Imperata cylindrica*), Pennisitum (*Pennisetum polystachyon*), and Wild rice (*Oryza rufipogon*) are some of the most noxious weeds in Thailand.

Botanical activities in Thailand

The establishment of the Royal Forest Department in 1896 marked the beginning of interest in conservation of the forest areas and the study on the Thai flora, particularly the species of commercial and economic value. The first botanical exploration in Thailand had occurred earlier during 1778-1779 by J.G. Koenig, a leading Danish botanist. Unfortunately, the majority of his collection was lost in transit to Copenhagen, Denmark.

The seminal study of the Thai flora was performed by Dr. A. F. G. Kerr and Professor W. G. Craib from 1907-1940. Kerr gathered a valuable collection of about 23,500 specimens from all over Thailand, while Craib identified these specimens at the Royal Botanic Gardens, Kew, in England. A main set of Kerr's collection is deposited at the Herbarium, Department of Agriculture (BK), in Thailand and another set at Kew (K). One of the major Thai floras, **Florae Siamensis Enumeratio**, was edited by Craib and Kerr in 3 volumes from 1925 to 1962.

Important progress in the study of the Thai flora was initiated in 1955 under the Thai-Danish co-operation. Field expeditions were undertaken intensively during 1957-1960 by Th. Sorensen, K. Larsen and B. Hansen from Denmark and by His Excellency, the Ambassador of Denmark to Thailand, Gunnar Seidenfaden. This work was carried out in co-operation with the leading Thai botanists Dr. Tem Smitinnand, the Royal Forest Department, and Professor Kasin Suvatabandhu, Department of Botany, Chulalongkorn University. These activities contributed approximately 15,000 herbarium specimens, including preserved specimens in alcohol and living material A series of botanical papers on taxonomy and ecology based on the 1957-1963 expedition were published in the **Natural History Bulletin of the Siam Society** and in the **Dansk Botanik Arkiv**.

The famous Thai botanist, Dr. Tem Smitinand has made over 20,000 collections since he began his work in 1940. A complete set of his specimens is deposited at the Forest Herbarium (BKF), Thailand, and other sets were distributed to the Royal Botanic Gardens, Kew and the Herbarium of the Botanical Institute, Aarhus University (AAU), Denmark.

Contemporary botanical activities include the work of the botanists of the Forest Herbarium, Royal Forest Department, and Queen Sirikit Botanic Garden, namely C. Phengklai, T. Santisuk, C. Niyomdham,

W. Nanakorn, K. Chayamarith, and R. Pooma. In 1999, a total of approximately 218,000 plant specimens have been collected from Thailand of which approximately 11,000 are Gramineae. Most of these specimens deposit at Herbarium, Royal Forest Department (BKF); and Herbarium, Department of Agriculture (BK).

Studies on indigenous Gramineae in Thailand.

The first comprehensive study of Gramineae in Asia was done by Sir Joseph Hooker (1897), in his **Flora of British India**. Standard works by other botanists on the Asian grass flora include: E.G. Camus and A. Camus (1912-1923), Gramineae of Indo-China (Laos, Cambodia and Vietnam) in **Flore Generale de I' Indo-Chine;** Ridley (1925), **Flora of the Malay Peninsula;** Keng (1933), **Grasses of China;** Rhind (1945), **The grasses of Burma;** Bor (1960), **The Grasses of Burma, Ceylon, India and Pakistan;** Ohwi (1965), **Flora of Japan;** Froideville (1968), in Becker and Bakhuizen van Dan Brink, **Flora of Java;** Gilliland (1971), **Flora of Malaya;** Tsvelev (1976), **Grasses of the Soviet Union;** Hsu (1978), **Flora of Taiwan;** Lazarides (1980), **The Tropical Grasses of Southeast Asia;** T. Koyama (1987), **Grasses of Japan and its Neighboring Regions,** and E. Watson and M. J. Dallwitz (1992), **The grass genera of the world.**

It was Craib (1913), who first published **Contributions to the Flora of Siam** (Monocotyledons), which listed species and cited specimens mainly collected by Dr. A.F.G. Kerr during 1907-1913; and later Craib and Kerr (1932-1939) published a series of **Flora Siamensis Enumeratio.** Since then all international activities were diminished due to the Second World War and the death of the authors. The Thai-Danish botanical projects have since 1957 inspired much of the recent study of the Thai flora. Specimens collected in these expeditions were identified and results were published in parts in **Dansk Botanisk Arkiv (Studies in the Flora of Thailand),** Bor (1962, 1965) and Larsen (1963). Starting from this point, the Thai government has realized the importance of floristic studies and supported the on-going Flora of Thailand Project, which was initiated in 1970.

At present botanical expeditions are regularly carried out in cooperation between Thai and foreign botanists. The study of certain families has been performed through cooperation of specialists from major herbaria all over the world: Orchidaceae by G. Seidenfaden and T. Smitinand; Leguminosae and Zingiberaceae by K. Larsen; Cyperaceae by T. Koyama; Palmae by J. Dransfield; Dipterocarpaceae by T. Smitinand and J. Vidal; Pteridophytes by staff taxonomists, Kyoto University, Japan etc. However, taxonomic studies in Thailand proceed relatively slowly, as there are only a few well-trained botanists and references and type specimens are insufficient. Consequently, the study of many families of Thai regional flora is still inadequate. Prior to this study, little taxonomic attention has been paid to the grasses of Thailand. The identification, distribution and economic uses of grasses from Thailand have often come from the literature of neighboring countries.

Economic importance of grasses in Thailand

The Gramineae is one of the largest and most widespread families of flowering plants. Members of the Gramineae have economic importance, especially as sources of food and fodder, as well as for paper making, lawns, ornamental plantings, soil binding, and moisture conservation, medicinal compounds, handcraft, building materials, and many other purposes. In Thailand, major examples of human and animal food are rice, *Oryza sativa*; maize, *Zea mays*; millet, *Sorghum vulgare*; sugarcane, *Saccharum officinarum*; Job's tears, *Coix lacryma-jobi*. The genera *Arthraxon, Bothriochloa, Chrysopogon, Coix, Dichanthium, Schizachyrium* and *Sorghum* are reported to be excellent fodder-grasses (Roshevits, 1931; Arber, 1965).

Grassland also has great ecology significance. In Thailand, natural grasslands are mostly occupied by lalang, *Imperata cylindrica*, which is considered to be one of the most aggressive weeds and wildcane, *Saccharum spontaneum*, common in wet areas, while elephant's eyelashes grass, *Themeda triandra* and *Hyperrhenia diplandra* are commonly found in open area and by the edge of the dry-dipterocarp forest.

A number of species in the genera *Bothriochloa, Capillipedium, Cymbopogon* and *Vetiveria* are sources of aromatic oils (Stapf, 1906). The most important are lemon grass and citronella in the genus *Cymbopogon* which contain diverse aromatic compounds differing considerably in scent. These species are

used in the flavor and perfume industries. *Cymbopogon citratus* and *C. martinii* are used for food and food flavoring and are also a good source of citronella. lemon grass and palmorosa oil.

Species of coarse grasses yield fibers and cellulose suitable for paper making or mixtures for pulp, as seen in *Bothriochloa intermedia*, *Cymbopogon nardus*, *Eulaliopsis binata*, *Heteropogon contortus*, *Imperata cylindrica*, *Saccharum officinarum*, *S. spontaneum* and *Vetiveria zizanoides*. However, the fiber length in paper pulp produced from these species are too short and inferior in strength compared with fibers obtained from other material such as pine and bamboo (Bhat and Karnick, 1952; Bor, 1960).

The common species *Chrysopogon aciculatus*, *Dichantium annulatum and Polytrias amaura* are planted as lawn grasses, but they grow extremely fast hence requiring frequent cutting. Soil binding species are commonly planted along roadsides and stream banks in Thailand to prevent erosion caused by heavy rainfall. Perennial species such as *Chrysopogon aciculatus*, *Dichanthium annulatum*, *Hyparrhenia rufa* var. *siamensis*, *Imperata cylindrica*, *Ischaemum muticum* and *Saccharum spontaneum* are good soil binders because their clumps, rhizomes and stolons effectively hold soil.

Imperata cylindrica and *Saccharum spontaneum* are among the most common weeds in Thailand. Both are fire tolerant, with thick rhizomes that makes them difficult to eradicate. They produce a huge number of light fruits with wooly hairs to be easily carried away by wind. However, *Imperata cylindrica* is an important weaving and building material for making roofs and walls for huts. Love grass, *Chrysopogon aciculatus* is also a common weed, the sharp awned fruits are easily attached to animals for dispersal. *Hyparrhenia rufa* var. *siamensis* is now becoming a roadside weed in northern Thailand at high elevation.

In recent years, Vetiver grass (*Vetiveria zizanoides)* has employed in enormous amount all over Thailand and has gained significant importance for soil erosion control and slope stabilization. The grass has planted as contour barriers across sloping lands provides a low cost and sustainable system with numerous advantages for environment conservation i.e. preventing and controlling soil erosion, maintaining soil moisture, trapping heavy metals and toxic materials before they reach valuable natural resources.

Other grasses are used for local medicines, may be the most common being *Cymbopogon nardus* and *Cymbopogon citratus* which has long been well known for its effectiveness in treating stomach and intestinal problems (Burkill, 1966). The hard fruits of *Coix lacryma-jobi* are used by the hill tribes of Northern Thailand for food and for decorative in earrings, necklaces, pendants and wristbands.

Conclusion

In conclusion, a total of 6 subfamilies, 19 tribes, 132 genera and 505 species of Gramineae are recorded for Thailand.

SPECIES ENUMERATION OF THE THAI GRAMINEAE
Synopsis of subfamilies, tribes, subtribes, genera & species. (Excluding Bambuseae)

GRAMINEAE A.L. de Jussieu

Total: Subfamilies 6, Tribes 19, Genera 132, Species 505

SUBFAMILY 1. ARUNDINOIDEAE Tateoka
TRIBE 1. ARISTIDEAE C.E. Hubbard
Genus 1. Aristida L. (7)

TRIBE 2. ARUNDINEAE Dumort.
Genus 1. Arundo L. (2)
Genus 2. Danthonia DC. (1)
Genus 3. Elytrophorus P. Beauv. (1)
Genus 4. Phragmites Adans. (2)

TRIBE 3. THYSANOLAENEAE C.E. Hubbard
Genus 1. Thysanolaena Nees (1)

SUBFAMILY 2. BAMBUSOIDEAE Asch. & Graeb.
TRIBE 4. ORYZEAE Dumort.
Genus 1. Hygroryza Nees (1)
Genus 2. Leersia Sw. (2)
Genus 3. Oryza L. (8)
Genus 4. Zizania L. (1)

TRIBE 5. PHAREAE Stapf
Genus 1. Leptaspis R.Br. (1)

SUBFAMILY 3. CENTOTHECOIDEAE Soderstr.
TRIBE 6. CENTOTHECEAE Ridley
Genus 1. Centotheca Desv. (2)
Genus 2. Lophatherum Brongn. (1)

SUBFAMILY 4. CHLORIDOIDEAE Rouy
TRIBE 7. CYNODONTEAE Dumort.
Subtribe A. Boutelouinae Stapf
Genus 1. Bouteloua Lag. (1)
Subtribe B. Chloridinae Presl
Genus 1. Chloris Sw. (5)
Genus 2. Cynodon A. Rich. (4)
Genus 3. Enteropogon Nees (1)
Genus 4. Eustachys Desv. (1)
Genus 5. Gymnopogon P. Beauv. (1)
Genus 6. Microchloa R. Br. (2)
Subiribe C. Zoysiinae Benth.
Genus 1. Perotis Ait. (3)
Genus 2. Tragus Haller. (1)
Genus 3. Zoysia Willd. (3)

TRIBE 8. ERAGROSTIDEAE Stapf
Subtribe A. Eleusininae Dumort.
Genus 1.Acrachne Chiov. (1)
Genus 2.Dactyloctenium Willd. (1)
Genus 3.Desmostachya Stapf (1)
Genus 4.Eleusine Gaertn. (2)
Genus 5.Eragrostiella Bor (1)
Genus 6.Eragrostis Wolf (35)
Genus 7.Leptochloa P. Beauv. (5)
Genus 8.Myriostachya Hook.f. (1)
Genus 9.Neyraudia Hook.f. (2)
Genus 10. Tripogon Roem. & Schult.(3)
Subtribe B. Monanthochloinae Potztal
Genus 1.Aeluropus Trin. (1)
Genus 2.Allolepis Soders. & Deck. (1)
Subtribe C. Sporobolinae Benth.
Genus 1. Sporobolus R. Br. (10)

TRIBE 9. LEPTUREAE Holmberg
Genus 1.Lepturus R. Br. (1)

SUBFAMILY 5. PANICOIDEAE A. Br.
TRIBE 10. ANDROPOGONEAE Dumort.
Subtribe A. Andropogoninae Presl
Genus 1.Andropogon L. (2)
Genus 2.Arthraxon P. Beauv. (10)
Genus 3.Cymbopogon Spreng. (14)
Genus 4.Schizachyrium Nees (3)
Subtribe B. Anthistiriiane Presl
Genus 1.Heteropogon Pers. (2)
Genus 2.Hyparrhenia Fourn. (4)
Genus 3.Iseilema Anderss. (5)
Genus 4.Parahyparrhenia A. Camus (1)
Genus 5. Pseudanthistiria Hook.f. (1)
Genus 6. Themeda Forssk. (6)
Subtribe C. Chionachninae Clayton
Genus 1.Chionachne R.Br. (1)
Genus 2.Polytoca R. Br. (2)
Genus 3.Sclerachne R.Br. (1)
Subtribe D. Coicinae Reichenb.
Genus 1.Coix L. (4)

Subtribe E. Dimeriinae Hack.
Genus 1. Dimeria R.Br. (9)
Subtribe F. Germainiinae Clayton
Genus 1. Apocopsis Nees (7)
Genus 2. Germainia Bal. & Poitr. (7)
Subtribe G. Ischaeminae Presl
Genus 1.Apluda L. (1)
Genus 2. Ischaemum L. (16)
Genus 3. Kerriochloa C.E. Hubb. (1)
Genus 4. Sehima Forssk. (2)
Genus 5. Thelepogon Roem.& Schult(1)
Subtribe H. Rottboelliinae Presl
Genus 1. Coelorachis Brongn. (5)
Genus 2. Eremochloa Buse (7)
Genus 3. Hackelochloa O. Ktze. (2)
Genus 4. Hemarthria R. Br. (7)
Genus 5. Mnesithea Kunth (3)
Genus 6. Ophiuros Gaertn.f. (2)
Genus 7. Phacelurus Griseb. (2)
Genus 8. Rottboellia Linn.f. (1)
Genus 9. Thaumastochloa C.E. Hubb. (1)
Genus 10. Vossia Wall. & Griff. (1)
Subtribe I. Saccharinae Griseb.
Genus 1. Eulalia Kunth (15)
Genus 2. Eulaliopsis Honda (1)
Genus 3. Imperata Cyr. (1)
Genus 4. Lophopogon Hack. (1)
Genus 5. Microstegium Nees (9)
Genus 6. Miscanthus Anderss. (2)
Genus 7. Pogonatherum P. Beauv. (2)
Genus 8. Polytrias Hack. (1)
Genus 9. Saccharum L. (7)
Genus 10. Spodiopogon Trin. (3)
Subtribe J. Sorghinae Bluff
Genus 1. Bothriochioa O. Ktze. (5)
Genus 2. Capillipedium Stapf (4)
Genus 3. Chrysopogon Trin. (7)
Genus 4. Dichanthium Willemet (7)
Genus 5. Hemisorghum C.E. Hubb. (1)
Genus 6. Pseudosorghum A. Camus (2)
Genus 7. Sorghum Moench (11)
Genus 8. Vetiveria Bory (2)
Subtribe K. Tripsacinae Dumort.
Genus 1. Zea L. (1)

TRIBE 11. ARUNDINELLEAE Stapf
Genus 1.Arundinella Raddi (9)
Genus 2.Garnotia Brongn. (5)

TRIBE 12. ERIACHNEAE Eck.–Borsboom
Genus 1.Eriachne R.Br. (2)

TRIBE 13. ISACHNEAE Benth.
Genus 1.Coelachne R.Br. (4)
Genus 2.Isachne R.Br. (12)
Genus 3. Sphaerocaryum Hook.f. (1)

TRIBE 14. PANICEAE R.Br.
Subtribe A. Cenchrinae Dumort.
Genus 1.Cenchrus L. (3)
Genus 2.Pennisetum A. Rich. (6)
Genus 3.Pseudoraphis Griff. (2)
Subtribe B. Digitariinae Butzin
Genus 1.Digitaria Hall. (26)
Subtribe C. Melinidinae (Hitchc.) Pilger
Genus 1.Melinis P. Beauv. (1)
Genus 2.Rhynchelytrum Nees (1)
Subtribe D. Setariinae Dumort.
Genus 1. Acroceras Stapf (3)
Genus 2. Alloteropsis Presl (2)
Genus 3. Axonopus P. Beauv. (1)
Genus 4. Brachiaria Griseb. (12)
Genus 5. Cyrtococcum Stapf (5)
Genus 6. Echinochloa P. Beauv. (6)
Genus 7. Eriochloa Kunth (2)
Genus 8. Hymenachne P. Beauv. (1)
Genus 9. Ichnanthus P. Beauv. (2)
Genus 10. Oplismenus P. Beauv. (4)
Genus 11. Ottochloa Dandy (1)
Genus 12. Panicum L. (19)
Genus 13. Paspalidium Stapf (2)
Genus 14. Paspalum Linn. (9)
Genus 15. Pseudechinolaena Stapf(1)
Genus 16. Sacciolepis Nash (6)
Genus 17. Setaria P. Beauv. (10)
Genus 18. Stenotaphrum Trin. (2)
Genus 19. Thuarea Pers. (1)
Subtribe G. Spinificinae Ohwi
Genus 1.Spinifex L. (1)
Genus 2.Xerochloa R.Br. (1)

SUBFAMILY 6. POOIDEAE Macfarlane & Watson
TRIBE 15. AVENEAE Dumort.
Subtribe A. Alopecurinae Dumort
Genus 1.Agrostis L. (1)
Subtribe B. Aveninae Presl
Genus 1.Avena L. (1)
Genus 2.Trisetum Pers. (1)
Subtribe C. Phalaridinae Reichb.
Genus 1.Anthoxanthum L. (2)

TRIBE 16. MELICEAE Reichenb.
Genus 1.Melica L. (1)

TRIBE 17. POAEAE Clayton
Genus 1.Briza L. (1)
Genus 2. Poa L . (1)

TRIBE 18. STIPEAE Dumort.
Genus 1.Milium L. (1)
Genus 2.Stipa L. (1)

TRIBE 19. TRITICEAE Dumort.
Genus 1.Hordeum L. (1)
Genus 2.Titicum L. (1)

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EFFECT OF *SALVINIA MOLESTA* (D.S. MITCHELL) ON GROWTH AND YIELD OF RICE (*ORYZA SATIVA* L)

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Abstract: *Salvinia molesta* (D.S. Mitchell) is a problematic weed that clogs irrigation canals, reduce the quality of drinking water, invades rice fields, and creates a habitat for hosts of human diseases. The rice fields could be infested with *S. molesta* through irrigation water. The rice farmers in Sri Lanka manually remove *S. molesta* from rice fields, which consumes time, labour, and money, assuming that the weed would reduce rice yields. However, there is a scarcity of scientifically valid information on competitive performance of *S. molesta* with rice in Sri Lanka. Thus, a field experiment was carried out to investigate the impact of *S. molesta* on growth and yield of rice.

Rice (*Oryza sativa* L, var. BG 300) was established by broadcasting or transplanting with two different levels of fertilizer application, namely, (a) basal fertilizer only, and (b) basal + top dressing. *Salvinia molesta* treatments were (a) introduction at crop establishment, (b) introduction at 2 weeks after crop establishment, and (c) no salvinia (control). The experiment was conducted in a randomized complete block design with four replicates.

There was no significant effect of *S. molesta* on stand establishment of rice. However, the number of spikelets per plant was reduced when only the basal application was fertilizer was done. The N content of the flag leaf of rice was also reduced when the fertilizer application was done only as a basal dressing irrespective of the presence of *S. molesta* in the field. The mulching effect of *S. molesta* significantly reduced the broadleaved weeds in the rice field but not grasses and sedges.

The results indicated that *S. molesta* could act as a mulch to control broadleaved weeds in rice fields. Proper fertilizer management would overcome any detrimental effects of *S. molesta* on growth and yield of rice. However, precautions should be taken to avoid infestation of *S. molesta* from rice fields to irrigation canals.

Key words: ***Salvinia molesta*, rice, crop establishment, fertilizer, weed control**

Introduction

Salvinia molesta (D.S. Mitchell) is a free floating fern and is well recognized as one of the worst aquatic weeds, which has invaded water bodies in Sri Lanka. The plant mostly propagates vegetatively and, forms a thick mat on the water surface within a short period. This aggressive propagation behaviour of S. molesta has resulted in some significant negative effects such as choking of irrigation canals, supporting vector proliferation of human diseases, reducing the quality of drinking water, and invading rice fields (Cronk and Fuller, 1995).

In Sri Lanka, *S. molesta* exists in water bodies from which irrigation water requirement for agricultural production is fulfilled. Thus, rice fields irrigated from these salvinia-infested sources would become a victim of this weed. Although there is no accurate information on the extent of infestation of rice fields with *S. molesta* in Sri Lanka, it is believed that a considerable % of rice fields in North Western province, a major rice growing region of the country, is invaded by this weed (Dr. S. Abeysiriwardena, Deputy Director Research, Rice Research and Development Institute; personal communication). Sri Lankan farmers manually remove *S. molesta* from their rice fields fearing negative impact of the plant on growth and development of rice thus, resulting in higher cost of production. Although much energy is spent on to remove *S. molesta* from rice fields, there is no scientifically valid evidence that *S. molesta* affects the growth and yield of rice. In addition, our preliminary studies have indicated that presence *S. molesta* in rice fields could reduce the emergence of certain weeds.

Thus, a study was initiated to determine the effects of *S. molesta* on growth and development of rice and its efficiency on weed control in rice fields.

Materials and Methods

The field experiments were carried out at the Rice Research and Development Institute, Batalagoda (North Western province), Sri Lanka. The soil type was a red yellow podsolic with a pH of 5.9, and the annual rainfall of the region was 2250-2285 mm with an average temperature of 23-28°C.

Rice (*Oryza sativa* L, var BG 300, 3-month old variety) was used as the test crop and established by (a) wet-seeding at the rate of 100 kg/ha, and (b) transplanting at a density of 3 seedlings per hill. *Salvinia molesta* (D.S. Mitchell) was introduced at two different stages of growth of rice namely, (a) at time of crop establishment and (b) at 2 weeks after crop establishment. The crops received two levels of fertilizer, namely (a) application of basal dressing only, (b) application of both basal and top-dressing. A plot with no salvinia was maintained as a control treatment for comparison of data. The rates of fertilizer application, water management and, insect-pests and disease control was carried out according to the recommendations of the Government Department of Agriculture (Technoguide, 1991).

The nutrient content of the soil before the establishment of rice and at time of flowering of rice, and the nutrient uptake of rice and *S. molesta* were recorded to elucidate the competitive effect of the weed on the crop. The yield components of rice namely, No. of tillers/plant, number of panicles/area, and number of spikelets/panicle were also recorded. The weed count, dry weight and the floristic composition of the weeds wee recorded at 2 and 6 weeks after establishment (WAE) of the rice crop, to determine the weed suppressing ability of *S. molesta* in rice fields.

The experiments were conducted in a randomized complete block design with three replicates. The results were analyzed by Analysis of Variance (ANOVA) using the SAS computer package. The treatment means were compared by the Least Significant Difference at p=0.05.

Results and Discussion

Effect of *S. molesta* on soil nitrogen levels

Presence of Salvinia in rice fields did not have a significant effect on the soil nitrogen level (Table 1). However, application of top dressing of fertilizer gave a 27% increase in the soil nitrogen level at time of flowering of rice, when compared to the plots without the top dressing of N fertilizer. The results indicated that *S. molesta* does not have a significant effect on the soil nitrogen level, which may be due to that the plant has no real root-contact with the soil (Room, 1983).

Table 1. Effect of *Salvinia molesta* on soil nitrogen level of paddy fields at time of flowering of rice, as affected by Salvinia.

Salvinia treatment	Basal fertilizer only		Basal + top dressing	
	Transplanted	Broadcasted	Transplanted	Broadcasted
No Salvinia	0.078 (0.087)	0.082 (0.091)	0.104 (0.092)	0.105 (0.098)
Salvinia at crop establishment	0.080 (0.095)	0.095 (0.097)	0.113 (0.092)	0.106 (0.097)
Salvinia at 2 WAE*	0.094 (0.089)	0.084 (0.099)	0.102 (0.094)	0.119 (0.095)
Mean	0.084	0.086	0.106	0.11
L.S.D. (p=0.05)	NS		NS	

*WAE: weeks after crop establishment; LSD - least significant difference; values in parenthesis indicate the initial soil N content in respective treatments.

Effect of *S. molesta* on the N content of the flag leaf of rice

Application of both basal and top dressing of fertilizer in the presence of *S. molesta* showed that the weed has no significant impact on the N content of the flag leaf of rice irrespective of the method of crop establishment (Table 2). The N content of the flag leaf was increased by 6.7% when fertilizer application was done as both basal and top dressings, when compared to basal dressing only. The results indicated that proper fertilizer management could overcome the negative impact of *S. molesta* on rice.

Table 2. Effect of *S. molesta* on N content (%) of the flag leaf of rice as affected by Salvinia.

Salvinia treatment	Basal fertilizer only		Basal + top dressing	
	Transplanted	Broadcasted	Transplanted	Broadcasted
No Salvinia	2.65	2.62	2.8	2.79
Salvinia at crop establishment	2.57	2.57	2.79	2.74
Salvinia at 2 WAE*	2.62	2.62	2.78	2.79
Mean	**2.61**	**2.60**	**2.79**	**2.77**
L.S.D. (p=0.05)	NS		NS	

* WAE: weeks after crop establishment; LSD - least significant difference

Effect of *S. molesta* on the yield component of rice

The stand establishment was not affected by the treatments. The panicle count of rice was 22% higher in broadcasted rice when compared to transplanted rice (Table 3). Similar results have been reported by Pons (1985). The number of spikelets per panicle was significantly increased with application of the top dressing of N fertilizer when compared to plots supplied only with the basal fertilizer mixture.

Salvinia reduced the number of spikelets of rice especially in the absence of the top dressing of N fertilizer in the broadcasted rice culture (Table 4). This could be due to the competitive effect of the weed under low fertilizer levels as indicated by the N content of the flag leaf (Table 2). Presence of *S. molesta* in rice field did not show any significant reduction in the yield components of rice (Tables 3 and 4).

Table 3. Panicle count of rice (No./m²) as affected by Salvinia

Salvinia treatment	Basal fertilizer only		Basal + top dressing	
	Transplanted	Broadcasted	Transplanted	Broadcasted
No Salvinia	166	222	208	228
Salvinia at crop establishment	156	222	198	220
Salvinia at 2 WAE	154	198	186	212
Mean	**158**	**214**	**197**	**220**
L.S.D. (p=0.05)	NS		NS	

* WAE - weeks after crop establishment; LSD - least significant difference

Table 4. Number of spikelets per panicle as affected by Salvinia

Salvinia treatment	Basal fertilizer only		Basal + top dressing	
	Transplanted	Broadcasted	Transplanted	Broadcasted
No Salvinia	135	133	166	153
Salvinia at crop establishment	133	123	168	161
Salvinia at 2 WAE	124	123	166	163
Mean	**130**	**126**	**166**	**159**
L.S.D. (p=0.05)	NS		NS	

* WAE - weeks after crop establishment; LSD - least significant difference

Weed suppression by *S. molesta*

Echinochloa crus-galli was the common grass weed found in the experimental plots. *Monochoria vaginalis* and *Commelina diffusa* were the common broadleaved weeds and *Cypeus iria* and *Fimbristylis miliacea* were the dominant sedges.

Presence of *S. molesta* in rice fields effectively suppressed the emergence of broadleaved weeds (Table 5) but not the grasses and sedges. This may be due to that grasses and sedges emerge earlier than the broadleaved weeds, before Salvinia has formed a dense mat on the rice fields. The emergence of the latter was suppressed due to the mulching effects of Salvinia.

Although the impact of suppression of broadleaved weeds was not reflected in the final yield (Table 4), the mulching effect of Salvinia could be useful when the plant is present in rice fields where boradleaves play a dominant role as weeds.

Table 5. Dry weight of broadleaved weeds (g/m^2)

Salvinia treatment	Basal Fertilizer only		Basal + top dressing	
	Transplanted	Broadcasted	Transplanted	Broadcasted
No Salvinia	14.4	21.9	16.6	31.7
Salvinia at crop establishment	13.2	9.9	10.8	7.7
Salvinia at 2 WAE	12.6	7.5	3.8	7.8
Mean	**13.4**	**13.1**	**10.4**	**15.7**
L.S.D. (p=0.05)	NS	13.7	7.3	17.3

* WAE - weeks after crop establishment; LSD - least significant difference

Conclusions

Presence of *S. molesta* at time of planting did not affect the stand establishment of rice. Salvinia did not have a significant effect on soil nitrogen content. In the absence of top dressing of fertilizer (nitrogen) could reduce the N content of the flag leaf of rice plant. However, under the present experimental conditions, Salvinia had no significant effect on rice yields when both the basal and top dressing of fertilizers were provided to the crop.

Acknowledgements:

The authors wish to thank the Director General of the Government Department of Agriculture, Sri Lanka, and the Director and Deputy Director of Research of the Rice Research and Development Institute (RRDI), Sri Lanka for their assistance.

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MORPHOLOGIC AND GENETIC VARIATIONS IN UPLAND AND LOWLAND ECOTYPES OF PURPLE NUTSEDGE (*Cyperus rotundus* L.) IN RAINFED RICE-ONION SYSTEMS

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Abstract: Morphologic and genetic variations of upland and lowland ecotypes of purple nutsedge were determined in laboratory and greenhouse studies. Tubers of upland and lowland ecotypes of purple nutsedge were collected from three villages in Nueva Ecija province, Philippines where the weed was observed to grow in both wet and dry seasons in the same field. The tubers were sprouted and grown in the greenhouse to determine if morphologic and genetic variation between the two ecotypes exists. Morphologic characterization of the two ecotypes showed significant variation. The lowland ecotype was significantly taller, had more offshoots, more seeds per inflorescence and flowered later than the upland ecotype. Tuber number and tuber weight were, however, significantly higher in the upland ecotype. Genetic analysis using RAPDs technique showed distinct variation between the upland and lowland ecotypes in two villages. The lowland ecotype either possessed one additional DNA band or a band in a different position or absence of a band, with each of the tested primers. Cluster analysis revealed variability between the upland and lowland ecotypes particularly in the two villages where the rice-onion rotation is done continuously. These variations in the morphologic and genetic characteristics between the upland and lowland ecotypes may have resulted from the alternate wet and dry regimes over the years which favored the selection of a type of purple nutsedge that can adapt to both upland and lowland conditions. This has significant implications in the management of purple nutsedge, which is the most dominant weed in rice-onion rotation systems.

Key words: purple nutsedge, morphologic and genetic variation, RAPD, rice-onion rotation systems

Introduction

Rice is traditionally grown during the wet and dry seasons in Central Luzon, Philippines. However, the declining water supply and poor irrigation facilities have prompted farmers to plant other crops during the dry season. High value upland crops widely grown after rice include onion, garlic, eggplant, watermelon and string beans. These crops are more profitable and require less water than rice.

Crop rotation causes weed shifts but when rotation of the same crops is done continuously, this can lead to the emergence of a dominant weed that can adapt to both lowland and upland condition. For the past 20 years, purple nutsedge thrived only in upland areas. A weed survey in San Jose, Nueva Ecija province, Philippines however, revealed that purple nutsedge now ranks as the second most dominant weed in lowland rice (Baltazar, et al 1997a). The same weed survey also showed that in one village, purple nutsedge comprised 44% of the total weed population in lowland rice. Apparently, the alternate wet and dry conditions and the low paddy water levels during the wet season are favoring the selection of a lowland ecotype of purple nutsedge (Baltazar, 1997b). Komai et al (1983) likewise reported the occurrence of lowland ecotypes of purple nutsedge in Thailand and Japan.

The occurrence of a lowland ecotype of purple nutsedge is quite alarming as it poses greater weed problems for the farmers. Purple nutsedge is difficult to control as it possesses tubers that multiply rapidly even under unfavorable conditions. The increasing dominance of purple nutsedge in both cropping seasons makes it difficult to control this weed, when it grows in upland crops, particularly vegetables. At present, there is no selective herbicide that can effectively control this weed. Cultivation can separate the tubers from the mother plant consequently breaking apical dominance and enhance germination of dormant tubers. Hand weeding and mechanical weeding to remove the tubers are

laborious and impractical to do in large fields. Purple nutsedge when left uncontrolled can easily establish and dominate other weeds in an area.

With the recent developments in weed shifts and the emergence of weeds such as purple nutsedge that can adapt to both lowland and upland conditions, it is deemed necessary to study the mechanism of adaptation of this weed. Morphologic characterization has shown some variations in parameters such as biomass and plant height which indicate phenotypic plasticity of the weed. It is possible that there is a physiological or genetic basis for the adaptation of purple nutsedge to both saturated and flooded conditions.

This study was conducted to determine the morphologic and genetic variations in the upland and lowland ecotypes of purple nutsedge.

Materials and Methods

Collection of tubers

Tubers of purple nutsedge were collected from 12 fields where the weed was observed to grow in both wet and dry seasons in three villages namely, Abar 1st, Santo Tomas and Palestina, in San Jose, Nueva Ecija province. Tubers of purple nutsedge growing in rice paddies collected during the 1997 wet season were used for the lowland setup. For the upland setup, tubers were collected during the fallow period following onion in the 1997- 1998 dry season.

Morphologic variation

Uniformly sized tubers were sprouted in petri dishes then transferred to plastic bags lined with moist filter paper to germinate until the seedlings reached one cm. For the upland setup, size #12 clay pots were filled with clay loam soil obtained from the PhilRice Central Experiment Station. For the lowland setup, size #12 clay pots without holes were filled with Maligaya clay soil (fine montmorillonitic isohyperthermic Ustic Epiaquerts). Three seedlings were planted in each pot then thinned to one plant per pot when the seedlings reached 4-5 cm. In the upland setup, the soil moisture was maintained at saturation until harvest. Water was maintained at 3-5 cm simulating flooded condition in the lowland setup until harvest. Plants were grown in natural environmental conditions from September to December 1997 (lowland set up) and from March to July 1998 (upland). Each treatment was replicated four times and arranged in completely randomized design. Plant height, number of off shoots and number of leaves were recorded biweekly. The number of days to flowering was determined when 50% of the florets had emerged. Plants were harvested at 120 days after emergence (DAE). Fresh weight of tubers, tuber number, and number of rays/inflorescence and number of seeds/inflorescence were recorded.

Genetic variation

Plants were sprouted and grown as in the morphologic variation study. Freshly harvested leaves of 40-45 day old purple nutsedge were cleaned and cut into small pieces. A sample of 8 g from each plant was ground in mortar and pestle with liquid nitrogen. The finely ground tissue was placed in plastic tubes and added with 20 ml of previously boiled 1.5X CTAB extraction buffer composed of 1.5% CTAB (alkyltrimethyl ammonium bromide), 0.075 M Tris-HCl pH 8.0, 15 mM EDTA pH 8.0, 1.5 M NaCl (w/v). The samples were incubated in a water bath at 56°C for 20 min with mild shaking then extracted with 20 ml (1 vol) chloroform isoamyl alcohol (24:1; v/v). The mixture was again incubated for 30 min at room temperature with mild shaking in a rotary shaker then centrifuged at 2800 rpm for 30 min. The upper layer (aqeous phase) was collected and transferred into a new tube and added with 2 ml of 10% CTAB and mixed gently. Twenty ml (1 vol) of chloroform isoamyl alcohol (24:1, v/v) was added and mixed using a rotary shaker at room temperature for 20 min then centrifuged at 2800 rpm for 30 min. The upper layer was again collected and added with 20 ml (1 vol) CTAB precipitation buffer made up of 1% CTAB, 50 mM Tris-HCl pH 8.0, and 10 mM EDTA pH 8.0. The mixture was mixed slowly using a rotary shaker until DNA precipitate formed then stored overnight at 4°C to make a more fibrous DNA clot. The mixture was centrifuged at 2800 rpm for 20 min to separate the DNA clot. The supernatant was discarded by inverting the tube in a paper towel to get rid of the excess liquid. Five ml of 1M NaCl with 5 µl RNAse (stock:10 mg/ml) was added to the DNA precipitate. The mixture was incubated in 56°C water bath until the DNA was dissolved completely then added with 10 ml of 99.5%

cold ethanol. The DNA was collected by swirling the sterile bent pipette until the DNA adhered to the tip. The DNA was washed by immersing in a tube with 70% EtOH for 7 min, then transferred to another tube with 70% EtOH for 30 min and then in a tube with 99.5% EtOH for 5 min. The DNA was air dried for 2 min, redissolved in 2 ml of 10% TE buffer and stored at 4°C.

Random Amplified DNA (RAPDs) analysis

The standard RAPDs protocol developed by Williams et al (1990) was optimized to obtain good amplification of purple nutsedge genomic DNA. DNA concentrations ranging from 2, 5, 10 and 15 ul were tested to determine the optimum concentration. Different concentrations of magnesium chloride, deoxy nucleotide triphosphates (dNTPs) mix and PCR buffer were tested in the optimization process. The Polymersae Chain Reaction (PCR) mixture which gave the best amplification was composed of 6.8 ul sterile distilled water, 2.0 µl 10x PCR buffer, 0.4 µl 5mM dNTPs, 3.8 µl 10 mM MgCl2, 1 µl random decamer primer manufactured by Operon Technologies Inc. (Alameda, CA), 1 µl of homemade Taq polymerase to yield 15 µl of PCR mixture. Five µl of genomic DNA (adjusted to a concentration of 5 ng/µl) was transferred to plastic thermocycler wells and 15 µl of the PCR mixture was added. One drop of mineral oil was overlaid to the mixture to prevent evaporation. Properly labeled samples were placed in automated thermocycler (PTC-100 Programmable Thermal Controller, MJ Research, Inc.) programmed to pass 45 cycles, each consisting of 5 min at 95°C (initial denaturation), 1 min at 95°C (annealing), 1 min at 36°C (extension) and 1 min at 72°C (denaturation). At the end of 45 cycles, a final extension step was allowed to proceed at 72 °C for 7 min.

Five µl of the loading dye was added to the amplified DNA products prior to gel electrophoresis. The gel was prepared by using 2% agarose gel in 1X TAE buffer. Ethidium bromide (5 mg/ml) was added to stain the DNA bands. Fifteen µl sample was taken out of the plastic thermocycler wells and loaded to the wells of the gel. The voltage was set at 90 volts for 4 hr. The gel was viewed in a UV transilluminator then photographed using a Polaroid camera.

To ensure that the amplification products were consistent and reproducible, the DNA extracts were subjected to three PCR runs for each primer at different times. Different batches of PCR cocktails were used in each PCR run. A control without the DNA extract was included in each run. Only those bands that appeared consistently in all trials were included in the scoring. Bands generated in RAPDs were scored either as present or absent designated as 1 and 0, respectively. Genetic variation between populations of lowland and upland ecotypes of purple nutsedge was determined using the Nei's distance formula (Nei, 1972). A dendogram was created using the unweighted pair group method with arithmetic averages (UPGMA) cluster analysis. All genetic distance calculations and the dendogram were made with the aid of NTSYS-pc version 1.8 (Rohlf, 1993).

Results and Discussions

Morphologic variation

The morphologic parameters measured are summarized in Table 1. Plant height and number of offshoots of the lowland ecotype were significantly higher in Abar 1st and Palestina compared to the upland ecotype. The number of leaves and inflorescence per plant and rays per inflorescence did not significantly vary between the lowland and upland ecotypes in all three sites. Significantly more and bigger tubers were observed in the upland ecotypes from Santo Tomas and Palestina. More seeds per inflorescence were obtained from the lowland ecotype than from the upland ecotype. However, only the lowland ecotype from Abar 1st showed significantly more seeds per inflorescence. The lowland ecotype flowered significantly longer by 12-14 days in Abar 1st and Santo Tomas compared to Palestina. Initial morphological characterization showed that the lowland ecotypes were taller and had 60% more biomass than the upland types. When submerged in 5 cm water, tubers of the lowland ecotype grew as well as the upland ecotype (Baltazar et al, 1997b).

Genetic variation

The upland and lowland ecotypes showed genetic variation in 42 out of the 65 primers that produced polymorphic DNA bands. Differences were seen in the number and position of DNA bands of lowland and upland ecotypes (Figure 1). The lowland ecotypes either possessed an extra band or had

missing bands or possessed a band in a different position compared to the upland ecotypes as shown in the polymorphic bands amplified with OPAO-02. Polymorphic bands amplified with the primer are indicated by arrows labeled a, b, c, d. DNA bands generated with OPAO-02 showed variable polymorphism in most sites as shown by the differences in RAPDs product patterns.

Table 1. Growth parameters measured in upland and lowland purple ntusedge collected from three sites.

Growth Parameters	Abar 1st [a]			Sto. Tomas [a]			Palestina [a]		
	Low land	Up land	Difference	Low land	Up land	Difference	Low land	Up land	Difference
Plant height (cm)	106	93	13*	99	103	4	83	63	20**
No. of offshoots	18	7	11*	13	9	4	13	7	6*
No. of leaves	315	221	93	282	386	104	275	294	19
No. of Inflorescence	8	10	2	9	10	1	8	7	1
No. of rays / Inflorescence	47	48	1	71	79	8	49	48	1
No. of tuber/plant	27	36	9	38	56	18*	37	66	29**
Wt. of tuber/plant (g)	18	27	9	22	38	16*	23	51	28**
No. of seed/ inflorescence	56	0	56**	51	28	11	35	23	18
Days to flower	44	30	14**	36	24	12**	27	28	1

[a] Average of four replications
* Significant at 5* level, ** Highly significant at 5% level

Genetic dissimilarity distance was obtained using the bands generated with RAPDs. The genetic distance ranged from 0.15 to 0.45 with the majority of the gene frequency occurring at 0.23 to 0.36 (Figure 2). The data indicate genetic variability among the different populations of lowland and upland ecotypes of purple nutsedge. A dendogram (Figure 3) for the 24 populations of upland and lowland ecotypes of purple nutsedge was generated using UPGMA cluster analysis. Several branches were present on the dendogram with the lowland and upland ecoytpes in all fields in Palestina forming a single broad cluster. This observation is expected as the rice farms in Palestina are sometimes left fallow

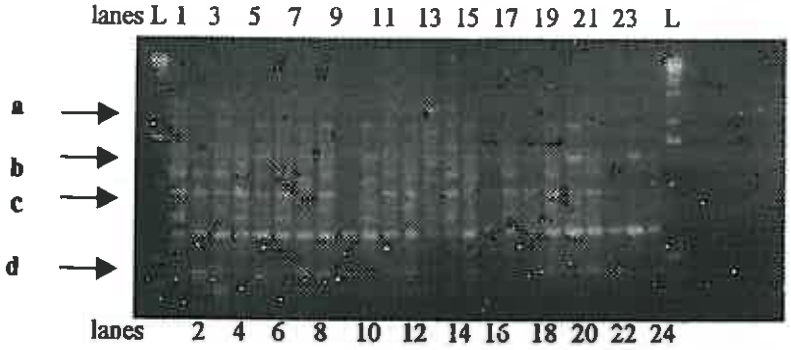


Figure 1. Genomic DNA fragments from 24 populations of upland and lowland ecotypes of purple ntusdege amplified with OPAO-02 primer. Lanes: L, DNA size marker; 1, Field 1 Abar 1st lowland (L); 2, Field 1 Abar 1st upland (U) ; 3, Field 2 Abar 1st U; 4, Field 2 Abar 1st L; 5, Field 3 Abar 1st U; 6, Field 3 Abar 1st L; 7, Field 4 Abar 1st L; 8, Field 4 Abar 1st U; 9, Field 1 St. Tomas U; 10, Field 1 Sto. Tomas L; 11, Field 2 Sto. Tomas U; 12, Field 2 Sto. Tomas L; 13, Field 3 Sto. Tomas U; 14, Field 3 Sto. Tomas L; 15, Field 4 Sto. Tomas L; 16 Field 4 Sto. Tomas U; 17, Field 1 Palestina L; 18, Field 1 Palestina U; 19, Field 2 Palestina U; 20, Field 2 Palestina L; 21, Field 3 Palestina U; 22, Field 3 Palestina L; 23, Field 4 Palestina U; 24 Field 4 Palestina L.

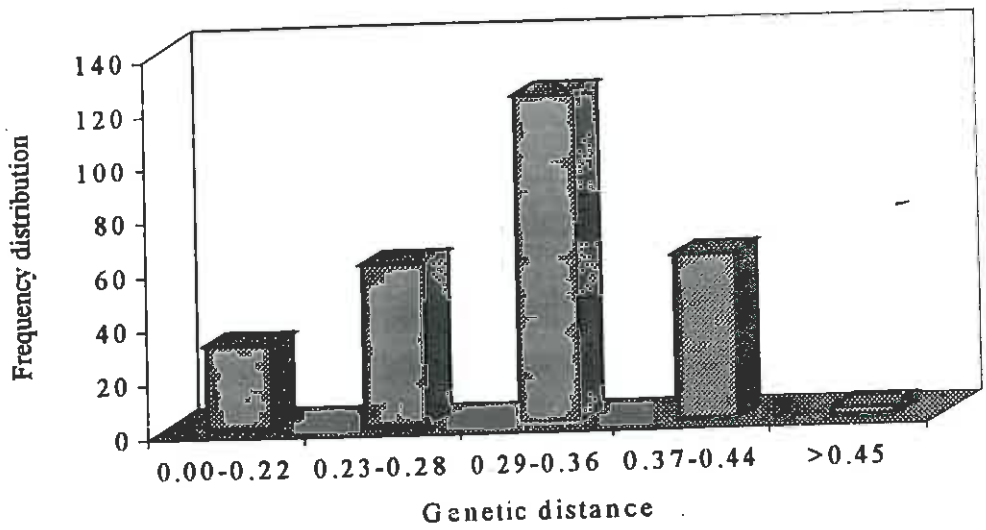


Figure 2. Frequency distribution of genetic dissimilarity distance of upland and lowland ecotypes of purple nutsedge collected from three villages.

during the wet season resembling an upland condition. Two distinct and separate clusters were formed for Santo Tomas and Abar 1st. The lowland ecotype from three fields in Abar 1st was distinctly separated from the upland ecotype. Similarly, the lowland ecotype from two fields were separated from the cluster formed by the upland ecotype from Santo Tomas. These results indicate genetic variation between the lowland and upland ecotypes of purple nutsedge particularly in Abar 1st and Santo Tomas. A more systematic sampling from a small area might lead to a more distinct clustering that separates the lowland ecotype from the upland ecotype.

There are two possible reasons for the variation between the lowland and upland ecotypes of purple nutsedge in Abar 1st and Santo Tomas. First, it may have resulted from the alternate wet and dry regimes over the years which favored the selection of a type of purple nutsedge that can adapt to both upland and lowland conditions. Second, although it has very limited viable seeds, sexual reproduction can play a part in the genetic variation of the weed. Purple nutsedge can produce 131 million seeds per hectare, with 5% germination (Ranade and Burns, 1925). In the morphologic variation study, more seeds per inflorescence were obtained from the lowland ecotype of purple nutsedge compared to the upland ecotype. It is possible that the level of variation that occurred resulted from mutation and the resulting genotype was maintained in subsequent generations through asexual propagation (ie through tubers). Purple nutsedge does not come from a single global clone as shown by the distinct genetic variation among populations from America, India and Brazil (Okoli et al, 1997). Wills (1998) made a comprehensive study and reported that large morphologic variation exists among purple nutsedge populations in the world. Environment plays a significant role not only on the morphologic variation of purple nutsedge but on the genetic variation as well.

The morphologic and genetic variation observed has significant implications in the management of purple nutsedge in rice–onion rotation systems. The two types of purple nutsedge may have variable responses to control measures. If so, different weed management strategies for each type may have to be developed during the rice and onion cropping seasons.

Acknowledgements:

This project was supported by IPM-CRSP funded by USAID Global Bureau Grant No. LAG 4196-G-00-3053-00, with Virginia Tech as lead institution and Philippine Rice Research Institute, University of the Philippines Los Baños and the International Rice Research Institute as collaborating institutions.

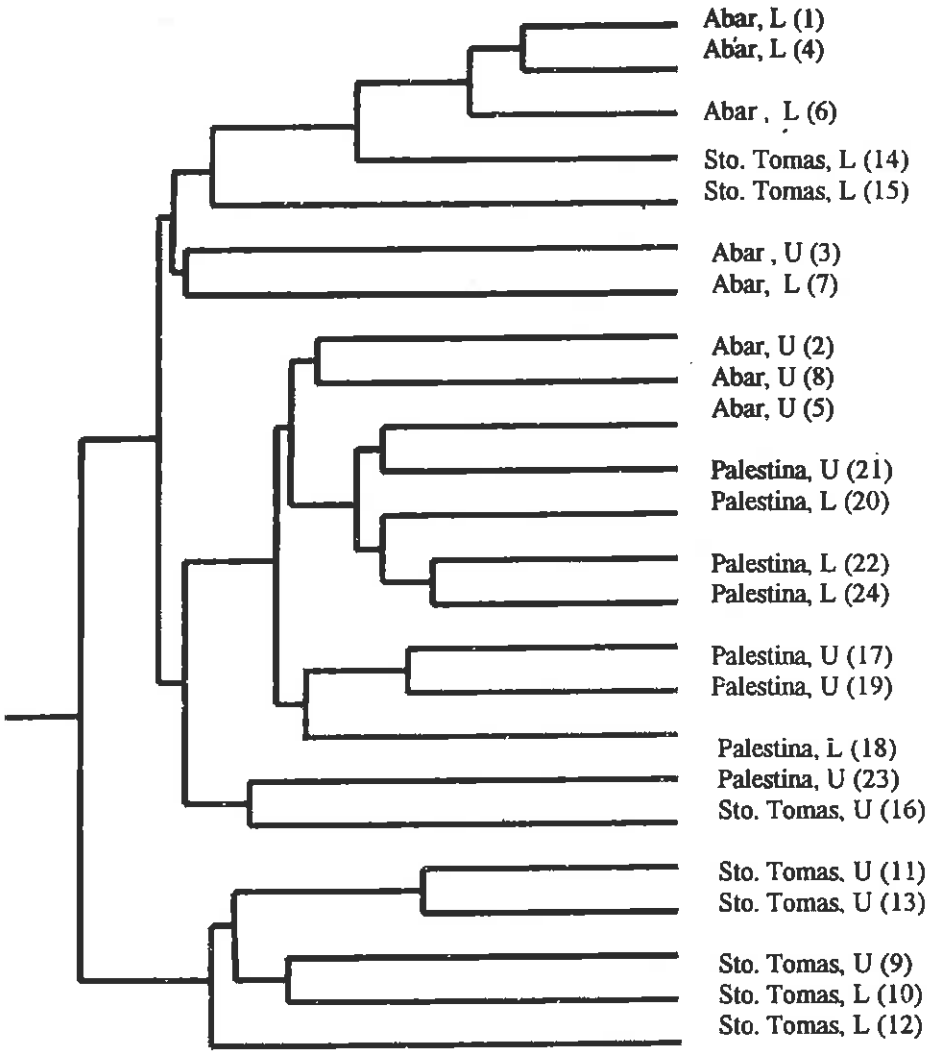


Figure 3. Dendogram based on Nei's genetic distance for 24 populations of purple nutsedge collected from three villages. Letters U (upland) and L (lowland) indicate ecotype.

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RESEARCH ON DAMAGE AND POPULATION CHANGE OF WEEDS AT SPRING WHEAT FIELDS IN QINGHAI

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Abstract: Results of the investigation of weeds at spring wheats fields in Qinghai in 1992 and 1997 showed that weed damage decreased evidently and weed species occurring were the same , but the composition of the weeds had changed. The damage index of *Avena fatua ,Elsholtzia densa,Chenopodium album, Brassica junce*, and *Thlaspi arvense*, which were predominant weeds, changed from 26.18, 15.68, 18.44, 6.67 and 4.4 in 1992 into 16.51, 3.2, 2.24, and 2.4 in 1997. The damage index of other weeds *Sonchus brachyotus, Galium aparine,* and *Convolvulus arvensis* changed from 11.84, 7.4, and 7.05 into 14.21, 9.16, and 10.66 and became the predominant weeds in 1997. The main reasons for the change were continuous application of one kind of herbicides and unsuitable cultivate measures.

Key words: weed damage, wheat, population change

Introduction

Field weeds serve as one of important factors influencing agricultural producing and product quality. Spring wheat fields in Qinghai are subject to severe weed infestation. Total infestation field areas amount to above 267.3 thousand hectare and severe ones reach 133 thousand hectare according to the survey results released during "the seventh five-year plan ". With the innovation of weeding technology and development of plaughing systems, weed infestation and community succession have changed in fields. Based on pastfive-scale visual rating method measurement, we adopt" upset W9 points sample" method to study weed infestation and population succession process. And through comparative and typical experimental studies, investigate weed infestation and population shift trends and provide scientific foundation for weed control.

Materials and Methods

Five-scale visual rating method and upset "w"9 points sample method are applied respectively to investigate herbicide application and weed community succession, analyzing weed infestation situation and population shift.

Results and Analysis

1. Situation of weed infestation occurrence in wheat fields.

Weed species in wheat fields reach more 182 and have no variation basically according to the surrey conducted in 1986, 1994 and 1998. Incomplete investigation conducted at east Qinghai agricultural areas during growth period (after primary control) with the method of upset "w"9 points sample indicated that field weed are featured by high frequency, and density. weed species with relative abundance above 7.6 total 17 (see table 1). Comprehensive study on frequency, density, relative abundance and field infestation revealed that major infestation weeds involved *Chennopodium album, Polygonum aviculare ,Avena fatua, Convolvus arvensis, Sonchus brachyotus,Laminum amplexicaule,Sonchus oleraceus, Elsholtzia densa, Cephalanoplos setosum*, and *Galium aparine.*

2. Weed population and community succession in wheat-rape rotation fields

(1) Weed population succession.

In recent years, Triallate, 2,4-D and Trifluralla as we as single cyclical herbicide applied to wheat and rape and bean fields respectively decreased total and severe infestation rate.

Comparison of the two investigation results attained in 1986 and 1994 showed that originally dominant weed species, Such as *Avena fatua,Elsholtzia densa, Chenopodium album, Polygonum aviculare, Brassica juncea* and *Thlaspi arvense* are controled, infestation rate decrease fron 26.18, 15.68, 18.44, 13.57, 6.67 and 4.4 to 16.51, 7.9, 3.2, 7.9,2.24 and 2.4 respectively. Originally sub-dominant and high-tolerance species, Such as *Sonchus brachyotus, Galium aparine, Convolvus arvensis* and *Cephalanopos setosum* become more harmful, weed infestation index rise from 11.84, 7.41, 7.05, 5.07 to 14.21, 9.16, 10.66 and 7.14 respectively.In someareas,infestation of *Galeopsis bifida,Polygomum convolvulus*
and *Vicia sativia* enhance gradually.

(2). Weed community infestation and variation in weed infestation in different ecological areas.

Variation of weed population cause change in dominant species of involved in weed community. Weed community in which wild oat and annual 2,4-D sensitive broad leaf weeds are dominant tend to decrease, while community in which perennial weeds or together with annual weeds are dominant tend to increase.

Analysis on the basis of ecological areas showed that weed infestation in valley areas are effectively controlled due to sufficiently tillage. Infestation emergence of perennial weeds increased in fields. It's valuable to point out that good water and heat condition one benefit for fast development of annual weeds unless close attention is paid to.Despite insufficient water and lower productive force in mountainous areas infestation occurrence of wild oat and annual weeds decrease thanks to comprehensive application of herbicide in recent years. Infestation occurrence of *Convolvus arvensis* and *Cephalanoplos setosum* increase. With the curb of mountainous areas and improvement of productive conditions, more attention should be paid to weed control. Suitable water condition in valley areas create growth conditions for weeds.

Field weed infestation rate decrease 6.6 percentage compared to 65.8%. Severe infestation rate decrease 17.8 percentage compared to previous 31.3% .Owing to application of chemical herbicides occurrence infestation of major weeds, such as *Avena fatua, Elsholtzia densa, Sonchus brachyotus, Lepyrodiclis holosteoides, Chenopodium album, Thlaspi arvense* and *Brassica juncea* apparently decline. While occurrence infestation of 2, 4-D tolerant weeds , such as *Galium aparine,Galeopsis bifida*, and *Convolvus arvensis* tend to increase. Occurrence infestation of weeds (*Avena fatua,Sonchus brachyotus* and *Cephalanoplos setosum*) in wheat fields in west and south Qinghai agricultural areas (mainly state-owned farm) tend to rise because of dry weather. Lower efficiency of herbicide and lack of management. Weed infestation index increase by 19.13, 16.8 and 3.50 compared to previous 27.87, 4.50, 14.5 respectively.

3. Reason for weed community and population succession in wheat fields.

(1). Application of herbicide and weed community succession.

Fixed-point investigation with six kinds of herbicide in succession six years. indicated that wild oat increase by 38 times broad leaf weed 1.8 times in control plots. 2,4-D plus Difenzoquat treatment prevent wild oat and some broad-leaf weeds while increase herbicide-tolerant weeds (*Galaopsis bifida* and *Galium aparine*) by 3.44 times. In 2,4-D treatment plots, wild oat increase by 44.8 times. broad-leaf weeds increase 0.27 times. In Triallate treatment plots , wild oat are controlled, while broad leaf weed increase by 5.17 times. Five years continuous treatment with Maicaoguang control wild oat and annual broad leaf weeds, while increase perennial *Cephalanoplos setosum* ten times. Application of Quizalofop-ethyl to rid wild oat in rape fields, fasten weed community succession compared to the control. Trunk/m^2 of wild oat decrease by 95.4% compared to previous 778 trunks, fresh weight decrease by 99.4% on the basis of 3199g, Trunk/m^2 of broad leaf weeds increased by 21.8%, fresh weight by 109.3% compared to 214 trunks and 436.5g respectively. Herbicide will at last lose effect owing to continuous application same corps which cause development of herbicide-resistant species and succession of weed community. Long-term application of single. herbicide and directional selection of weed community mainly cause weed community succession in field.

(2). Effect of crop rotation of tillage systems

Occurrence of weeds in continuous cropping wheat fields increase by 42.9--71.4 % compared to those in wheat-bean or wheat-rape rotation fields. Continuous cropping benefit occurrence of perennial weeds such as *Convolvus arvensis*, *Vephalanoplos setosum*. Wild oat can be easily controlled, while infestation of broad-leaf especially perennial. Broad -leaf weeds increase in continuous wheat-rape rotation cropping system. Improper deep tillage benefit preservation of weed seeds, however shallow tillage is profitable for germination of weed seeds and do little damage to below ground roots and stems.

(3). Effect of management

In respect to field management, because of labor shortage decline in productive forces and aging of agricultural machines after field contracting policy was adopted, weed infestation aggravate and vicious weeds extend. In the other hand, Improper management of seed preservation provide conditions for vicious weeds spreading with transport, causing significant succession of distribution and infestation occurrence of weed population.

Control strategy

Put forward the following control strategy in regard to weed infestation and population succession trend in Qinghai wheat field:

Continuously control weed community infestation occurrence in wild oat-oriented fields, especially in wild oat-dominant areas. Encourage comprehensive application of chemical herbicide which include Triallate, Difenzoquat, Puma super, Maicaoguang and Dalapon. In wheat-rape(or bean)rotation cropping fields, weed control in wheat field as well as in rape field should be conducted simultaneously. Herbicides suitable for broad-leaf crops(bean and rape)fields include Trifluralin ,Quizalofop-ethyl. Haloyfopmethyl, whip supper, Agil, Ethametsulfuron.

Explore and improve match technology system for chemical weed control in wheat fields. Use variety of herbicides according to different crop growth periods and different species.

Enhance scientific research on weeds and herbicides, Understand the nature of weed emergence and the scope and effectiveness of herbicides, use herbicides properly and successfully, raise the technological level of weed control.

Scientific rational rotation and tillage systems, enhancement of field management and agricultural technology integrated with chemical weed control and essential to weed control and prevention. Increasing products, promoting crop growth rates, preventing weeds from spreading, sustaining stability of field systems one the goal of weed control.

References(abbreviation)

Table 1 Major weed occurrence and weed infestation change in Qinghai fields

Species	1998 RA	U	RD	RF	1986 weed infestation index	1994 weed infestation index
Chenopodiumalbum	36.6	80.4	15.7	100.0	18.44	3.20
Polygonum aviculare	19.3	49.2	4.9	100.0	13.58	7.90
Avena fatua	16.2	38.1	4.0	95.2	26.18	16.51
Convolvus arvensis	14.4	38.6	2.9	85.7	7.05	10.66
Sonchus brachyotus	14.3	31.8	3.5	90.5	11.84	14.21
Elsholtziadensa	9.3	22.8	2.1	57.1	15.68	7.60
Cephalanoplos setosum	9.1	19.6	1.6	71.4	5.27	7.14
Galium aparine	8.7	21.7	1.7	57.1	7.41	9.16
Polygonum convolvnlus	7.8	19.6	1.4	52.4	3.51	4.62
Brassica juncea	4.7	9.0	0.4	47.6	6.67	2.20
Lepyrodiclis holosteoides	2.6	4.2	0.2	28.6	10.80	10.70
Thlaspi arvense	1.2	1.6	0.1	14.3	4.40	2.40
Polygonum nepalense	21.6	30.7	11.8	52.4	/	/
Stellaria media	20.3	36.5	10.1	47.6	/	/
Hypecoum leptocarpum	17.6	40.7	5.1	90.5	/	/
Lamium amplexicaule	13.9	30.2	3.8	81.0	/	/
Sonchus oleraceus	9.5	22.8	2.5	52.4	/	/
Chenopodium foetidum	8.1	17.5	1.5	61.9	/	/
Plumbagella micrantha	7.6	18.5	1.9	42.8	/	/
Fagopyrum tataricum	7.8	19.6	1.4	52.4	/	/

THE CHANGE OF WEED COMMUNITY IN WHEAT-MAIZE CROPPING SYSTEM AND ITS CONTROL IN BEIJING

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Abstract: Main weeds shifted from lambsquarters (*Chenopodium album*) and Japanese hop (*Humulus scandens*) were the main weeds in wheat fields in Beijing in 1980's, but American slougrass (*Beckmannia syzigachne*) and equal alopercurus (*Alopecurus aequalis*) were problem weeds in some wheat fields in 1990's. In summer maize fields, barnyardgrass (*Echinochloa crus-galli*), crabgrass (*Digitaria* spp.) and amaranthus (*Amaranthus* spp.) were main weeds in 1980's, but now chingma (*Abutilon theophrasti*), sibiran cocklebur (*Xanthium sibiricum*) and mataplexis japonica (*Japanese metaplexis*) are becoming problem weeds. The reason of the weed community shift was sensitive weeds decreased and insensitive weeds increased due to continuous application of one kind of herbicides. Integrated management has been adaopted to effectively control weeds. Effective new herbicides are needed to solve problem weeds.

Beijing is composed of about 38% plain area and 62% mountan with 10-1500m high above sea level. Most areas are below 100m elevation. Temperature ranges from –20℃ to 40℃. Annual precipitation is about 600mm. In summer temperature is high and rainfall rich. Main cropping system is winter wheat-summer maize.

Beijing Plant Protection Station and Beijing Weed Science Research Council organized a weed survey together during 1985-1990 with visual estimation of 5 scales (Table 1).

Weed damage areas and degrees in the main crops were presented in table 2. According to the survey, the important weed species in winter wheat were lambsquaters (*Chenopodium album* L.), common knotgrass (*Polygonum aviculare* L.), ivy glorybind (*Calystegia hederacea* Wall.), Japanese hop (*Humulus scandens* Merr.), shepherdspure (*Capsella bursa-pastoris*), flixweed tansymustard (*Descurainia sophia* (L.) Schur), dockleaved knotweed (*Polygonum lapathifolium* L.), belvedere (*Chenopodium serotinum* L.), wormseed mustard (*Erysimum cheiranthoides* L.), common cephalanoplos (*Cephalanoplos segetum* Bunge), and convolvulate knotweed (*Polygonum convolvulus* L.).

Table 1. Scales of visual estimation of weed damage

Damage Degree	Degree	Relative Height %	Relative Cover %	Relative Aboundance
Serious	5	>100	30—50	
		50—100	>50	
Rather Serious	4	>100	10—30	
		50—100	30—50	
		<50	>50	
Middle	3	>100	5—10	
		50—100	10—30	
		<50	30—50	
		<50	<5	50—100
Light	2	>100	3—5	
		50—100	5—10	
		<50	10—30	
		<50	<5	25—50
Appear but No Damage	1	>100	<3	
		50—100	<5	
		<50	<10	<25

Because of continuous use of 2,4-DB ester, populations of lambsquaters and Japanese hop, which are sensitive to 2,4-D, have decreased in recent years. Damage areas by these weeds have been reduced from 74.9% to less than 50%. Tendei catchweed (*Galium aparine*), ivy glorybind (*Calystegia hederacea*), weeping alkaligrass (*Puccinellia distans* (L.) Parl.), equal alopecurus (*Alopecurus aequalis*), conical silene (*Silene conoidea* L.), tender chorispora (*Chorispora tenella* DC), corn gromwell (*Lithospermum arvense* L.), convolvulate knotweed (*polygonum convolvulus* L.), American sloughgrass (*Buckmannia syzig achne*), and common reed (*Phragmites communis* Trin.) are tolerant or resistant to the herbicide and now their populations are increasing in some areas (Jiang and Ni 1999).

At present, several new herbicides are used in wheat in Beijing to solve different weed problems. Fluroxypyr is used to tendei catchweed, ivy glorybind, conical silene, and convolvulate knotweed. Tribenuron-methyl is used to control conical silene, tender chorispora, and flixweed tansymustard. Amidosulfuron is used to control tendei catchweed, flixweed tansymustard, conical silene, ivy glorybind, common cephalanoplos and other broadleaf weeds. Puma (fenoxaprop-p-ethyl) is used to control equal alopecurus and wild oat. Isoproturon is used to control American sloughgrass. Glyphosate is sprayed about 3-4 days before harvest of wheat to control common reed. The weed grows higher than wheat and its leaves can recept the large amount of the glyphosate, which is rapidly transported to roots and rhizome and kills these underground propagules.

According to the survay, main weeds were crabgrass (*Digitaria sanguinalis*), redroot amaranth (*Amaranthus retroflexus*), goosegrass (*Eleusine indica*), barnyardgrass (*Echinochloa crus-galli*) in maize in Bejing (Table 3). In Beijing, atrazine, acetochlor, metolachlor and their mixtures were widely used in maize field in the 90's. The mixtures could effectively control above weeds. Damaged area by these weeds has been reduced from 90.1% to less than 70%. However, some weeds which tolerate or resist to atrazine and amide group herbicides have increased. These weeds include chingma abutilon (*Abutilon theophrasti*), copperleaf (*Acalypha australis*), purslane (*Portulaca oleracea*), ivy glorybind, Japanese metaplexis (*Metaplexis japonica*), and pharbitis (*Pharbitis* spp).

To effectively control weed damage in maize, integrated management has been adopted. Main measures that have been taken include: 1. cultivate winter wheat well. Well-grown wheat could prevent summer weeds from occurrence before harvesting wheat; 2. spray herbcides such as fluroxypyr in wheat to control ivy glorybind and other weeds which could growth continually in maize; 3. extend the technique of no-tillage with mulching with straws of wheat in maize. Mulching with the straws could reduce about 40-50% weeds in maize fields (Zhu 1989); 4. use new herbicides such as nicosulfuron, rimsulfuron and their mixtures which provide better weed control than other herbicides; 5. improve techniques of herbicide application, including using good quality sprayers and applyig herbicides at right time and evenly.

Table 2 Weed Damage Area of Main Crops in Beijing (1990)

Crops	Planting Area (ha/year)	Total Damaged Area(%)	Damaged Area (%)			
			Light Damage	Middle Damage	Rather Serious Damage	Serious Damage
Wheat	0.18 milion	74.9	29.3	23	+	22.6
Maize	0.22 milion	90.1	18.8	27.1	20.9	23.3
Vegetables	0.0227 milion	86.1	21	21.4	18.1	25.6
Orchards	0.104 milion	97.2	8.3	19.2	24.3	45.4
Turf	1180	86.4	29.5	26.5	+	30.4

Tab[illegible] Main Weeds Appearinged in Maize, Vegetable and Orchard in Beijing

Weed	Mmaize	Vegetables	Orchard
Dig[illegible] sanguinalis	+++	++	++
Am[illegible] hus retroflexus	++	++	++
Ele[illegible] indica	++	+	+
Ech[illegible] hloa crusgalli	++	++	+
Ecl[illegible] prostrata	+	+	
Aca[illegible] a australis	+	+	+
Set[illegible] iridis		+	+
Cal[illegible] ia hederacea	+		+
Por[illegible] a oleracea	+	++	+
Cyp[illegible] microiria	+	+	
Set[illegible] glauca	+	+	+
Am[illegible] hus ascendens		+	+
Imp[illegible] a cylindrica			+
Abu[illegible] theophrasti	+		
Xan[illegible] n sibiricum	+		
Jap[illegible] e mataplexis	+		
Che[illegible] odium album		+	+
Ch[illegible] odium serotinum		+	
Ch[illegible] odium glaucum		+	
Hu[illegible] s scandens	+	+	++
Ce[illegible] noplos segetum			+
Sol[illegible] nigrum		+	+

+ :lig[illegible] +:middle, +++:heavy

Ackn[illegible] edgements:

[illegible] would like to thank Plant Protection Station of Beijing for gathering materials of weed survey.

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THE IMPACT OF CROPPING PRACTICES ON RICE-WEED COMMUNITIES

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Abstract: It is well known that cropping practices have a strong influence in determining weed composition in rice and that rice yield losses due to different weed species vary across cropping seasons. Understanding the factors that determine the dynamics of weed communities is therefore essential in the design of integrated weed management practices that maximize the impact of cultural practices in weed control. In this paper we describe the establishment of a long-term field trial to quantitatively follow the changes in rice weed communities under varying cropping practices, and report some of the initial findings. An area of land on the IRRI experimental station, which had previously been fallowed, and which possessed a wide diversity in plant species, was chosen for study. Seven rice cropping patterns were imposed, in which crop establishment method, cropping sequence and weed management practices were compared. Ordination techniques were used to describe initial weed community shifts. Cropping practices resulted in rapid changes in weed community composition over three successive seasons. In this paper we focus on the changes in unweeded plots, where *Echinochloa glabrescens* was strongly selected by two seasons of transplanted rice, whereas there was a tendency for *Leptochloa chinensis*, *Fimbristylis miliacea*, and *Ludwigia octovalvis* to be favored by wet seeding. When rice was rotated with a dry fallow, *Ischaemum rugosum*, *Cyperus difformis* and *Sphenoclea zeylanica* increased in abundance. Future work will be directed at explaining the mechanisms driving those shifts and identifying the relative role of biotic and abiotic factors governing these shifts.

Keywords: Weed community shifts, cultural control, correspondence analysis.

Introduction

Weed species respond both ecologically and evolutionarily to agricultural practices (Mortimer, 1994) and crop intensification has often resulted in the occurrence of intractable weed species. This process of inter-specific and intra-genotypic selection in a weed flora is a consequence of the net effects of tillage practices, fertilizer use, water management, cropping sequence and herbicide use in differentially influencing the survival and reproduction of weeds. In rice, over-reliance on chemical weed control has resulted in increasing cases of herbicide resistance worldwide (Gressel and Baltazar, 1996), greater risks of water pollution (Hill *et al.*, 1997), increasing abundance of more competitive grass weeds (Janiya and Moody, 1989) and arguably less sustainable management systems. Moreover, weed species shifts are known to be rapid in rice production systems (Mortimer and Hill, 1999) and understanding the mechanisms governing the structure and dynamics of weed communities therefore is valuable in assessing the sustainability of weed management. In addition to protecting crop yield, sustainable weed management systems implicitly recognize that weed species respond both ecologically and evolutionarily to management practices and embrace the concept of integrated weed management (Blacklow, 1997).

In Asia, farmers report that rice weed communities vary both temporally and spatially in rice fields. The composition of the weed flora in any rice ecosystem has been shown to depend on location (Janiya and Moody, 1983), the weed flora in the soil seed bank and the cropping history (Janiya and Moody, 1989). Availability of water is the pre-eminent factor governing the type and characteristics of the rice production system. In assured supply, water allows transplanted and direct seeded irrigated rice to be intensively grown in high input systems. In rainfed systems, water supply governs the duration and period of the cropping season and choice of cultivar, and variance in supply determines, in particular, the weed flora, crop growth and weed-crop interactions. Both ecosystems exhibit characteristic weed

communities and rainfed rice exhibits a greater diversity of weed species than irrigated rice when poorly weeded.

Understanding the processes and mechanisms that change weed species composition, that in turn contribute to variance in yield loss due to weeds, requires a broad scientific approach involving observational data from farmers' fields, field experiments manipulating agronomic practices, and the development of a mechanistic understanding of weed-crop growth and competitive interactions. In addition to efficacy of control measures, of equal interest is the role of component agronomic practices in regulating weed population and community size. Here, we describe the establishment of a long-term field experiment to quantify the changes in weed flora that occur in different rice cropping patterns and report the trajectories of those communities during the first three seasons of rice cropping. Emphasis is placed in this paper upon analysis of weed communities in the absence of chemical weed control to provide a background assessment of the impact of cultural control. The experiment is intended to provide a facility for validation studies for models describing weed species shifts in direct-seeded rice in the future.

Materials and Methods

Site management and weed flora

The experiment was initiated in the wet season of June 1997 on an area of fallow land previously untreated with herbicides on the IRRI experimental station, Los Baños, Laguna, Philippines. The land was plowed twice, harrowed three times and leveled. Fifty-six plots, each measuring 12 m x 12 m, were sown with a mixture of weed species, incorporating seed into the soil at the onset to encourage a common weed flora across all plots. Species sown were *Cyperus difformis* L., *C iria* L., *Echinochloa colona* (L.) Link, *E. crus-galli (L.)* P. Beauv., *E. glabrescens* Munro ex Hook. f., *Fimbristylis miliacea* (L.) Vahl, *Ischaemum rugosum* Salisb, *Leptochloa chinensis* (L.) Nees, *Ludwigia octovalvis* (Jacq.) Raven, and *Sphenoclea zeylanica* Gaertn. In the first season, all plots were planted to wet-seeded rice at the rate of 100 kg seed/ha and no weed control practices or fertilizers were applied to allow weed multiplication.

Table 1. Cropping sequences in the design of the long-term field experiment. Rice establishment methods were wet seeded (WSR) and transplanted (TPR) in irrigated (IR) or rainfed (RF) conditions. Future cropping patterns will continue as indicated for seasons 2 and 3. See text for details.

Cropping pattern	Crop number and season		
	1 1997 Wet	2 1998 Dry	3 1998 Wet
CP1	WSR	WSR (IR)	WSR (IR)
CP2	WSR	TPR (IR)	WSR (IR)
CP3	WSR	TPR (IR)	TPR (IR)
CP4	WSR	Fallow	WSR (IR)
CP5	WSR	Fallow	WSR (RF)
CP6	WSR	Mungbean	WSR (IR)
CP7	WSR	Mungbean	WSR (RF)

Experimental treatments

In the second crop season, seven rice cropping patterns were imposed which involved either two crops a year or one crop followed by a fallow (Table 1). These were: (1) irrigated rice established each season by direct-seeding, (2) irrigated rice established alternately in a cycle of direct-seeding and transplanting, (3) irrigated rice continuously transplanted (4) alternate irrigated direct-seeded rice followed by a fallow season, (5) alternate rainfed direct-seeded rice followed by a fallow season, (6) alternate irrigated direct-seeded rice followed by a mungbean crop and a short fallow, and (7) alternate rainfed direct-seeded rice followed by a mungbean crop and a short fallow. A seeding rate of 100 kg/ha was used for direct-seeded rice in all cropping practices. In transplanted rice, 3 seedlings/hill were planted on a 20 cm x 20 cm hill spacing. In the rice crop in each cropping practice, two weed control treatments were applied factorially; a) no weeding and b) herbicide (pretilachlor + fenclorim (Sofit 300 EC, 0.45 kg a.i./ha in 300 l/ha) applied 3 days after seeding (DAS) or transplanting (DAT) followed by one hand weeding at 40 DAS/DAT. No fertiliser was applied in the first season but in the second and third seasons, all rice plots received 40N:40P:40K kg/ha as a basal application, 30N kg/ha at 30 DAS/DAT, and 30N kg/ha at panicle initiation. Molluscicide as niclosamide, (Baylucide 250 EC, 250 g a.i./ha in 192 l/ha) was applied as required. In direct-seeded rice, soil was saturated after seeding for 3-5 days and then the water level raised to an average depth of 8 cm by 14 DAS, until harvest. A continuous 8 cm depth was used for transplanted rice. In rainfed plots, water levels fluctuated according to precipitation, depths not exceeding 15 cm. Plots planted with mungbean were rotovated twice, and 40 cm spaced furrows constructed by machine. Seeds were drilled in rows at a rate of 20-25 kg/ha. Cypermethrin (Cymbush 5 EC, 5 g a.i./ha in 190 l/ha) was applied for insect control but no weed control measures were applied. All treatment combinations were replicated four times in a split plot randomized complete block design, main plots being cropping pattern.

Sampling and analysis

In rice, weed density and biomass were taken at 45 DAS/DAT from two 1m x 1 m quadrats randomly located in each plot. Weeds were sorted by species, counted and dried at 80°C for 48 hours, then weighed. Grain yield was measured from a 10 m^2 area at the center of each plot. Grain was dried and yield was converted to kg/ha at 14% moisture. In mungbean, weed density and biomass were measured by destructive harvesting at 44 days after emergence and at harvest in three 1m x 1m quadrats in each plot. Correspondence analysis (Ter Braak, 1995) quantitatively compared the weed flora amongst individual plots and redundancy analysis associated species change with cropping practices in unweeded plots. Both biomass and density of plants/m^2 were examined separately and only analyses based on weed density estimates are presented in this paper.

Results and Discussion

Figure 1 gives rice grain yields in the third season according to cropping sequence. Highest yields were achieved in irrigated, weeded plots (CP1, 2 and 3). Yields of similarly weeded plots in

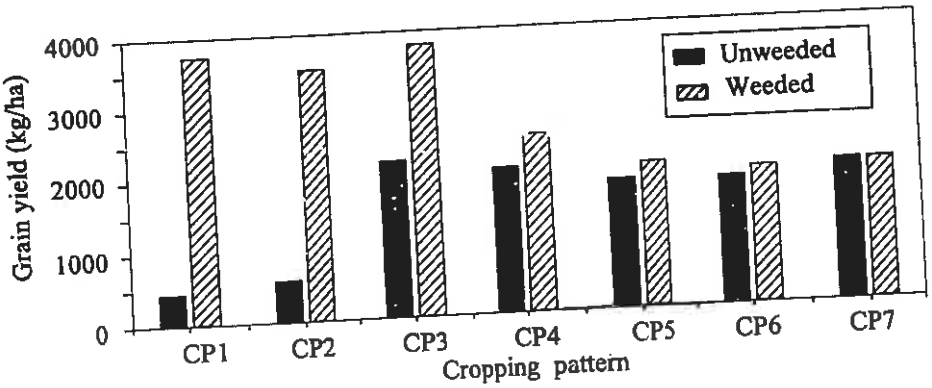


Figure 1. Mean rice yields in season 3 in relation to cropping practice (Table 1). SEM for CP1, 2 and 3 = 252 kg/ha; for CP4, 5, 6 and 7 = 449 kg/ha.

cropping patterns four and six, in which a fallow or mungbean crop had replaced rice in the second season, were on average 1486 kg/ha lower. There were no significant differences amongst yields in plots, CP4, 5, 6 and 7.

Partial correlation coefficients of yield and the abundance of weed groups (broadleaf, sedge and grass) not only changed with cropping season but the magnitude of the correlation also changed within groups (Table 2). Correlations of yield with both weed density and biomass were consistent (in sign and magnitude) in the first season but not in the third season of continuously cropped rice or where a fallow or mungbean crop intervened. Several hypotheses may be advanced to explain these changing relationships. One is that seasonal abiotic variables are influencing inter-specific responses. Another is that the weed species shifts are occurring within the community, as a result of individual species responses, for instance, to cropping sequence, within-season cultural practices and competitive interactions. To begin to explore hypotheses about weed species shifts, we have used ordination techniques to investigate pattern in species composition in relation to cropping practices.

In the first cropping season, a total of 36 weed species were observed and included both common rice weeds and species typical of upland rice crops. Inter-relationships among unweeded plots over three cropping seasons, on the basis of species composition, using correspondence analysis are presented in Figure 2. The dynamics of the weed communities are indicated by the change in location in ordination space over seasons. The first two eigenvectors (axes) in the analysis accounted for 42% of the variation within the data set. In the first season, wide variation in species composition of individual plots was evident (Fig. 2, triangles).

Table 2. The relationship between rice yield and components of the weed flora. Data are partial correlation coefficients ($P_{H_0} \leq 0.05$) between yield and weed density or weed biomass, 35-45 DAS/DAT in seasons 1 and 3. Season 3 data are pooled across selected cropping patterns.

Group	Season 1 Wet seeded rice	Season 3 CP1, 2 and 3	Season 3 CP4, 5, 6 and 7
		Weed density	
Broadleaf	0.2232 (0.3181)	-0.8409 (0.0023)	-0.0688 (0.8152)
Grass	-0.2099 (0.3486)	-0.5739 (0.0828)	-0.3295 (0.2499)
Sedge	-0.4889 (0.0210)	-0.5879 (0.0739)	0.1443 (0.6226)
		Weed biomass	
Broadleaf	0.2360 (0.2904)	-0.5210 (0.1226)	0.4360 (0.1192)
Grass	-0.2699 (0.2244)	-0.5065 (0.1352)	-0.3531 (0.2155)
Sedge	-0.6239 (0.0019)	-0.8435 (0.0022)	0.1611 (0.5821)

Subsequently, plots in the second season were clearly delineated from those in the first (Fig. 2, circles) with no distinction between wet seeded and transplanted plots. In the third season, plots continuously cropped with irrigated rice (Fig. 2, squares) grouped separately from those in which a fallow period or mungbean crop was interposed (Fig 2, diamonds). Again no clear separation of weed communities in the third season was observed according to method of crop establishment (Fig. 2, third season, open and closed symbols).

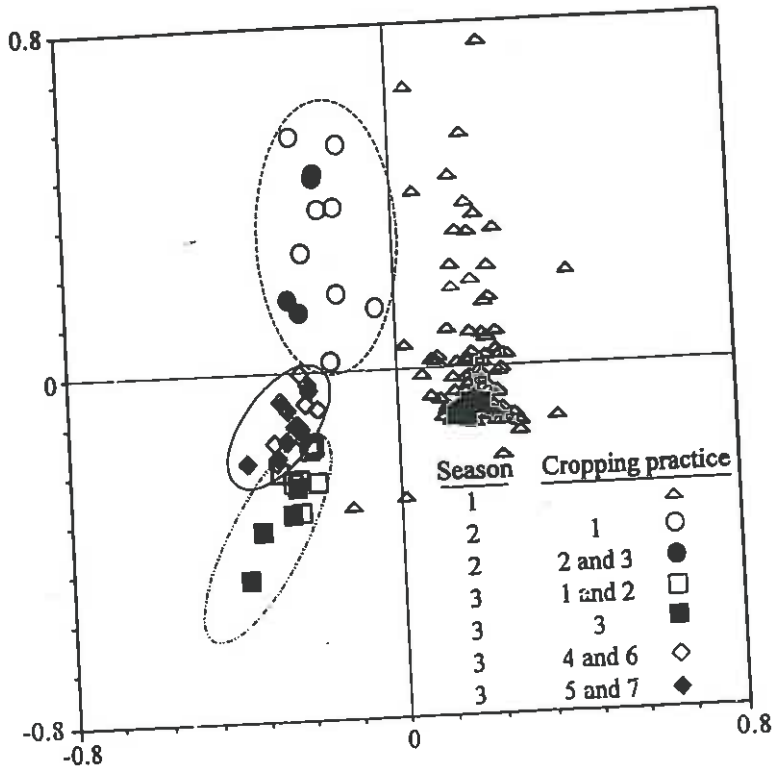


Figure 2. Correspondence analysis of the weed community responses over three successive cropping seasons in rice. See Table 1 and text for details.

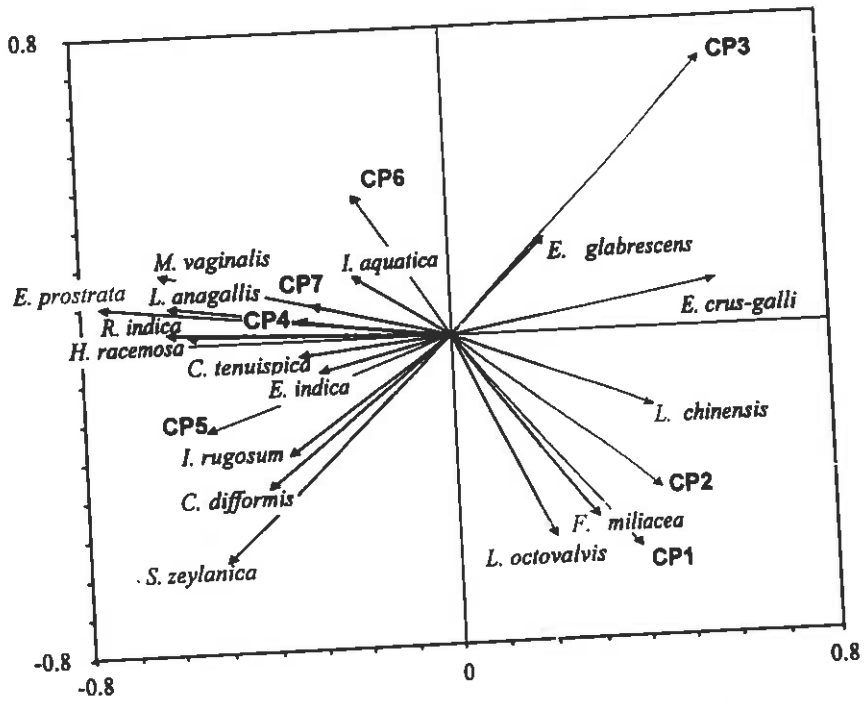


Figure 3. Redundancy analysis of the relationships between species and cropping practice. A visual indication of the response of species to cropping practices is indicated by the similarity in direction of arrows; arrow length reflects the relative degree of response. For clarity, not all species are shown.

Figure 3 shows the relationships between weed species response, based on co-occurrence within sites, and cropping practices (represented as a nominal variable). It reflects the correlation between change in species abundance and cropping practice that was evident by the third season. Species indicated are: *Cyperus difformis, Cyperus tenuispica* Steud., *Echinochloa crus-galli, Echinochloa glabrescens, Eclipta prostrata* (L.) L., *Eleusine indica* (L.) Gaertn., *Fimbrystylis miliacea, Hedyotis racemosa* Lam., *Ipomoea aquatica* Forssk., *Ischaemum rugosum, Leptochloa chinensis, Lindernia anagallis* (Burm.f) Pennell, *Ludwigia octovalvis, Monochoria vaginalis* (Burm.f) Presl, *Rotala indica* (Willd.) Koehne, *Sphenoclea zeylanica*. The biplot suggests that cropping practices had become strong agents of inter-specific selection by this season. Certainly, there was a clear separation between continuously cropped, irrigated plots (CP1, 2 and 3) and those where rice was alternated with fallow or mung beans (CP 4, 5, 6 and 7). Typical irrigated rice weeds (*E. glabrescens* and *E. crus-galli*) were strongly associated with transplanting (CP3) whereas *L. chinensis, F. miliacea* and *L. octovalvis* were associated with direct seeding (CP1, CP2). There was also a contrasting association of *I. rugosum, C. difformis* and *S. zeylanica* with rainfed wet seeded rice following a fallow period (CP5). Weeds more typical of upland or rainfed situations e.g. *Lindernia anagallis, Eclipta prostrata* were associated with CP4 and CP7. This analysis indicates rapid weed species shifts are clearly detectable with numerical techniques. Observed changes in composition, however, are unlikely to represent endpoints to these shifts Moreover Figure 3 only presents the changes that had occurred by the third season which are reflected in terms of weed density at 45 DAS/DAT. Further analysis is ongoing to explore these relationships with respect to biomass and hence potential weed reproduction. Nevertheless the diametric responses of particular species to cropping patterns supports the hypothesis that relative species abundance will continue to change in the directions indicated (Fig. 3). Empirical observations such as these are but the first step to studying the causal mechanistic processes that may be occurring and and focus attention on species most likely to be responsive. The importance of the water profile (depth and duration) in determining abiotic conditions that govern weed germination and seedling survival in direct-seeded rice is poorly understood (c.f. Pane and Mashor, 1996; Namuco *et al.*, these proceedings) as is the influence of water management on the dynamics of rice-weed competition (Caton *et al.*, 1999). Analysis of the vital attributes of weed species together with the growth dynamics of key components of the crop-weed assemblage will be important next steps in exploring the impact of agronomic practices on the mechanisms governing weed species responses and yield.

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THE USE OF WEED DENSITY TO PREDICT LOSS IN WHEAT YIELD DUE TO WEED COMPETITION

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Abstract: The relationship between natural population densities and wheat yield were estimated in three field studies at Sakha research station and wheat fields in Kafr El Sheikh governorate in Egypt. Polynomial regression and economic analysis referred that there was a negative relationship between weed density and wheat yield and number of spikes/m^2 where 50-60 weeds/m^2 density decreased wheat yield by 1.22 t/ha as compared with zero level of weed density accompanied with decreasing in the profitability. Thus, estimation weed density at 4-5 leaf stage can be used to predict wheat yield loss and making decisions of weed control in wheat fields.

Key words: weed density, polynomial regression, net income and profitability.

Introduction

There is a pressing need to determine weed density with which wheat yield start to decrease to be used as an aid for researchers and extension agents when making weed control decision. This will help to avoid upusing herbicides and decrease environmental pollution. This can be achieved by studying the relationship between weed density and wheat yield. Such relationship was studied by Poole and Gill (1987). They described the relationship between grasses and wheat, but they preferred to develop wheat prediction from two or more weed species. Thus, our present study concentrated on the relationship between natural weed populations density and wheat yield where three field studies were conducted one in Sakha in 1997 season and two studies in farmer fields in Kafr El-Sheikh governorate around Sakha Station during 1996/97 and 1997/98 winter seasons.

Materials and methods

Estimation the relationship between weed density and wheat yield

a- Under Sakha Station Experiment :

One field experiment was conducted at Sakha Station planted with wheat variety Sakha 163 in November, 1997. Where two treatments in four replicates with 25 m^2 plot size was conducted as follow (1) Weed free all season (2) Unweeded treatment.200 readings for weed density/m^2. 25 from each plot were recorded at 4-5 leaf stage had been done. Harvest had bean doen in May1998, wheat yield in grams and number of spikes for every square meter which weeds, previously count were estimated.

b- Under farmer condition :

20 farmer fields were grown with wheat variety Sakha 163 .10 fields one month after sowing in each of 1996 / 97 and 1997 / 98 seasons in Kafr El Sheikh governorate. 20 m^2 were taken from every field and divided into two equal parts and two weed control treatments were applied (1) weed free all season (2) Unweeded treatment. At 4-5 leaf stage weeds were count from each square meter. At harvest, wheat grain yield and number of spikes for the previous each square meter were determined. Thus data of weed density and wheat yield and number of spikes/m^2 (600 reading for each character) were statistically analyzed by the computer of Central Research Statistic laboratory in Agricultural Research Center, Giza, Egypt. The polynomial regression was used. The best degree was the second degree (quadratic) for presenting relationship between weed density and wheat yield. The most

dominant weed species were: wild beet *(Beta vulgaris)* lamsquarter *(chenopodium album)* field bind weed *(convolvulrs arvensis)* sting *(emex spinasus)*, sun spurge *(Euphorbia helioscopia)*, rye grass *(Lolium multiflurom)*, bur clover (*medicogo* sp.) and canary grass *(phalaris paradoya)* Economic analysis had been doen.

Results and Discussion:

The relationship between weed density and wheat yield and number of spikes/m^2 in Sakha experiment are representing in the two equations.

$Y=9.24-0.0268\ X + 0.0000298\ X^2$ and $Y = 621.570 - 1.399\ X + 0015\ X^2$
where Y = grain yield (t/ha) or number of spikes /m^2 and X represent number of weeds .

The predicted data in Table (1) show that weed density of 50 weeds/m^2 cause yield reduction in wheat yield t/ha and number of spikes/ m^2 was estimated by 13.2 and 10.0% respectively, as compared with weed free level. In general the decline yield was increased with increasing weed density Economic analysis in Sakha showed that the productivity of weed free plots arrived to 9.24 t/ha and decreased and whereas, 50-60 weeds density/m^2 to 8.12 t/ha and 100-120 weeds/m^2 to 6.03 t/ha, resulting in decreasing the profitability % from 96 to 70 to 23% with the previous rates of weed infestation respectively Table (2). Under farmer conditions data in table (3) indicated that 50 weeds density/m^2 decreased wheat and number of spikes/m^2 by 21.5 and 21.9 %, respectively, than weed free level, meanwhile the reduction caused by 300 weeds/m^2 were 76 and 71 and 71 % for the respective previous characters in 1996/97 season. In 1997/98 season in data in table (3) exerted decrease in wheat yield t/ha and number of spikes/m^2 with the increase weed density.

The relationship between weed density and wheat yield or number of spikes/m^2 are presented in the following two equations in the same respective which

$Y= 9.41 - 0.0298\ X + 0.00045\ X^2$ and $Y = 333.1 - 1.63\ X + 0.00307\ X^2$ in 1996/97 and $Y = 4.7020 - 0.0082\ X + 0.0\ X^2$ and $Y = 317.23 - 0.5068\ X + 0.0012\ X^2$ in 1997/98 season in the same respective.

Data in table (4) showed that the profitability decreased with increasing the level of weed infestation from 0,50-60 and 100-120 weeds /m^2 levels which decreased from 47to 13 % at 0 and 50-60 weeds/m^2 meanwhile there was loss in the return for every Egyptian pounds by 38 % at 100-120 weeds/m^2.

The previous result indicated clearly that the return of every Egyptian pound invested in wheat production can loss about 0.31 Egyptian pound or more at 100-120 weeds / m^2 infestation level.

We can conclude that weed density which counts at 4-5 leaf stage of wheat correlate with yield loss and can be used to predict loss. These results are in agreement with result obtained by Poole and Gill (1987), they indicated that weed density is more easily estimated than weed biomass and decisions on control practice which can made as soon crop emergence where weed biomass may be have little relevance. The use of weed mixture in the present study avoided the problem of the competitiveness relationship of the remaining weeds and as mentioned by Haizel and Harper (1973), Spitters and Van Bergh (1973) and Poole and Gill (1987).

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Table 1 Relationship between weed density of total weeds and wheat yield (t/ha), number of spikes and number of Sakha, and 1997.

Weed density /m²	Wheat yield		Number of spikes	
	T/ha*	% reduction	M²*	% reduction
0	9.24	0.0	622	0.0
50	8.02	13.2	559	10.0
100	6.96	24.6	498	20.0
150	6.03	34.7	446	28.3
200	5.27	43.0	403	35.0
250	4.65	49.7	367	41.0
300	4.18	54.8	339	455.0
350	3.85	58.3	318	48.9
400	3.68	60.1	306	50.8
450	3.66	60.4	300	51.8
500	3.78	59.1	303	51.3

* F = significant * significant

Table 2 Effect of weed density on productivity and economic returns of wheat crop Sakha, 1997.

Weed density No/m²	Yield productivity t/ha	Total income LE	Net income LE	Benefit cost rotation	Profitability %
0	9.24	6773	3322	1.69	96
50-60	8.02	5879	2428	1.7	70
100-120	6.03	4420	969	1.28	28

Table 3 Relationship between annual weed density and wheat yield t/ha, number of spikes and number of tillers/m^2 in Kafr El-Shikh 1996 and 1997/98.

Weed density /m^2	Wheat yield		Number of spikes	
	T/ha *	% reduction	M^{-2}*	% reduction
		1996/97		
0	6.41	0.0	383	0.0
50	5.03	21.5	299	21.9
100	3.88	39.5	231	39.7
150	2.96	53.8	178	53.5
200	2.26	64.7	140	63.4
250	1.79	72.1	118	69.2
300	1.55	75.0	111	71.0
350	1.53	76.0	118	69.1
		1997/98		
0	4.662	0	314	0
50	4.340	7	295	6
100	4.073	13	279	11
150	3.400	16	269	14
200	3.821	18	264	16
* F =	significant		* significant	

Table 4 Effect of weed density on productivity and economic returns of wheat crop under farmer conditions in Kafr El-Sheikh governorates, 1997.

Weed Density/m^2	Yield productivity t/ha	Total income LE	Net income LE	Benefit cost rotation	Profitability %
0	6.91	5065	1614	1.47	47
50-60	5.3	3885	434	1.13	13
100-120	2.96	2170	1281	0.62	-



3. Weed Control and Management

BASED UPON CHEMICAL WEED CONTROL AND ATTACHING IMPORTANCE TO INTEGRATED WEED MANAGEMENT

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Abstract: About 250 species of weeds have been determined as the field weeds in China. It is estimated that more than 43 million hectares of the main crop fields are heavily infested with weeds and the average reduction of crop yield caused by weeds is estimated at 13.4%. About 17.5 million tons of grains, 255 thousand tons of lint cotton and 500 thousand tons of soybeans were lost by the most harmful weeds annually. Conventional weed control measures, such as plowing, harrowing, cultivation and hand pulling are popularly adopted for reducing weed damages. Along with rural economic development, rapid expansion of industries and development of commerce have caused an outflow of farm population to industrial and commercial sites. For getting more income, many farming people want to increase labor productivity and lighten labor intensity for improving agricultural production condition, so that chemical weed control becomes more important and attractive to farming people. The herbicide application area was steadily enlarged from 3 million hectares in 1980 up to 48.7 million hectares in 1998. Chemical weed control has changed cultural practices, saved labor and retained high crop yields, meanwhile, continuous use of the herbicides on crops for a number of years caused residual phytotoxicity on crops, weed shift problem and resistant weed development. Integrated weed management is a most effective measure to eliminate weeds from crop fields through adopting various effective agricultural measures and keeping favorable ecological conditions integrated with chemical weed control.

Key words: chemical weed control, integrated weed management

Introduction

About 250 species of weeds have been determined as the field weeds in the mainland of China, among them more than 10 species are the most important weeds causing greater losses to crop yield. More than 43 million hectares of the main crop fields are heavily infested with weeds and about 10 million hectares of crop fields are severely damaged. The average reduction of crop yield caused by weeds is estimated at 13.4%.

In the past time, most Chinese farmers were used to practicing agricultural weed control measures, Crop rotation, deep or shallow plowing, harrowing, cultivation and hand pulling were popularly adopted for reducing weed damages. Naturally, if crop fields were infested with any one group of weeds at a population level enough to cause reduction in yield, the farmers would do weeding by cultivation with some simple elements or by hand pulling, but in some crop fields because the weeding could not be carried out in time, the crop yield would often be reduced to a low level.

Development of chemical weed control

In the early 1960's, in the southern rice production areas, such as Guangdong and Hunan provinces, although the rice production are characterized by abundant labor supply, chemical weed control got more or less important and attractive to farming people due to the rural economic development. Pentachlorophenol and nitrofen were early introduced for grass weed control in the rice seed-beds and paddy fields; and in other provinces, diuron and prometryne were used for weed control in upland crops but within a small area.

In 1970's, according to the recommendation of Ministry of Agriculture and Chinese Academy of Agricultural Sciences, the herbicide field trials and field demonstrations for chemical weed control in rice, wheat and cotton were continuously conducted in more than 10 provinces. Many achievements in increase of crop yield and reduction of workdays in hand weeding promoted local authorities and weed control experts to pay more attention to chemical weed control extension. The herbicide application area of crop fields was steadily enlarged from several hundred thousand hectares before 1970 up to more than 3 million hectares in 1980.

In 1980`s, along with rural economic development, due to an outflow of farm population to industrial and commercial sites resulting in farming labor shortage, more and more farming people wanted to increase labor productivity and to reduce labor intensity for improving agricultural production condition, the herbicide application area was steadily enlarged from 3 million hectares in

1980 up to 48.7 million hectares in 1998, more than 50 kinds of herbicides were popularly used in crop fields, about 56% of the total rice fields and 45% of the total upland crop fields were applied with the herbicides for weed control, annually increased area of herbicide application was enlarged to more than 2 million hectares in recent years

Weeds and their chemical control in main crops

Rice

The rice growing regions which are mainly distributed in the south parts of China, there are more than 100 weed species that cause damage. The most important weeds causing great losses to rice yield are: barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), flat-stalk bulrush (*Scirpus planiculmis* F. Schmidt.), dwarf arrow-head (*Sagittaria pygmaea* Miq.), distinct pondweed (*Potamogeton distinctus* A. Benn.), knotgrass (*Paspalum distichum* L.), late juncellus □*Juncellus serotinus* [Rottb] C. B. clarke), chinese sprangletop□*Leptochloa chinensis* [L] Nees), sheathed monochoria□*Monochoria vaginalis* [Burm.f.] Presl ex Kunth), rush-like bulrush□*Scirpus juncoides* Roxb.), difformed galingale □*Cyperus difformis* L.), yerbadetajo□*Eclipta prostrata* L.), amphibious knotweed□*Polygonum amphibium* L.), alligator alternanthera (*Alternanthera philoxeroides* [Mart.] Griseb.), bur beggarticks (*Bidens tripartita L.)*, etc. In general, the number of the major weeds in same rice field are usually less than 3-4 species, barnyardgrass, flat-stalk bulrush, distinct pondweed and other broadleaf weeds in different agriculturai regions are the dominant weed species in rice. About 15.3 million hectares of paddy fields are heavily infested with weeds and the reduction of rice yield caused by weeds is at 10-20%. Average rice yield loss might be about 10 million tons annually.

The herbicide application area in paddy fields was enlarged from 0 3 million hectares in 1967 up to about 18.7 million hectares in 1998. The major herbicides such as propanil, thiobencarb, molinate, butachlor and oxadiazon are popularly used for grass weed control, among these herbicides, butachlor is the leading chemical. and quinclorac has been developed for big barnyardgrass seedling control. MCPA was more effective to cyperus weeds and economical in use, being most attractive to farmers in some rice growing regions and diuron and prometryne are also used to control distinct pondweed by post-emergence application after transplanting for 4 or 5 weeks resulting great effectiveness in southwestern plateau paddy fields. By now, MCPA has gradually been being replaced by bentazon and bensulfuron. For flat-stalk bulrush control, some farmers are used to adopt dymron by soil incorporation before seeding or transplanting.

wheat

The wheat growing areas consists of spring wheat being distributed in the northeastern and northwestern parts of China; and winter wheat being distributed both in the plains of North China and in the river basin areas at the middle and lower reaches of Changjiang River (Yangtse River). About 10 million hectares of wheat fields are heavily infested with weeds by wild oat (*Avena fatua* L.), japanese alopecurus□*Alopecurus japonicus* Steud.), small goosefoot (*Chenopodium serotinum* L.) aquatic myosoton (*Myosoton aquaticum*□L.□Moench.), tender catch-weed bedstraw (*Galium aparine* L. var. *tenerum* (Gren. et Godr.□Rcbb.) and other broadleaf weeds. The annual reduction of wheat yield caused by weeds is at 15%, about 4 million tons of wheat grains were lost annually.

In the northwestern parts of china the dominant weed in wheat is wild oat, this weed could cause a reduction in yield by up to 50-60%, triallate applied by soil incorporation before seeding or diclofop-methyl and difenzoquat used as post-emergence application are effective to control this difficult-to-control weed. Nowaday metsulfuron-methyl and fenoxaprop-ethyl are being used in large scale.

In the North China, 2,4-D butyl ester was popularly used for controlling small goosefoot, japanese hop (*Humulus scandens*□Lour.□Merr.) and other Chenopodium spp. in corn-wheat or cotton-wheat double cropping areas;

And in the south parts of China; along with the river basin areas at the middle and lower reaches of Changjiang River, japanese alopecurus, aquatic myosoton and tender catch-weed bedstraw are the main weeds in the regions of rice-wheat double cropping system. These weeds can cause reduction in wheat yield by 20-30%, chlorotoluron was an important herbicide used popularly in the early 1980's. Nowadays, dicamba, metsulfuron-methyl and chlorsulfuron become more attractive herbicides

Other upland grain crops

About 6.6 million hectares of other upland grain crops mainly including maize, sorghum and millet are distributed throughout China damaged by grass weeds as crabgrasses (*Digitaria spp.)*, goosegrass (*Eleusine indica* (L.) Gaertn.), barnyardgrass, chinese sprangletop, green bristlegrass

(*Setaria viridis* (L.) Beauv.), knotgrass, bermudagrass (*Cynodon dactylon* (L.) Pers.), nutgrass galingale (*Cyperus rotundus* L.). etc. and broadleaf weeds as goosefoots (*Chenopodium* spp.), knotweeds (*Polygonum* spp.) amaranths□*Amaranthus* spp.), lambsquarters and Purslane□*Portulaca oleracea* L.), yield reduction in average is at 10.4□, about 2.5 million tons of cereal grains were lost annually.

Atrazine, acetochlor, alachlor pendimethalin, chlorotoluron, metolachlor diuron, oxyfluorfen, and prometryne are widely used for grass weed control; bentazon, 2,4-D butyl ester and fomesafen are popularly used by post-emergence application for broadleaf weed control. Nicosulfuron and thifensulfuron have been used by pre-emergence application to control broadleaf weeds in recent years, and glyphosate and paraquat are being tested for eliminating perennial weeds by placement spray at the late growing stage of corn. In some areas of South China, dymron are applied by soil incorporation before seeding for controlling nutgrass galingale.

Cotton

There are two main cotton growing regions distributed in the plains of north part of China and the river basins at the middle and lower reaches of Changjiang River. In north part of China, there are less rainfalls before cotton blossoming stage so that the weed damage is not so serious as in the Changjiang River basins where much rainfalls in the cotton seeding time enable the weed emergence. About 2.2 million hectares of cotton fields are heavily infested with crabgrasses (*Digitaria* spp.), goosegrass, barnyardgrass, foxtail, bermudagrass, knotgrass and some broadleaf weeds such as amaranths, knotweeds, lambsquarters and nutgrass galingale (*Cyperus rotundus* L.). Annual yield reduction of cotton caused by the above weeds was at 14.8%, resulting in a yield loss of 255 thousand tons of lint cotton.

Trifluralin, butralin, alachlor, acetochlor, chlorotoluron diuron and oxyfluorfen are widely used for grass weed control. Fluometuron has been evaluated as the ideal herbicides, but not yet extended to large area. Glyphosate and paraquat are being tested for eliminating perennial weeds by placement spray at the late stage of cotton growth. Dymron applied by soil incorporation before cotton seeding for controlling nutgrass galingale gave a satisfactory result. Sethoxydim, fluazifop-butyl, quizalofop-ethyl and haloxyfop are widely used for grass weed control after cotton seedling stage.

Soybeans

The main soybeans growing regions are distributed in the northeastern parts of China and in the North China. About 2 million hectares of soybeans fields are heavily infested with barnyardgrass, goosefoots, knotweeds, amaranths, siberian cocklebur (*Xanthium sibiricum* Patrin.), crabgrasses, goosegrass and some perennial weeds causing yield reduction of soybeans at 19.4%, more than 500 thousand tons of soybeans were lost by the most harmful weeds annually.

Since 1978, the big state farms in Heilongjiang province began to import many new kinds of herbicides as alachlor, linuron, trifluralin, amiben and metribuzin being used for pre-emergence application, resulting in the achievement of controlling the main weeds mentioned above and retaining the high yields of soybeans. Till now, the highly selective herbicides such as bentazon, fomesafen, fluazifop-butyl, sethoxydim and diclofop-methyl are popularly used by post-emergence application to control broadleaf weeds or grass weeds. The total area of chemical control in the main soybeans growing regions are estimated more than one million hectares.

Change of cultural practice in main crops

Chemical weed control has changed cultural practice in rice, wheat, cotton and soybeans, saving labor and retaining higher crop yields. In some developed areas, the paddy fields no longer need cultivation after the herbicides applied and transplanted rice is gradually replaced by direct-seeded rice. Direct-seeded rice by drilling and broadcasting is being adopted by the state farms and individual farms. Cotton cultures are managed with the form of close planting, minimal cultivation, simplifying thinning and training procedures. The culture of soybeans cropped in most big state farms has been changed from wide-interrow 60-70 cm planting into 30-50 cm close planting with zero or minimal cultivation.

Problems in chemical control

Herbicides are highly effective to control dominant weed species, but continuous use of the same herbicides in certain crop fields for a number of years may cause weed shift and residual phytotoxic

effect to succeeding crop problems in different ecological regions, as the example:

Weed shift

In the rice growing regions, in Jiangsu Province and Zhejiang Province located the river basins at the lower reaches of Changjiang River, the long term use of butachlor or molinate in transplanted rice results the dominant barnyardgrass population being eliminated and other grass weeds as chinese sprangletop, knotgrass and the broadleaf weeds as dwarf arrow-head and alligator alternanthera or the sedges as late juncellus and flat-stalk bulrush become dominant.

In the wheat growing regions of North China including Beijing and other adjacent provinces, the long term use of 2,4-D-butyl ester or 2,4-D-Na salt for controlling annual broadleaf weeds as small goosefoot, lambsquarters (*Chenopodium album* L.) and japanese hop, the other biennial weeds or 2,4-D-tolerant broadleaf weeds as sophia tansymustard□*Descurainia sophia*□L.□Schur.), tender chorispora (*Chorispora tenella* (Pall.) DC.), shepherdspurse (*Capsella bursa–pastoris* Medic.), corn gromwell (*Lithospermum arvense* L.), cone-like silene (*Silene conoidea* L.), field bindweed (*Convolvulus arvensis* L.), field sowthisle (*Sonchus brachyotus* DC.), common cirsium (*Cirsium segetum* Bge.) and ivy glorybind (*Calystegia hederacea* Wall.) become the dominant weeds.

In the cotton growing areas located the river basins at the middle reaches of Changjiang River, because of the long term use of trifluralin and butralin for controlling grass weeds as common crabgrass (*Digitaria sanguinalis* (L.) Scop.), the broadleaf weeds as redroot amaranth (*Amaranthus retroflexus* L.) and geminate speedwell (*Veronica didyma* Tenore) become the dominant populations;

Residual phytotoxic effect to succeeding crop

Long lasting effective herbicides as chlorsulfuron, metsulfuron-methyl, chlorimuron-ethyl, amindosulfuron, imazethapyr, atrazine, etc. applied in wheat, maize, soybeans and oil-seed-rape have caused the phytotoxicity of the succeeding crops as rice, maize or wheat by soil residual effect. respectively, in recent years□

For overcoming the above important problems in herbicide application, the alternative use of different kinds of herbicides and the herbicides used in their combinations could reduce the rates of individual products while increasing the number of target weed species. In the past, nitrofen was mixed with pentachlorophenol, thiobencarb, butachlor or molinate used as pre-emergence herbicides. Nowadays, propanil with bentazon or with MCPA as post-emergence herbicides is used for controlling sheathed monochoria, water plantain (*Alisma orientale* (G. Sam) Juzepcz), difformed galingale and other broadleaf weeds or sedges. The mixtures based on thiobencarb, molinate or butachlor combined with simetryn have given good weed control in transplanted rice. The new kind of sulfuronyl herbicide, bensulfuron has shown excellent activity on flat-stalk bulrush and some broadleaf weeds but not effective to grass weeds, being used in combination with butachlor as tank mixture can obtain satisfactory results.

One herbicide applied in combination with other herbicides for broadening herbicide spectrum and controlling resistant weeds, such as butachlor combined with bensulfuron in rice; fenoxaprop-ethyl combined with chlorsulfuron or metsulfuron-methyl in wheat; diuron combined with acetochlor in cotton; alachlor combined with chlorimuron in soybeans; and for reducing the application rate of atrazine with the long lasting effects to avoid the phytotoxicity of the succeeding crops., atrazine is combined with acetochlor applied in maize.

Agricultural method integrated with chemical weed control

The herbicide application causes the shift of weed species and the residual phytotoxic effect on the crops problems, since 1980's, in order to solve these problems, integrated weed management has been being attended in China,.

Chinese farmers adopted various effective agricultural methods integrated with chemical control on main crops and got more effective results than they had only used herbicide application before. These successfully agricultural measures include the following items:

Deep plowing

Most perennial weeds are more difficult to be eliminated with chemical control, in autumn or in winter time, deep plowing the fields to a depth of 20-30 cm can expose the vegetative organs of the perennial weeds such as pondweeds, dwarf arrow-head and nutgrass galingale to winter cold resulting the freezing and drying of these underground organs. As an example, one autumn plowing to a depth of 20 cm reduced the number of distinct pondweed plants about 60% compared with that check fields.

Even if the fields were plowed to a depth of 15-18 cm in comparison with a shallow tillage to a depth of 10 to 15 cm, the density of distinct pondweed plants was reduced significantly.

Proper manipulation of land preparation

In the growing season, first tillage carried out about one month before sowing can remove perennial weeds; second tillage done at two weeks before sowing encourages germination of weeds after plowing; and a last tillage practiced at one to three days before sowing followed by levelling can eliminate weed emergence. More the harrowing less the weeds remained than only one harrowing.

Shallow cultivation can destroy weed seedlings and sprouts of annual weeds without turning up the weed seeds from deeper soil layer to the soil surface.

Land paddling and levelling in paddy fields are very important for reducing the broadleaf weed emergence and keeping uniform depth of water layer enable rapid drainage and re-flooding for satisfactory rice stands, being favorable to water management for killing weed seedlings by submerging.

Crop spacing

The major weed species in seedbeds of rice is barnyardgrass, after transplanting, about 3-6% of these weed plants grow with rice in the planting hills, they may cause the reduction of crop yield up to 20-50%, so it is very important to eliminate these weeds in rice seedbeds before transplanting rice seedlings into paddy fields and to keep weed free in hills as well as possible. High seeding rates used in the seedbeds are favorable to suppress barnyardgrss. In some rice growing regions, the seeding rates at more than 1000 kg/ha are more popular and the rate as high as 2200 kg/ha has been used. The seeding rate is increased from 500 kg/ha to 1500 Kg/ha resulting a significant reduction in weed density, but sedges are least effected by increasing seeding rates.

In transplanted rice fields, the density of rice plants at 100 to 200 plants/m^2 are desired for competing with weeds; rice transplanted in hills at the distance of 25 cm×25 cm, the yield losses from weeds were more than that of 20 cm×20 cm spacing. Rice seedlings transplanted at the planting distance on 25 cm×25 cm, the number of flat-stalk bulrush plants per unit area was 1.5, 2.5 or 3 times more than that in transplanted on 20 cm×20 cm, 15 cm×15 cm or 10 cm×10 cm respectively.

Transplanting old rice seedling

In southeast China, in irrigated paddy fields, transplanting old rice seedlings with 5-6 leaves having more effective tillers than younger ones and jointing early could rapidly form crop canopy and result in more competitive effectiveness of the rice plants to minimize weed infestation; the index of rice leaf area increased about 3 times more than the younger seedlings on two weeks after transplanting before the peak of weed emergence, and the ratio of leaf space between rice plants and weeds reached 10:1, and barnyardgrass., cow's hair-felt spikesedge (*Eleocharis yokoscensis* (Fr. et Sav.) Tang et Wang), difformed galingale, flat-stalk bulrush and yerbadetajo were suppressed.

Cropping system

Double cropping of rice after wheat, oil-seed rape, barley, broadbeans or other winter cropping crops in some temperate regions is an effective cropping system for reducing rice damage from perennial weeds.

In the rice-wheat double cropping regions, rotating rice with a upland crop such as maize, cotton, sweet potatoes, sesame or soybeans can break the life cycle of both the water tolerant and upland weeds, after two-year rotation of the paddy fields to upland condition, the infestations of water tolerant weeds as dwarf arrow-head, chinese sprangletop and barnyardgrass in the rice and upland weeds as common crabgrass and goosegrass in the spring upland crops were reduced significantly. and japanese alopecurus was reduced in the succeeding winter wheat fields.

Elimination of weeds from crop fields through adopting various effective agricultural measures and keeping favorable ecological conditions integrated with chemical weed control is a most effective measure.

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CONTROL AND DEMOGRAPHY OF WILD RADISH (*RAPHANUS RAPHANISTRUM*) RESISTANT TO ALS INHIBITORS HERBICIDES

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Abstract: Wild radish (*Raphanus raphanistrum* L.) populations, resistant to acetolactate synthase (ALS) inhibitors herbicides, were sprayed with some selective herbicides to study their control and demography in a wheat crop during the 1998 season in Western Australia. Glean® (chlorsulfuron) on its own or followed by Eclipse® (metosulam), both are ALS inhibitors herbicides, failed to control the highly resistant biotype, but gave reasonable kill of the partially resistant. The herbicides 2,4-D amine and Jaguar® (a mixture of bromoxynil and diflufenican), both with modes of action different from the ALS inhibitors herbicides, gave effective kill of the resistant biotypes. Two and a half fold increase in the final grain yield of wheat was recorded following the Jaguar treatment. Despite an increase in grain yield when 2,4-D amine was applied as a follow-up treatment to kill the survivors from earlier sprays of Glean and Eclipse, the increase was not significant probably because of the late control of wild radish. Irrespective of the resistance status of wild radish, it was established that control of the early emerging wild radish was important because of their competitiveness and ability to produce abundant seeds thereby increasing seed return to the soil. The Glean and Eclipse survivors were the early-emerged wild radish with high seed output and competitive ability.

Key words: wild radish, herbicide resistance, acetolactate synthase inhibitors, chlorsulfuron, metosulam, 2,4-D amine, bromoxynil, diflufenican

Introduction

Although herbicide resistance has developed a strong foothold in Australian agriculture and has become a major constraint to crop production, alternative herbicide options are still available for the farmers. For example, for removal of wild radish (*Raphanus raphanistrum* L.) resistant to the Group B (ALS inhibitors) herbicides from cereal crops, a number of alternative herbicides are available. In the case of wild radish populations that are still susceptible to Group B products, the majority of farmers are aware that it is important to avoid repeated use of the products in order to extend the number of effective applications of the herbicide group. These are the farmers who are aware of herbicide mode of action groups and how to use them in anti-resistance strategies. However, there are others who lack this knowledge as exemplified from reports received of wild radish infestations being sprayed with two or even three applications of various Group B products in response to control failures. To simulate this practice as well as to adopt an informed approach, a field trial was undertaken last season using herbicides commonly used for the control of wild radish. The trial was designed to demonstrate to farmers the importance of matching resistance to herbicide choices. At the same time, it aimed to identify the stages of wild radish growth that are most critical for regulation of the resistant populations based on the demographic approach.

Materials and Methods

Four populations of wild radish that were resistant to Group B herbicides, together with their respective susceptible populations collected from the same sites, were grown in small plots within a wheat crop. Each of the radish plot was seeded with 200 seeds. The experiment was a split-plot design with the eight different radish populations as the sub-plots and the herbicide treatments as the main plots. The herbicide treatments included chlorsulfuron (Glean, 75% a.i.) as the basic treatment (applied at Zadok's growth scale point Z12 of the wheat crop) to which some of the wild radish biotypes selected for this study were either highly resistant to or partially resistant. The second treatment was metosulam (Eclipse, 71.4% a.i.) (applied at Z14-15 of the wheat crop) as a follow-up to Glean to simulate the

practice of spraying with two applications of Group B products, in response to control failures. The third treatment used 2,4-D amine (50% a.i.), a Group I herbicide, to control the resistant survivors from earlier Group B applications. 2,4-D amine was applied at Z30. Jaguar was the fourth herbicide treatment applied on its own at the Z12 stage of plant growth. Jaguar is a mixture of bromoxynil (25% a.i.) and diflufenican (2.5% a.i.), belonging to herbicide Group C and F, respectively. Herbicide rates in g a.i./ha are shown in Table 1 and product rates are indicated in Figures 1 and 2. Data on wild radish control and crop yield were obtained. Emergence and subsequent fates of cohorts of wild radish seedlings were monitored to assess the effectiveness of the various treatments in relation to wild radish growth stage. Seed production of wild radish survivors within individual cohorts was also recorded.

Results and Discussion

Wild radish control and crop yield

The herbicide Glean on its own was found to be ineffective against the highly resistant biotype. A follow-up spray with Eclipse did not improve control significantly. This confirmed the futility of spraying with two applications of Group B products in response to control failures. Good control was achieved when 2,4-D was sprayed on the resistant survivors from earlier Group B applications. The use of Jaguar was however the most effective treatment (Figure 1).

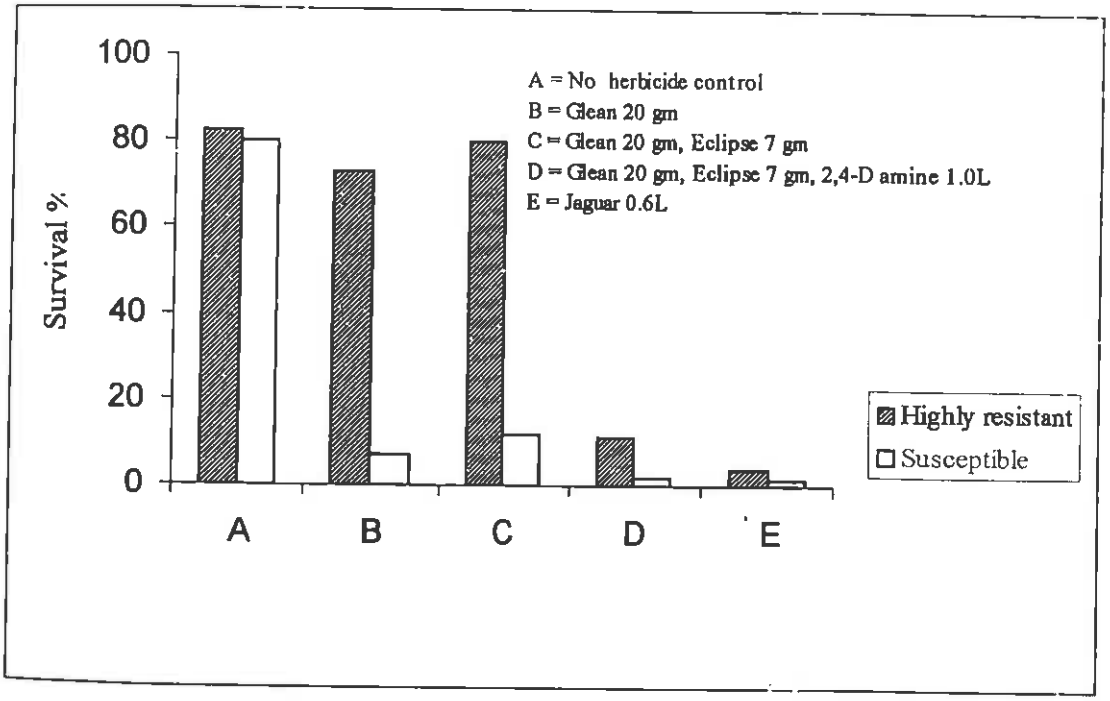


Figure 1 **Survivorship of highly resistant and susceptible wild radish following various herbicide treatments.**

Glean when sprayed on the partially resistant biotype was fairly effective. A follow-up spray with Eclipse significantly increased the kill of the partially resistant biotype. This was in contrast to the lack of kill of the highly resistant biotype. As expected, 2,4-D as a follow-up spray killed most of the survivors from earlier Group B sprays. Jaguar on its own was again the most effective treatment (Figure 2).

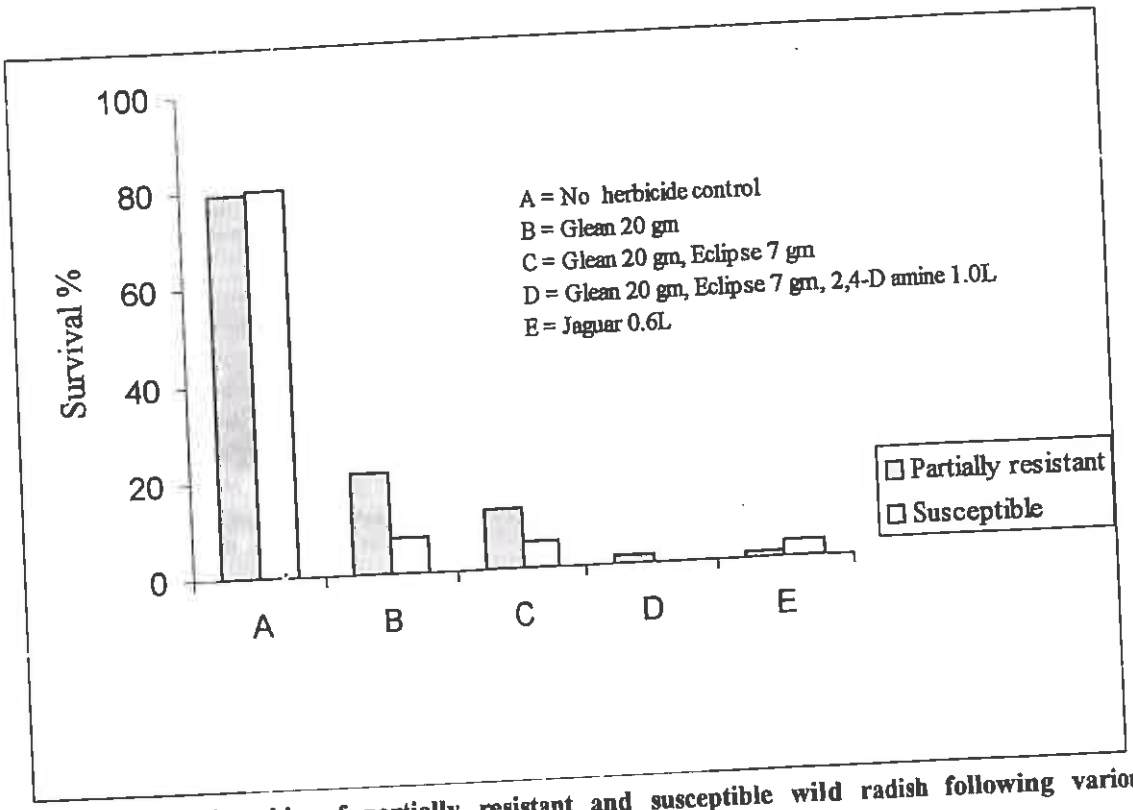


Figure 2. Survivorship of partially resistant and susceptible wild radish following various herbicide treatments.

The best grain yield of wheat was obtained following the Jaguar treatment irrespective of the resistance status (Table 1). Although yield increase was obtained following control of the Glean and Eclipse survivors with 2,4-D, there was a significant increase in only the partially resistant population. The application of Eclipse following Glean also increased yield significantly in the partially resistant but not the highly resistant population.

Table 1. The final wheat yield (t/ha) following the control of resistant and susceptible wild radish with some selected herbicides

Treatment	Rate (g a.i./ha)	Radish collection 1		Radish collection 2	
		Highly resistant	Susceptible	Partially resistant	Susceptible
Unsprayed control		2.41	2.91	2.60	2.43
Glean	15	2.30	4.65	3.18	5.03
Glean, Eclipse	15, 5	2.51	5.28	4.50	5.39
Glean, Eclipse, 2,4-D	15, 5, 500	3.09	5.07	5.10	5.27
Jaguar (brom./diflu.)	150/15	5.34	5.38	5.70	5.70
LSD (P = 0.05)		1.09	1.39	1.13	0.94

Wild radish survival and reproduction

Although new germinations of wild radish occurred following Glean application at 6 weeks after crop sowing, survivors from these late germinations did not produce viable seed, were spindly in growth and consequently were of no importance. This was in agreement with the findings of Panetta *et al.* (1988) when they reported that no radish plants which emerged later than 21 days after crop emergence produced seeds. Wild radish survivors from early germinations before the application of Glean were highly competitive and produced abundant seeds. Production ranged from 100 to 1,000 seeds per plant. In an earlier study on seed production, Cheam (1986) also showed that seed production was highest from plants which emerged early, and there was a progressive reduction with later emergence. The pre-Glean radish emergence totalled 89% of the 1998 emergence and up to 70% of the highly resistant biotype survived after Glean application. In contrast, only 1.6% of the 11% post-Glean emergence survived but none produced seed. Most of the survivors from Glean and the later application of Eclipse were killed by the 2,4-D and Jaguar treatments. Despite the odd wild radish seedlings that emerged after 2,4-D application, none survived. New wild radish emergence after the Jaguar treatment averaged 6% of the initial seedbank, but the final survival was only 0.4%.

The results have clearly demonstrated the importance of using another herbicide group with a different mode of action for effective control of Group B resistant wild radish. An almost two and a half times yield increase could be obtained by making the right herbicide decision. However, it is essential that integrated weed management is practised and no single herbicide group is relied upon. Control of the early emerging wild radish is also important because of their ability to compete and produce abundant seeds.

Acknowledgements:

This is a collaborative project by Agriculture Western Australia, Western Australian Herbicide Resistance Initiative and the CRC for Weed Management Systems. Z. Zulkifli, B. Roberts, F. Piesse, H. Singh and B. Thomas provided technical assistance.

Appreciation is also extended to staff of the Avondale Research Station for their assistance.

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CURRENT ADVANCES AND FUTURE NEEDS IN INTEGRATED WEED MANAGEMENT IN EARLY 21 CENTURY IN CHINA

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Abstract: Integrated weed management (IWM) has been developed rapidly since mid 80' as the rural culture and economy improved greatly in China. IWM has mad great contribution to the achievement in feeding of 12 billions population successfully. Since 80' more than 700 weed species were identified, 60 most important field weed species were classified. It was estimated that chemical weed control prevented 2% grain loss of the total agricultural production from weed competition each year in China. Weed population dynamics and weed community changes were studied, ecological weed suppression was noticed. Chemical weed control has become as one of the important and reliable measures in weed management systems in all major crop. (rice, wheat, maize, cotton, soybean, vegetable and fruits) production. Hence, chemical weed control techniques were studied and improved, acreage of herbicide treatment increased 50% in the last 5 years. Chinese herbicide industry has also developed very fast since 1990. However, there are also some problems, such as carry over effect of long persistent herbicides to rotation crops, herbicide resistant weed species appeared. To meet the requirements of sustainable agriculture in early 21 century in China, further research on studying the nature and factors influencing weed population dynamics, monitoring and managing herbicide resistant weeds, understanding the interactions between weeds, crops, herbicides and environment, farmer training, computer based decision supporting system and new techniques for sustainable weed management need to be carried out.

Key words: integrated weed management (IWM) in China, important field weed species, chemical weed control, future needs

Introduction

China is an ancient country in culture and agriculture with a long histroy of more than 7000 years. Since very early time, Chinese ancestor had known to combat weed problems with various practices, especially the ecological weed control. They raised fish in paddy rice, the fish fed on weeds and produced manure for rice, resulted in good yields of both fish and rice.

China is a developing, agricultural country with 1.2 billion populations, of which 80% working on the 1 billion hectares of arable lands as farmers. It was estimated that about 0.5 billion tons of grain and 4.5 million tons of cotton were yielded from the total agriculture annually.

Herbicides have been introduced to Chinese farmers since late 50's, intensive IWM research and demenstration programmes involving in many weed scientistes at the national level have been carried out for rice, wheat, maize, cotton and soybean, the five most important crops in China. Many important achievements of academic interests and /or practical importance have been realized.

Weed problems

Weeds have always been one of the major threats of Chinese agriculture. More than 700 weed species were identified, 60 of them were classified as the most important field weed species in major crops in China. It was estimated that weed infested area was about 40 million hectares in 1996, with various control measures implemented there was still about 3 million tons of grain losses.

Rice is the most important grain crop grown in China, with about 31 million hectares throughout China. Weeds in rice have to be controlled for meeting the increasing needs of human demands for food. Table 1 listed the most important weed species in transplanted and direct seeded rice.

Table 1 Weed species in rice.

Grasses	Broadleaved weeds	Cyperus
Echinochloa crus-galli	*Alternanthera philoxeroides*	*Cyperus difformis*
Leptochloa chinensis	*Ammannia baccifera*	*Juncellus serotinus*
Paspalum conjugatum	*Eclipta prostrata*	*Scirpus juncoides*
Paspalum distichum	*Monochoria vaginalis*	*Scirpus planniculmis*
	Potamogeton distinctus	
	Rotala indica	
	Sagittaria pygmaea	

Wheat, about 30 million hectares, is the second important grain crop grown in China. As in rice, weeds in wheat also have to be controlled to meet the increasing needs of human demands for food. Table 2 listed the most important weed species, of which 8 grass and 22 broad leaf weed species in wheat.

Table 2 Weed species in wheat.

Grasses	Broadleaved weeds	Cyperus
Alopecurus chinensis	*Calystegia hederacea*	
Alopecurus japonicus	*Capsella bursa-pastoris*	
Avena fatua	*Cephalanoplos setosum*	
Beckmannia syzigachne	*Chenopodium album*	
Cynodon dactylon	*Chorispora tenella*	
Poa annua	*Convolvulus arvensis*	
Polypogon fugax	*Descurainia sophia*	
Sclerochloa kengiana	*Euphorbia helioscopia*	
	Galeopsis bifida	
	Galium aparine	
	Hemistepta iyrata	
	Humulus scandens	
	Lapsana apogonocides	
	Lithospermum arvense	
	Malachium aquaticum	
	Pinellia ternata	
	Polygonum aviculare	
	Rorippa montana	
	Stellaria media	
	Silene conoidea	
	Veronica didyma	
	Vicia sativa	

Maize is also grown very widely in China, occupies over 20 million hectares of arable lands. About 9, of which 4 grass and 5 broad leaf weed species, weed species need to be controlled (Table 3).

Table 3 Weed species in maize.

Grasses	Broad leave weeds	Cyperus
Digitaria sanguinalis	*Acalypha australis*	
Echinochloa crus-galli	*Amaranthus retroflexus*	
Eleusine indica	*Calystegia hederacea*	
Setaria viridis	*Portulaca oleracea*	
	Xanthium sibiricum	

About 7 million hectares of soybean is grown in China. Table 4 listed the most weed species in soybean, of which 2 grass and 10 broad leaf weed species need to be controlled for good crop production.

Table 4 Weed species in soybean.

Grasses	Broadleaved weeds	Cyperus
Echinochloa crus-galli	*Acalypha australis*	
Setaria glauca	*Amaranthus retroflexus*	
	Amethystea caerulea	
	Cephalanoplos segetum	
	Chenopodium album	
	Commelina communis	
	Equisetum arvense	
	Polygonum lapathifolium	
	Sonchus brachyotus	
	Xanthium sibiricum	

Cotton is the most important fibber crop grown in China, with about 4 million hectares throughout China. Weeds in cotton have to be controlled for good harvest. Table 5 listed the most important weed species in cotton.

Table 5 Weed species in cotton.

Grasses	Broadleaved weeds	Cyperus
Cynodon dactylon	*Acalypha australis*	*Cypurus rotundus*
Digitaria sanguinalis	*Amaranthus retroflexus*	
Eleusine indica	*Cephalanoplos segetum*	
	Convolvulus arvensis	
	Eclipta prostrata	
	Pinellia ternata	
	Veronica didyma	

Oil seed rape is another very important crop grown in China, with about 4 million hectares throughout China. Table 6 listed the most important weed species in soybean, of which 1 grass and 5 broad leaf weed species need to be controlled for good yield.

Table 6 Weed species in oil seed rape.

Grasses	Broadleaved weeds	Cyperus
Avena fatua	*Cephalanoplos setosum*	
	Chenopodium album	
	Convolvulus arvensis	
	Galeopsis bifida	
	Sonchus brachyotus	

Achievements

Integrated weed management

Integrated weed management (IWM) has mad great contribution to the achievement of feeding 1.2 billion populations successfully in China.

A central government financed national project of integrated weed management has been running since 1985. With the efforts of Chinese weed scientists and government support, the project has revealed the biological and developing characteristics of identified severe weeds in agriculture systems, population dynamics, community changes. Especially, since the concept of ecological weed management has been implemented in crop systems in 1996, research on crop density management, accurate fertiliser management, water management and mulching is obviously improving crop competitive ability, depressing weed growth, reducing the weed impact on crops and lowering herbicide dose.

Although manual, mechanical and biological weed control had been employed since early days in Chinese history, field herbicide test only started in the late 50's, virtually, chemical weed control started in late 70's. As culture and economy in rural areas improved greatly since mid 80's, countrywide chemical weed control began in China, and being adopted swiftly. By the mid of 80's, chemical weed control covered 13 million hectares of arable lands, at the beginning of 90's, it was almost doubled. Chemical weed control is becoming as one of the important and reliable measures in weed management systems in all major crop (rice, wheat, maize, cotton, soybean, vegetable and fruits) production. Chemical weed control techniques were studied and applied, hence, herbicide use was improved, and acreage of receiving herbicide treatment increased about 100% in the last 5 years (Zhang *et al.*, 1998). By 1998, over 43 million hectares of crop fields had been receiving herbicide treatments. It was estimated that chemical weed control prevented 2% grain loss from weed competition each year in China.

Herbicide production in China

As herbicides have been playing an important role in Chinese crop protection, Chinese herbicide industry has developed very fast since 1990. More than 40 herbicides (Table 7) and over 200 herbicide products. including 101 mono-formulations and 108 mixtures, were produced in the country these days. During 1992 to 1995, herbicide production increased by 17.67%, 23.17%, 18.18% and 14.66% each year, by 1996 it tripled the 1991's production. In the last 5-6 years annual increase rates of herbicide production were far higher than insecticides. Annual production of glyghosate, acetochlor and butachlor has accessed 5000 tons since 1995 (Hu, 1998). Table 8 shows a clear trend that herbicide production is steadily increasing from the beginning of this decade. It will continue to grow.

Table 7 Herbicides Produced in China.

Herbicides			
acetochlor	chlorsulfuron	glyphosate	propanil
acifluorfen	clomazone	hexazinone	pyrazosulfuron
alachlor	cyanazine	imazethapyr	quinclorac
anilofos	2,4-D	isoproturon	quizalofop
atrazine	diclofop	MCPA-Na	sethoxydim
bensulfuron	difenzoquat	metolachlor	simetryn
bentazon	diuron	metsulfuron	sulfometuron
butachlor	ethametsulfuron	napropamide	thifensulfuron
butralin	ethaprochlor	nitrofen	thiobencarb
clethodim	fenoxaprop	oxadiazon	triallate
chlorimuron	fluazifop-p	oxyfluorfen	tribenuron
chlorotoluron	fomesafen	prometryn	trifluralin

Table 8 Increased herbicide production (%) in China

Year / Pesticide	1991	1992	1993	1994	1995	1996	1997	1998
Herbicide	7.82	8.90	12.43	12.9	11.23	15.75	14.49	19.64

Compounds most used in major crops

Nowadays about 50% crop fields are receiving herbicide treatment at least once a year, under certain circumstances, some crops have to be sprayed 2 or 3 times in order to keep weeds under checked.

Table 9 shows the compounds most used on major crops. In addition, some new chemicals from foreign companies are tested in fields.

Table 9 Herbicides most used in major crops

Rice	Wheat	Maize	Soybean	Cotton	Vegetable
butachlor	tribenuron	metochlor	acetochlor	metachlor	oxyflurofen
acetochlor	chlorsulfuron	acetochlor	fomesafen	acetochlor	butachlor
propanil	metsulfuron	atrazine	alachlor	trifluralin	haloxyfop
thiobencarb	chlortoluron	metribuzin	chlorimuron	fluometuron	quizalofop
oxyfluofen	isoproturon	nicosulfuron	imazethapry	oxyflurofen	sethoxydim
quinclorac	2,4-D	propisochlor+ atrazine	metribuzine	butralin	fluazifop
bensulfufon	MCPA	butachlor + atrazine	fluazifop	fluazifop	
metsulfuron	dicamba	acetochlor + atrazine	haloxyfop	diclofop	
acetochlor + bensulfuron + metsulfuron	triallate		sethoxydim	sethoxydim	
butachlor + bensulfuron+ metsulfuron	diclofop				
quinclorac + bensulfuron+ metsulfuron	fenoxaprop-p				
	isoproturon + fenoxaprop-p				
	isoproturon + tribenuron				

Important issues in weed management system

Weed flora shifts

Due to the continuous herbicide use, change of cropping system, global change of temperature, weed floras in major crop fields is changing; some relatively unimportant weeds are becoming disturbance. For instance, *Leptochloa chinensis*, *Juncellus serotinus* in rice, *Bechmannia syzigachne* and *Pinella ternata* in wheat, *Veronica didyma* and *Pinella ternata* in cotton, *Commelina communis* in soybean are becoming nuisances to Chinese crop growers. Another country wide weed survey is needed for clarifying the changes and forecasting or predicting the future weed flora shifts.

Poor spray equipment and application technology

Most farmers have been using the same knapsack sprayer with cone nozzle for spraying insecticide, fungicides and herbicides since early 60's. As we know that this kind of nozzle is not suitable for most herbicide treatments. Farmers are used to apply pesticides by crossing the lance while they walk cross the field. The way of applying herbicides with the cone nozzle resulted in uneven spray pattern and less effective weed control. Although there are new models of sprayers, like "METABI", farmers are unwilling to adopt them due to the high price, especially compared to the old style sprayers.

Carry over effect of long persistent herbicides to rotation crops

Chlorosulfuron and metsulfuron, members of sulfonylureas caused damage to rotation crops, such as rice, maize and cotton. Their use, therefore, is more restricted to the areas that the herbicides can decomposition fast enough to be safe to rotation crops.

Atrazine and imazethapry are other long persistent herbicides that are very active for the control

of most weeds in maize and soybean. Farmers in China are relatively poor compared with the farmers in developed countries, they are still not willing to drop off the chemicals and switch to more safe compounds, although they are aware of the potential risks.

Suspected herbicide resistant weeds in China

Table 10 shows the 4 suspected herbicide resistant weed species in China (Heap, 1998), although those cases are needed to be further confirmed. There is a relevant survey carrying out, as Chinese weed scientists have already realised the need.

Table 10 Suspected weed species resistant to herbicides in China

Year	Weed Species	Herbicide	Location
1980	*Conyza sumatrensis*	paraquat	Taiwan
1990	*Alopecurus japoniens*	chlortoluron	South China
1993	*Bachmannia syzigachne*	chlortoluron	South China
1993	*Echinochloa crus-galli*	butachlor	South China
1993	*Echinochloa crus-galli*	thiobencarb	South China

Future needs for sustainable weed management

Duo to continuing use of herbicides in the same family or with the same mode of action, and changing of agricultural practices, weed flora has been changing in crop systems. More studies on ecology of weeds of community, on understanding the nature and factors influencing weed population dynamics, on preventing, monitoring and managing herbicide resistant weeds, therefore, are needed for a better understanding of interactions between weeds, crops, herbicides and environment. As the increased requirement for better living environment and higher quality of food for both of human beings and wild life, ecological and biological weed management, ecological and economical weed control threshold, optimising herbicide use are strongly recommended in China.

To meet the requirements of sustainable agriculture in early 21st century in China, field schools for improving farmer's knowledge of weed threats, computer based decision supporting system and new techniques for sustainable weed management are also needed in the future.

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CURRENT STATUS OF WEED CONTROL IN RICE IN SRI LANKA

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Abstract: Of the total cultivated rice extent in Sri Lanka 85% is direct seeded. Forty percent of yield losses are accountable to weeds, 28% to floods, 12% to drought and 12% to insect pests and diseases. Chemical weed control is practiced by nearly 90% of farmers. Although farmers spend around 40 US$/ha for herbicide application, weeds accounted for a further yield loss around 130 – 170 kg/ha in the treated fields. Two herbicides, 2, 4-D and MCPA, were introduced in late 1950's for weed control in rice. Propanil, introduced in 1960's continues to be used by a majority of farmers. However, the broad spectrum herbicides, oxadiazon + propanil, thiobencab + propanil, quinclorac, fenoxyprop ethyl, sethoxydim, pretilarchlor, oxyfluorfen, butachlor and mefenacet introduced after the 1980's did not become popular. Particularly, the pre-emergence herbicides did not become popular due to toxicity symptoms caused by poor land leveling. At present, 70% of farmers use propanil followed by MCPA combination. Bispyribic Sodium, cyalaphopbutyl and clomozone with different modes of action for efficient weed management were recently recommended. Among these, bispyribic sodium, an early post emergence herbicide, with a broad spectrum controlling ability for dominant grass, broadleaf and sedges is widely used. Its outstanding selectivity for direct seeded rice and broad application window are major reasons for quick acceptance by farmers. Success has been achieved under research management to replace currently used MCPA by sulfonylurea compounds.

Key words: Herbicides, rice, weed control, propanil

Introduction

Rice is the staple food and paddy farming is the main source of employment for the majority of the rural population of Sri Lanka. About 1.8 million farm families are engaged in paddy cultivation around the country. Population of Sri Lanka was 18.6 million in 1998 and the present growth rate is 1.2% the annual per capita consumption of rice has fluctuated around 100 kg/year. Sri Lanka has 0.73 million ha of land suitable for paddy cultivation. Rice is cultivated twice a year, the major season (Maha) and minor season (Yala). The average cultivated extent for major and minor seasons would be 0.530 and 0.296 million ha respectively. Thus the annual cultivated paddy extent would be about 0.83 million ha. Out of the 0.83 million ha of annual cultivated paddy extent about 47% is under major irrigation, 22% under minor irrigation and 31% under rainfed conditions (Table 1).

Table 1 Cultivated area and the average yield under different cultivation systems in Sri Lanka.

System of cultivation	Season	Average area cultivated (ha)	Grain yield (t/ha)
Major irrigation	Major	256,000	4.66
	Minor	177,000	3.90
Minor irrigation	Major	136,000	3.27
	Minor	56,000	3.03
Rainfed	Major	168,000	2.99
	Minor	77,000	2.55

Rice Production

The annual paddy production in Sri Lanka for the last 10 years has been around 2.5 million t indicating a stagnation in rice yields. The Current annual rice requirement is 2.9 million t. This shows that we are at a 14% deficit over the required production at present. Since Sri Lanka has reached a stage where further expansion in rice area is not possible the present yield level of 3.5 t/ha should be increased at least up to 4.1 t/ha within the next five years to maintain the present self-sufficiency level. Improvement of the annual cropping intensity, generation of technologies to improve the productivity, introduction of high yielding varieties and reduction of the yield losses due to different constraints are the alternatives available to increase the rice production in the country. The cost of rice cultivation (US$/ha) under farmer manage condition are shown in Table 2.

Table 2 Cost of rice cultivation (US$/ha) in Sri Lanka (excluding family labour)

Operation	Labour quantity	Cost US$	Machinery equipment cost/US$	Material cost/US$	Total cost/US$
Ploughing			71.42		71.42
Plastering bunds	20	38.57			38.57
Establishment	12.5	24.10		25.00	49.10
Fertilizer	2.5	4.82		65.71	70.57
Weed Control	2.5	4.82		8.92	13.75
Pest & Diseases control	2.5	4.82		3.14	7.96
Water management	20	38.57			38.57
Harvesting	32.5	62.67			62.67
Threshing & transplanting	22.5	43.39	14.92		58.31
Total	115.0	221.76	86.34	102.78	410.92

Source: Department of Agriculture, Sri Lanka (1998)

Rice land weed flora

Numerous weed species are found in rice growing environments in Sri Lanka. The weed flora varies from place to place due to type of rice culture, soil type, hydrology tillage, cultural practices and irrigation pattern *etc.* Grasses are dominant in irrigated systems and sedges are dominant in rainfed systems. Weed problems are more severe in irrigated rice lands due to rotation of water issue patterns. Chandrasena (1988) reported 134 weed species belonging to 32 taxonomic families from rice fields in Sri Lanka. Among these more than 70 species are grasses and more than 50 species are sedges. About 10-20 weed species belong to Scrophulariaceae, Asteraceae, Fabaceae, Amaranthaceae and Commelinaceae. However, it has been reported that 10-12 species may be considered as economically important in rice culture. Grasses are considered as the major weed group effecting rice culture. The most important grass species are; *Echinochloa crusgalli, Echinochloa colonum, Ischemum rogosum, Lepthchloa chinensis* and *panicum repens*. The next important weed family is Cyperaceae which includes *Cyperus iria, cyperus difformis, Fimbistylis littoralis* and *Cyperus rotundus*. Broad-leaf weeds are more dominant in Wet Zone and also in transplanted rice culture. They are *Monochoria veginalis, Ludwigia perrenisis* and *Ludwilgia octavalvis*. Common major weeds in rice fields are shown in Table 3. Of the above weed species *Echinochola crusagali* is rated as the most trouble some weed in both well and poorly drained soils. Furthermore *Isheamum rugosum* and *Leptochloa chinensis* are becoming important in rice fields due to continuous application of herbicides which kills annual weeds.

Table 3 Common weed species recorded in rice in Sri Lanka

Grasses	Sedges	Broadleaves
Echinochloa colonum	*Cyperus iria*	*Mononochoria vaginalis*
Echinochloa crussgalli	*Cyperus difformis*	*Commelina diffusa*
Panicum repens	*Cyperus rotundus*	*Eclipta alba*
Ischeamum rugosum	*Fimbristylis miliacea*	*Eichornia crassipes*
Isachne globosa	*Fimbristylis dichotama*	*Limnocharis flava*
Leptochloa chinensis	*Fuirena ciliaris*	*Linderina* spp.
Paspalum distichum	*Scirpus supinus*	*Ludwigia perenesis*
		Ludwigia octovalvis

Yield losses due to weeds

Weeds are considered the major constraint in rice production in Sri Lanka. According to Herath Banda *et al.*, (1998) the yield losses from all biotic and abiotic constraints is 2 t/ha which is about 54% of the current farm level yield. They further indicated that nearly 40% of the losses are on account of weeds, 28% due to floods and 12% droughts (Table 4). The details of the yield losses from weeds are show in Table 5. Weed problems are more severe in the dry

zone compared to the wet zone. Even in field where chemical weed control measures had done the losses due to weeds are estimated at over 130 kg/ha for the major season and 168 kg/ha for the minor season (Herath Banda *et al.*, 1998). The amount of loss could be further aggravated depending on the agronomic practices, unavailability of water and crop establishment method.

Table 4 Estimates of yield losses from biotic and abiotic stresses. (Estimates from farmers report)

Constraints	Normalized yield loss		Estimated loss in production (000 t)	Value of the production lost (Million US$)	Percent share of total losses
	(kg/ha)	As % of yield			
Insects	204	5.5	176.7	35.3	10.2
Diseases	23	0.6	19.9	4.0	1.2
Weeds	803	21.7	695.4	139.1	40.0
Floods	566	15.3	490.2	98.0	28.2
Drought	243	6.6	210.4	42.0	12.1
Iron toxicity	43	1.2	37.2	7.4	2.1
Soil salinity	124	3.4	107.4	21.5	6.2
Total	2006	54.3	1737.0	347.4	100.0

Source: Constraints to Increase Rice Production in Sri Lanka, Herath Banda *et al.* (1998)

Table 5 Estimates of losses from weeds with and without management by agro-ecological zone

Agro-ecological Zone/Season	Percent of Farmers controlling weeds	Estimates of weed losses (kg/ha)		Estimated cost of controlling weeds (Rs/ha)
		with control	without control	
Maha season				
Wet Zone	87	94	544	943
Intermediate zone	89	104	607	1368
Dry Zone	86	194	1209	1448
Yala Season				
Wet Zone	78	135	600	1000
Intermediate Zone	75	165	679	n.a.
Dry Zone	78	205	1200	1500

Source: Constraints to Increase Rice Production in Sri Lanka, Herath Banda *et al.* (1998)

Weed Control

The factors contributed to the emergence of weeds as a major problem in rice cultivation are; 1. increased extent under wet seeded rice (broadcasting of pre-germinated seeds into puddled soil), 2. usage of short-duration rice varieties, 3. poor land preparation and 4. unavailability of water. Wet seeded rice became an alternative to transplanted rice in Sri Lanka due to higher labour cost, unavailability of labour for seedling establishment, availability of short duration varieties and shortage of water. It was observed that shifting of wet seeding to transplanting more common in dry zone as compared to Wet and Intermediate zones. Since more than 95% farmers use their own seed paddy the chances of contaminating rice seed with weed seeds also increased. As a result weed problems are increasing year by year. Farmers are of the view that chemical weed control is the most reliable and economical tool for weed control, especially large scale rice farmers. In Sri Lanka starting from early 1980's the tendency of an increase in use of chemical weed control has been observed (fig 1a and fig 1b). Phenoxy herbicides 2, 4-D and MCPA were introduced in late 1950's. Propanil was introduced in the 1960's and still continues to be used by majority of farmers. At present, more than 80% of the farmers use the combination propanal followed by MCPA. After 1980's more than 10 broad-spectrum herbicides were recommended to control weeds in wet seeded rice (Table 6). Usually herbicides are widely used in major rice growing areas in the dry and intermediate zone. Hand weeding is more popular than herbicides in Mid-country Wet Zone where the majority of the rice lands are transplanted. Herbicides such as PCP, Linuron molinate and

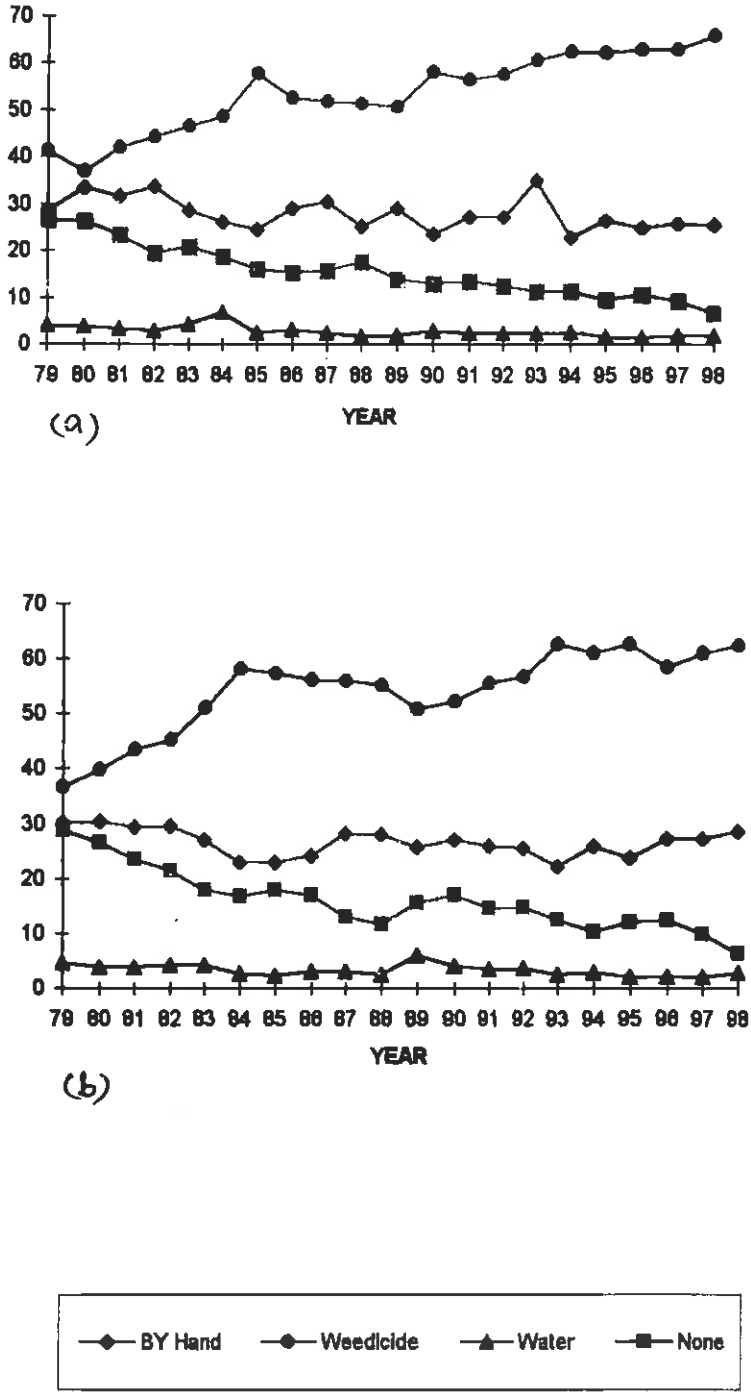


Fig 1. Percentage Distribution of sown area according to weeding
(Fig 1a. Major Season, Fig 1b. Minor Season)

Butachlor had been reported as pre-emergence for rice crop. These herbicides were effective on transplanted rice but less effective in broadcast sown rice. In the early 1980s oxadiazon, pretilachlor, piperopos and oxyflurofen were introduced. Considerable phyto-toxicity problems were encountered in broadcast seeded rice. The reason may be due to poor land leveling and poor water management in early rice growing period. Thus propanal and MCPA continued to be the leading herbicides in rice cultivation (Table 6). In the late 1980s several herbicide mixtures were introduced. These mixtures include propanil. oxadiazon + propanal; thiobencarb + propanil, molinate + propanil, butachlor + propanil and qulinclorac + propanil (Amarasinghe, 1986). These herbicides mixtures could effectively control grasses but not broad-leaf and sedges. During the same period quinclorac, fenoxaprop ethyl, sethoxydin and mefenaset were introduced. However, these herbicides found unsuccessful in gaining popularity among farmers. As a result more than 80 percent of the rice farmers still continue to use propanil followed by MCPA for weed control.

Table 6 Sales of the common rice herbicides, propanil and MCPA, in Sri Lanka (t/kl)

Herbicide	Sales/Year (t/kl)								
	1989	1990	1991	1992	1993	1994	1995	1996	1997
Propanil 36% GC	1000.0	812.3	862.8	882.3	978.5	1129.8	1209.8	1070.7	915.87
MCPA 40	676.5	836.8	517.8	472.2	152.9	444.1	291.8	273.1	523.9
MCPA 60	178.8	172.5	172.5	175.4	177.4	177.1	288.6	359.9	260.1

Source: Office of the Registrar of Pesticides, Department of Agriculture, Sri Lanka

Continued application of propanil in some areas has lead to the emergence of resistant biotypes of Echinochloa (Marambe *et al*, 1998). To solve this problem bispyribic sodium, cylaphop butyl and clomozone with different mode of action for efficient weed management were recently recommended. Among these bispyriblic sodium has gained islandwide acceptance among rice farmers with in a short period being very effective under both research and farmer managed conditions. This is due to the preference of farmers for early post emergence activity, broad spectrum controlling ability for dominant grasses, broad-leaves and sedges as a one shot action. This has outstanding selectivity for wet seeded broadcast rice, direct seeding rice and broad application window 1-6 leaf stage of the weed with foliar appiication are the major reasons for quick acceptance by majority of farmers in all the zones in Sri Lanka. Thus the use of bispyribic sodium is now increasing. Sulfony urea herbicides have recently shown promise for control of broad leaves and sedges. Promising results have been shown with bensulfuron methyl, ethoxy, sulfuron and pyrosulfuron ethyl which are being tested under research condition and introduced to the farmer in near future to replace currently continuously used MCPA. Table 7. Department of Agriculture presently encourages farmers to adopt integrated weed management practices including prevention, cultural, physical, mechanical, bliological and chemical methods to reduce the yield losses due to weeds.

Table 7 Recommended herbicides for rice weed control in Sri Lanka

	Common name	rate of application kg/l/ha
3.4 DPA	Propanil 360 g/l Ec	7.51
Ronsta PL	Oxadizon + Propanil	3.51
Satunil	Thiobencarb 400 g/l+ Propanil 200 g/l Ec	5.01
Advance	Butachlor 350 g/l + Propanil 300 g/l Ec	2.01
Sofit	Pretilachlor 300 g/l Ec	1.61
Goal	Oxyflorfen 240 g/l Ec	0.251
Nabu	Sethoxydium 12.5 g/l Ec	0.81
Whipsuper	Fenoxupropethyl 75 g/l EW	0.30 - 0.35
Machect	Butacholar EC	1.61
Rilof H	Piperophos 330 g/l + 2 4 D 170 EC	1.251
Facet	Quniclorac50% wp	0.6
Hedonal	2.4 D 550 g/l SL	0.95 - 1.2
MCPA	MCPA 600 g/l SL	0.8 - 1.11
MCPA	MCPA 400 g/l SL	2.0 - 2.51
Nominee	Bisbyribac sodium 100 SC	0.300
Command	Clomozone 3ME	0.700
Clincher	Cyhalopop butyl EC	1.00

Technoguide for rice. Department of Agriculture, Peradeniya, Sri Lanka

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EFFECT OF DINITROANILINE HERBICIDES ON THE CONTROL OF WEEDS IN GROUNDNUT (*ARACHIS HYPOGAEA* L.)

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Abstract. A field experiment to control weeds in groundnut (*Arachis hypogaea* L.) was carried out at Oilseed Research Area, CCS Haryana Agricultural University, Hisar during kharif seasons of 1996 and 1998. The experiment was laid out in randomized block design consisting of ten treatments in three replications. *Trianthema portulacastrum* L., *Dactyloctenium aegypticum* L. Pitch and *Echinochloa colonum* L. were the dominant weeds. Integration of trifluralin and pendimethalin each at 1.0 kg a.i./ha with one hoeing at 30 days after sowing (DAS) proved more effective against weeds than herbicide application alone. Maximum seed yield 2379 and 3125 kg/ha was obtained in weed free plots during 1996 and 1998, respectively. Season long weed competition caused 56 and 60% yield reduction compared to weed free treatment in both the seasons, respectively. Among herbicide treatments, Integration of pendimethalin and trifluralin each @ 1.0 kg a.i./ha with one hoeing at 30 days after sowing gave yields which were at par with two hoeings at 3 and 6 WAS.

Key words: *Trifluralin, Pendimethalin, Trianthema portulacastrum, Echinochloa colonum*, DAS, WAS

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crop of India. Like other crops, it has poor competitive ability against weeds due to its slow growth behaviour with prostrate nature of growth, which permits early and vigorous crop weed competition. Heavy yield losses up to 80% were recorded in groundnut due to weed infestation (Prusty *et al*., 1990). Under the present conditions of nonavailability of labour for weeding and high costs involved therein, it has become extremely difficult to maintain crops free from weeds in the initial stages of growth. Chemical methods of weed control and integration of such methods with cultural practices have, therefore, assumed greater significance (Kalandaivelu and Sankran, 1986). Chemical weeding is easier, time saving and economical as compared to hand weeding alone (Brar and Mehra, 1989). Keeping in view these difficulties, present investigation was undertaken to study the effect of dinitroaniline herbicides on weed growth, pod yield and yield attributes of kharif groundnut.

Materials and Methods

The field experiment was conducted during the kharif season of 1996 and 1998 on sandy loam soil of oilseeds research area, CCS Haryana Agricultural University, Hisar (29°10'N, 75°46'E and 215.2 meters above sea level) in randomized block design with eleven treatments replicated thrice. Experimental soil was low in total available nitrogen (201 kg/ha), medium in available P (19.2 kg/ha) and high in available K (357 kg/ha). The rainfall received during the crop season was 256 and 496 mm in 1996 and 1998, respectively. The treatments included trifluralin and pendimethalin herbicides applied preplant incorporation and preemergence at different doses alone and in combination with hoeing (Table 1). The gross plot size was 6.0 x 4.5 M. Groundnut variety "MH-4" with 80 kg kernel/ha was sown on 28th June and Ist July, during 1996 and 1998, respectively, as per recommended package of practices. All the herbicides were sprayed using hand operated knapsack sprayer

with a spray volume 850 litres/ha. Groundnut was harvested on November 5 and 12 during 1996 and 1998, respectively. Data on weed count and their dry weight was recorded at 25 and 60 DAS from two randomly selected spots in each plot from the quadrats of 50 x 50 cm and expressed as per square metre. Weeds were oven dried till constant weight was achieved. Final dry weight was expressed in kg/ha. At maturity, pod number and pod yield were recorded besides working out economics.

Results and Discussion

The weed flora

The floristic composition of the experimental site revealed that Carpet weed (*Trianthema portulacastrum* L.), Cowfoot grass (*Dactyloctenium aegypticum* (Pitch), Barnyard grass (*Echinochloa colonum* (L.) Link) were the major weeds present in the experimental area.

Weed density

Application of herbicides alone or in combination with cultural practices resulted in significantly less number of weeds at 25 and 60 DAS during both the years as compared with unweeded control (Table 1). Two hoeings at 3 and 6 WAS resulted in least biomass at both the stages during both the years. At 25 DAS, all the herbicide treatments were equally effective in controlling the weeds as the weed density among different herbicide treated plots was at par among themselves. At 60 DAS, in a comparative evaluation of different treatment preemergence application of pendimethalin @ 1.0 kg a.i./ha and preplant incorporation of trifluralin @ 1.0 kg a.i./ha when supplemented with one hoeing at 30 DAS evinced superiority in reducing weed population as compared to application of herbicides alone. This might be due to the appearance of second flush of weeds due to rains. So the hand hoeing at 30 DAS proved useful in controlling the weeds appeared after rainfall.

Dry matter accumulation by weeds

At 25 DAS, significantly lower dry weight of weeds was recorded with two hoeings at 3 and 6 DAS as compared to rest of the treatments except weed free. During both the years, at 60 DAS, two hoeings at 3 and 6 WAS provided least dry weight of weeds which was at par with application of trifluralin and pendimethalin each @ 1.0 kg along with one hoeing at 30 DAS (Table 1). It is interesting to note that herbicide per se even at higher doses of application recorded more dry weight than the herbicides at lower dose in association with cultural operations. This is in agreement with the works of Ramakrishna and Ong (1988) and Yaduraju *et al.* (1980).

Pod yield

Computation of yield variation revealed that there was nearly 40-60% yield loss in weedy check (control) as compared to weed control treatments (Table 3). Highest pod yield (2379 and 3125 kg/ha) was recorded in weed free treatments during 1996 and 1998, respectively. Among herbicide treatments, use of trifluralin @ 1.0 kg a.i./ha when integrated with one hoeing at 30 DAS gave highest pod yield (2270 and 2855 kg/ha) during 1996 and 1998, which was at par with pendimethalin @ 1.0 kg a.i./ha in combination with one hoeing at 30 DAS and two hoeings at 3 and 6 DAS. Significantly higher pod yield obtained under use of herbicide along with one hoeing at 30 DAS and two hoeings at 3 and 6 WAS was in accordance with that cultural practices had cumulative effect in facilitating peg penetration and pod development with less weed competition in early stages, is supported by the significantly lower dry weight and weed density of weeds under these treatments (Rajah et al., 1984). Effectiveness of pendimethalin @ 1.0 kg a.i./ha along with one hoeing at 30 DAS in controlling weeds in groundnut have earlier been reported by Intnal *et al.* (1993) and Singh et al. (1997).

Oil content

Oil content remained unaffected by different weed control treatments (Table 3). However, maximum oil content 54.1 and 53.2% was recorded under trifluralin @ 1.0 kg a.i./ha + one hoeing and weed free conditions during 1996 and 1998, respectively.

Economics

During both the years, maximum net returns were obtained under weed free conditions which were significantly higher than rest of the treatments. Among other treatments, highest net returns (Rs. 17820 and Rs. 31165/- ha) were obtained with the application of trifluralin @ 1.0 kg a.i./ha + one hoeing at 30 DAS which were statistically at par with pendimethalin @ 1.0 kg a.i./ha + one hoeing at 30 DAS and two hoeings at 3 and 6 WAS treatments.

Thus from the present finding, the recommendation would be that trifluralin and pendimethalin each @ 1.0 kg a.i./ha + one hoeing at 30 DAS is very effective in boosting up the productivity of groundnut.

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Table 1. Weed density (No/m^2), as affected by different weed control treatments

S.No

Table 1. Weed density (No/m^2), as affected by different weed control treatments

S.No.	Treatments	*Trianthema portulacastrum L.*				*Dactyloctenium aegypticum L.*				*Echinochloa colonum L.*			
		1996		1998		1996		1998		1996		1998	
		25 DAS	60 DAS	25 DAS	60 DAS	25 DAS	60 DAS	25 DAS	60 DAS	25 DAS	60 DAS	25 DAS	60 DAS
1	Trifluralin @ 1.0 kg a.i./ha, PPI	1.82 (2.66)	2.07 (4.0)	1.41 (1.33)	2.17 (0.66)	1.0 (0)	1.0 (0)	2.63 (7.33)	2.61 (7.33)	1.0 (0)	1.0 (0)	2.04 (5.33)	1.66 (2.66)
2	Trifluralin @ 1.25 kg a.i., PPI	1.13 (0.66)	2.07 (4.00)	2.17 (0.66)	2.17 (0.66)	1.0 (0)	1.0 (0)	2.18 (4.66)	2.66 (8.0)	1.0 (0)	1.0 (0)	1.95 (4.66)	1.66 (2.66)
3	Pendimethalin @ 1.0 kg a.i./ha pre-emergence	2.27 (5.33)	3.9 (14.66)	2.17 (0.66)	2.17 (0.66)	1.41 (1.33)	1.41 (1.33)	2.82 (8.0)	2.81	1.41 (1.33)	1.82 (2.66)	2.76 (10.6)	1.91 (3.33)
4	Pendimethalin @ 1.5 kg a.i./ha, pre-emergence	1.54 (2.0)	2.07 (4.0)	1.0 (0)	2.17 (0.66)	2.04 (5.33)	1.27 (1.66)	1.86 (4.0)	2.01	1.0 (0)	1.41 (1.33)	(2.15 (6.33)	1.82 (2.66)
5	Pendimethalin @ 1.0 kg a.i./ha, PPI	1.41 (1.33)	2.48 (2.66)	1.0 (0)	2.48 (2.66)	1.41 (1.33)	1.41 (1.33)	2.82 (7.22)	1.95	1.0 (0)	1.41 (1.33)	2.44 (7.33)	1.65 (2.0)
6	Pendimethalin @ 1.5 kg a.i./ha, PPI	1.66 (2.66)	2.17 (0.66)	2.17 (0.66)	1.0 (0)	1.41 (1.33)	1.41 (1.33)	2.18 (4.66)	1.41	1.0 (0)	1.41 (1.33)	1.66 (2.66)	(1.57 (0.66)
7	Trifluralin @ 1.0 kg a.i./ha (PPI) + one hoeing 30 DAS	2.33 (5.33)	1.0 (0)	2.17 (0.66)	1.0 (0)	1.82 (2.66)	1.0 (0)	1.0 (0)	1.0	1.0 (0)	1.41 (1.33)	1.86 (4.0)	1.65 (2.0)
8	Pendimethalin @ 1.0 kg a.i./ha (pre-emergence) + one hoeing 30 DAS	2.28 (5.33)	1.41 (1.33)	2.17 (0.66)	1.0 (0)	1.65 (2.0)	1.41 (133)	1.0 (0)	1.57	1.0 (0)	1.0 (0)	1.82 (2.66)	1.0 (0)
9	Two hand hoeings 3 and 6 WAS	1.82 (2.66)	1.41 (1.33)	2.17 (0.66)	1.41 (1.33)	1.57 (0.66)	1.0 (0)	1.41 (1.33)	1.57	1.0 (0)	1.0 (0)	1.82 (2.66)	1.0 (0)
10	Weedy	7.46 (95.3)	9.86 (98.0)	6.44 (40.6)	7.31 (52.6)	8.39 (70.6)	8.0 (66.0)	7.02 (48.6)	6.19	9.37 (94.6)	6.51 (42.6)	14.86 (222)	13.45 (173)
11	Weed free	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
	C.D. at 5%	0.28	0.39	1.53	0.63	1.24	0.36	1.28	1.35	2.05	1.74	6.89	0.52

*Data in parenthesis indicate original data which was later transformed to $\sqrt{x+1}$

Table 2 Dry matter accumulation (kg/ha) by weeds at different stages of crop growth as affected by different weed control measures

S.No.	Treatments	Weed dry matter accumulation (kg/ha)			
		1996		1998	
		25 DAS	60 DAS	25 DAS	60 DAS
1	Trifluralin @ 1.0 kg a.i./ha, PPI	251	726	394	1293
2	Trifluralin @ 1.25 kg a.i./ha, PPI	246	519	361	953
3	Pendimethalin @ 1.0 kg a.i./ha, pre-emergence	285	828	330	1474
4	Pendimethalin @ 1.5 kg a.i./ha, pre-emergence	265	630	306	1080
5	Pendimethalin @ 1.0 kg a.i./ha, PPI	282	799	315	1296
6	Pendimethalin @ 1.5 kg a.i./ha, PPI	258	626	308	963
7	Trifluralin @ 1.0 kg a.i./ha (PPI) + one hand hoeing 30 DAS	228	290	379	516
8	Pendimethalin @ 1.0 kg a.i./ha, pre-emergence + one hand hoeing 30 DAS	249	299	353	570
9	Two hoeing 3 and 6 WAS	123	198	209	346
10	Weedy	708	249	745	5680
11	Weed free	0	0	0	0
	C.D. at 5%	72.6	110.6	34.8	216

Table 3 Effect of different weed control treatments on number of pods/plant, pod yield, oil content (%) and net returns (Rs./ha)

S. No.	Treatments	No. of pods/plant		Pod yield (kg/ha)		Oil content (%)		Net returns (Rs/ha)	
		1996	1998	1996	1998	1996	1998	1996	1998
1	Trifluralin @ 1.0 kg/ha, PPI	29.0	33.1	1739	2268	51.3	53.1	12693	21686
2	Trifluralin @ 1.25 kg/ha, PPI	28.2	34.9	1730	2395	53.2	48.6	12315	23620
3	Pendimethalin @ 1.0 kg, pre-emergence	28.4	31.7	1703	2078	50.0	49.2	11856	18231
4	Pendimethalin @ 1.5 kg, pre-emergence	29.6	32.0	1723	2146	54.1	50.5	11521	18712
5	Pendimethalin @ 1.0 kg, PPI	26.5	33.1	1565	2257	51.2	52.5	9510	21274
6	Pendimethalin @ 1.5 kg, PPI	28.7	32.2	1743	2165	53.3	51.1	11861	19035
7	Trifluralin @ 1.0 kg/ha (PPI) + one hoeing at 30 DAS	32.0	40.2	2270	2855	54.5	49.7	17820	31165
8	Pendimethalin @ 1.0 kg/ha (pre-emergence) + one hoeing at 30 DAS	31.7	39.6	2240	2795	53.2	48.6	17085	29920
9	Two hoeings 3 and 6 DAS	32.2	40.0	2191	2808	50.9	49.1	16252	30991
10	Weedy check	18.5	20.9	1043	1221	51.4	49.5	1986	5012
11	Weed free	36.9	46.5	2379	315	52.6	53.2	22698	35380
	C.D. at 5%	1.95	5.7	214	403	NS	NS	4678	4021

EFFECT OF MULCHING PRACTICES ON WEED MANAGEMENT, GROWTH AND YIELD OF COTTON

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Abstract: A field experiment was conducted at Annamalai University Experimental Farm, Annamalainagar to study the effect of mulching practices on weed control, growth and yield of cotton during 1998. The experiment was laid out in randomised block design replicated four times. Six treatments viz., no mulch (control), mulching with water hyacinth (*Eichhornia crassipes*) at 10 cm thickness, coir pith at 2 cm thickness, saw dust at 2 cm thickness, paddy straw at 10 cm thickness and sugarcane trash at 10 cm thickness were tested. Among the mulching treatments, sugarcane trash at 10 cm thickness significantly decreased the weed count, weed biomass and increased the weed control efficiency, weed control index and growth and yield of cotton. Application of coir pith was the next best treatment. Results evidently proved that all the mulching treatments caused suppressing of weeds and there by improved the seed cotton yield. This technology could be considered as eco-friendly, which also takes care of the soil fertility maintenance.

Key words: Cotton, mulches, weed control efficiency, weed count, weed dry matter

Introduction

Cotton is an important fibre crop of Tamil Nadu. In some parts of Tamil Nadu and Andhra Pradesh, cotton is also grown in rice fallows after the harvest of *rabi* rice. The average seed cotton yield in rice fallow is very low as the crop faces severe competition from weeds during the initial stage of growth. Slow crop growth during early period coupled with wider row spacing of cotton favours the weed to make a rank growth. Nutrient depletion to the tune of 10 to 90 per cent (Singh *et al.*, 1988) causes major set back to the crop. In order to make judicious use of various inputs, it is essential to keep the weed under check from early stages of the crop growth. Weed control through herbicide has harmful effect on non-target species and herbicidal residues in edible parts cause severe mammalian toxicity. Weed control through organic mulch is eco-friendly in nature and leaves no residual toxicity to the environment. Mulch excludes sunlight and inhibits top growth. Mulching is said to be one of the best means to combat weeds by avoiding aeration and by increasing the soil temperature by 5 to 10 per cent (Song Meizhen *et al.*, 1998). This resultant increase in soil temperature has been reported to be lethal to many soil inhibiting pests including weeds. Mulch also provides a barrier against emerging weeds (Rao, 1983) and thus has post emergence weed control ability. Keeping this in view, the present investigation was carried out to study the effect of mulching practices on weed management, growth and yield of cotton.

Materials and Methods

A field study was conducted to study the effect of mulching on weed control in cotton during winter 1998 at Annamalai University Experimental Farm, Annamalainagar, India. The experiment was conducted in randomised block design with four replications with six treatments viz., no mulch (control), mulching with water hyacinth (*Eichhornia crassipes*) at 10 cm thickness, coirpith at 2 cm thickness, sawdust at 2 cm thickness, paddy straw at 10 cm thickness and sugarcane trash at 10 cm thickness. The soil is clayey loam in nature. The available nitrogen, phosphorus and potassium contents of soil were 222, 25 and 351 kg/ha respectively. Cotton cv Suvin was sown on the first week of January 1998 and the method of sowing was dibbling with a spacing of 60 x 30 cm. A fertilizer schedule of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha was followed. The different mulch materials were separately spread over the surface of each bed in the inter row and intra row space of cotton at 10 DAS. The mulch material was spread at a specified thickness as per the treatment schedule. First irrigation was given two weeks after

sowing and sub sequent ones as and when needed. The recommended plant protection measures were adopted. Data on plant height, monopodial and sympodial branches, seed cotton yield and weed count and dry weight of weeds were recorded.

Results and Discussion

Weed flora observed in cropped field: The major weed flora found during the cropping season were *Trianthema portulacastrum* L., *Eleusine indica* (L)., *Digitaria sangunalis* (L.) Scop and other weeds present in the experimental field were: *Cynodon dactylon* L., *Cyperus rotundus* L., *Commelina benghalensis* L. and *Amaranthus viridis* L.

Effect on weed population, weed dry matter and WCE: There was a significant reduction in weed population and dry weight of weeds with the mulching treatments compared to no mulch. Sugar cane trash at 10 cm thickness reduced weed population and weed dry matter and increased the weed control efficiency than other treatments. The growth of weeds in the mulch treatments was poor. This could be due to blocking of sunlight and aeration. Similar results were reported by Kaliappa (1980). Weed control by residual sugarcane trash mulch has been reported by Cui Fengjun *et al.* (1994). Coir pith at 2cm thickness was the next best. The no mulch (control) recorded the highest weed count, dry matter of weed and lowest in the weed control efficiency.

Table 1 Effect on weed population, weed dry weight and WCE

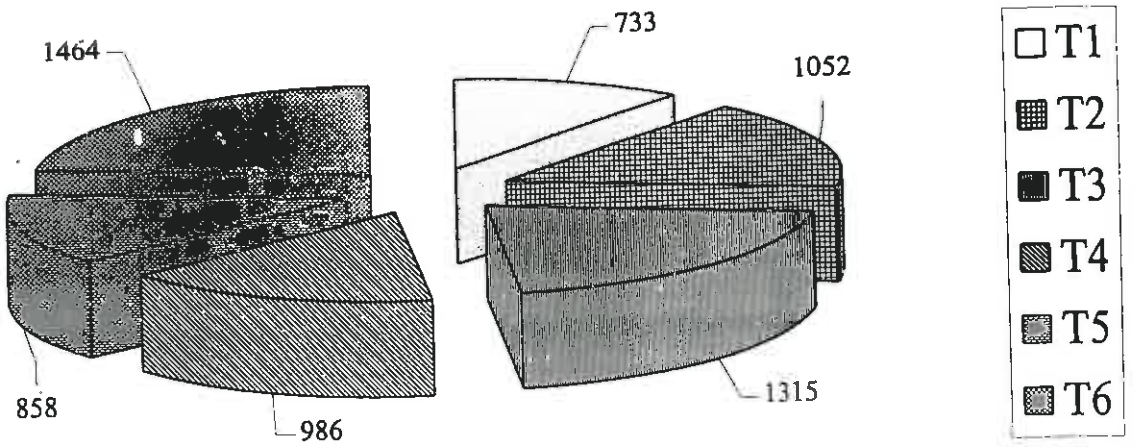
Treatments	Weed number/ m^2	Weed DMP (g/m^2)	Weed Control Efficiency (%)
Weedy check	225	157.5	-
Water hyacinth at 10 cm thickness	51	40.25	77.33
Coir pith at 2 cm thickness	34	28.50	84.00
Saw dust at 2 cm thickness	106	79.50	52.88
Paddy straw at 10 cm thickness	78	58.25	65.33
Sugarcane trash at 10 cm thickness	20	15.19	91.00
CD (P = 0.05)	12.8	7.51	-

Effect on crop yield: Mulching treatments significantly increased the growth and yield components and seed yield than the no mulch treatment. Sugarcane trash mulch at 10 cm thickness recorded the highest number of monopodial branches (2.85), sympodial branches (12.98) and seed cotton yield (1464 kg/ha). Increased growth and yield of cotton observed in sugarcane trash mulching treatment might be due to the beneficial effect of mulches in conserving soil moisture and in suppressing the emerging weeds, thereby influencing the growth and yield components of crop and finally seed cotton yield. Kathiresan *et al.* (1991) reported that sugarcane trash mulch conserved the soil moisture by avoiding weed growth in sugarcane. Coir pith at 2 cm thickness was the next best treatment. The least seed cotton yield (733 kg/ha) was observed with no mulch obviously, severe weed competition and relatively slow growth of cotton during early stages resulted in low seed cotton yield in the above treatment.

Table 2 Effect on monopodial and sympodial branches and number of bolls per plant

Treatments	Monopodial branches	Sympodial branches	Number of bolls/ plant
T1 - Weedy check	2.11	8.96	6.8
T2 - Water hyacinth at 10 cm thickness	2.56	11.34	8.8
T3 - Coir pith at 2 cm thickness	2.62	12.11	9.9
T4 - Saw dust at 2 cm thickness	2.33	9.44	7.1
T5 - Paddy straw at 10 cm thickness	2.42	10.77	7.6
T6 - Sugarcane trash at 10 cm thickness	2.85	12.98	10.8
CD (P = 0.05)	0.28	0.35	0.54

Fig. 1 Seed cotton yield (kg/ha)



Acknowledgements:

The authors express their sincere thanks to the Authorities of Annamalai University for providing facilities for the conduct of field trials at Experimental Farm, Department of Agronomy.

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EFFECT OF SOWING METHODS AND WEED CONTROL ON CONTROLLING WILD OATS AND PRODUCTIVITY OF WHEAT IN EGYPT

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Abstract: Wild oats, as a predominant grassy weed in wheat fields in Assiut governorate is one of main cultural practices which can play an important role in controlling weeds as wild oats. Two field experiments were conducted in naturally infested fields with wild oats in two districts i.e. Manfalout and Abo-Teag in Assiut Governorate to show the effect of sowing methods and weed control treatment on wild oat control and wheat productivity.
Results can be summarized concisely as follows:
1-Herati method (wet method) decreased significantly number and fresh weight of wild oats, howerer, Afir (drill) (dry method) method increased grain yield significantly than Herati or Afir (broadcasting) method.
2-Concerning weed control treatments, Grasp herbicide is more effective in reducing significantly the number and fresh weight of wild oats and reflected on increasing of wheat grain ton/ha.
3- These results indicated to the need for find of integration between herbicides and sowing methods for satisfactory wild oats control in wheat.

Key words: sowing methods, wild oat, controlling, weight, grain yield

Introduction

The major problem that affects on the stand production of wheat is associated weeds (Broad-leaved and grasses). Wild oat (*Avena fatua, L.*) is one of the most troublesome grassy weed in Upper Egypt, that spread quickly in wheat fields. Wheat yield losses increased due to wild oat population (O'Donova and Sharma 1983). Several workers have show that the integration wild oat control using herbicides, sowing methods, hand weeding and also preceding winter crop treatment is sutabie manner to get rid of this weed (Al-Marsafy and Hassanein 1993), (O'donova 1998), (El-wekil et al 1994) and (Hassanein et al 1993) found that Herati method decreased all weeds and increase yield of wheat than Afir methods. Thus this work aimed to identify the role of three sowing methods and weed control treatments for wild oat control in purpose of developing system of cultural practices which can integrate with Grasp herbicide in wild oat management in wheat fields.

Materials and Methods

Two field experiments were conducted in Manfalout and Abo-Teag sites in Assuit Governorate during 1997/1998 seasons in naturally infested with wild oat (*Avena L. fatua, l*) Each experiment had nine treatments which were the combination of three sowing methods and three weed control treatments in four replications in split plot design. Main plots contained sowing methods which were: (1) Afir (dry) broadcasting (2) Afir (dry) drilling (3) Herati (wet) methods. Subplot treatments were (1)-untreated (2) Grasp 10% (tralkoxydim) herbicide at rate of 2.38 L/ha. at 3-4 leaf stage and (3) hand weeding
Sub-plot size was 84 m^2 (7x12 m). Seed var. Giza 164 was estimated after 110 days from sowing. Grain yield was determined from 10.5 m^2 from each sub-plot at harvest. Data were statistically analyzed and LSD was used 5% level to verify the significance means.

Results and Discussion

A. Wild oats:

Data in table (1), denote the following:

Herati sowing method differed significantly as compared by both Afir (drill) and Afir(broadcast) from the point of view effect on wild oats (means of Manfalout and Abo-Teag sites). The values were 22.17, 26.83 and 5.9 plants of wild oat/m^2 in Manfalout , whereas were 18 , 21 and 6 plants/m^2 in Abo-Teag. As for fresh weight in g/m^2 data indicated that Afir drill, Afir broad casting and Herati gave 289.42, 338.42 and 82.17 in Manfalout and 235.42 , 267.5 and 78 g/m^2 , respectivily.

B. Wheat grain yield:

Results in table (1), showed that Afir (drill) method differed significantly from both Herati and Afir (broadcast) methods from the view point of their effect on wheat grain yields means of the previous two sited. The respective values in such cases were determined by 5.7, 5.3 and 5.0 t/ha.

Concerning the effect of other treatments beaing Grasp, Handweeding and unweeded check, the respective values of grain yield were 6.0, 5.3 and 4.7 t/ha.

In spit that the interaction between sowing methods and weed control treatments in table (2) appeared with no significancy, yet it is clear that Grasp with Herati sowing method performed better than others.

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Table 1 Effect of sowing methods on wild oat controlling and wheat grain yield (Assuit governorate in 1997/1998 season).

Sowing methods	Sites									
	Manfalut					Abo-Teag				
	No. of wild oats/m^2		Weight of wild oats/m^2		Yield t/ha	No. of wild oats/m^2		Weight of wild oats/m^2		Yield t/ha
	O	T	O	T	Grain	O	T	O	T	Grain
Afir drill	22.17	1	289.42	2.26	5.96	18	1.25	235.92	2.16	5.38
Afir broadcasting	26.83	1.5	338.42	2.34	5.29	21	1.31	267.5	1.24	4.75
Herati	5.9	0.8	82.17	1.64	5.46	6	1.18	78	1.68	5.04
L.D.S.		0.07		0.082	NS		0.05		0.05	0.24

O = Original data

T = Transformed data

Table 2 Effect of interaction of sowing and weed control methods on wild oat controlling and wheat grain yield (Assuit governorate in 1997/1998 season).

Sowing methods	Wedd control treatments	Sites									
		Manfalut					Abo-Teag				
		No. of wild oats/m^2		Weight of wild oats/m^2		Yield t/ha	No. of wild oats/m^2		Weight of wild oats/m^2		Yield t/ha
		O	T	O	T	Grain	O	T	O	T	Grain
Afir drill	Unweeded	34	1.54	647.5	2.81	5	28	1.46	532.5	2.73	4.5
	Grasp 10 %	14	1.17	54.5	1.74	6.88	11	1.07	42.75	1.63	6.25
	Handweeding	18.5	1.29	166.25	2.22	6	15	1.19	132.5	2.18	5.38
Afir broadcasting	Unweeded	38	1.59	725	2.85	4.5	30	1.49	571.25	2.75	4
	Grasp 10 %	16.75	1.25	65.25	1.82	6.13	13	1.44	51.25	1.71	5.5
	Handweeding	25.75	1.43	230	2.39	5.25	20	1.32	180	2.25	4.75
Herati	Unweeded	10.25	1.05	192.5	2.28	5.25	9	0.99	170	2.22	4.88
	Grasp 10 %	2.5	2.52	10.25	1.02	5.75	3	0.59	11.5	1.09	5.25
	Handweeding	5	0.77	43.75	1.63	5.34	6	0.84	52.5	1.72	5

L.D.S M * S = No sinnificance

O = Original data

T = Transformed data

EFFECT OF TILLAGE AND TIME OF SOWING ON THE EFFICACY OF HERBICIDES AGAINST *PHALARIS MINOR* IN WHEAT

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Abstract : Field experiment was conducted at the Punjab Agricultural University Regional Research Station, Gurdaspur (India) in winter seasons of 1997-98 and 1998-99 to study the effect of tillage and time of sowing on the efficacy of herbicides against *Phalaris minor* in wheat crop. The results indicated that the wheat crop grown under conventional tillage system gave relatively more suppression of *Phalaris minor* which in turn showed 55.6 per cent reduction in dry matter production of this weed and thus resulted in 17.9 per cent higher grain yield over zero tillage system. Sowing of wheat on 15 November registered 12.8 per cent reduction in dry matter of *Phalaris minor* compared to 25 November sowing and hence produced 20.5 per cent more grain yield. In zero tillage system when the crop was sown on 15 November, the sequential application of glyphosate 0.5 kg /ha and isoproturon 0.94 kg /ha resulted in 20.8 per cent higher grain yield compared to alone post emergence application of isoproturon 0.94 kg/ha. While in the conventional tillage system under the same set of treatments, the increase was only 5.0 per cent.

Key words : *Phalaris minor*, tillage, sowing dates, isoproturon, glyphosate

Introduction

Wheat (*Triticum aestivum* L.) occupies the prime position among the food crops in India and is second important food crop next to rice. The adoption of rice-wheat cropping system especially in the Northern part of the country has brought in its wake the problem of *Phalaris minor* as a troublesome weed of this crop causing yield reduction to the extent of 30-80 per cent (Brar and Walia, 1993; Malik *et al.* 1996). Phenyl urea herbicides including isoproturon, methabenzthiazuron and metoxuron were introduced during late 70's for the control of *Phalaris* (Gill *et al.* 1978). Among them the use of isoproturon was largely accepted by the farmers. This herbicide by and large provided desired control of *Phalaris minor* up to 1990. Due to continuous use of isoproturon over 12-15 years, reports of poor control of *Phalaris minor* were started pouring in from different wheat growing regions due to development of resistance by this herbicide against *Phalaris minor* (Malik and Singh, 1993; Walia *et al.* 1997). Alternative herbicides namely Sulfosulfuron, Clodinafop, Fenoxaprop-p-ethyl though proved effective against *P.minor* (Walia *et al.*, 1998) but there is risk of development of cross resistannce. There is a need to develop integrated weed management approach to avoid the sole reliance on the herbicides and may also help in checking/delaying the resistance mechanism in weeds.

Materials and Methods

The field investigations were conducted at the Punjab Agricultural University Regional Research Station, Gurdaspur (32°02 N, 75°22'E latitude, 260 m above Mean Sea Level) Punjab, India during two consecutive winter seasons of 1997-98 and 1998-99 on a field where rice-wheat cropping sequence wass being followed for about one decade. The soil of the experimental field was sandy loam in texture and neutral in reaction. The soil tested medium in organic carbon (0.40%) low in available nitrogen ($KMnO_4$-N, 210 kg/ha), higher in available phosphorus (Olsen P, 26 kg/ha) and medium in available potassium (NH_4OAC-K 192 kg/ha) in the plough layer. Sixteen treatments replicated thrice were laid out in split plot design with combination of 2 tillage treatments viz. zero tillage and conventional tillage and 2 dates of sowing viz., 15 November and 25 November in the main plots and 4 herbicide treatments viz., control, glyphosate @ 0.50 kg/ha applied 3 days before sowing, isoproturon @ 0.94 kg/ha after first irrigation and sequential application of glyphosate (0.50 kg/ha) and isoproturon (0.94 kg/ha) in the sub plots. The herbicides as per treatments were applied with Knapsack sprayer fitted with flat fan nozzle by using 500 litres of water per hectare. The gross and net plot size of 8m x 5m and 5.7m x 4.0m, respectively was maintained.

A heavy pre-sowing irrigation was applied about two weeks before sowing. In case of conventional tillage treatment, experimental plots were prepared by giving at least four cultivations each followed by planking about 5 days before the actual date of sowing (as per treatments). In case of zero tillage no prior cultivation was given and only a small furrow to place the seed was opened at time of sowing which was subsequently covered by giving a light planking. Glyphosate as per treatments was sprayed 3 days before sowing in both the tillage treatments.

Bread wheat variety PBW343 was sown on experimental dates by pora method in rows 23 cm apart using seed rate of 100 kg/ha. The crop was fertilized with 125 kg N, 62.5 kg P_2O_5 and 30 kg K_2O/ha. Half of the nitrogen along with full dose of phosphorus and potassium drilled at sowing whereas the remaining half dose of nitrogen was applied after first irrigation. The first irrigation was applied at crown root initiation (CRI) stage of wheat. Total of 3 irrigations were applied in each year and the crop received well distributed rainfall of 554.7 and 126 mm in 1997-98 and 1998-99, respectively. The field was heavily infested with *Phalaris minor* which was equally distributed throughout the field. Broadleaf weeds (mainly *Medicago denticulata)* were controlled by spraying recommended dose of 2,4-D sodium salt in all the plots at about 40 days after sowing (DAS).

Periodic data on dry matter and plant height of *Phalrsis minor* as well as of wheat plants were recorded at monthly intervals beginning from 60 DAS up to crop maturity. At harvest, data on yield attributes, grain and straw yield of wheat were recorded. The periodic weed count recorded by randomly placing a quadrat of 0.5m x 0.5m size at four places in each plot was computed to give number of plasnts of *Phalaris minor*/m^2. Similarly, dry matter of *Phalaris minor* at periodic intervals was recorded by randomly placing the quadrat of the same size in each plot and pulling the *Phalaris minor* plants. For the dry matter accumulation by wheat, plants from the 0.5 metre row length from the outer rows of wheat were harvested. These (plants of weed and wheat) were dried first in shade and then in oven at 65°C till constant weight was obtained. Data of number and dry matter of *Phalaris minor* were subjected to square root transformation prior to statistical analysis. The crop was harvested in the last week of April in both the years.

Results and Discussion

Effect on *P .minor*

Tillage

At harvest stage, *Phalaris minor* under zero tillage accumulated significantly more dry matter than under conventional tillage system in both the years (Table 1). Conventional tillage caused mean suppression of 55.6 per cent in dry weight of *Phalaris minor* as compared to zero tillage. Repeated cultivations under conventional tillage system on the other hand may distribute the seeds of *Phalaris minor* throughout the soil profile (Koshinen and McWhorter, 1986) and might have adversely affected the germination of its seeds found in the lower layers or some germinated seeds/emerged seedlings might have been uprooted by cultivation. While in zero tillage the seeds of *Phalaris minor* remain confined to upper soil surface and thus germinated in more numbers and hence led to production of more dry matter (Phillips and Phillips, 1984).

Sowing dates

Dry matter accumulation (Table 1) by *Phalaris minor* at harvest stage in both the years were not influenced by sowing dates but sowing of wheat on 15th Nov proved superior in terms of reduction in dry matter of *Phalaris minor* by 12.8 per cent and resulted in 20.5 per cent more grain yield over 25th Nov sown crop.

Herbicides

Different herbicide treatments significantly influenced and dry matter production of *Phalaris minor* at harvest stage in both years. Sequential application of glyphosate 0.5 kg/ha (3 DBS) and isoproturon 0.94 kg /ha (35 DAS) provided significantly better control in terms of dry weight of *Phalaris minor* at harvest stage in both years as compared to control and alone application of glyphosate 0.5 kg /ha. Sequential application of glyphosate 0.5 kg/ha and isoproturon 0.94 kg /ha even significantly reduced, dry matter of *Phalaris minor* at harvest stage in both years (Table 1)

than isoproturon applied alone @ 0.94 kg /ha. Isoproturon alone significantly reduced the dry matter accumulation of *Phalaris minor* as compared to unweeded control and also glyphosate applied alone in both years. Mean data of dry matter production of *Phalaris minor* at harvest envisaged that sequential application of glyphosate and isoproturon reduced the dry matter of *Phalaris minor* by 92, 88 and 67.3 per cent, compared to unweeded check, application of glyphosate and application of isoproturon alone, respectively. Isoproturon alone also reduced the dry weight of *Phalaris minor* by 75.4 and 63.5 per cent over that of unweeded check and alone application of glyphosate, respectively. Similarly better control of *Phalaris minor* with isoproturon has been reported by Walia and Gill (1985).

Interaction effect

The interaction effect of tillage and date of sowing (Table 2) in both the years at harvest stage revealed that zero tillage under 25th November sowing produced almost the same dry matter of *Phalaris minor* as was produced in conventional tillage system. While in case of early sowing (15th Nov) the dry matter accumulation by *P.minor* was significantly more in conventional tillage system as compared to zero tillage planting system. Interaction between tillage and herbicides was also found significant in both the years (Table 3). The data indicated that in 1997-98 the dry matter accumulation by *P. minor* was reduced significantly under conventional tillage system compared to zero tillage planting system under all herbicide treatments except with sequential applications of Glyphosate 0.5 kg/ha and isoproturon o.94 kg/ha where the differences were non-significant. In 1998-99, the dry matter accumulation by *P. minor* reduced under conventional tillage planting system over zero tillage only in unweeded check and with post emergence application of isoproturon 0.94 kg/ha, while the differences were non-significant when glyphosate 0.5 kg/ha was applied alone or its sequential application with isoproturon 0.94 kg/ha.

Effect on wheat

Tillage

Grain yield of wheat in case of conventional tillage system was significantly higher in both the years with mean increase of 17.9 per cent over that of zero tillage (Table 1). This increase was due to the significantly reduction in the dry matter accumulation by *Phalaris minor* over zero tillage.

Sowing dates

Sowing on early date (15 November) in both years resulted in significantly higher grain yield of wheat with mean increase of 20.5 per cent over its delayed sowing (25 November). Higher intensity of *Phalaris minor* in case of 25 November sowing might have offered competition for space and growth resources to crop plants as compared to 15 November sown crop. Similar effect of sowing time on yield was reported by Malik and Singh, 1993 ; Kurchania *et al*, 1993.

Herbicides

Grain yield of wheat with application of different herbicides was significantly higher than control in both the years (Table 1). Sequential application of glyphosate 0.5 kg /ha and isoproturon 0.94 kg /ha significantly outyielded all other herbicide treatments and registered mean increaseof 18.0, 66.0 and 126.3 per cent in grain yield of wheat over alone application of isoproturon, glyphosate and unweeded control, respectively. Likewise post-emergence (35 DAS) application of isoproturon 0.94 kg /ha alone produced significantly higher grain yield (40.9%) of wheat than application of glyphosate alone which in turn (36.3%) was significantly superior to unweeded check in both years. Better control of weeds and consequent improvement in different yield attributes as a result of herbicide application contributed to increase in grain yield of wheat. Similar yield increases with application of isoproturon have been reported Walia and Gill(1985).

Interaction effect

Table 4 revealed that application of isoproturon alone under conventional tillage and sequential application of glyphosate 0.5 kg /ha and isoproturon 0.94 kg /ha under both conventional and zero tillage systems in case of 15 November sowing and sequential application of glyphosate and

isoproturon under conventional tillage in case of 25 November sowing produced identical grain yields of wheat which were significantly higher than rest of the treatment combinations of tillage, sowing dates and herbicide treatments. In case of crop sown on 15 November under zero tillage, sequential application of glyphosate 0.5 kg /ha and isoproturon 0.94 kg /ha resulted in 20.8 per cent higher grain yield compared to application of 0.94 kg /ha isoproturon alone whereas, under same set of treatments in conventional tillage, the increase was only 5.0 per cent. In case of wheat sown on 15 November under conventional tillage , grain yield with application of isoproturon 0.94 kg /ha alone (44.2 q/ha) can be obtained under zero tillage with sequential application of glyphosate and isoproturon (45.3 q/ha). However in case of delayed sowing to 25 November, grain yield under conventional tillage (44.2-46.4 q/ha) was higher than zero tillage with application of isoproturon alone or sequential application of glyphosate and isoproturon. This was due to poor germination and growth of wheat and increased population of *Phalaris minor* under delayed sowing particularly under zero tillage system. Population of *Phalaris minor* under zero tillage system was higher as compared to conventional tillage system even in early sowing which required application of glyphosate in addition to isoproturon for its effective control.

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Table 1 : Effect of tillage, date of sowing and herbicide treatments, dry matter accumulation by *P. minor* (q/ha) at harvest stage and grain yield (q/ha) of wheat

Treatments	Dry matter of *P. minor* (q/ha) (DAS)		Grain yield (q/ha)	
	1997-98	1998-99	1997-98	1998-99
Tillage				
Zero tillage(ZT)	2.7(11.1)	3.9(17.3)	30.3	28.3
Conventional tillage (CT)	1.8(4.6)	2.7(8.0)	33.9	34.8
CD (0.05)	0.3	0.7	2.5	1.7
Date of sowing				
15th Nov (D1)	2.2(7.2)	3.2(11.9)	36.0	33.4
25th Nov (D2)	2.3(8.5)	3.4(13.4)	28.2	29.4
CD (0.05)	NS	NS	2.5	1.7
Herbicides (kg/ha)				
Unweeded check (H1)	3.4(16.1)	4.8(25.0)	20.7	18.1
Glyphosate 0.50 (H2)	2.9(10.7)	4.1(17.0)	26.2	26.7
Isoproturon 0.94 (H3)	1.7(3.6)	2.5(6.5)	36.7	37.7
Glyphosate (0.50) fb Isoproturon (0.94) (H4)	1.1(0.9)	1.8(2.4)	44.7	43.1
CD (0.05)	0.3	0.6	4.0	1.9

Table 2. Interactive effect of tillage and sowing dates on the dry matter accumulation (q/ha) by *Phalaris minor* at crop harvest stage

Tillage	Sowing dates			
	15th Nov	25th Nov	15th Nov	25th Nov
	1997-98		1998-99	
Zero tillage	2.4(8.6)	2.0(4.6)	3.5(13.7)	3.0(10.2)
Conventional tillage	3.0(13.6)	1.6(3.3)	4.3(21.0)	2.5(5.9)
CD (0.05)	0.4		0.8	

Table 3. Interactive effect of tillage and herbicide treatments on the dry matter accumulation (q/ha) of *Phalaris minor* at crop harvest stage

Tillage	Herbicide treatments			
	Unweeded Check	Glyphosate (0.50 kg/ha)	Isoproturon (0.94 kg/ha)	Glyphosate (0.50 kg/ha) fb. Isoproturon (0.94 kg/ha)
		1997-98		
Zero tillage	4.3(24.4)	3.1(12.5)	2.2(6.2)	1.2(2.2)
Conventional tillage	2.5(7.9)	2.6(8.8)	1.1(1.0)	1.0(0.6)
CD (0.05)	0.4			
		1998-99		
Zero tillage	6.0(36.6)	4.4(18.5)	3.3(10.7)	2.1(3.6)
Conventional tillage	3.7(13.4)	3.9(15.4)	1.8(2.3)	1.4(1.1)
CD (0.05)	0.9			

Table 4. Interactive effect of tillage, sowing dates and herbicide treatments on the grain yield (q/ha) of wheat during 1998-99

Tillage/sowing dates	Herbicide treatments			
	Unweeded check	Glyphosate (0.50 kg/ha)	Isoproturon (0.94 kg/ha)	Glyphosate (0.50 kg/ha) fb Isoproturon(0.94kg/ha)
Zero tillage				
15th Nov	12.5	26.1	37.5	45.3
25th Nov	12.5	25.4	28.1	36.4
Conventional tillage				
15th Nov	26.3	28.8	44.2	46.4
25th Nov	21.0	26.4	41.2	44.3
CD (0.05)	3.8			

EFFECT OF TILLAGE PRACTICES, SEEDING RATES AND HERBICIDES ON WEED INFESTATIONS IN DIRECT-SEEDED RICE

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Abstract: Crop protection in the form of weed control is essential for direct-seeded rice, especially against grass weeds. To investigate the integrated role of tillage practices, seeding rates and herbicide use, a field experiment was conducted in February to October 1998 in an on-station trial. Two tillage regimes were tested: a) conventional farmer practice, three rounds of tillage followed by land levelling by hand and b) reduced tillage, one round of early tillage and levelling. Three rice (MR 84) seeding rates were compared, 0 kg/ha, 60 kg/ha and 100 kg/ha, together with the herbicide regimes, 2,4-D amine, quinclorac and an unsprayed check. Reduced tillage resulted in heavy infestation (dry weight at 60 DAS) of *Fimbristylis miliacea*. Conventional tillage lowered total weed biomass but increased the proportion of broadleaf weeds, especially *Monochoria vaginalis*. The biomass of *Echinochloa crus-galli* was similar under both tillage treatments. A seeding rate of 100 kg/ha significantly reduced sedge and broadleaf weed biomass at 60 DAS but there was no corresponding reduction in *E. crus-galli*. As expected, both herbicides were effective in selective weed control. Noticeable compensatory responses occurred in other components of the weed flora when weed groups were chemically removed, emphasizing the need for broad-spectrum weed control. Rice yields were highest in conventionally tilled plots sprayed with 2,4-D, confirming the importance of repeated tillage in land preparation for yield protection.

Key words: direct-seeded rice, seed rate, weed shifts, reduced tillage.

Introduction

Weed species shifts in response to weed management practices have been widely reported in wet seeded rice (Moody, 1995; Azmi and Baki, 1996) and chemical control of broadleaf species has resulted in increases in grasses especially *Echinochloa* species, *Leptochloa chinensis* (L.) Nees *and Ischaemum rugosum* Salisb. In particular, barnyard grass (*Echinochloa crus-galli* (L.) P. Beauv.) is considered to be a major weed of direct-seeded rice in Peninsular Malaysia. This weed can be selectively controlled by using herbicides such as fenoxaprop-ethyl, molinate, propanil, quinclorac, cyhalofop-butyl and thiobencarb (Azmi and Lo, 1990). Normally, pre-emergence applications are the most effective in grass control because of the lesser efficacy of late post-emergence herbicides and the need to protect rice from weed competition in the early life of the crop (Azmi, 1994). The increasing occurrence of herbicide resistance in *E. crus-galli* (Gressel and Baltazar, 1996) argues strongly for the use of integrated weed management (IWM) practices for control of this weed together with other species. Empirical approaches to the design of IWM involve agronomic trials of combinations of weed control practices coupled with an understanding of the biology and ecology of individual weed species in field conditions (Mortimer *et al.*, 1997). Central to development of IWM in direct-seeded rice is an understanding of the interaction amongst tillage practices, water management and herbicides in determining weed seedling recruitment and, in the longer term, the dynamics of the weed seed bank.

Conventional farmer tillage practice for direct seeding in Malaysia involves a sequence of land cultivation between rice crops, typically, dry tillage (after harvest) followed by wet tillage at 10-14 days before rice sowing (DBS) and wet tillage, immediately prior to sowing. Dry tillage results in burial of weed seed dispersed onto the soil and encourages germination of weed seeds especially volunteer rice after harvest whilst wet tillage may cause a flush of weed emergence and a consequential reduction in the size of the weed seed bank if a second round of wet tillage occurs. However, in many ecotypes, burial of *E. crus-galli* seed through land cultivation induces seed dormancy, which may result in persistent seed

populations with half lives of over three years (Watanabe and Azmi, 1995). In consequence, reduced tillage practices may be advantageous in controlling this weed. In this paper, we report the first season results of a planned two season trial, contrasting the effects of different intensities of tillage in relation to chemical control and seeding rate on yield and weed abundance.

Materials and Methods

The experiment was initiated at the Malaysian Agricultural Research and Development Institute (MARDI) station, Bertam, Seberang Perai in Malaysia in February to October 1998 (off season) and continued into the main season 1998/99. A rice field heavily infested with *E. crus-galli* was surveyed prior to harvest in 1997 to determine the spatial distribution of the weed. The presence or absence of plants was recorded in every 1 m^2 of the field. Based on this survey, freshly collected *E. crus-galli* seed were sown (at 1000 seeds/m^2) onto the soil surface into vacant areas, prior to the start of the experiment and the imposition of tillage treatments. The experiment was conducted as a split-split-plot design with four replications where main plots consisted of tillage treatments, conventional practice versus reduced tillage; subplots were rice seeding rates (0 kg/ha, 60 kg/ha and 100 kg/ha, cultivar MR 84); and sub-subplots were chemical weed control regimes. Table 1 gives details of the tillage practices and herbicides applied. Individual sub-subplots were 5 m x 5 m in size.

Table 1. Tillage and herbicide treatments applied.

	Tillage
Conventional	Dry tillage (after harvest) followed by wet tillage at 14 days before sowing (DBS), wet tillage 1 DBS and land levelled by hand before crop seeding.
Reduced	Dry tillage (after harvest) followed by land levelling by hand before crop seeding.
	Herbicide
2,4-D amine	1000 g a.i. /ha in 250 l/ha at 20 DAS.
Quinclorac	250 g a.i. /ha at 10 DAS.
Unsprayed	Check.

Land was tilled by a two wheeled tractor drawn rotovator to an average depth of 30 cm. Levelling was completed by hand according to conventional farmer practice using a hand tool leaving a puddled soil surface devoid of weeds. After land preparation, pre-germinated rice seeds (MR 84) were broadcast onto saturated soil, which remained drained to provide good conditions for crop establishment. Plots were imundated at 8 DAS and the water level maintained thereafter at 5 to 10 cm. Fertilizer was applied at the rate of 40 kg N, 40 kg K_2O and 40 kg P_2O_5/ha as a topdressing at 15 DAS. Further application of N 60/ha was equally split at 50 DAS and at panicle initiation stage. Trebon (ethfenprox 10%) and sumicidin (fenvalerate 3%) were used for insect control.

Weeds were sampled at 60 DAS from four 0.5 m x 0.5 m quadrats placed at random in each plot, away from a central 4 m x 4 m area. Weeds were washed, sorted by species, dried at 80°C to constant weight, then weighed. Yield data were obtained from the centre 16 m^2 of each plot. Grain yield estimates were converted to kg/ha at 14% moisture. Data were analyzed by analysis of variance, where appropriate using a square root (x + 1) transformation to homogenise error variance. Least significant differences (LSD), $P \leq 0.05$ are given for comparison of means within treatment groups as indicated on individual figures. Note transformed scales are used in some figures.

Results and Discussion

Reduced tillage resulted in a lower rice grain yield in comparison to conventional tillage, meaned over both seeding rates, no significant increase occurring with a seeding rate of 100 kg /ha. Highest yields were achieved in 2,4-D treated plots, Figure1.

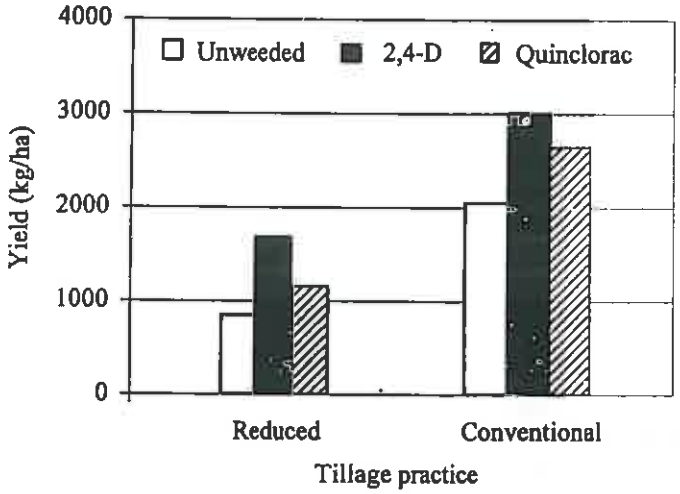


Figure 1. Grain yield as affected by tillage and herbicide application.

The predominant weed species present were *E. crus-galli*, *Fimbristylis miliacea* (L.) Vahl, *Monochoria vaginalis* (Burm.f.) Presl and *Limnocharis flava* (L.) Buchenau. However the majority of the biomass measured at 60 DAS comprised *E. crus-galli*, *F. miliacea* and *M. vaginalis* and their abundance was strongly influenced by both tillage and herbicide treatments. Overall, a higher weed biomass was observed under reduced tillage (544 g m^{-2}) compared to conventional practice (315 g m^{-2}), and elevating seeding rate (from 60 to 100 kg ha^{-1}) significantly reduced weed biomass under both conventional and reduced tillage (Fig. 2).

Comparison of weed biomass in unsown plots (0 kg/ha) showed that taxa were ranked in the order sedge > broadleaves > grass (data not shown) and the dominance of sedges was again evident at rice seeding rates of 60 and 100 kg ha^{-1}, but at both rates the biomass of grasses and broadleaf weeds was similar. Differences in tillage practice did not effect the abundance of grass weeds (Fig. 3) whereas the predominant sedge component (*F. miliacea*) was increased six fold by reduced tillage. Conversely the biomass of broad-leaf weeds especially *M. vaginalis* was more abundant after conventional tillage. A significant reduction of biomass, was achieved by increasing seeding rate from 60 to 100 kg/ha in *F. miliacea* but not in *M. vaginalis* (Fig. 4). In contrast to previous findings (Azmi, 1997), there was no reduction in grass weed, or *E. crus-galli*, biomass by increasing seeding rate.

The differential effect of the herbicides in weed control is shown in Figure 5. The use of 2,4-D resulted in a lowering of sedge and broadleaf species biomass but an increase in grass biomass.

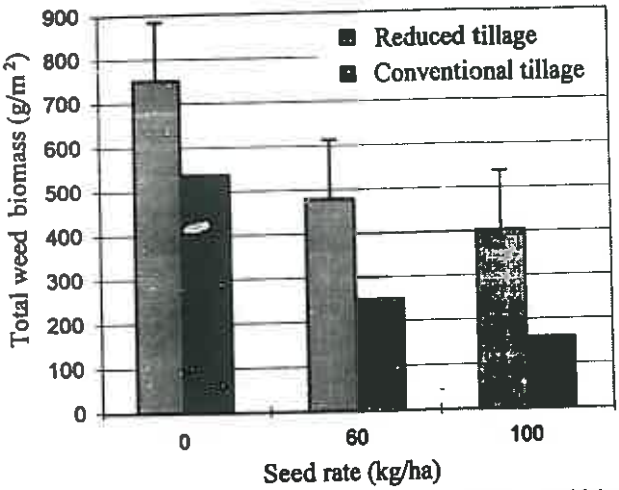


Figure 2. The effect of tillage treatments and seeding rates on total weed biomass (60 DAS).

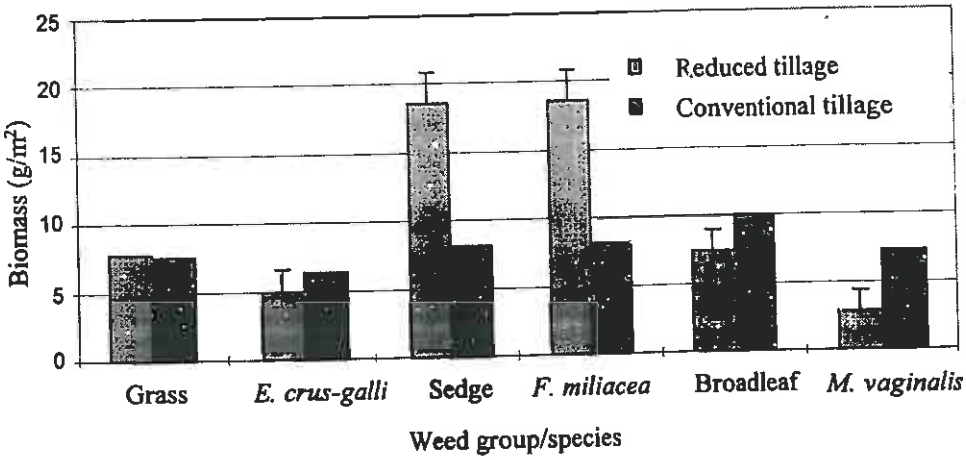


Figure 3. The effect of tillage treatments on weed biomass (60 DAS) by weed group and dominant weed species within each group. Transformed means, square root (x+1).

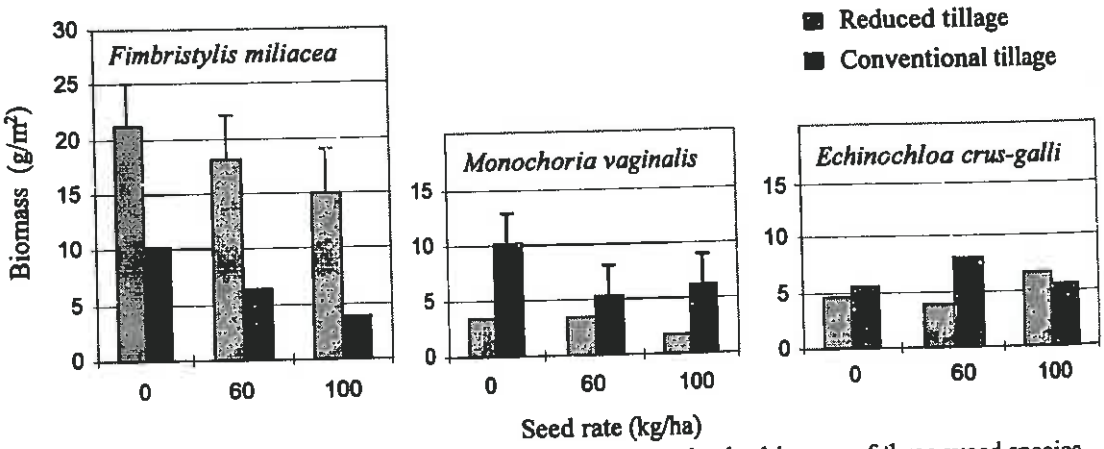


Figure 4. The effect of tillage treatments and seeding rate on the dry biomass of three weed species. Transformed means, square root (x+1).

The opposite was true when quinclorac was applied and whilst *E. crus-galli* was substantially reduced, there were significant increases in the other components of the flora and especially *F. miliacea* and *M. vaginalis*. These responses illustrate competitive release amongst species within the weed community as a response to chemical management. Whilst this phenomenon is not surprising, the magnitude of the response to the removal of grasses by broadleaf species was notably large, biomass being equivalent to that observed in the unsprayed plots. A similar, strong, reciprocal response in *E. crus-galli* was seen to the removal of broadleaf species and sedges.

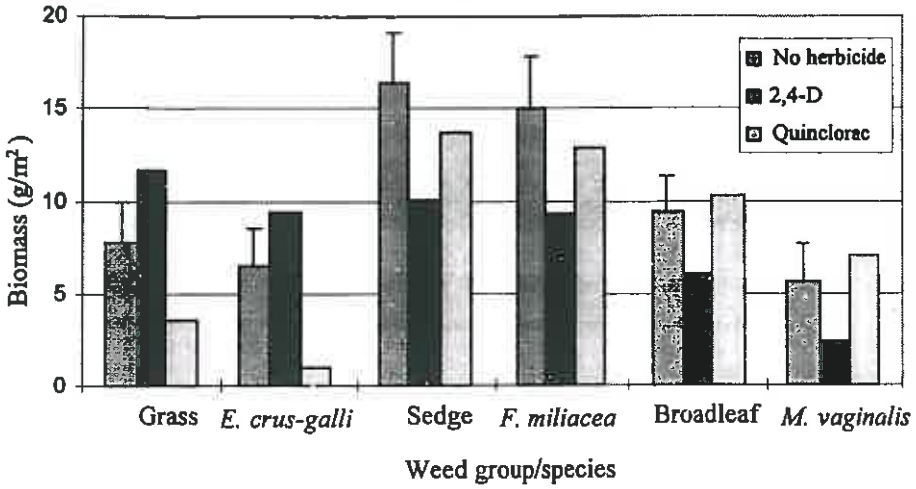


Figure 5. The response of the weed flora to 2,4-D and quinclorac measured at 60 DAS. Data are transformed, square root (x+1), and averaged over tillage treatments.

These results re-affirm that land preparation plays an important role in determining both the relative and absolute abundance of weeds in wet seeded rice in Malaysia. In this experiment, the tillage treatments themselves differed only in the inclusion (or not) of the wet tillage regimes; all other management treatments and agronomic practices being the same. It is therefore likely that tillage practice is primarily affecting weed seedling recruitment which is latterly reflected in weed biomass. Three mechanisms may be hypothesized. The first is that wet tillage inverts the soil profile and buries weed seed dispersed on the surface from recent generations, resulting in a reduction in the size of the seed pool in the surface layers from which weed seedlings can be recruited. Second, in creating puddled soil conditions, wet tillage breaks weed seed dormancy causing seedling emergence. The third is that the sequence of double wet tillage promotes germination in the first event and subsequently causes seedling mortality in the second. The *net* effect of these mechanisms may be seen as a decline or increase in weed population recruitment which may be reflected in biomass 60 DAS, assuming that competitive interactions amongst species within the developing rice canopy do not override effects at recruitment. Without more detailed understanding of seed and seedling dynamics of *F. miliacea* and *M. vaginalis*, it is only possible to speculate on the effects of tillage on the dynamics of these species. In the reduced tillage treatment, the change in weed biomass was primarily due to an increase in the sedge component, of which *F. miliacea* was the dominant species. This species is short-lived, exhibits no seed dormancy, once established can set seed in aerated soil and populations are recruited from the surface layers of a seed bank which is typically very large (Sahid *et al.*, 1995). In this experiment, sufficient time elapsed between dry tillage and the imposition of land leveling for a cycle of seed reproduction by this species to be completed. Therefore there may have been high seed densities of *F. miliacea* on the soil surface (from both the previous rice crop and the intervening fallow) which, in the reduced tillage treatment, were not subjected to the first and third mechanism postulated above. Increase in the biomass of *M. vaginalis* under conventional practice requires an alternate explanation. The presence of standing water generating anaerobic conditions is required to promote germination in this hydrophyte, in which germination is typically not a rapid response with the onset of anaerobiosis (Yamasue and Ueki, 1983). Fourteen days of saturated soil conditions during wet tillage is probably sufficient to break seed dormancy and, in net terms, little seedling mortality appears to be arising from the second wet tillage event. The lack of

selective response in *E. crus-galli* to these tillage treatments indicates the well-known adaptation of this species to a range of soil environments (Maun and Barrett, 1986).

These results illustrate that, whilst conventional land preparation is advantageous in sedge control, it comes with the corollary that effective control of *M. vaginalis* and of *E. crus-galli* is essential and that no advantage will be gained by increasing seeding rate above farmer practice (60 kg/ha). Reduced tillage is of benefit in controlling *M. vaginalis* and other broadleaf species but with the risk of much increased yield loss due to *F. miliacea* at least. These remarks can be interpreted in two ways. In simple practical terms they argue for technologies ensuring broad spectrum weed control. If however cultural control is to be employed to maximum effect in achieving that objective, knowledge of the impact of tillage practices on weed seedling dynamics is clearly needed. Lack of seed dormancy in freshly dispersed seed of *F. miliacea* (Pons and Eussen, 1987) implies that the seed bank may be transient and the species may rapidly decline under appropriate management regimes. In the absence of *F. miliacea*, reduced tillage will decrease biomass of *M. vaginalis* and consequent yield loss. However, long term elimination of *F. miliacea* from the seed bank may involve fallow management and attention to non-cropped land and is unlikely to be an economic option for farmers. However if the relative abundance of *F. miliacea* and *M. vaginalis* strongly tracks the preceding tillage practice, then alternating the frequency and timing of tillage may contribute to effective integration of weed practices in direct-seeded rice. However in a broader context, there remains the need to understand the weed species shifts that may arise from selective herbicide use. Results from the second season in this experiment will be reported elsewhere.

Acknowledgements

We thank the Swiss Development Corporation (SDC) for support of this research through the IPM Network and Dr. K. L. Heong (IPM Net Coordinator, IRRI). The authors also wish to thank Mr. Chew See Eng, MARDI for assistance rendered in conducting the study.

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Effects of Mixtures of Cyclosulfamuron and Pendimethalin on Weed Control in Rice in Southeast Asia

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Abstract: The efficacy and crop selectivity of cyclosulfamuron and pendimethalin mixtures were evaluated against major weed species in paddy rice in four countries in Southeast Asia.

Field trials were carried out in wet sown direct-seeded rice in Thailand, Malaysia and the Philippines and in transplanted rice in Indonesia. Cyclosulfamuron was applied in a tank mix combination with pendimethalin at application rates ranging from 20-40 gai/ha and 330-750 gai/ha, respectively. The treatments were applied at timings of 5-12 days after seeding (DAS) and 3 days after transplanting (DAT). Popular farmers' commercial standard herbicides in each of the four countries were included as reference checks.

Overall results from the field trials clearly demonstrated the outstanding biological efficacy of cyclosulfamuron and pendimethalin tank mixtures in controlling the various major weeds in direct-seeded and transplanted rice. Excellent weed control of *Echinochloa* spp., currently the most troublesome grass weeds in S.E. Asia, was observed in all four countries. The other major weed species: *Leptochloa chinensis, Ischaemum rugosum, Monochoria vaginalis, Sphenoclea zeylanica, Fimbristylis* spp., and *Cyperus* spp., were also very well controlled. The performance of cyclosulfamuron and pendimethalin mixtures were nearly always superior to the farmers' commercial standard herbicides in terms of overall weed control; because of the superior bioefficacy results very little follow-up of hand weeding was required compared to current commercial products.

Although, some crop phytotoxicity symptoms were observed on the very young direct-seeded rice seedlings soon after application of cyclosulfamuron+pendimethalin, the rice crop recovered very quickly without significant effect on crop yield. The mixture was completely safe to transplanted rice seedlings.

Keywords: Cyclosulfamuron, pendimethalin, tank mixtures, wet sown direct-seeded rice, lowland transplanted rice, weed control.

Introduction

The use of chemical weed control in rice production is a well-accepted practice in Southeast Asia. Most rice farmers in the region are looking for herbicides that will provide effective, broad spectrum, season-long control of the major weed species and labor-cost saving. In most cases, however, these benefits can only be provided through the use of mixtures of two kinds of herbicides either as a tank-mix or ready-mix formulation or by sequential applications. In recognition of the need for an improved rice herbicide program, American Cyanamid Company has risen to the challenge and developed a tank mix offer of cyclosulfamuron and pendimethalin appropriate for weed control in rice crops in all the major rice growing areas of Asia.

Cyclosulfamuron is a sulfamoylurea herbicide discovered at the Agricultural Research Center of American Cyanamid Company in Princeton, NJ, USA. Its weed control spectrum and herbicidal activity have already been reported at the 14th and 16th APWSS in Brisbane and Malaysia, respectively (1,2,3).

This herbicide is highly effective against broadleaf and sedge weeds at low dose rates, and has moderate activity against grasses. Combination with grass herbicides is expected to provide broad spectrum weed control similar or superior to currently available one-shot products. Pendimethalin, a dinitroaniline herbicide also from American Cyanamid Company has a strong activity against grasses and is therefore an ideal mixing partner for cyclosulfamuron.

This paper presents summary data of the field performance of cyclosufamuron and pendimethalin tank mixtures against major weed species in rice in S.E. Asia.

Materials and Methods

Thailand. Field trials were conducted in wet sown direct-seeded rice in Suphan Buri region during the 1996 and 1997 planting seasons. Pre-germinated seeds of variety Suphanburi 1 were broadcast on the plots at a seeding rate of 125 kgs/ha. Treatments were laid out in a randomized complete block design, each replicated four times. Cylclosulfamuron and pendimethalin tank mixtures were applied at dose rate ranging from 20-40 + 375-750 gai/ha, respectively and at application timings of 8 and 12 days after seeding (DAS). Herbicide treatments were applied by knapsack sprayer with a flat fan nozzle at a spray volume of 500 liters/ha. Percent weed control was assessed at 30 and 60 days after application (DAA). Percent phytotoxicity was recorded at 7, 15 and 30 DAA. Saturnil EC (40% thiobencarb/20% propanil) was used as the farmer standard check. Grain yield was obtained from whole plots at harvest.

Malaysia. Field trials were conducted in wet-sown direct seeded rice in the Muda region. Pre-germinated seeds of variety MR 84 were broadcast on the plots at a seeding rate of 60 kgs/ha. Treatments were laid out in a randomized complete block design each replicated four times. Herbicides were applied by conventional knapsack sprayer with a flat fan nozzle at a spray volume of 450 liters/ha. Cyclosulfamuron and pendimethalin tank mixtures were tested at dose rates of 20 and 500-750 gai/ha, respectively and sprayed at application timings of 5, 8 and 10 days after seeding. Percent weed control was assessed at 35 days after application (DAA) for broadleaf weeds (BLWs) and sedges and 60 DAA for grasses. Percent phytotoxicity was recorded at 10, 21, and 35 DAA. Satunil EC (40% thiobencarb/20% propanil) and propanil alone were used as reference standard checks. Grain yield data were taken from whole plots at harvest.

Indonesia. Field trials were conducted in transplanted rice using the IR 64 variety in 3 locations in West Java. Treatments were laid out in a randomized complete block design, each replicated three times. Herbicides were applied by a CKS sprayer with a poly jet biru nozzle at a spray volume of 500 liters/ha. Cyclosulfamuron and pendimethalin mixtures were tested at dose rates ranging from 20-30 + 330 gai/ha during the 1998 cropping season and sprayed at one application timing of 3 DAT. Percent weed control was assessed at 56 DAA. Metsulfuron-methyl + 2,4-D amine combination applied as tank-mix was used as the farmer standard check. Grain yield data were taken from the whole plot at harvest.

Philippines. Field trials were conducted in wet-sown direct-seeded rice in Luzon and Visayas areas. Pre-germinated seeds of IR 64 or PSB-RC14 were broadcast on the plots at seeding rates of 100-150 kg/ha. Artificial seeding of *Echinochloa crus-galli* seeds were also done when the infestation level in the test areas was considered low. Treatments were replicated four times in a randomized complete block design. Herbicides were applied by knapsack sprayer with a flat fan nozzle at a spray volume of 300 liters/ha. Cyclosulfamuron and pendimethalin mixtures were tested at dose rates ranging from 20-30 + 375 gai/ha in the 1996 cropping season at application timings of 5 and 10 DAS. In 1998, the mixtures were tested at 25 +330 gai/ha and sprayed at application timing of 7 and 10 DAS. Percent weed control was assessed at 15, 30, 45 and 60 DAA. Percent phytotoxicity was taken at 7, 14 and 21 days after DAA. Two popular commercial herbicides, Sofit 300 EC (30% pretilachlor with safener) and Advance EC (35% butachlor/35% propanil) were used as reference standard checks. Grain yield data were taken from 10m^2 center of each plot measuring 20 m^2 at harvest.

Results and Discussion

Thailand. Cyclosulfamuron and pendimethalin tank mixtures applied early post-emergence at various dose rate combinations provided broad spectrum control of grasses, sedges and BLWs (Table 1 and 2). Increased rates did not provide any distinct advantage, as the level of control for all combinations was basically similar especially against sedges and BLWs where weed control was 100%. Likewise, application timing did not affect efficacy as the mixture performed similarly at 8 and 12 DAS. However, it caused initial phytotoxicity to rice seedlings that recovered fully 2-4 weeks after application (Table 3). Rice seedlings seemed to be more tolerant at application timing of 12 DAS. Early phytotoxicity had no direct effect on the grain yield as shown in the significant yield increases for all the cyclosulfamuron plus pendimethalin treatments

The commercial standard, thiobencarb/propanil ready mixture also provided complete control of sedges and BLWs, but not against the grass weeds like *Echinochloa crus-galli* and *Leptochloa chinensis*. The level of control was clearly inferior to the cyclosulfamuron and pendimethalin tank mixtures.

Table 1. Efficacy of cyclosulfamuron and pendimethalin tank mixtures against various weeds in wet-sown direct-seeded rice in Suphan Buri, Thailand, 1996 and 1997 cropping seasons.[1]

Treatment	Dosage (gai/ha)	Appl'n Timing (DAS)	Mean % Weed Control At 60 DAA			Grain Yield (tons/ha)
			Grasses	Sedges	BLWS	
Cyclosulfamuron + Pendimethalin	20 + 375	8	89	100	100	5.75
Cyclosulfamuron + Pendimethalin	20 + 750	8	92	100	100	5.6
Cyclosulfamuron + Pendimethalin	25 + 375	8	95	100	100	5.5
Cyclosulfamuron + Pendimethalin	25 + 750	8	95	100	100	5.65
Cyclosulfamuron + Pendimethalin	40 + 375	8	84	100	100	5.5
Cyclosulfamuron + Pendimethalin	40 + 375	8	89	100	100	5.7
Thiobencarb/ Propanil EC	1333/667	8	83	100	100	5.75
Hand Weeding[2]	-	-	(13)	(< 1)	(< 1)	5.15
Untreated Check[2]	-	-	(38)	(1)	(2)	2.7

[1]Average of 2 trials. [2]Numbers in parenthesis are % ground cover of weeds.
Grasses- *Echinochloa crus-galli, Leptochloa chinensis, Ischaemun rugosum*
Sedges- *Fimbristylis millaceae, Cyperus difformis*
BLWS- *Sphenoclea zeylanica*

Table 2. Efficacy of cylosulfamuron and pendimethalin tank mixtures against various weeds in wet-sown direct-seeded rice from two trials in Suphan Buri, Thailand, 1996 and 1997 cropping seasons.[1]

Treatment	Dosage (gai/ha)	Appl'n Timing (DAS)	Mean %Weed Control At 60 DAA			Grain Yield (tons/ha)
			Grasses	Sedges	BLWS	
Cyclosulfamuron + Pendimethalin	20 + 375	12	82	100	100	5.60
Cyclosulfamuron + Pendimethalin	20 + 750	12	89	100	100	5.35
Cyclosulfamuron + Pendimethalin	25 + 375	12	86	100	100	5.05
Cyclosulfamuron + Pendimethalin	25 + 750	12	93	100	100	5.90
Cyclosulfamuron + Pendimethalin	40 + 375	12	93	100	100	5.45
Cyclosulfamuron + Pendimethalin	40 + 375	12	94	100	100	5.70
Thiobencarb/Propanil	1333/667	12	78	100	100	5.10
Handweeding[2]	-	-	(8)	(1)	(< 1)	5.25
Untreated Check[2]	-	-	(40.5)	(2.5)	(2.0)	2.50

[1]Average of 2 trials. [2] Numbers in parenthesis are % ground cover of weeds.
Grasses- *Echinochloa crus-galli, Leptochloa chinensis, Ischaemun rugosum*
Sedges- *Fimbristylis miliaceae, Cyperus difformis*
BLWS- *Sphenoclea zeylanica*

Table 3. Phytotoxicity of cyclosulfamuron and pendimethalin tank mixtures on wet-sown direct-seeded rice in Suphan Buri, Thailand, 1996 and 1997 cropping seasons[1]

Treatment	Rate (gai/ha)	Mean % Phytotoxicity at 7, 15, 30 DAA					
		Application Timing at 8 DAS			Application Timing at 12 DAS		
		7DAA	15DAA	30DAA	7DAA	15DAA	30DAA
Cyclosulfamuron + Pendimethalin	20 + 375	25	10	0	19	5	0
Cyclosulfamuron + Pendimethalin	20 + 750	37.5	20	5	25.5	10	0
Cyclosulfamuron + Pendimethalin	25 + 375	24.5	10	0	19	5	0
Cyclosulfamuron + Pendimethalin	25 + 750	39	20	5	26.5	10	0
Cyclosulfamuron + Pendimethalin	40 + 375	25.5	10	0	19	5	0
Cyclosulfamuron + Pendimethalin	40 + 750	39	20	5	27	10	0
Thiobencarb/ Propanil	1333/667	30	10	0	20	10	0
Handweeding	-	0	0	0	0	0	0
Untreated Check	-	0	0	0	0	0	0

[1]Average of two trials.
Phytotoxicity assessment using 0 to 100 scale; 0% = no injury; 100% = complete kill

Malaysia. Cyclosulfamuron and pendimethalin tank mixtures were most effective at 20 + 750 gai/ha when applied at 5 DAS (Table 4). However, it was only moderately effective against the same weeds when applied at the later timing of 10 DAS. This indicates that the latest application timing for effective grass control could be done only at 8 DAS. Sedges and BLWs were effectively controlled regardless of timing and dose rates. For cost-effective and broad spectrum weed control, overall data would suggest the optimum rate to be 20 + 500 gai/ha at an application timing of between 5 to 8 DAS. This recommendation is just as good as the ready mixture of thiobencarb/propanil and better than propanil alone. Propanil alone did not provide adequate control of BLWs. Yield data among herbicide treatments did not differ much from each other but significantly 2-3x better than the untreated check.

The cyclosulfamuron and pendimethalin tank mixtures were only slightly phytotoxic to wet-sown direct-seeded rice (Table 5). The degree of phytotoxicity significantly decreased at later application timings.

Table 4. Efficacy of cyclosulfamuron and pendimethalin tank mixtures against various weeds in wet-sown direct-seeded rice at 35-60 DAA in Muda Area, Malaysia[1].

Treatment	Dosage (gai/ha)	Appl'n Timing (DAS)	Mean % Weed Control at 35-60 DAA			Grain Yield (tons/ha)
			Grasses	Sedges	BLWS	
Cyclosulfamuron + Pendimethalin	20 + 500	5	82	89	91	5.0
Cyclosulafamuron + Pendimethalin	20 + 750	5	97	87	93	5.1
Cyclosulafamuron + Pendimethalin	20 + 500	8	89	93	90	5.1
Cyclosulafamuron + Pendimethalin	20 + 750	8	87	93	91	5.1
Cyclosulafamuron + Pendimethalin	20 + 500	10	69	97	89	5.2
Cyclosulafamuron + Pendimethalin	20 + 750	10	69	96	85	5.1
Thiobencarb/Propanil	1000/500	5	89	93	91	5.3
Propanil	3000	14	87	87	67	5.1
Untreated Check	-	-	45	23	15	1.8

[1]Average of 4 trials.
Grasses-*Echinochloa crus-galli*
Sedges-*Cyperus iria, C. difformis, Fimbristylis millaceae*
BLWs-*Ludwidgia hysopifolia*

Table 5. Phytotoxicity of cyclosulfamuron and pendimethalin tank mixtures on wet-sown direct-seeded rice in Muda Area, Malaysia.

Treatment	Dosage (gai/ha)	Appl'n Timing (DAS)	Mean Percent(%) Phytotoxicity		
			10 DAA	14 DAA	35 DAA
Cyclosulfamuron + Pendimethalin	20 + 500	5	10	0	0
Cyclosulfamuron + Pendimethalin	20 + 750	5	10	0	0
Cyclosulfamuron + Pendimethalin	20 + 500	8	5	0	0
Cyclosulfamuron + Pendimethalin	20 + 750	8	5	0	0
Cyclosulfamuron + Pendimethalin	20 + 500	10	3	0	0
Cyclosulfamuron + Pendimethalin	20 + 750	10	5	0	0
Thiobencarb/Propanil EC	1000/500	5	5	0	0
Propanil EC	3000	14	12	0	0
Untreated Check	-	-	0	0	0

[1]Average of 4 trials.
Phytotoxicity assessment based on % thinning and stunting; 0% = no injury, 100% = complete kill

Indonesia. Cyclosulfamuron + pendimethalin tank mixtures at 30+330 gai/ha provided consistent and excellent control of the four most dominant weeds in West Java area: *Cyperus* spp, *Fimbristylls littoralis*, *Monochoria vaginalis* and *Marsilea crenata* (Table 6). Reduced efficacy against *M. crenata*, however, was obtained when the tank-mix rate of cyclosulfamuron was lowered from 30 to 20 gai/ha although the efficacy against the other three weed species still remained excellent. Metsulfuron-methyl as the standard check provided acceptable to good control of the four weeds but was clearly inferior to the cylosulfamuron + pendimethalin treatments. Grain yield among herbicide treatments did not differ much but it was higher on plots treated with cyclosulfamuron + pendimethalin mixtures.

The population level of *Echinochloa* spp. and other grass weeds was very low in the West Java area, hence, no grass control assessment was done in these trials.

In terms of crop selectivity, cyclosulfamuron + pendimethalin treatments were completely safe to transplanted rice seedlings (Table 7). On the other hand the standard check was moderately phytototoxic, but complete recovery was observed 24 days after application.

Table 6. Efficacy of cyclosulfamuron and pendimethalin tank mixtures against various weeds in lowland transplanted rice in West Java areas, Indonesia. Jan-May 1998 cropping season.[1]

Treatment	Dosage (gai/ha)	Appl'n Timing (DAS)	Mean % Weed Control at 56 DAA				Grain Yield (tons/ha)
			Sedges		Broadleaves		
			Cyperus spp.	*Fimbristylis littoralis*	*Marsilea crenata.*	*Monochoria vaginalis*	
Cyclosulfamuron + Pendimethalin	20 + 330	3	95	97	53	97	4.85
Cyclosulfamuron + Pendimethalin	30 + 330	3	95	100	88	100	4.91
Metsulfuron-methyl + 2,4-D amine	4 + 720	15	80	83	71	72	4.48
Handweeding (2x)	20 + 750	-	(10)[2]	(12)	(10)	(16)	4.60
Untreated Check	-	-	(20)	(24)	(17)	(36)	3.82

[1]Average of 3 trials.
[2]Figures in parenthesis are % weed cover

Table 7. Phytotoxicity of cyclosulfamuron and pendimethalin tank mixtures on lowland transplanted rice in West Java area, Indonesia.

Treatment	Dosage (gai/ha)	Appl'n Timing (DAT)	Phytotoxicity Rating		
			7 DAA	14 DAA	24 DAA
Cyclosulfamuron + Pendimethalin	20 + 330	3	0	0	0
Cyclosulfamuron + Pendimethalin	20 + 750	3	0	0	0
Metsulfuron-methyl + 2,4-D amine	1000/500	15	2	1	0
Hand weeding(2x)	3000	-	0	0	0
Untreated Check	-	-	0	0	0

[1]Average of 4 trials.
Phytotoxicity rating based 0 to 1 scale; 0 = no injury, 4 = complete kill

Philippines. Cyclosulfamuron and pendimethalin tank mixtures at 20-30 + 375 gai/ha provided broad spectrum control of grasses, sedges and BLWs (Table 6). The mixtures when applied at 5 DAS were more effective against the grass weeds, *Echinochloa* and *Leptochloa spp*, than when applied at 10 DAS. Sedges and BLWs were completely controlled regardless of dose rates and application timing. The level of control against all weeds was generally similar to the safened pretilachlor but superior to the ready mixture of butachlor/propanil which appeared weak against the grass weeds. Grain yield was higher on all cyclosulfamuron + pendimethalin and pretilachlor treatments, which was about 100% more than the untreated check.

The mixtures when applied at 5 DAS produced phytotoxicity early on but decreased significantly at 21 DAA (Table 7). Phytotoxicity was not an issue when the mixtures were applied at 10 DAS. These findings led to fine tuning trials using the optimum rate of 25 + 330 gai/ha and application timing of 7-10 DAS. In these trials, the outstanding efficacy of the mixtures has been confirmed (Table 8). Phytotoxicity was only slight and the affected seedlings fully recovered 1-2 weeks after application (Table 9).

Table 8. Efficacy of cyclosulfamuron and pendimethalin tank mixtures against various weeds in wet-sown direct-seeded rice in Luzon and Visayas, Philippines, 1996 cropping season.[1]

Treatment	Rate (gai/ha)	Appl'n Timing (DAS)	Mean % Weed Control At 45 DAS			Grain Yield (tons/ha)
			Grasses	Sedges	BLWS	
Cyclosulfamuron + Pendimethalin	20+ 375	5	91	100	100	4.80
Cyclosulfamuron + Pendimethalin	30 + 375	5	94	100	100	5.02
Cyclosulfamuron + Pendimethalin	20 + 375	10	82	100	100	4.54
Cyclosulfamuron + Pendimethalin	30 + 375	10	89	100	100	4.53
Pretilachlor EC/Safener	300	3	87	97	100	4.70
Butachlor/ Propanil EC	350/350	6	67	97	99	3.73
Untreated Check	-	-	0	0	0	2.42

[1]Average of 3 trials.
Grasses-*Echinochloa crus-galli, E. glabrescens, Leptochloa chinensis*
Sedges-*Cyperus iria, C. difformis, Fimbristylis littoralis*
Broadleaves-*Sphenoclea zeylanica, Monochoria vaginalis*

Table 9. Phytotoxicity of cyclosulfamuron and pendimethalin tank mixtures on wet-sown direct-seeded rice in Luzon and Visayas, Philippines, 1996 cropping seasons[1]

Treatment	Dosage (gai/ha)	Appl'n Timing (DAS)	Mean Percent(%) Phytotoxicity		
			7 DAA	14 DAA	21 DAA
Cyclosulfamuron + Pendimethalin	20 + 375	5	15	15	5
Cyclosulfamuron + Pendimethalin	25 + 375	5	20	15	10
Cyclosulfamuron + Pendimethalin	20 + 375	10	0	0	0
Cyclosulfamuron + Pendimethalin	30 + 375	10	0	0	0
Pretilachlor EC/Safener	300	3	0	0	0
Butachlor/Propanil EC	350/350	8	0	0	0
Untreated Check	-	-	0	0	0

[1]Average of 3 trials.
Phytotoxicity assessment based on % thinning, stunting and yellowing of seedlings; 0% = no injury, 100% = complete kill

Table 10. Efficacy of cyclosulfamuron and pendimethalin tank mixtures against various weeds in wet-sown direct-seeded rice from three trials in Nueva Ecija, Philippines, 1998 cropping season.[1]

Treatment	Rate (gai/ha)	Appl'n Timing (DAS)	Mean % Weed Control at 60 DAA			Grain Yield (tons/ha)
			Grasses	Sedges	BLWS	
Cyclosulfamuron + Pendimethalin	25 + 330	7	96	99	99	4.65
Cyclosulfamuron + Pendimethalin	25 + 330	10	88	99	99	4.65
Pretilachlor ECSafener	300	3	95	99	99	4.79
Butachlor/ Propanil EC	350/350	6	88	99	99	4.48
Untreated Check	-	-	0	0	0	3.03

[1]Average of 3 trials.
Grasses- *Echinochloa crusgalli, E. glabrescens, Leptochloa chinensis*
Sedges-*Cyperus iria, Cyperus difformis, Fimbristylis littoralis*
BLWS-*Sphenoclea zeylanica, Monochoria vaginalis*

Table 11. Phytotoxicity of cyclosulfamuron and pendimethalin mixtures on wet-sown direct-seeded rice in Luzon and Visayas, Philippines, 1998 cropping seasons.[1]

Treatment	Dosage (gai/ha)	Appl'n Timing (DAS)	Mean% Phytotoxicity		
			7 DAA	14 DAA	21 DAA
Cyclosulfamuron + Pendimethalin	25 + 330	7	9	2	0
Cyclosulfamuron + Pendimethalin	25 + 330	10	7	<1	0
Pretilachlor EC/ Safener	300	3	<1	0	0
Butachlor/ Propanil EC	350/350	8	0	0	0
Untreated Check	-	-	0	0	0

[1]Average of 3 trials.
Phytotoxicity assessment based on % thinning, stunting and yellowing of seedlings; 0% = no injury, 100% = complete kill

Conclusions

Cyclosulfamuron and pendimethalin mixtures offer excellent, broad spectrum and residual control of *Echinochloa* spp. and other economically important lowland weed species including: *Leptochloa chinensis, Ischaemun rugosum, Monochoria vaginalis, Sphenoclea zeylanica, Fimbristylis* spp., and *Cyperus* spp. The superior overall performance of the mixture gives rice farmers a new and superior option for cost-effective weed control compared to currently available rice herbicide programs. Follow-up herbicide application or additional hand-weeding are no longer necessary where cyclosulfamuron and pendimethalin are used, thus giving considerable cost and labor-saving benefits to the rice farmers.

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EFFECTS OF SEEDING RATE AND CULTIVAR OF FIELD PEA ON THE WEED INCIDENCE AND PRODUCTIVITY OF INTERCROPS OF FIELD PEA AND CANOLA

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Abstract: Effects of seeding rate and cultivar of field pea on the weed incidence and productivity of intercrops of field pea and canola were studied in a field experiment conducted at Northam, Western Australia [31^0 43' S, 116^0 41' E, altitude 150m] from June to November 1998. Intercropping with canola significantly lowered the number of weeds/m^2 and dry weight of weeds compared to the pure stand of field pea. Increasing the seeding rate of field pea resulted in the reduction in the number of weeds/m^2 and dry weight of weeds. The seeding rate of 80 kg/ha recorded significantly lower number of weeds/m^2 and weed dry weight than the seeding rate of 40 kg/ha. Intercropping significantly reduced the number of weeds/m^2 in both field pea cultivars. However, the reduction was greater in intercrops with cv. Laura [tall] than with cv. Magnet [semi-leafless]. Intercropping significantly reduced the weed dry weight of intercrops with both cultivars. Better smothering of weeds by intercrops with the seeding rate of 80 kg/ha and tall field pea cultivar, Laura, can be attributed to the higher leaf area index achieved by this treatment. Intercrops of field pea and canola were more productive than their pure stands. Intercrops of 80 kg/ha of field pea cv. Laura and 6 kg/ha of canola recorded the highest yield of 2.89 t/ha and the highest Land Equivalent Ratio of 1.79 showing that this intercrop yielded 79% more than the mean yield of the pure stands.

Key words : Intercropping, weed incidence, seeding rate and cultivar of field pea, canola, productivity

Introduction

Weed interference is one of the main constraints to crop growth and yield. Use of herbicides to control weeds have negative effects on the environment, high cost, problem of personal safety, and often being crop specific [Lemerle and Hinkley, 1991; Zuofa, Tariah and Isirimah, 1992; Itulya and Aguyoh, 1998]. Intercropping has been reported to achieve more efficient weed control than pure stands of component crops [Altieri and Liebman, 1986; Weil and McFadden, 1991; Zuofa, Tariah and Isirimah, 1992]. The efficiency of intercrops in controlling weeds is affected by various agronomic practices including crop cultivar [Malik, Swanton and Michaels, 1993; Monks and Oliver, 1988] and seeding rate [Mohler and Liebman, 1987; Weil and McFadden, 1991]. This paper reports a study on the effects of seeding rate and cultivar of field pea [*Pisum sativum* L.] on the weed incidence and productivity of intercrops and pure stands of field pea and canola [*Brassica napus* L.] in the Mediterranean environment of the central grainbelt of Western Australia.

Material and methods

Experimental treatements and design

The experimental treatments were, all possible combinations of two field pea cultivars, Laura and Magnet and three field pea seeding rates, 40, 80 and 120 kg/ha in pure stands and in intercrops with canola at 6 kg/ha, and a corresponding pure stand of canola. These treatment combinations were arranged in a randomised complete block design with five replications. Individual plot size was 2.0 m x 8.0 m.

Establishment and management

The experimental site was cultivated to a depth of 15 cm on 25 May 1998 and was limed at the rate of 1.0 t ha^{-1} on 28 May 1998. The site was sprayed with knockdown herbicide Roundup at the rate of 800 ml ha^{-1} on 5 June 1998. Pure stands and intercrops of field pea cvv. Laura and Magnet with various seeding rates and 6 kg ha^{-1} of canola cv Karoo were sown on 8 June 1998. Field pea was inoculated with group E-rhizobium before sowing. Superphosphate at the rate of 200 kg ha^{-1} and urea at the rate of 76 kg ha^{-1} were top dressed and harrowed at the time of sowing. Another 76 kg ha^{-1} of urea was applied along the rows of canola on 23 July. At the flowering stage of canola, aphids were controlled by spraying with Endosulfan at the rate of 2.1 l ha^{-1}.

Observations and records

At 95 DAS [flowering stage of field pea and canola], weeds from four, 1 m^2 areas were removed from each plot, counted, then dried at 75°C for 48 hours and weighed. Leaf area index of the crop was determined using a 10 plant sample of each crop from each plot. Grain yield was determined by harvesting an area of 4 m^2 from each plot at the physiological maturity of canola at 16 November 1998. Productivity of intercrops was assessed using Land Equivalent Ratio [LER]. LER = Lp + Lc, where Lp = Grain yield of field pea in intercrop/ Grain yield of field in pure stand, and Lc = Grain yield of canola in intercrop/ Grain yield of canola in pure stand.

Results

Weed density and dry weight

The major weeds that interfered in the experiment were barley grass [*Hordeum leporinum* Link], capeweed [*Acrtotheca calendula* (l.) Levyns], clover [*Trifolium spp*], medics [*Medicago spp*], doublegee [*Emex australis* Steinh] and wild radish [*Raphanus raphanistrum* L.]. These species constituted over 75% of the total weed population.

Intercrops of field pea with canola significantly reduced the number of weeds per m^2 compared to the pure stands [P<0.01, Table 1]. Field pea cvv. Laura and Magnet in intercrops significantly reduced the number of weeds per m^2 by 41% and 23% respectively compared to the corresponding pure stands. Seeding rate of 80 kg/ha recorded the lowest number of weeds per m^2 which was significantly lower than that of the lower seeding rate of 40 kg/ha.

Weed dry matter yield of 110.4 and 167.9 g/m^2 was recorded in pure stands of field pea cvv. Laura and Magnet respectively. These were significantly higher than the corresponding intercrops and pure stand of canola [P<0.01, Table 1]. In both cropping systems, weed dry matter yield was lowest at the field pea seeding rate of 80 kg/ha [Table 1].

Grain yield

Grain yield of intercrops of field pea and canola was consistently higher than that of the pure stands. Intercrops of 80 kg/ha of field pea cv. Laura and 6 kg/ha of canola recorded the highest yield of 2.88 t/ha which was significantly greater than that of the corresponding pure stands [P<0.01, Table 2]. Increasing seeding rate of field pea to 120 kg/ha significantly reduced the grain yield of the intercrops [Table 2].

Intercrops of field pea and canola at all seeding rates produced LERs greater than unity [P<0.01, Table 2]. In consistent with grain yield, the highest LER of 1.79 was recorded by the intercrop of 80 kg/ha of field pea and 6 kg/ha of canola.

Total LAI of intercrops of field pea and canola were significantly greater than that of their pure stands [P<0.01, Table 2]. Intercrops of 80 and 120 kg/ha of field pea and 6 kg/ha of canola recorded significantly higher LAI than the intercrops of 40 kg/ha of field pea and 6 kg/ha of canola.

Table 1. Effects of seeding rate and cultivar of field pea on the number of weeds per m^2 and dry matter yield of weeds of intercrops and pure stands of field pea and canola at 95 days after sowing

Treatments	Number of weeds per m^2	Dry matter yield of weeds [g/m^2]
40 kg ha^{-1} of field pea	62.08 b	139.80 b
80 kg ha^{-1} of field pea	45.41 a	76.07 a
120 kg ha^{-1} of field pea	49.16 ab	99.54 ab
LSD [P≤0.05]	13.49	42.82
Pure stand of canola	41.66 a	69.26 a
Pure stand of Laura	62.77 b	110.39 b
Pure stand of Magnet	61.66 b	167.90 b
Intercrop of Laura and canola	37.22 a	73.26 a
Intercrop of Magnet and canola	47.22 a	69.00 a
LSD [P≤0.05]	12.18	33.49
Degree of significance	P<0.01	P<0.01

Values in columns and within the same treatment followed by the same letter are not significantly different at P≤0.05 as determined by LSD

Table 2. Effects of seeding rate and cultivar of field pea on the grain yield, Land Equivalent Ratio and Leaf Area Index of field pea and canola in intercrops and pure stands

Cropping system	Cultivar	Seeding rate	Grain yield [t ha^{-1}]	LER	LAI
Pure stands	Laura	40 kg ha^{-1}	0.53 a	-	1.55 ab
		80 kg ha^{-1}	1.05 b	-	3.21 b
		120 kg ha^{-1}	0.95 b	-	5.43 c
	Magnet	40 kg ha^{-1}	0.42 a	-	1.04 a
		80 kg ha^{-1}	0.92 b	-	2.41 a
		120 kg ha^{-1}	0.85 b	-	3.29 b
Intercrops	Laura	40 kg ha^{-1}	2.44 de	1.64 b	5.22 c
		80 kg ha^{-1}	2.88 e	1.79 b	7.86 d
		120 kg ha^{-1}	2.38 d	1.58 b	9.13 d
	Magnet	40 kg ha^{-1}	2.32 d	1.59 b	5.27 c
		80 kg ha^{-1}	2.68 e	1.67 b	6.54 cd
		120 kg ha^{-1}	2.00 c	1.28 a	7.80 d
Pure stands	Canola	6 kg ha^{-1}	2.17 cd	-	4.68 bc
LSD [P≤0.05]			0.26	0.24	1.89
Degree of significance			P<0.01	P<0.01	P<0.01

Values in columns and within the same crop followed by the same letter are not significantly different at P≤0.05 as determined by LSD

Discussion

Weed suppression

The better weed control achieved by intercrops over the pure stands of field pea and canola can be attributed to the faster and more complete ground cover provided by the intercrop canopy compared to the slower and less complete ground cover provided by the pure stands. The present results are in agreement with previous studies where intercrops were reported to be more efficient in smothering weeds than pure stands [Altieri and Liebman, 1986; Weil and McFadden, 1991; Zuofa, Tariah and Isirimah, 1992]

Increasing the seeding rate of field pea from 40 to 80 kg/ha increased the weed smothering ability of intercrops and pure stands of field pea and canola. This is to be expected due to the increase in plant density which would have hastened the canopy closure thereby enhancing the weed smothering ability of intercrops and pure stands. Similar results have been reported in previous studies [Weil and McFadden, 1991; Zuofa, Tariah and Isirimah, 1992]. However, increasing the seeding rate of field pea from 80 to 120 kg/ha did not increase weed smothering effect of intercrops and pure stands despite further increase in plant density, which is contrary to the results reported in previous studies [Mohler and Liebman, 1987; Malik, Swanton and Michaels, 1993].

In intercrops, field pea cv. Laura smothered weeds better than cv. Magnet. This can be attributed to the fact that the former is a tall cultivar which develops a greater leaf area index and forms a canopy cover faster as opposed to the latter which is a shorter semi-leafless cultivar having a lower leaf area index and forming a canopy cover slower. These attributes of the canopy architecture may have conferred intercrops with cv. Laura a greater competitive ability to smother weeds than those with cv. Magnet. Studies by Malik, Swanton and Michaels [1993] have shown similar effects of cultivar on the weed smothering ability of intercrops.

Productivity of Intercrops

Intercrops of field pea and canola was more productive than the pure stands in terms of grain yield and LER with the intercrop of 80 kg/ha of field pea cv. Laura and 6 kg/ha of canola recording the highest yield of 2.88 t/ha and the highest LER of 1.79. LER of 1.79 indicates a 79% yield advantage of the intercrop over the mean yield of the pure stands of field pea and canola. This can be attributed to the more efficient use of light, water and nitrogen by the intercrops compared to the pure stands [P. Soetedjo, unpublished]. These results confirm previous studies on intercropping which reported enormous yield advantage of intercrops over pure stands which have been attributed to more efficient use of environmental resources by the intercrops [Ofori and Stern, 1987; Jena and Misra, 1988].

Acknowledgements : We wish to thank Ms Tammi Compton for technical assistance.

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EFFECTS OF CONTINUOUS NO-TILLAGE APPLIED GLYPHOSATE HERBICIDE ON WEED COMMUNITY OF IRRIGATED LOWLAND RICE

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Shifting weed community as due to continuous no-tillage applied Glyphosate herbicide (Polaris 240 AS) at 1.44 kg ae/ha and compared with farmer's practice (intensive tillage) was succeessively field evaluated at farmer's field of Solok (West Sumatera), Indonesia from wet season (WS) 1994/95 to WS 1998 (ten cropping seasons). Initial predominant-target weed species to be controlled on no-tillage system was *Fimbristylis littoralis* Gaudich (sedge community) and seconded by *Echinochloa colona* L.Link. (grass community). Weed species was predominantly shifted to *Ischaemum timorense* Kunth. (grass community which initially non-target species) after five cropping seasons and might withstand upto tenth cropping season. Continuous no-tillage systems improved growth of irrigated lowland rice and produced relatively higher grain yield than farmer's practice. Therefore, no-tillage systems which applied with Glyphosate herbicide at recommended rate was still applicable and recommendable up to ten succeessive planting seasons.

Keywords;Continuous no-tillage, lowland rice, weeds, Glyphosate.

INTRODUCTION

Conventional (intensive) tillage, one of ten pillars in increasing productivity of irrigated lowland rice is still a common practice by farmers in Indonesia. The objectives of intensive tillage are to puddle the soil that easiable transplanting, be part of weed control and incorporated organic matter (De Datta, 1981). Furthermore, the method is recorded as labors, time and cost consuming as well as irrigation water, and soil degradation by time prior to rice transplanting (Lamid and Hermawan, 1996; Utomo *et al*, 1994). Therefore, an altenative landpreparation method that environment and resources conservation instead of increasing farmer's income is badly needed to be explored.

Conservation tilllage such as no-tillage systems may be approachable recommended to irrigated lowland rice cultivation. Practisation of the said technology is dicatated by the occurence of weed community development and ratoon regrowth after harvesting of previous rice crop and relied on the application of nonselective and

post emergence herbicides (Bangun 1995). Previous research results indicated that no-tillage applied herbicide controlled weeds; coneserved irrigartion water, labors, time and cost; increased planting indexes; and be able to be practiced by family labor in a large scale. Therefore. continuous practice of no-tillage using herbicide may shift weed community or resistance development of a certain species, and determine growth and yield of rice crop (Mercado,1979; Utomo *et al*, 1995).

Objectives of study were to evaluate shifting weed community by group, and response of growth and yield of irrigated lowland rice as due to continuous no-tillage applied Glyphosate herbicide.

MATERIALS AND METHODS

Field evaluations were conducted at farmer's field (FF) of Solok (West Sumatera), Indonesia from wet season (WS) 1994/95 to WS 1998 (ten-succeessive cropping seasons). Study area was characterized by semi-technical irrigated systems and alluvial soil.No-tillage applied Glyphosate herbicide (Polaris 240 AS) at recommended rate (1.44 kg ae/ha) and farmer's practice (intensive tillage) were tested using plot demonstration with three replications.

No-tillage systems followed that the area was kept dry to moist condition for 20 days after harvesting of previous rice crop, and then applied with herbicide in srayin volume of 500 l water/ha using knapsack sprayer (15-liter capacity) or 10 days before rice transplanting. Soil was kept dry for another 5 days and then flooded. Meanwhile, intensive tillage was done through plowing, harrowing and levelling.

Rice seedlings (cv. Cisokan) at 21-days old were transplanted on plot demonstration (3 seedlings/hill) and spaced 25 by 25 cm between and within crop rows and hills, respectively. Crop was fertilized with Urea, TSP and KCl at the rates of 200, 150 and 100 kg/ha, respectively. One-third of Urea, and all TSP and KCl were braodcasted at palnting. A one-half of the remaining Urea was topdressed at 21 and 42 days after transplanting (DAT). Carbofuron (17 kg/ha Curater 3-G) was also broadcasted at planting and periodical spraying of Chlorfiriphos (2 cc Kiltop/l water) was done to control insects infestation. Leaf or neck blast desease was controlled by spraying Isoprotiolan (2 cc Fujiwan/l water) at maximum tillering, booting and flowering stages. Menwhile, manual weeeding was done at 21 and 42 DAT.

Data collected were: initial weed commuity, weed dryweights by groups (grass, broadleaf and sedge) at 21 DAT (before first weedimg), growth and yield of irrigated lowland rice.

RESULTS AND DISCUSSION

Weeds

There were 12 weed species observed with visual distribution varied with species where 3, 7 and 3 belonged to grass, broadleaf and sedge groups, respectively (Table 1). Based on their visual distribution, the main targetted weed species to be controlled for no-tillage systems with Glyphosate herbicide application was *F. milliacea* (abundant), and then followed by *E. Colona*, *L. flava, M. vaginalis* and *S. juncoides* (respectively frequent). However, weed dry weight by group was predominated by grass and then sedges.

Table 1. Visual distribution of weed group and species dryweight before setting experiment, FF. Solok (West Sumatera), Indonesia WS 1994/95

Group/Species	Visual Distribution[1)]	Dry Weight of Weed Group (sqm)
A. Broadleaf		**84.7**
1. *Echinocloa colona* (L.) Link.	**	
2. *Ischaenum timorencse* Kunth.	*	
3. *Leersea hexandra* Sw	*	
B. Grass		**8.1**
4. *Limnocharis flava* (L.) Buch	**	
5. *Ludwigia octovalvis* (Jacq) Reven	*	
6. *Ludwigia ascendens* (L.) Hara	*	
7. *Monochoria vaginalis* (Burm. f) Presl.	**	
8. *Lindernia procumben* (Krock) Philicox		
9. *Marsilea crenata* Presl		
C. Sedge		**39.0**
10. *Fimbristylis littoralis* Gaundich	***	
11. *Cyperus halpan* L.	*	
12. *Scirpus juncoides* Roxb.	**	

1) *** = Abundant, ** = Frequent dan * = Rare

Dryweights of weed group by continuous application of Glyphosate herbicide from season to season on plots of no-tillage (NT) and Intensive tillage (IT) varied with cropping seasons (Table 2). For grass group, two species (more population of *I. timorense* than *L. hexandra*) were observed with their inconsistent total dryweights with succeeding cropping seasons; 0.00 to 23.36 g/sqm under no-tilage and 0.00 to 29.17 g/sqm for intensive tillage. However, average of 10-cropping seasons indicated that those weed dryweights were 8.47 g/sqm, more than those from intensive tillage plot (6.73 g/sqm).

Table 2. Dryweights of weed groups on continuous no-tillage applied Glyphosate herbicide before first weeding of respective planting seasons, FF. Solok (West Sumatera), Indonesia WS 1994/95-1998

Planting Season	Grasses (g/sqm)[1]		Broadleaf (g/sqm)		Sedges (g/sqm)[2]	
	NT	IT	NT	IT	NT	IT
I	13.80	0.00	5.40[3]	0.00	0.80	0.00
II	0.79	0.00	0.00	0.00	12.99	0.00
III	23.36	0.00	0.00	0.00	0.00	0.00
IV	0.00	0.00	0.00	0.90	0.00	0.00
V	9.44	9.75	0.00	0.00	0.20	0.00
VI	10.47	23.37	0.00	0.00	0.00	0.00
VII	18.77	29.17	0.00	0.00	0.00	0.00
VIII	0.00	0.00	0.00	0.00	0.0	0.00
IX	3.06	0.00	0.00	0.00	0.31	0.00
X	5.05	4.98	0.96[4]	0.00	0.92	3.00
Average	8.47	6.73	0.64	0.09	1.52	0.03

1) Population *I. timorense* > *L. hexandra*
2) Only *F. littoralis*
3) Individual *L. octovalvis* > *L. flava* > *M. vaginalis*
4) Individual *C. baghallensis* > *L. octovalvis*

Broadleaved weed species on no-tillage systems was still observed at planting season I which more individual numbers in order of *L. octovalvis, L. flava and M. vaginalis* with their total dryweights of 5.40 g/sqm (Table 2). Weeds diappeared up to planting season IX and then appeared at planting season X. This was due to those weed seeds were brought in irrigation water to plot demonstration. Meanwhile, broadleaved weed species on intensive tillage plot was occasionally observed only at planting season IV at light weight (0.90 g/sqm). Data generally stated that continuous no-tillage systems would eliminate existing broadleaved weed population (average of

total dryweight from ten-planting seasons were 0.64 g/sqm while on plot of intensive tillage were 0.09 g/sqm).

Dryweights of sedge weed group also varied with planting seasons and tillage systems which consisted only by one species, *F. littoralis* (initially was a targeted weed species to be controlled). The weed was inconsistently observed at a certain planting seasons under no-tillage systems while only at planting X of intensive tillage systems. Based on average dryweight of ten-planting seasons indicated that no-tillage plot was 1.52 g/sqm and 0.03 g/sqm from intensive-tillage plot. They both were lower weight per unit area which assumed that unaffected to rice crop.

Performance of weed dryweight on no-tillage plot showed that weed species belonged to grass group, paricularly predominated by *I. timorense* (based on its dryweight), weighter than sedge and broadleaved weed groups. Therefore, initial predominant-weed species (*F.littoralis*) was shihted to *I. timorense* starting from planting season V onward. This was due to nodal stolon of the said weed species was capable of regrowing to produce new sprouting shoot as well as root since it was approaching soil surface. On the other hand, it was assumed that there was a specific enzym inside the node which capable of resisting mode action of herbicide. eventhough formerly expanded leaves were toxified by Glyphosate herbicide.

Grain Yield of Rice Crop

Rice grain yields varied with planting seasons and tillage systems (Table 3). No-tillage rice cultivation produced grain yields of 2133 to 5400 kg/ha depending on seasonal cropping, while on intensive tillage were 1517 to 5007 kg/ha. Data indicated that no-tillage systems seemed to be profitable in producing obtainable grain yield rather than intensive tillage. Data also indicated that grain yields of rice during dry season were much higher by no-tillage cultivation than intensive tillage one. This probably was due to lessened soil evaporation from undisturbed soil of no-tillage systems and increased water use efficiency by crop and nutrient uptake as well.

Table 3. Grain yields of rice crop on continuous no-tillage applied Glyphosate herbicide, FF: Solok (West Sumatera), Indonesia WS 1994/95-1998.

Planting Season	Grain Yield (kg/ha)[1)]	
	NT	IT
I. WS 94/95	2970	2830
II. DS 1995	2133	1517
III. WS 1995	2637	2770
IV. WS 95/96	3100	2517
V. DS 1996	4380	3233
VI. WS 96/97	4473	3263
VII. DS 1997	4413	3237
VIII. WS 97/98	4877	4067
IX. DS 1998	5400	5007
X. WS 1998	4727	4397
Average	3912	3284

1) 14% water content

Average of ten-planting seasons showed that no-tillage rice cultivation produced 3912 kg grain yield/ha, 628 kg or 19% higher than under intensive tillage cultivation. When they were seasonal observation which supported by obtainable grain yield, there were not decreasing or lower than intensive tillage (common farmer's practice). Data concluded that continuous no-tillage applied with Glyphosate herbicide et recommended rate was still applicable and might be recommendable up to ten-cropping seasons or presumably more.

CONCLUSION

Continuous no-tillage applied with Glyphosate herbicide to irrigated lowland rice cultivation shifted from grass, broadleaf and sedge weed group to relatively pure grass, particularly *I. timorense*. It was capable of regrowing from nodal stolo when approaching soil surface. The were no decreasing grain yield obtaiable of rice crop under no-tillage systems upto ten-cropping seasons. Therefore, it would be applicable and might be recommendable of continuous no-tillage irrigated lowland rice practice when applied with Glyphosate herbicide at recommended rate.

ACKNOWLEDMENT

The authors would like to extend their special appreciation and grateful to PT. Monagro Kimia, Jakarta through the contnuous assistant of Mr. Wisnu Hermawan (Product Development Executive Manager) in financial supporting this long-term field evaluation.

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ESTABLISHMENT OF IRRIGATED LOWLAND RICE UNDER ZERO AND CONVENTIONAL TILLAGE SYSTEMS IN THE PHILIPPINES

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Abstract: A long term trial to develop and evaluate methodology for zero-till establishment of lowland rice was established in 1998 at the International Rice Research Institute (IRRI). Zero-till crops were established with hand tractor mounted seeders, which placed the seed at 2-4 cm in either a narrow slit or furrow opened by a tine or a rotovator. Zero-till treatments were compared with conventional direct seeding on dry cultivated soil or direct wet seeding with pre-germinated seeds in puddled soil. Weed control using pre-emergence [butachlor, oxadiazon, pretilachlor] and post emergence [bentazon, cyhalofop butyl, 2,4-D] herbicides were evaluated under different crop establishment systems, and compared to handweeding and no weed control. Crop establishment at 21 days was similar for the zero-till and dry seeding and higher for wet seeding. Grain yields were similar from all crop establishment methods, but actual yields varied with different weed control treatments and greatly reduced where there was no weed control. Total weed weights did not vary much between establishment treatments within weed control treatments at 42-56 DAS or at maturity. Weeds were abundant where there was no weeding, with 3-4 dominant weeds in a group of 10-12 species in most treatments. *Fimbristyllis milliacea* and *Leptochloa chinensis* were major weeds under all establishment treatments , whilst *Cyperus difformis* and *S. maritimus* were abundant under wet seeding and *Echinocloa colona* and *L. octavalvis* were abundant on zero-till and dry seeded plots. Few weeds were present on any treatment with two handweedings. Herbicides generally reduced weeds, but there was considerable variation in control between herbicides and tillage treatments. Results suggest that zero-till technology have promise for establishment of irrigated rice and further research is being undertaken in this long-term trial to improve crop establishment, crop management and weed control for zero-till systems.

Keywords: zero-till, dry seeding

INTRODUCTION

The main benefits derived from tillage is the suppression of weed growth, control of volunteer plants (Smith, 1992) and to provide good soil tilth (soil structure) for crop growth before seeding. Several workers reported decrease in the number of weeds growing in association with transplanted rice with an increase in the number of preplanting harrowings and increased suppression of weeds in rice as the degree of tillage increased (Curfs, 1975).

Elias (1969) however reported that land preparation for rice could be reduced to one tillage operation without sacrificing grain yield if weeds were controlled prior to soil cultivation. It was reported that there were no differences in crop establishment, crop growth, and grain yield between rice crops grown with zero, minimum and conventional tillage (Mittra and Pierris, 1969). Mabbayad et. al (1968) found that grain yield, panicle number, and filled grain ratio were not significantly different with zero, minimum and conventional tillage. Seth et al. (1971) and other workers gave similar convincing results.

Many past and recent reports have indicated that zero or no-tillage techniques in transplanted rice, and wet-seeded rice are capable of replacing conventional operations (Mabbayad, 1968; Mabbayad and Buenacosa, 1967; Seth et al., 1971; Castin and Moody, 1985; Ardjasa et al, 1994; Utomo and Ardjasa, 1994). Probably the most important development of no-tillage techniques in rice are now taking place in the humid tropics where farms are small, water control with monsoonal floodings, and where equipment limitations are more severe (Watson and Allen, 1985). They also emphasized the need to provide a nearly complete control of the existing vegetation before crop emergence using non-selective herbicides particularly glyphosate. Failure to control weeds at the early stage will result to complete yield loss in zero and minimum tillage systems.

This experiment was conducted: 1) to identify efficient hand tractor mounted direct seeding planters appropriate under zero-till production in lowland irrigated rice 2) to determine the effects of different tillage systems and weed control strategies on weed growth and yield of lowland rice 3) to develop weed control strategies that will suit zero-till production in lowland irrigated rice.

MATERIALS AND METHODS

Under irrigated lowland rice condition, field trials were conducted at the International Rice Research Institute (IRRI) experiment station during the 1998 dry season and wet season (DS and WS) and 1999 dry seasons using a split-plot design with four replications. Tillage and crop establishment systems were assigned to main plots and weed control to sub plots.

Tillage, seeding method and weed control treatments

Four tillage/crop establishment systems were evaluated. These were: (a) Zero tillage (ZTCS or ZT1) - land was prepared by spraying glyphosate [N-(phosphonomethyl)glycine] at 1.0 (for 1998 DS and WS)- 2.0 (for 1999 DS only) kg a.i./ha 5 -10 days before sowing (using a six row hand tractor operated Chinese seeder) (b) zero tillage (ZTSS or ZT2) -land preparation same as (a) except that sowing was done with a two row hand tractor drawn slit seeder (c) dry seeding (CTDS or CT1) one plowing + 2-3 rotovations fb soil leveling, seeds were drilled manually in furrows (d) wet-seeding (CTWS or CT2) land was prepared under puddled condition, pre-germinated seeds (soaked for 24 hrs and incubated for 14 hrs) were broadcast evenly in the conventionally prepared wet seeded plots. After sowing, main plots a, b, and c were flash irrigated to saturate the soil and promote germination of rice seeds.

Four weed control treatments were assigned to sub-plots: (W1) No control (weedy check during 1998 DS/WS); oxadiazon was applied at 1.0-kg a.i./ha; 3 DAS for a, b, and c main plots and 6 DAS for the wet seeded plots [1999 DS]; (W2) - twice hand-weeding at 15 and 35 days after emergence (DAE) [1998 DS/WS and 1999 DS]; (W3) - butachlor [*N*-(buthoxymethyl)-2-chloro-*N*-2,6-diethylphenyl)acetamide] with safener at 2 kg a.i./ha applied pre-emergence 2 days after seeding during 1998 DS/WS; (W4) - the post-emergence herbicide applied was decided depending on the weed flora that would likely establish with the crop. Thus, bentazon (Basagran) at 2-kg a.i./ha was applied at 30 DAE [1998 DS]; cyhalofop-butyl at 100-g a.i./ha was applied 30 DAE followed by 2,4-D at 0.75-kg a.i./ha 2 days after [1998 WS]; Pretilachlor at 0.4 kg a.i./ha was sprayed 3 DAS for tillage a, b, and c and at 6 DAS in the wet seeded plots [1999 DS]. For the 1999 DS trial, all pre-emergence herbicides treatments were followed by bentazon at 2.0 kg a.i./ha at 30 DAE.

Seeding rate

A seeding rate of 100-kg seeds of IR72 was used in both trials. Both machine seeders [Chinese seeder and Slit seeder] were calibrated to deliver the desired seeding rate at time of sowing. Depths of seeding for both seeders were also adjusted to optimum planting depth (2-4 cm).

Fertilization and crop protection.

Initial application of fertilizer was at 14 DAS with 60-40-0 kg/ha N, P_2O_5, K_2O. Additional 40 kg and 20 kg N/ha were top-dressed at maximum and panicle initiation stages respectively. No amount of protection against snails and insect pests was done for both cropping seasons (1998 DS and WS) due to a pre-arranged agreement among researchers to protect the interest of an adjacent experiment (ecology of golden apple snails).

For the 1999 dry season trial fertilizer was first applied at 14 DAS at 30:20:0 N_2, P_2O_5, and K_2O. Top-dressing was done at the rate of 25:25:25 30 DAS. Additional fertilizer was top-dressed at 25 kg N at 40, 50 and 60 DAS. Molluscicide was sprayed at the early seedling stage of rice while insecticides were applied due to heavy stemborer infestation.

Weed flora.

The weed species associated with the different tillage/seedling establishment and weed control systems were determined at various stages of crop growth from two 0.5 x 0.5 m quadrats. The number of weed species were counted and classified into broad-leaved weeds, grasses and sedges, oven dried at

80 °C for 72 h and weight recorded. For the different weed species, relative dry weight (RDW) was determined by dividing dry weight per weed species by total dry weight and multiplying by 100.

Grain yield.

Grain yield was determined from two 2m x 5m area at the center of the plots. The yield samples were threshed, oven dried at 50 °C for 5 days, cleaned and weighed. Average grain yield from the two sampling areas was taken, corrected to 14% moisture content and expressed in t/ha.

RESULTS AND DISCUSSION

Effect of land preparation/method of seedling establishment and method of weed control on stand of irrigated lowland rice

Crop stand of irrigated lowland rice during 1998 dry and wet season trials was affected by method of land preparation and seeding method. Establishment of rice under conventional puddled soil condition was double than those in no-till and dry-seeded rice (Fig 1). Pre-germinated rice have a better chance of surviving compared to rice sown under upland type condition (dry seeding).

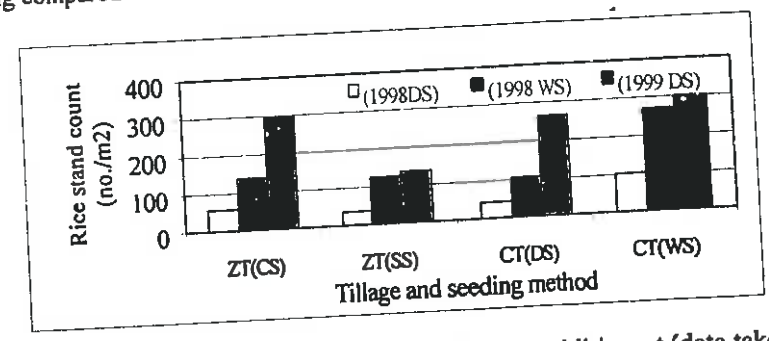


Figure 1. Effect of tillage and seeding method on crop establishment (data taken from hand-weeded plots) of irrigated lowland rice (IR72) at 21 days after emergence (DAE). IRRI. 1998-1999

Stand count of irrigated lowland rice at 21 DAE (during 1998 DS and WS) were similar in both zero tillage establishment systems and in conventional dry seeded rice. Low stand count was attributed to variability in seeding depth for both machine seeders and in furrow seeding resulting to poor seed germination. No significant differences were observed in all dry upland type seeding (sown using machine seeders and sown in furrows, dryland tillage) (Fig 1).

For the 1999 dry season trial, there was an improvement in the stand of irrigated lowland rice in all tillage systems, except those planted using the slit seeder in zero till plots (Fig 1). Rice seeds sown too deep in the soil (>2-4 cm) using the slit seeder could have germinated but failed to emerge successfully.

Effect of Land preparation on weed flora

No significant differences were noted in terms of weed weight at 42 DAE, however the composition of the weed flora differed as a result of land preparation. *E. colona, E. prostrata,* and *L. chinensis* increased in importance in all zero-till and dry-seeded plots particularly in the untilled ones. While *C. difformis* and *F. milliacea* increased in dominance in plots subjected to full cultivation. *L. octavalvis* was dominant in the dry-seeded plots while *S. zeylanica* became important only when plots were prepared under puddled condition. Until crop maturity, *F. milliacea* remained dominant in the full tillage plots and also increased in significance in the zero tilled plots (Fig.2).

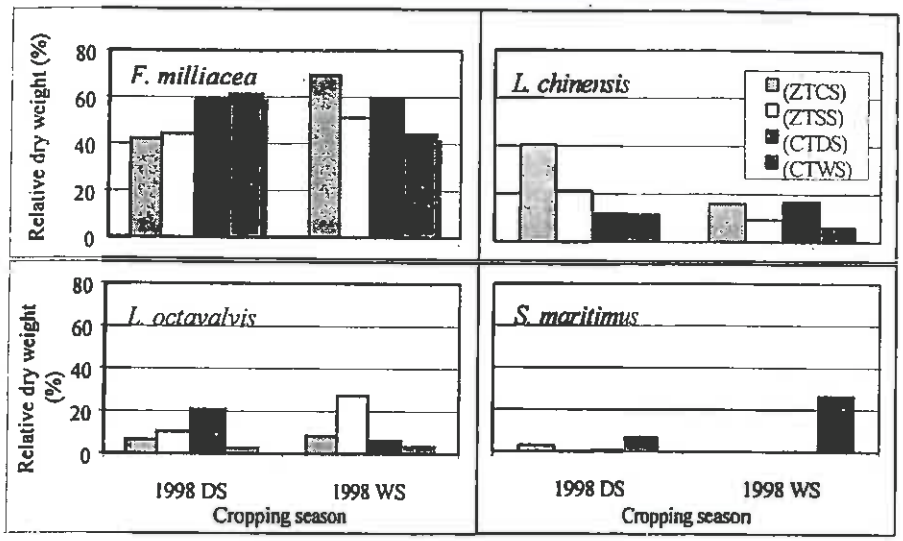


Figure 2. Effect of tillage and seeding method on weed weight of four major weed species associated with irrigated lowland rice in two cropping seasons.

Likewise, *L. chinensis* also maintained its importance later in the season. Occurrence of *C. difformis* decreased in cultivated plots while that of *L. octavalvis* increased in the zero-till plots. *S. maritimus*, which was irrelevant in the dry season, was added to the weed flora. An observation of particular importance was that as the degree of cultivation increased, *S. maritimus* became more important. Cultivation of the soil allowed more vegetative propagules of *S. maritimus* to resurface where favorable conditions break their dormancy rendering them viable to grow.

Effect of land preparation/method of seeding and weed control on weed growth and yield of irrigated lowland rice

In the 1998 DS trial, weed growth in the zero till plots was heavy and did not differ for all treatments at 42 DAE (Table 1a). Butachlor (with safener) applied pre-emergence gave only partial weed control in the zero tillage plots but effective in all cultivated plots. The presence of plant debris in the surface of the no-till plots at the time of herbicide application served as protective shield for the weed seedlings, thus escaping injury. Weed species controlled by butachlor were replaced by *S. maritimus* particularly in the tilled plots. Bentazon applied post emergence (30 DAS) on the other hand was effective for some period being a contact herbicide but its effect was not lasting. Bentazon (Basagran) controlled sedges and broadleaf weeds and was superior to butachlor in controlling *S. maritimus*. Hand weeding was delayed due to low weed density at 15 DAE and 35 DAE, thus the heavy weed weight at initial sampling (42 DAE). Twice hand weeding, though labor intensive and time consuming, however, proved to be efficient in controlling weeds in all tillage treatments. At crop maturity, the lowest weed weights were in the zero-till plots (data not shown).

Under conventional wet-seeding, yield from plots either hand-weeded or sprayed with butachlor were high but did not differ to plots sprayed with bentazon. With twice handweeding, yield from the ZT1 plot and from the CT1 plots were similar with those under wet seeding. However, if butachlor was applied as weed control in the ZT1 plots, yield can be comparable to yield of wet-seeded rice regardless of weed control used. In the absencce of any form of weed control yield reduction was higher in tilled plots. On the other hand bentazon failed to increase yield of zero-till lowland rice.

The following season (1998 WS) resulted to varying degree of differences in terms of weed control. Handweeding on time was excellent in controlling weeds and did not differ with butachlor applied pre-emergence across tillage (Table 1b). Soil moisture and the reduced amount of plant debris in the soil surface increased the herbicidal activity of butachlor in zero-till plots. *S.maritimus* left unchecked in the previous season contributed to the high weed weights recorded in the tilled plots treated with butachlor. Post emergence control of weeds with cyhalofop-butyl followed by 2,4-D gave inadequate control in the zero till plots yet remarkably better in the wet-seeded plot. In zero-till

Table 1. Weed weight at 42-56 DAE and grain yield at harvest as affected by tillage, seeding method and weed control in irrigated lowland rice (IR72). IRRI. 1998 DS/WS and 1999 DS.

1998 DRY SEASON

(1a)

Weed control	Land preparation/seeding method									
	Weed Weight (g/m2) - 42 DAE				w-mean	Grain yield (t/ha)				w-mean
	ZT1	ZT2	CT1	CT2		ZT1	ZT2	CT1	CT2	
W1	70.7a	91.4a	60.0ab	78.6a	75.2	1.5c	1.4c	.55c	1.2b	1.2
W2*	73.3a	61.2ab	79.5a	64.5a	69.6	3.5a	3.2ab	3.8a	4.2a	3.6
W3	64.8a	96.8a	18.7c	18.5b	49.7	3.8a	3.3a	2.8b	4.3a	3.6
W4	88.2a	39.8b	24.8bc	50.3ab	50.8	2.5b	2.6b	3.1ab	3.7a	2.9
T-mean	74.3	72.3	45.7	52.9		2.8	2.6	2.6	3.4	
			LSD (.05)					LSD (.05)		
2-T Means at each W			51.6					0.71		
2-W means at each T			36.0					0.66		

1998 WET SEASON

(1b)

Weed control	Land preparation/seeding method									
	Weed Weight (g/m2) - (50 DAE)				w-man	Grain yield (t/ha)				w-mean
	ZT1	ZT2	CT1	CT2		ZT1	ZT2	CT1	CT2	
W1	193.0a	140.0a	150.4a	125.0a	152.1	0.2b	0.1c	0.5c	0.9c	0.4
W2	8.0b	11.3c	4.8b	3.9b	7.0	2.1a	2.1a	2..2a	2.9ab	2.3
W3	20.18b	25.1bc	47.2b	68.3ab	40.2	1.8a	2.2a	1.5b	2.6b	2.1
W4	185.3a	91.5ab	50.3b	9.8b	84.9	1.8a	1.2ba	2ab	3.3a	2.0
T-mean	101.6	67.0	63.2	51.7		1.5	1.4	1.5	2.4	
			LSD (.05)					LSD (.05)		
2-T Means at each W			51.6					0.48		
2-W means at each T			36.0					0.40		

1999 DRY SEASON

(1c)

Weed control	Land preparation/seeding method									
	Weed Weight (g/m2) - 56 DAE				w-mean	Grain yield (t/ha)				w-mean
	ZT1	ZT2	CT1	CT2		ZT1	ZT2	CT1	CT2	
W1	33.4a	65.6b	18.4a	31.1a	3.1	3.7a	4.8a	4.7a	4.3a	4.4a
W2	9.7a	3.6c	9.8a	22.4a	11.37	4.2a	4.5a	5.2a	4.0a	4.5a
W3	22a	189.7a	34.8a	40.3a	71.67	3.6a	4.1a	4.3a	5.1a	4.0a
W4	5.8a	26.3c	11.6a	2.9a	11.65	4.0a	4.9a	4.6a	5.1a	4.6a
T-mean	17.7	72.3	18.6	24.2		3.9	4.9	4.7	4.6	
			LSD (.05)					LSD (.05)		
2-T Means at each W			39.5					ns		
2-W means at each T			41.3					ns		

Means in columns followed by a common letter are not significantly different at 5% (DMRT)

* Average of four replications

For tillage, seeding method and weed control treatments (please refer to materials and methodology)

*application delayed due to very low weed population at designated schedule of handweeding.

condition twice hand weeding and pre-emergence application of butachlor provided better weed control than sequential application of cyhalofop-butyl and 2,4-D.

Grain yield for the 1998 wet season trial was low due to lodging as a consequence of strong winds and heavy rains and lodging incidence was more serious in the zero-till plots. Grain recovery at harvest was low due to premature grain shattering brought about by strong winds. Weed control treatments did not differ. Yield did not differ in the zero-till and dry seeded plots but lower compared to the cultivated wet-seeded plot.

Herbicide treatments had significantly low yield in all zero-till and dry seeded plots. An exception was that in ZT2 plot treated with butachlor that yielded similarly with the CT2 plot treated with similar herbicide. In cultivated wet-seeded plots, sequential application with cyhalofop-butyl and 2,4-D gave yield that did not differ from plots twice handweeded. However, grain yield in all zero-till and dry-seeded plots hand-weeded twice was similar statistically. Plots with no weed control gave very little yield due to heavy weed growth.

In the 1999 dry season trial, yield from plots subjected to twice handweeding showed no significant differences from those treated with pre-emergence fb post-emergence herbicides regardless of tillage and seeding method (Table 1c). Inconsistencies were noted in the activity of herbicides particularly butachlor in the ZT2 (full zero tillage using the slit seeder) plots though consistently better and did not differ with other tillage systems.

Experiences and lessons learned from these trials indicate the promise of establishing lowland irrigated rice in zero till systems with the use of hand tractor mounted seeders provided good crop establishment while pre-planting and post-planting weeds are managed effectively. Glyphosate at 2 kg a.i./ha or higher rate was superior in controlling pre-seeding weeds and volunteer rice in zero till plots. Lower rate failed to provide acceptable vegetation control. Twice handweeding and sequential application of pretilachlor and bentazon were promising weed control strategies in zero-till systems. Under full zero-till condition enhancement in the activity of pre-emergence herbicides needs to be further looked into to minimize inconsistencies in weed control. Other herbicides or combinatios needs to be evaluated in future trials.

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IMPACT OF WEED CONTROL ON GROWTH AND YIELD OF URDBEAN (*Vigna mungo*)

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Abstract: A field investigation was carried out at Annamalai University Experimental Farm during 1997 to evaluate the effect of hand weedings and herbicides on the weed flora, growth and yield of urdbean (*Vigna mungo*). The experiment was conducted in a randomised block design replicated four times with seven treatments viz., weedy check, one hand weeding on 20 DAS, two hand weedings on 20 and 40 DAS, fluchloralin and pendimethalin each @ 0.5 and 1.0 kg/ha. All the weed control treatments significantly increased the growth and yield components and final yield of urdbean, attributable to reduced weed competition for nutrients, moisture, light and space. In respect of weed biomass and weed count, weedy check treatment recorded the highest value and twice hand weeding on 20 and 40 DAS gave the least value, followed by pendimethalin @ 1.0 kg/ha.

Key words: Urdbean, hand weeding, weed control efficiency, pendimethalin, fluchloralin

Introduction

Urdbean (*Vigna mungo*) is one of the most important pulse crop grown in South India. It is mostly cultivated in rice fallows. For exploitation of land and human resources, the utilization of such rice fallow land is very important. With the advent of short duration, drought resistant, photo and thermo-insensitive varieties, urdbean can be one of the ideal crop suitable for growing in rice fallows capitalising the residual soil moisture. However, the productivity of urdbean in rice fallows is very low. Among the various reasons for the low productivity, inadequate crop stand and higher weed competition are major constraints (Bayan and Gogoi, 1998). The emergence and rapid growth of weeds leads to severe crop weed competition, mainly for nutrients, particularly during the early stages of crop growth. The magnitude of losses due to weeds has been reported to the extent of 50 per cent (Vats and Sidhu, 1976). The present investigation was therefore undertaken to develop an effective and economical weed control schedule in urdbean raised under rice fallow conditions.

Materials and Methods

The field experiment was conducted during January 1997 at Annamalai University Experimental Farm, Annamalainagar, India. The experiment was conducted in a randomised block design replicated four times with seven treatments viz., weedy check, one hand weeding on 20 DAS, two hand weedings on 20 and 40DAS, fluchloralin @ 0.50 kg/ha, fluchloralin 1.0 kg/ha, pendimethalin @ 0.5 kg/ha and pendimethalin @ 1.0 kg/ha. The soil of the experimental field was clayeyloam in texture. The soil was low in available nitrogen (202.0 kg/ha), medium in available phosphorus (22.5 kg/ha) and high in available potassium (346.5 kg/ha). Sowing of urdbean cv ADT 5 was done on first week of January 1997 with a spacing of 30 x 10 cm. The crop was fertilized with uniform dose of 25 and 50 kg/ha of nitrogen and phosphorus respectively. Hand weeding was done as per the treatment schedule. Pre-emergence application of fluchloralin and pendimethalin was made with the help of hand compression sprayer fitted with a flat fan nozzle using a spray volume of 500 L/ha. Weed population and weed biomass were recorded at 45 days after sowing and weed control efficiency of different treatments was computed based on the formula suggested by Misra and Tosh (1979). Data on pod number per plant, seeds per pod, test weight and seed yield were recorded at the time of harvest.

Results and Discussion

Effect on weeds: The weed flora of the experimental field consisted of *Trianthema portulacastrum* L. *Cyperus rotundus* L, *Euphorbia hirta* L., *Phyllanthus niruri* L, *Commelina benghalensis* L., *Digitaria sangunalis* (L). Scop and *Eragrostis minor* L. Among the weed control treatments, hand weeding on 20 and 40 DAS recorded the lowest population and dry weight of weeds and highest value of weed control efficiency. Among the herbicides used at two different levels (0.5 and 1.0 kg/ha) pendimethalin at 1.0 kg/ha was more effective in controlling the weeds than fluchloralin. Increased weed control efficiency and decreased weed population and weed dry matter were noticed with higher dose of herbicides. The highest weed population and weed dry weights were recorded with weedy check treatment could be due to its ineffectiveness in checking the intra row weeds. These results are in conformity with those reported by Panwar *et al.* (1985) and Yadva *et al.* (1985).

Table 1 Effect on weed population, weed dry weight and WCE

Treatments	Weed number/ m^2	Weed dry weight (g/m^2)	Weed control efficiency (%)
T1 - Weed check	115	74.0	-
T2 - One hand weeding (20 DAS)	39	21.3	66
T3 - Two hand weeding (20 & 40 DAS)	12	6.8	90
T4 - Fluchloralin @ 0.5 kg/ ha.	45	24.4	60
T5 - Fluchloralin @ 1.0 kg/ ha.	24	14.5	79
T6 - Pendimethalin @ 0.5 kg/ha.	28	16.8	75
T7 - Pendimethalin @ 1.0 kg/ha.	16	9.2	86
CD (P = 0.05)	18	8.5	

DAS : Days After Sowing

Effect on crop yield and yield attributes: With the significant reduction of weed weight in weed control treatments, the seed yield of urdbean increased significantly over control. The reduced weed competition by weed control treatments had a positive impact on the yield attributing characters. Twice hand weeding recorded the highest number of pods/plant ultimately resulting in the highest seed yield (858 kg/ha). These results are in line with the findings of Gupta *et al.* (1990). In respect of the herbicides, pendimethalin @ 1 kg/ha was found better than fluchloralin, with an increased yield of 128 kg/ha over the latter. Highest dose of herbicides performed better than lower doses. Mohamed Ali and Durai (1987) reported that pre-emergence application of pendimethalin @ 1.0 kg/ha was selective and effective in controlling weeds and in increasing the seed yield of blackgram. The increase in grain yield could be attributed to increase in number of pods/plant and decrease in weed density (Ramanathan and Chandra Shekharan, 1998). The lowest seed yield (400 kg/ha) was obtained with weedy check which might be due to higher weed interference.

Fig. 1 Pods per plant

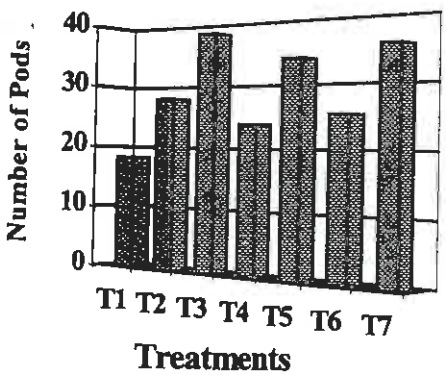


Fig. 2 Seed yield/ha.

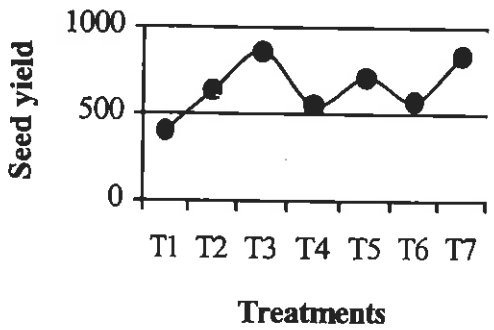


Table 2 Effect of weed control treatments on number of grains/ plant and test weight

Treatments	Grains/ pod	1000 grain weight (g)
Weed check	5.12	21.35
One hand weeding (20 DAS)	5.28	25.10
Two hand weeding (20 & 40 DAS)	5.58	28.50
Fluchloralin @ 0.5 kg/ ha.	5.17	22.55
Fluchloralin @ 1.0 kg/ ha.	5.32	26.00
Pendimethalin @ 0.5 kg/ha.	5.30	24.90
Pendimethalin @ 1.0 kg/ha.	5.43	27.70
CD (P = 0.05)	NS	1.15

NS: Non Significant

Acknowledgements:

The authors express their sincere thanks to the Authorities of Annamalai University for providing facilities for the conduct of field trials at the Experimental Farm, Department of Agronomy.

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INTEGRATED WEED MANAGEMENT IN TEA PLANTATIONS IN NORTH EAST INDIA

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Abstract : India is the largest producer of Tea (*Camelia chinensis*) in the World. Tea production in India has gone up significantly from 285 million kgs. in 1951 to 860 million kgs. in 1998 of which North East India contribute about 74%. A survey, revealed that the production of Tea is hampered to the tune of 25% by weed infestation. The weed flora and its characteristics differ to some extent from one tea growing area to the other. Chemical weed control in Tea gained a firm ground in North East India in the late sixties with the introduction of Paraquat dichloride. Later with the introduction of new molecules like 2-4D and Glyphosate, Tea planters had a feeling that no other form of weed control would be necessary. However, over past three decades, it was observed that only chemical control cannot solve the problem of weed control. Some weed species like *Cynodon dactylon, Imperata cylindrica*, etc. have developed resistance over the years against some herbicides. Hence, the approach of Integrated Weed Management (IWM). This may be defined as management of weeds utilising all suitable techniques and methods in as compatible a manner as possible and maintaining weed infestation at levels below those causing economic crop loss at the optimum cost and environmentally friendly manner. The main reason of chemical weed control becoming popular in Tea Estates is because it is less labour intensive. It is the need of the day to re-look into the total approach and adopt an eco-friendly way of handling weeds in order to achieve higher productivity.

Key words : Integrated weed management, glyphosate, 2-4D, paraquat, oxyfluorfen

Introduction

Weed competition in tea can result in loss of crop to the extent of 10 to 25% (Rao et al, 1977). It hampers overall growth and vigour of young teas and adversely affects their long term productivity. It has been observed that use of chemical herbicides alone over a period of nearly 25 years cannot solve the problem. Some weed species like *Cynodon dactylon, Imperata cylindrica, Paspalum sp.* etc. have developed resistance against paraquat.

Continuos use of 2-4D during the last decades has shifted the general weed spectrum to grasses. Glyphosate has been extensively used to control grassy weeds.

Therefore, a study was undertaken to find out the synergistic effect of different methods of weed control.

Materials and Methods

The integrated weed management involve :

1. Chemical methods : herbicides used are glyphosate, paraquat, 2-4D, oxyfluorfen,
2. Cultivation methods :
3. Manual methods : weeding manually by hand hoe,
4. Green cropping : growing of *Crotoleria sp. and Boga madeloa.* in between the rows of tea plants
5. Shade trees : shade trees present in the trial plot were *Derris robusta, Albizia labbeck,*
6. Mulching : mulching by lopped *Crotoleria sp. and Boga madeloa,*

The trial plot had presence of the following weed species :

Arundinella bengalensis, Axonopus Compressus, Cynodon Dactylon, Imperata cylindrica, Paspalam conjugatum, Ageratum Sp. and Borreria hispada.

Chemical were sprayed by using ASPEE BAKPAK sprayer using WFN 40 nozzle. The trial was conducted over a period of 4 months (June to Sept 1998) during the peak tea flushing and monsoon period. The bioefficacy was assessed against control plot and yield per ha. was recorded.

Result and discussion:

The results of the experiment for control of weeds by different methods are presented n table 1 & 2. It is evident that T1 has shown the best result as compared to the other treatments. T6 also has shown a good result over T2, T3, T4, T5, T7. The result of T5 was better over T2, T3, T4. The difference in yield per. ha. between T5 & T6 is also marginal.

The T1 shows the best result in both weed control and yield/ha.

Acknowledgements

The author is grateful to M/s. Excel Industries Ltd., India, College of Agriculture of Calcutta University, Calcutta, Dr. F. Rehman, Consultant & Tea Scientist and to all colleges for their kind help and support.

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Table 1

Effect of different methods of weed control (mean of 3 replications)

Treatment		Dyas after Operation (% of control)						
		15	30	45	60	90	120	Mean
Glyphosate (3ltr./ha) + Shade + Mannual	T1	98	95	97	90	80	60	86.6
Paraquat (2ltr./ha) + 2-4D (1kg/ha)	T2	90	82	65	50	40	12	56.5
Mulching + Green Crop	T3	95	90	75	60	55	30	67.5
Mannual	T4	90	70	62	30	18	5	45.83
Oxyfluorfen (500ml/ha) + Glyphosate (2ltr./ha)	T5	92	85	80	75	61	58	65.5
Glyphosate + Green cropping	T6	95	90	88	82	75	58	81.3
Contrl	T7	0	0	0	0	0	0	0

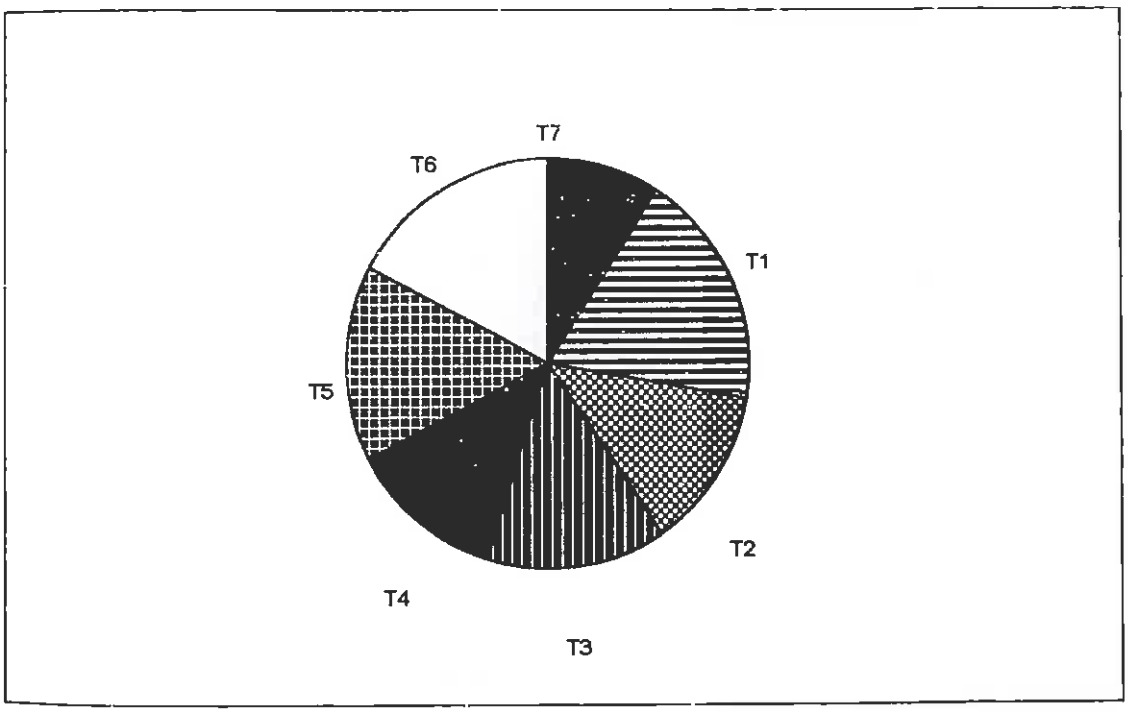
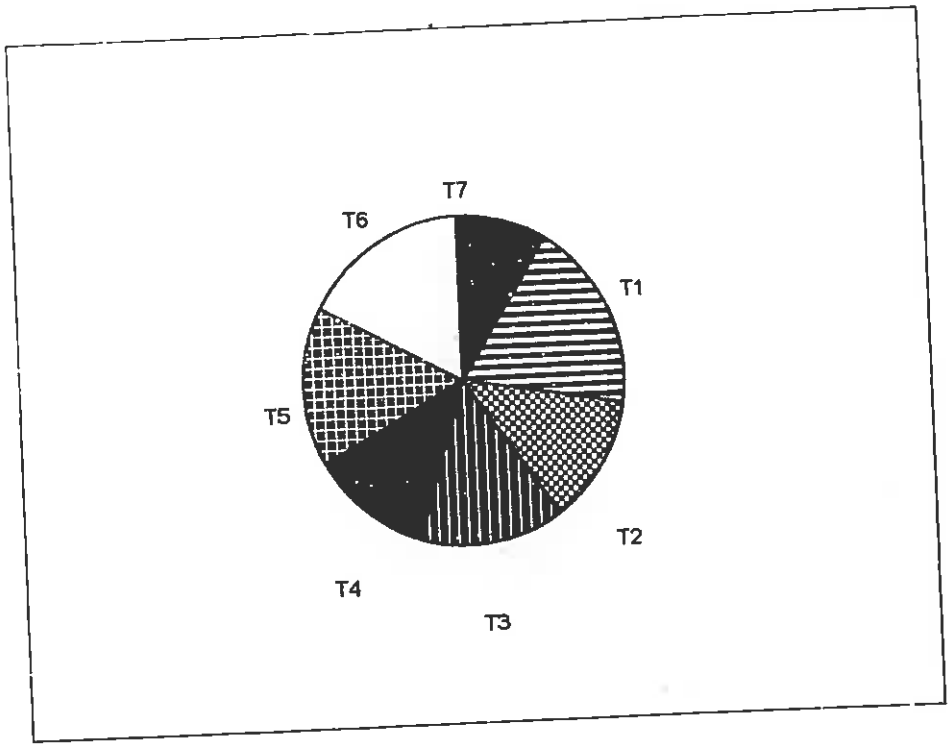


Table 2

Yield (kg/ha.) in different methods of weed control

Treatment		Dyas after Operation				
		30	60	90	120	Mean
Glyphosate (3ltr./ha) + Shade + Mannual	T1	2200	2150	2080	2020	2112.5
Paraquat (2ltr./na) + 2-4D (1kg/ha)	T2	2120	2100	1970	1900	2022.5
Mulching + Green Crop	T3	2105	1800	1950	1875	1932.5
Mannual	T4	2005	1970	1900	1810	1921.2
Oxyfluorfen (500ml/ha) + Glyphosate (2ltr./ha)	T5	2170	2120	2010	1960	2065
Glyphosate + Green cropping	T6	2230	2110	2000	1950	2072.5
Contrl	T7	1950	1830	1800	1760	1835



INTEGRATED WEED MANAGEMENT PRACTICES ON NODULATION AND YIELD OF MUNGBEAN (*Vigna radiata* (L.))

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Abstract: Field experiment was conducted at Annamalai University Experimental Farm, Annamalainagar during the rice fallow season of 1997 to determine the most effective integrated methods of weed control. The experiment was laid out in randomised block design with four replications with six treatments viz. pendimethalin @ 1.0 kg/ha, fluchloralin @ 1.0 kg/ha, pendimethalin @ 1.0 kg + one hand weeding on 20 DAS, fluchloralin @ 1.0 kg + one hand weeding on 20 DAS, two hand weeding on 20 and 40 DAS and weedy check. Integrated weed management combining pendimethalin @ 1.0 kg/ha + one hand weed on 20 DAS was most effective method of weed control and produced the maximum seed yield followed by fluchloralin @ 1.0 kg/ha + one hand weeding. Weedy condition for the entire crop season reduced the seed yield by 35 % as compared to twice hand weeding. Integration of one herbicide with one hand weeding provided better growth, yield attributes and consequently higher yield. In respect of nodulation twice hand weeding treatment recorded the highest nodule number and nodule weight followed by pendimethalin @ 1.0 kg with one hand weeding treatment.

Key words: mungbean, pendimethalin, fluchloralin, hand weeding, nodulation

Introduction

Mung bean is an important crop in South and South East Asia particularly in India. Weeds offer severe competition with this crop during early stages of growth and reduce yields. Losses due to uncontrolled weed growth upto 95% in wet season and 77% in dry season (Ramanamurthy and Rao, 1996). Therefore the weed management is the most important agronomic aspect that plays an important role in exploiting the yield potential of mungbean provided other inputs are not limiting. Application of selective herbicides may control certain species or group of weeds and may not be effective on other weed species. In such situation, while one group of weeds is effectively eliminated, the other group takes over and offers severe competition to the crop. High dose of herbicides may leave residues in the soil to injure the next crops to follow and also create the pollution problem (Pahwa and Jai Prakash, 1996). Continuous use of the herbicide may also lead to resistance in weeds. To over this problem integrated weed management practices will solve the problems. The present study was under taken to study the effect of integrated weed control measures on nodulation and yield mungbean.

Materials and Methods

The study was carried out during rice fallow season of 1997 at Annamalai University Experimental Farm, Annamalainagar, India. The soil of the experimental field was clayey loam in texture. The soil was low in available nitrogen (208.0 kg/ha), medium in available phosphorus (19.0 kg/ha) and high in available potassium (330 kg/ha). Mungbean cultivar VBN1 was sown in the second week of January 1997. Recommended seed rate (25 kg/ha) and fertilizer (25 kg N and 50 kg P_2O_5/ha) was used. The experiment with six treatments was laid out in randomized block design with four replications (Table 1). pendimethalin and fluchloralin were applied as pre-emergence (two days after sowing) along with one hand weeding was done on 20 DAS. Apart from these, manual hand weeding twice on 20 and 40 DAS along with weedy check (untreated) was also included. Weed population and dry weight were recorded at 45 days after sowing. Root system was removed from the soil under running water without any loss of roots and nodules and five plants for each treatment were taken for recording the various data.

The nodules were counted and removed by hand to determine the fresh weight and yield attributes and seed yield of mungbean were recorded at crop harvest.

Results and Discussion

Effect on Weeds: The predominant weeds of the experimental field were: *Trianthema portulacastrum* (L), *Amaranthus* viridis (L), *Phyllanthus niruri* as broad leaf weed and *Cynodom dactylon* (L), *Echinochloa colonum* (L) and *Eleusine indica* as grasses. All the weed control treatments resulted in significant decrease in weed population as compared to weedy check. Maximum dry weed weight (104 g/m^2) was observed in unweeded control plots. All the treatments recorded significantly lower dry weed weight as compared to weedy check. Application of pendimethalin @ 1.0 kg/ha as pre-emergence plus one hand weeding at 20 DAS recorded significantly lower weed weight than all other treatment. The next best was fluchloralin @ 1.0 kg/ha plus one hand weeding on 20 DAS. This might be due to the combined effect of both herbicide and manual weeding in successfully checking the weed growth. All the integrated treatments were found to be superior over the individual weed control treatment. These results are in conformity with those reported by Sandhu *et al.* (1993).

Table 1 Effect on weed population, weed dry weight and WCE

Treatments	Weed number/ m^2	Weed dry weight (g/m^2)	Weed control efficiency (%)
Pendimethalin @ 1.0 kg/ha.	32.9	69.4	31.95
Fluchloralin @ 1.0 kg/ ha.	39.3	75.9	18.46
Pendimethalin @ 1.0 kg/ha. + hand weeding on 20 DAS	14.2	42.1	70.53
Fluchloralin @ 1.0 kg/ ha. + hand weeding on 20 DAS	20.4	48.3	57.67
Two hand weeding on 20 & 40 DAS	23.0	53.2	48.13
Weedy check	48.2	104.0	-
CD (P = 0.05)	3.5	19.4	-

DAS : Days After Sowing

Effect on nodulation and yield: Herbicides were safe to the root nodule production and were superior to unweeded control. Hand weeding treatment had more nodule numbers (31). The increased in nodule number probably due to increased aeration of *Rhizosphere* in disturbed soil condition. There was a 35 % yield reduction by weeds. The highest yield was recorded with the application pendimethalin @ 1.0 kg/ha plus one hand weeding on 20 DAS followed by fluchloralin @ 1.0 kg/ha plus one hand weeding. The lower weed population and higher weed control efficiency resulted in higher grain yield in these treatment. The lower seed yield was obtained with weedy check (530 kg/ha), which might be due to higher weed interference. These results are in agreement with the findings of Gupta *et al.* (1990).

Table 2 Effect on nodule number, nodules fresh weight (g/ plant) and seed yield

Treatments	Nodule number/ plant	Nodule weight (g/plant)	Seed yield (kg/ ha.)
Pendimethalin @ 1.0 kg/ha.	21.5	2.64	702
Fluchloralin @ 1.0 kg/ ha.	18.7	2.52	654
Pendimethalin @ 1.0 kg/ha. + hand weeding on 20 DAS	28.0	3.84	921
Fluchloralin @ 1.0 kg/ ha. + hand weeding on 20 DAS	24.2	2.80	843
Two hand weeding on 20 & 40 DAS	31.0	4.98	810
Weedy check	14.3	1.94	530
CD (P = 0.05)	2.2	0.63	24.5

DAS : Days After Sowing

Acknowledgements:

The author expresses his sincere thanks to the Authorities of Annamalai University for providing facilities for the conduct of field trials at the Experimental Farm, Department of Agronomy.

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LONG TERM EFFECT OF SOIL SOLARIZATION ON WEED COMPETITION AND SEED YIELD OF SOYBEAN

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Abstract: Soil solarization is one of the novel non-chemical methods of pest control whose adoption by farmers is restricted because of higher cost of polethylene films. A field experiment was carried out to look into the possibility of skipping the treatment in the third year after 2 years of continuous solarization. The weed control was excellent in treatment when solarization was practiced continuously for 3 years. However, it did not differ when soil solarisation was skipped in the third year provided the soil was not disturbed before planting the 3rd year's crop. Similarly, the productivity of soybean was highest in 3-year soil solarisation treatment closely followed by 2-year soil solarisation without tillage. Although herbicides (chlorimuron, metolachlor, metribuzin and pendimethalin) gave satisfactory control of weeds in the beginning, the seed yields of soybean were significantly lower than solarisation treatments because of competition of weds later stages.

Key words: Soil solarization, Soybean, Weed management

Introduction

In order to reduce the adverse effect of pesticides on environment, newer alternative methods of pest control are urgently required. Soil solarization is one such method, capable of controlling soil borne pathogens, nematodes and weeds(Katan *et al. 1976*). The technique is simple and practicable in most Asia-Pacific regions where summers are hot. The method has been widely tested in India and excellent results on the control of soil-borne pathogens (Lodha and Solanki, 1992; Rao *et al.*, 1995), nematodes (Kamra and Gaur, 1995; Patel *et al.*, 1995) and weeds (Biradar *et al.*, 1997; Habeeburahaman and Hosmani, 1995; Yaduraju and Ahuja, 1998) have been reported. Reviewing the topic Yaduraju and Kamra (1998) have reported excellent yield responses in many crops. However, the higher cost polyethylene (PE) films was considered a big disadvantage for its large scale adoption by farmers particularly in under developed and developing countries. As the PE films are used for a short duration of 4-6 weeks, they could be reused, but their storage until next summer could be a practical difficulty. It is, therefore worth investigating whether we could skip the treatment after 2 years continuous solarization so that the overall cost of pest management could be brought down considerably.

Materials and methods

An experiment was laid out at the IARI, New Delhi, India in a field which was under soil solarization trials since 1995. The soil was sandy loam. The treatments consisted of 3 years solarization in the same plot and solarization for 2 years with or without preparatory tillage compared with non-solarized plots which received herbicides at doses mentioned in Table 2 as pre-em application in soybean. Solarization was normally carried out for 6 weeks during May-June period in each year by covering thin transparent PE films of 100 um thickness. The field was irrigated and disked before first year solarization, subsequent solarizations were done following an irrigation but without any tillage. Conventional tillage of two diskings and a planking was, however, given in all non-solarized plots. The maximum temperature was measured at 0, 5, 10 and 15 cm soil depths at 1500 hrs daily during the solarization period. Soybean (Cv.Pusa –22) was planted in 9 July, 1997 at 40 cm row spacing. The herbicides were sprayed as pre-em a day after planting by using a knapsack sprayer delivering 250l/ha water. The data on weeds were recorded at 30 DAS by planting a 0.5 M x 0.5 M quadrate from each plot. Each plot measured 2.0 M x 6.0 M and the treatments were replicated three times in a

randomized block design. The weed data was subjected to square root transformation before analysis of variance.

Results and Discussion

The PE mulching led to an appreciable increase in maximum soil temperature at all depths (Table 1). The increase was about 9°C over non-solarised plots at the soil surface and it decreased with increase in soil depth with about 7°C more temperature recorded at 15cm depth.

Table 1 Effect of PE mulching on the mean maxi.num temperature (°C) of soil at 4 depths during 1997.

Depth(cm)	Non-solarized	Solarized
0	49.3	58.7
5	42.9	51.6
10	39.9	47.0
15	36.8	43.9

All solarization treatments significantly decreased the density of broadleaved weeds (BLW's) as compared to control, whereas significant reduction in the density of grassy weeds was only noticed when solarization was carried out for 3 years (Table 2). Solarization for 2 years was comparable to 3-year solarization in checking all weeds. However, 2-year solarization with tillage in the 3rd year gave significantly more number of BLW's as compared 2 other solarization treatments This was expected, as tillage would have brought up to the surface the weed seeds that were not damaged by previous solarization treatments. Solarization effect is normally maximum in the surface soil and it decreases with increasing soil depth (Horowitz *et al.*, 1983; Kumar *et al.*, 1993; Standifer *et al.*, 1984). While all herbicides decreased the population of BLW's, only application of metolachlor and metribuzin reduced the grasses significantly as compared to control. . The data on weed biomass, were basically similar to weed density data. Solarization for 3 years was significantly better than all herbicides against control of BLWs. All solarization and herbicide treatments significantly reduced the total biomass of weeds as compared to control.

Table 2. Effect of solarization and herbicides on weed control in soybean at 30 DAS

	Weed count (no./m^2)			Weed biomass (g/m^2)			
	Grasses	BLW	Sedges	Grasses	BLW	Sedges	Total
3-Solarizations	5.7	5.7	6.7	12.5	17.6	5.8	21.5
2-Solarizations	7.7	6.9	7.2	16.8	19.0	8.5	26.8
2-Solarizations+ Tillage	7.8	9.6	6.9	18.5	20.3	8.4	28.4
Metribuzin (@ 500 g a.i./ha)	5.7	10.2	7.4	14.8	24.5	9.0	34.2
Pendimethalin (@ 750 g a.i./ha)	6.9	9.3	8.1	14.8	16.8	9.1	24.4
Metolachlor (@ 1000 g a.i./ha)	5.5	10.1	6.9	12.9	27.7	9.5	30.8
Chlorimuron (@ 9 g a.i./ha)	8.0	8.4	5.9	17.6	15.7	8.0	25.3
Hand weeding (at 3 & 5 WAS)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Control	8.7	13.0	8.1	20.3	35.6	10.1	40.6
LSD(P=0.05)	2.8	2.0	2.5	5.1	3.2	1.9	5.6

* Square root transformation, BLW – broad leaved weeds

The soybean crop responded significantly to weed control treatments (Table 3). Solarization for 2 or 3 years recorded better growth of soybean plants than control. Solarization for 2 years + tillage was, however, on par with control. Late weeding (at 5 WAS), however, stimulated the soybean growth in all solarized plots. Maximum seed yield of soybean was recorded in 3 year solarization + HW, which was comparable with all solarization treatments except 2 year solarization +tillage.

Table 3. Effect of solarilization and herbicides on crop growth and yield of soybean

Treatment	Fresh wt. (g/plant)	Pods (no./plant)	Seed yield (kg/ha)
1. 3 yr. Solarization	19.3	32.6	2145
2. 3 yr. Sol. + HW*	29.8	42.7	2337
3. 2 yr. Solarilization	21.3	36.9	1775
4. 2 yr. Sol. + HW	23.6	51.1	2107
5. 2 yr. Sol. + Tillage	12.5	31.2	1305
6. 2 yr. Sol. + tillage + HW	22.6	44.6	2082
7. Metribuzin (@ 0.50 kg/ha)	17.1	42.5	1367
8. Pendimethalin (@ 0.75 kg/ha)	12.7	37.7	1432
9. Metolachlor (@ 1.0 kg/ha)	19.5	36.8	1782
10.Chlorimuron (@ 9 g/ha)	18.5	35.5	1520
11.Hand weeding (at 3 and 5 WAP)	20.0	40.1	2070
12. Control	14.9	29.5	965
LSD (P=0.05)	5.0	NS	397

* HW = hand weeding at 5 WAP

All herbicide treatments recorded significantly higher seed yield of soybean as compared to control, however, these yields were significantly lower than two hand weeding treatments. This could be due to the weed competition at later stages of crop growth. Weeds such as *Digera arvensis, Commelina benghalensis* were predominant in herbicide treated plots and were very competitive until the harvest of crop. Amongst herbicides, metolachlor recorded the highest seed yield (1782 kg/ha), which was significantly higher than the yield obtained with metribuzin (1367 kg/ha). 3-year solarization gave yields comparble to two hand weeding treatment (2070 kg/ha). While 2-year solarization also gave similar yield, 2-year solarization + tillage gave significantly lower yield, probably because of increased weed infestation. A late hand weeding, however, pushed up the yield to the level of 2 hand weeding treatment. Supplementary weeding in other solarized treatments, although enhanced the yield, it was statistically not significant. Thus it may be concluded that solarization carried out for two consecutive summers was sufficient to take care of weeds in the third year as well.

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PERFORMANCE OF THREE RICE VARIETIES PLANTED BY CHINESE SEED DRILL UNDER DIFFERENT WEED MANAGEMENT

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Abstract: An experiment was conducted at Khumaltar in rice planted by Chinese seed-drill during 1997 summer season The design of the experiment was a split plot. The sub-plot was 2.4 m by 4 m. The main plot comprises of three rice cultivars namely Khumal-4, Khumal-7 and Chinung-242. The sub-plots consist of three weed management practices such as weedy check, hand weeding two, and pre-emergence application of butachlor @ 1 l a.i./ha. Fertilizer was given @ 100:50:30 NPK kg/ha with split dose of Nitrogen. The main weeds observed in the experimental plot were *Cyprus iria, C. difformis, Fimbristylis littoralis, Commelina diffusa, Echinochloa crusgalli*. Rice was Planted by the Chinese seed drill after ploughing and harrowing the field. There was a positive effect on grain yield which was effected by the weed management. Interaction of weed management on yield was recorded in all the rice cultivars. There was a increasing trend of yield with the weed management. Highest percent of yield loss (66-74) was recorded in Chinung-242, 59-64 percent in Khumal-4 and lowest percent (29-46) in Khumal-7. In comparison to Khumal-4 and Khumal-7, Chinung-242 was highly effected due to weeds. The tested rice cultivars planted by seed drill have given comparable yield either with handweeding two or application of butachlor @ 1 l a.i. /ha with transplanted condition. Hence, this could be an alternate method of transplanting during the labor constraint period.

Key words: weeds, rice, Chinese seed-drill, planting, cultivars

Introduction

Transplanting of rice is the most common and popular planting method throughout Nepal. However, in some areas, rice is broadcasted. Broadcast seeding is generally done after the fields are ploughed when dry. In transplanting the process involved are plowing, puddling and planting in standing water and results into the dispersion of aggregate clay to muddy suspension. One of the major limiting factor in lowering the yield of both the rice is the weeds. The weed problem in upland rice is extremely severe causing substantial yield reduction because weeds and rice seedlings emerge and grow at the same time causing yield losses (Mukhopodhyaya, 1967).

Yield loss by weeds in direct seeded and transplanted rice ranged from 14-93 percent and 17-47 percent respectively (Ranjit, 1997) . Losses of grain yield due to weeds in direct sown rainfed upland rice vary from 40 to 80 percent and in many cases there may be complete failure of the crop (Thakur *et al.*, 1994).

Rice grown under different cultures such as direct sowing in dry soil (line sowing) broadcasting and transplanting have given the equal yields both in mid hills and in terai areas. This different rice culture was significantly influenced by the weed management (Ranjit and Chuarasia, 1996).

However, planting of wheat by Chinese seed-drill have sown a good result in the past. Generally weeds are the major problem in the direct shown rice. And handweeding is difficult especially in broadcast seeding. But row to row spacing could be maintained when rice is planted by Chinese seed -drill where weeding operation becomes more easier compared to broadcast seeding. Hence, this study was conducted to find out the performance of rice cultivars planted by Chinese seed-drill under different weed management practices.

Methodology

This study was conducted in Khumaltar during the summer season of 1997. The design of the experiment was a split plot replicated thrice. The sub-plot size was 2.4 x 4 m (9.6 m^2). The seed rate was 90 kg/ha. Chemical fertilizer was applied at the rate of 100:30:30 NPK kg/ha. Three rice cultivars namely Khumal-4, Khumal-7 and Chinung-242 were included for this study. Three weed control methods namely weedy check, handweeding two and butachlor 50 EC @ 1 l a.i./ ha were included. Rice was planted by Chinese seed-drill in dry soil after ploughing and harrowing in June 20, 1997. Water was accumulated in the rice field as the monsoon started. Butachlor was applied two days after seeding on June 22, 1997. About 75 percent rice emergence was recorded on June 29, 1997. Half dose of nitrogen was top dressed on forty five days of rice seeding. Rice cultivars Khumal-4 and Khumal-7 matured few days earlier which were harvested on Nov. 4, 1997 and Chinung-242 on Nov. 11, 1997.

First and second weed count/ 0.5 m^2 were performed on 4 and 8 weeks of rice seeding. Weed biomass was taken from 0.5 m^2 quadrate after 8 weeks of rice seeding. All other agronomic parameters such as plant height cm., tillers / m^2, thousand seed weight, grains per panicle, grain and straw yield were recorded.

Result and Discussion

The main weeds observed in the experimental plots were *Eclipta alba* (Asteraceae) *Commelina diffusa* (Commelinaceae) *Nymphea sp.*(Nyphyaeceae), *Monochoria vaginalis* (Potenderaceae) among the broad-leaved weeds. *Digitaria ascendens Echinochloa crusgalli* (Poaceae) *Cyperus iria C. difformis Fimbristyhis littoralis* (Cyperaceae) among the narrow - leaf weeds

Among these weeds the commonly recorded were *Cyperus sp., E. crusgalli* and *Fimbristylis littoralis* during the flowering, maturity to harvesting time of rice varieties. The visual observation during the rice maturity period showed that the *Echinochloa crusgalli* heads were observed more in Chinug-242 compared to Khumal-4 and Khumal-7. It might be because of short plant type compared to Khumal-4.

Effect of Chinese seed- drill and weed control methods on weeds

In comparison to grassy weeds broad-leaved weeds were less in number. There is no significant differences in weed number in different rice varieties. However, a significant difference was recorded in weed management treatments. More than 90 and 50 percent weed was suppressed by the application of butachlor 50 EC @ 1l a.i./ha. and handweeding over control respectively.

No significant weed biomass was recorded in different rice varieties. However, the fresh and dry weed weight were recorded higher in Khumal-7 and Chinung-242 than in Khumal-4. But significantly different weed biomass was recorded in weed management practices. Significantly less weed biomass was recorded in handweeding and butachlor treatments compared to weedy check.

The biomass of narrow-leaf weed was higher than the biomass of broad-leaf weeds. The dry weed biomass was highest in Khumal-7 (214 gm/0.5m^2) and Chinung-242 (194 gm/0.5m^2) varieties compared to Khumal-4 (111 gm/0.5 m^2) in the unweeded check Tables 1 & 2.

Effect of Chinese seed- drill and weed control methods on yield parameters of rice

75 percent rice emerged ten days after seeding. Khumal-4 and Khumal-7 rice varieties matured first. So it took about 138 days to harvest. But Chinung was slightly late than those two varieties which took about 149 days to harvest.

Data pertaining to plant height, seeds/panicle, tillers/m^2, 1000 seed wt, grain yield and fresh and dry (sun dry) straw weight are given in Table 3 & 4.

Plant height ranged from 119 cm (Khumal-4) to 104 cm (Chinung-242). There is no significant differences in plant height among the weed management treatments. It ranged from 109 cm to 110 cm in weedy check and butachlor treatments

Significantly different tillers/m^2 was recorded in Khumal-7 (405/m^2) and Khumal-4 (385/m^2) with the lowest in Chinung-242 (318/m^2).

Filled seeds per panicle didn't differ in Chinung-242 (99) and Khumal-7 (100). But was significantly different in Khumal-4 (115). In weed management treatments the filled seeds per panicle ranged from 111 to 126 in weedy check and butachlor @ 1l a.i./ha respectively.

Thousand seed weight varied significantly within the rice varieties and weed management. It ranged from 19 gm (Khumal-4), 26.6 gm (Chinung-242) and 28.2 gm (Khumal-7). When this 1000 seed weight was compared with the seed weight from the transplanted condition has shown comparable weight of 18 gm (Khumal-4), 29 gm (Chinung 242), and 27 gm (Khumal - 7).

There was no significant yield differences among the rice cultivars. But significant yield difference was recorded in weed control methods. About 52 to 60 percent yield loss was recorded over weedy check. Increasing trend of yield was noted in all the rice cultivars either with handing weeding or application of butachlor . Range of yield loss varied with the cultivars such as 29 to 46 percent in Khumal-7, 59 to 64 percent in Khumal-4, and higher range of 66 to 74 percent in Chinung 242. Among the tested cultivars, Chinung 242 was highly effected by the weeds in weedy check with the yield of 1829 kg/ha, followed by Khumal-4 (2525 kg/ha) and Khumal-7 (3760 kg/ha) .

The tested rice cultivars planted by seed-drill have given comparable yield either with handweeding two or application of butachlor @ 1 l a. i./ha with transplanted condition. Hence, the rice yield could be increased even in direct seeding if proper weed management is done. Handweeding could be done easily in Chinese seed drill seeding compared to broadcast seeding. Hence, this could be an alternate and beneficial method over transplanting because of less labor required at peak season.

Acknowledgments: The author is thankful to Nepal Agriculture Research Council and CIMMYT/Nepal for the financial support to participate the 17th APWSS conference.

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Table 1 Effect of Chinese seed drill and weed management on weed count and weed biomass at 8 weeks of rice seeding

S N	Treatment	weed count / 0.50 m^2			weed wt gm/ 0.50 m^2			
					Fresh		Dry	
		Br	Nar	Total	Br	Nar	Br	Nar
	Varieties							
1	Khumal-4	27	67	94	58	256	8	47
2	Chinung-242	20	71	91	66	469	8	84
3	Khumal-7	21	67	88	108	457	11	83
	F-Test				ns	ns	ns	ns
	Weed control							
4	Weedy check	18	142	160	62	908 ^{a}	8 ^{b}	165 ^{a}
5	Hand weeding two	24	47	71	66	188 ^{b}	7 ^{b}	34 ^{b}
6	Butachlor 2 l a i/ha	25	16	41	104	87 ^{b}	13 ^{a}	14 ^{b}
	F-Test				ns	s	s	s
	LSD (0.05)					289	5	50
	Interaction							
	LSD (0.05)							
	CV %				58	71	52	68

Br = Broadleaf, Nar = narrow-leaf

Table 2 Interaction of Chinese seed drill and weed management on dry weed biomass in rice

Weed Management practices	Rice varieties								
	Khumal-4			Chinung-242			Khumal-7		
	Nar	Br	Total	Nar	Br	Total	Nar	Br	Total
Weedy check	105	6	111	187	7	194	204	10	214
Hand weeding two	24	3	27	43	3	46	34	13	47
Butachlor 2 l a i/ha	11	15	26	21	15	36	10	10	20
Mean									

Nar = narrow-leaf Br = Broadleaf

Table 3 Influence of Chinese seed drill and weed management on yield parameters of rice

S. No	Treatments	Pl. ht. cm	Seeds/ panicle F	Seeds/ panicle Un	Total	Tiller /m²	1000 seed wt.gm	Grain yield kg/ha	Straw yield kg/ha Fresh	Straw yield kg/ha Dry
	Vareties									
1	Khumal-4	119[a]	149[a]	13	162	385[a]	19.0[c]	5266	19750	6167
2	Chinung-242	104[b]	99[b]	9	108	318[b]	26.6[b]	4712	16528	4458
3	Khumal-7	105[b]	100[b]	10	110	405[a]	28.2[a]	5325	20125	6000
	F-Test	S	S	NS		S	S	NS	NS	S
	LSD (0.05)	7		-		57	0.5	-	-	-
	Weed control									
1	Weed check	109	111	8	119	345	24.2[b]	2705[c]	12056[b]	3167[b]
2	Hand weeding two	110	111	11	122	371	24.8[a]	5605[b]	19681[a]	6028[a]
3	Butachlor 2 l a i/ha	110	126	11	137	392	24.9[a]	6994[a]	24667[a]	7431[a]
	F-Test	NS	NS	NS		NS	S	S	S	S
	LSD (0.05)	-	-	-		-	0.4	662	5143	1537
	Interaction	NS	NS	NS		NS	NS	NS	NS	NS
	LSD (0.05)	-	-	-		-	-	-	-	-
	CV %	5	16	44		17	2	13	27	27

F = filled, Un = unfilled

Table 4 Interaction of Chinese seed drill and weed management on yield of rice varieties

Weed Management practices	Rice varieties			
	Khumal-4	Chinung-242	Khumal-7	Mean
Weedy check	2525	1829	3760	2705[c]
Hand weeding two	6186	5354	5274	5605[b]
Butachlor 2 l a i/ha	7086	6954	6942	6994[a]
Mean	**5266**	4712	**5325**	
Yield loss	59-64%	66-74%	29-46%	

Resistance Biotype of *Monochoria korsakowii* against Sulfonylurea Herbicides in the Reclaimed Paddy Fields in Korea

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Abstract: Resistant biotype of *Monochoria korsakowii* to sulfonylurea herbicides was first discovered in 1998 in reclaimed rice fields of the west coastal area, Korea that had received these herbicides for 9 years. Sulfonylureas, bensulfuron-methyl, ethoxysulfuron, imazosulfuron and pyrazosulfuron-ethyl at 1/2, 1, 2, 3 and 4 times the recommended rate(bensulfuron-methyl 51 g ai ha^{-1}, ethoxysulfuron 21 g ai ha^{-1}, imazosulfuron 75 g ai ha^{-1}, pyrazosulfuron-ethyl 21 g ai ha^{-1})were applied at 7 an 12 days after planting in both resistant biotype and susceptible one under glasshouse condition maintaining temperature at 20-30°C. Approximately 60% of resistant biotype was survived at the dose of 4-fold higher than the recommended one of each sulfonylurea type, while susceptible one was completely killed even at half of the recommended dose.

Key words: Sulfonylurea, Herbicide, Resistance, *Monochoria korsakowii*

INTRODUCTION

Herbicide resistance in weeds, which has been mainly dominated by triazine (Sereda et al, 1996), now includes resistance to newer classes of chemistry such as the sulfonylurea herbicides. These herbicides inhibit acetolactate synthase(ALS), a key enzyme in the synthesis of the branched chain amino acids, valine, leucine, and isoleucine(Saari et al, 1992). The relatively long residual activity and continuous use of these herbicides has developed resistant weeds. Biotypes of *Lactuca serriola* L., *Stellaria media* [L.] Vill., and *Kochia scoparia*[L.].Scrrad resistant to sulfonylurea herbicides. were selected in monoculture wheat-growing areas by chlorosulfuron in the last many years(Sarah et al, 1996). Recently, resistant biotypes of *M. korsakowii*, *Elatine triandra* Sckk., and *Scirpus juncoides* Roxb. were discovered in rice fields in Japan that had been treated with sulfonylurea-based herbicides for several years(Wang et al, 1997). Sulfonylurea herbicides have been treated for 9 years continuously in about 10,000 ha of the reclaimed rice fields, mainly practicing wet-direct seeding rice culture, in the western coastal area of Korea. M. korsakoii has been not well controlled by sulfonylureas since 1997. The objective of this research was to determine development of resistant biotype against sulfonylurea herbicides.

MATERIALS AND METHODS

Plant materials: Soil predominated with *M. korsakowii* which had been treated with sulfonylurea-based herbicides for 9 consecutive years in reclaimed rice fields of the west coastal area of Korea in October 1998 was sampled. Suscepible seeds were obtained from the untreated area in the vicinity of Suwon city, Kyoungki province. The collected samples for two biotypes were preserved to break dormancy for one month at 4 °C and germinated in growth chamber (Conviron E-15) maintaining 12-hr photoperiod, constant 30±2 °C, and 75±10% relative humidity. Ten pregerminated seeds with 2 or 3 mm were selected and planted in plastic pot(20 x 20 x 15 cm) filled with paddy soil(clay loam) with three replications under glasshouse maintaining temperature 25±5 °C. Age of seedlings when herbicides were applied were at two to three cm tall.

Response to herbicide application:. The recommended dose of bensulfuron-methyl, ethoxysulfuron, imazosulfuron, and pyrazosulfuron-ethyl were 51, 21, 75 and 21 g ai ha^{-1}, respectively. The granular type of each sulfonylurea. at 1/2, 1, 2, 3, and 4 times the recommended dose was applied at 7 and 12 days after planting in plastic pots having 3 cm water depth. The number of surviving plants and

plant length were determined at 20 day after herbicide application.

RESULTS AND DISCUSSION

Table 1 shows the history of sulfonylurea herbicide application for last 9 years from 1990. *M. korsakoii* has been well controlled by sulfonylurea type herbicides for 7 years from 1991, but efficacy of these herbicides have been declined starting 1997 which was 8 th year of consecutive application.

The plants of *M. korsakowii* collected from the reclamed rice field of the west coastal area, mainly practicing wet-direct seeding rice culture system in Korea demonstrated a high level of resistance to sulfonylurea herbicides. It was found that the resistant biotypes showed no injury at all(0% mortality) at the recommended dose of each sulfonylurea herbicides applied at 7 and 12 days after planting, but the susceptible one was completely killed even at half of the recommended dose. Although efficacy of each sulfonylurea type varied, but even at the dose of 4 times the recommended one, approximately 60% of resistant biotypes survived and grew normal(Table 2, 3). Four-fold higher than the recommend dose of bensulfuron-methyl, imazosulfuron, and pyrazosulfuron-ethyl applied at 12 days after planting inhibited about 40% of plant height of resistant biotypes compared with control, but ethoxysulfuron inhibited about 10% at all applied rates(Fig.1, 2), indicating least efficacy against resistant biotypes. Phytotoxic symptom developed much slowly in resistant biotype as compared with susceptible one. Thus, it can be concluded that the suspected resistant biotype of *M. korsakowii* collected from reclaimed rice fields in the west coastal area of Korea is truly resistant to sulfonylurea herbicides.

Table 1. History of herbicide use and efficacy on *M. korsakowii* at reclaimed rice fields where the resistant biotype was observed.

Years	Herbicides	Efficacy(resistance)
1986-1989	Nonsulfonylurea herbicides	Effective (not emerged)
1990	Bensulfuron 0.17%/quinclorac 1% GR	Effective(not emerged)
1991-1996	Pyrazosulfuron 0.07%/molinate 5% GR	Effective(not emerged)
1997-1998	Pyrazosulfuron 0.07%/molinate 5% GR	No effect(emerged)

Table2. Survival rate(% of control) of *Monochoria korsakowii* treated with sulfonylureas at 7 days after planting.

Dose	Bensulfuron-methyl		Ethoxysulfuron		Imazosulfuron		Pyrazosulfuron-ethyl	
	R-type[1)]	S-type[1)]	R-type	S-type	R-type	S-type	R-type	S-type
0.5X	-	0	-	0	-	0	-	0
1X[2)]	100	0	100	0	100	0	100	0
2X	100	0	75	0	100	0	50	0
3X	92	0	67	0	86	0	50	0
4X	67	-	50	-	67	-	42	-

1) R-type: resistant type, S-type: susceptible type
2) Standard dose(g ai ha^{-1}):Bensulfuron-methyl(51g), Ethoxysulfuron(21g) Imazosulfuron (75g), Pyrazosulfuron-ethyl (21g)

Table 3. Survival rate(% of control) of *Monochoria korsakowii* treated with sulfonylureas at 12 days after planting.

Dose	Bensulfuron-methyl		Ethoxysulfuron		Imazosulfuron		Pyrazosulfuron-ethyl	
	R-type[1)]	S-type[1)]	R-type	S-type	R-type	S-type	R-type	S-type
0.5X	-	0	-	0	-	0	-	0
1X[2)]	100	0	100	0	100	0	100	0
2X	82	0	100	0	100	0	83	0
3X	67	0	100	0	100	0	92	0
4X	58	-	100	-	68	-	92	-

1) R-type: resistant type, S-type: susceptible type
2) Standard dose(g ai ha^{-1}):Bensulfuron-methyl(51g), Ethoxysulfuron(21g) Imazosulfuron (75g), Pyrazosulfuron-ethyl (21g)

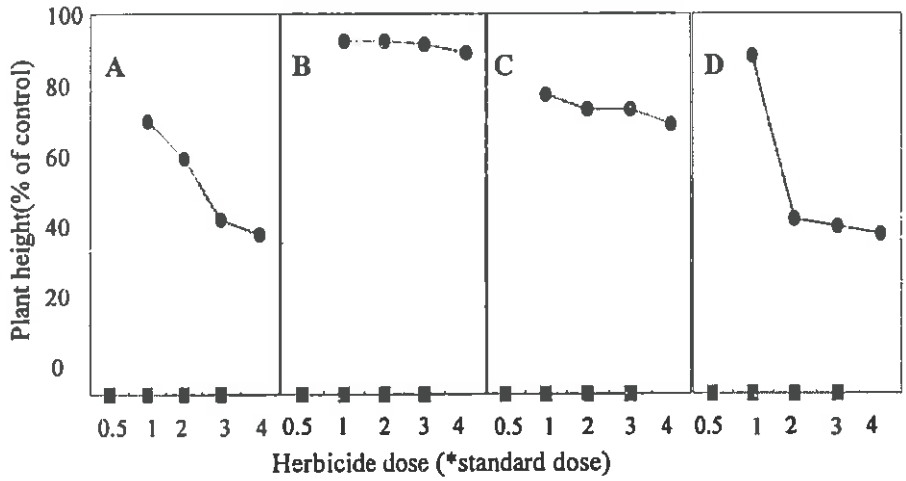


Fig 1. Plant height of two biotypes (R-type: ●–● S-type:■–■)of *Monochoria korsakowii* affected by different rates of sulfonylureas at 7 days after planting
A: Bensulfuron-methyl, B: Ethoxysulfuron, C: Imazosulfuron, D: Pyrazosulfuron-ethyl

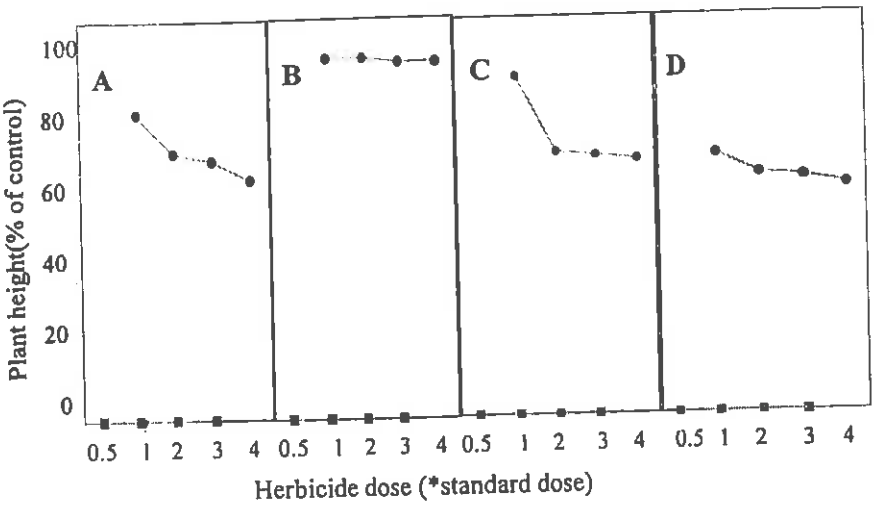


Fig 2. Plant height of two biotypes(R-type:●_● S-type:■_■) of *Monochoria korsakowii* affected by different rates of sulfonylureas at 12 days after planting
A: Bensulfuron-methyl, B: Ethoxysulfuron, C: Imazosulfuron, D: Pyrazosulfuron-ethyl

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SELECTIVE CONTROL OF PRUPLE NUTSEDGE (*Cyperus rotundus*) IN MAIZE AND ASPARAGUS

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Abstract: The efficacy of several herbicides against purple nutsedge (*Cyperus Rotundus* L.) was investigated in a series of ten field experiments over two growing seasons. In maize crops the most effective herbicide halosulfuron reduced the population and ground cover of purple nutsedge at rates between 32.5 and 130 g ai/ha. Repeat annual applications were necessary to reduce the number of tubers to low levels. Halosulfuron caused chlorosis and some stunting of young maize plants but they grew out of the damage and neither grain yields nor crop maturity were affected. Based on these and other field results, halosulfuron has now been registered in New Zealand for control of purple nutsedge in maize. Although well tolerated by asparagus, halosulfuron was not as effective on purple nutsedge in this crop, probably due to lack of shading and competition from the crop in the first few weeks after spraying. EPTC delayed weed emergence for up to 8 weeks and bromacil significantly reduced plant numbers and tuber production. Glyphosate applied at the end of spear harvest (close-up) appeared to be the most effective treatment in asparagus.

Key Words: purple nutsedge, *Cyperus rotundus*, halosulfuron, maize, asparagus

Introduction

Described by Holm *et al.* (1977) as the world's worst weed, purple nutsedge (*Cyperus Rotundus* L.) has not had a big impact on cropping in New Zealand until recently. It was first recorded in New Zealand by Cheeseman in 1883 and is now distributed throughout most of the North Island and also in parts of the South Island (Healy and Edgar, 1980). In recent years it has spread into arable lands, particularly affecting many maize (*Zea mays* L.) and some asparagus (*Asparagus officinalis* L.) crops. As seeds of purple nutsedge are rarely viable, its spread is associated with the movement of tubers and appears to have been aided by cultivation equipment travelling from site to site.

Purple nutsedge is capable of producing tubers three weeks after shoot emergence and a plant originating from one tuber can produce up to 99 tubers within three months (Rao, 1968). It is capable of vigorous competition in all crops resulting in large yield losses (Holm *et al.*, 1977; Santos *et al.*, 1997). Purple nutsedge has demonstrated allelopathic properties in some trials, but these have not been widely observed in the field (Parsons and Cuthberston, 1992).

Several selective and non-selective herbicides have been used in maize with varying success for control of purple nutsedge (eg. Hawton *et al.* 1992; Webster and Coble, 1997). Residual herbicides such as bromacil, EPTC and norflurazon are known to provide some control of this weed (Parsons and Cuthberston, 1992; Sheinbaum, 1985). New Zealand is one of the few asparagus producing countries using bromacil as a selective herbicide in this crop (Rahman and Sanders, 1983). The recently released sulfonylurea herbicide, halosulfuron (NC319; MON 12037) has shown good activity against purple nutsedge following soil or foliar applications (Suzuki *et al.*, 1991; Vencill *et al.*, 1995). The product was registered in 1994 in Australia for use on turf and in the USA for use in maize, sorghum and turf. The objective of this study was to determine the efficacy of halosulfuron along with several other herbicides for control of purple nutsedge and the tolerance of maize and asparagus crops to these herbicides.

Materials and Methods

Ten field trials were conducted in maize and four in asparagus over two growing seasons (1995-97). All trials were randomised block designs, with treatments replicated 4 or 6 times. Individual plots were 10 m x 6 m for maize containing eight crop rows and 6 m x 6 m for asparagus. All herbicide treatments were applied with a CO_2 powered precision sprayer in 300 litres/ha water at 210 kPa. Regular

assessments were made in all efficacy trials of phytotoxic damage to purple nutsedge shoots, ground cover and initiation of flowering. Purple nutsedge plant populations were determined on several occasions by counting in two to five randomly placed $0.1m^2$ quadrats in each plot (depending on the density of infestation). At some sites, after the nutsedge foliage had died back at the end of the season, two soil samples were collected from each plot to a depth of 300 mm using a 75 mm diameter corer. The numbers and dry weight of tubers were measured from the washed samples.

All data were subjected to analysis of variance and least significant difference (LSD) test was used to separate the means. Stabilising transformations were performed where necessary prior to analysis.

Herbicide efficacy and tolerance trials in maize

Two trials in each growing season tested the tolerance of maize to herbicides in the absence of purple nutsedge. Two further trials in each season investigated their efficacy against this weed. Additionally, two trials in 1996/97 evaluated the efficacy of repeat applications of halosulfuron. All trial sites had been in maize for several years. The soils were all sandy loams with high organic carbon contents (5.9% to 7.4%) and pH levels between 5.6 and 6.1. The trials were planted between mid October and early November with maize cv. Pioneer 3751. Pre-emergence applications of acetochlor + atrazine (base-treatment) were made within 2 days of planting. The post-emergence treatments of halosulfuron (with the wetting agent Citowett at 120 ml/100 litres) were applied 5 to 6 weeks after planting. At this time the maize plants were 25 – 40 cm tall with 6 – 9 leaves, while the purple nutsedge plants were 5 – 10 cm high with 4 – 8 leaves. Regular visual assessments were made of any phytotoxic damage to maize crop and plant height was determined on two occasions by measuring 10 plants/plot. Maize grain yields were determined by harvesting 100 plants from central rows of each plot. The cobs were then shelled and grain weight and moisture content determined. Grain yields were adjusted to 14% moisture content.

Herbicide efficacy and tolerance trials in asparagus.

The site for the efficacy trials was a 10 year old block of asparagus cv. UC157, with a severe infestation of purple nutsedge over the entire block. The tolerance trials were conducted in a 12 year old block of asparagus in the absence of purple nutsedge. The herbicides were applied either as crop pre-emergence in first week of September or as a close-up treatment (end of asparagus harvesting and beginning of fern stage) in mid December. Regular visual assessments were made of any phytotoxic damage to asparagus spears as well as the ferns, The trials were harvested for two months (early October to early December) and the total number and yield of spears for each plot was recorded. The harvesting was similar to that used for commercial blocks, with spears cut at 180 mm length on alternate days. At the end of the seasons, fern stems were also counted (three rows of 2 m each) to assess treatment effects.

Results and Discussion

Herbicide efficacy trials in maize

Data in Table 1 give results from the two efficacy trials in the 1996/97 growing season; one trial where halosulfuron was applied for the first time and a second trial at the same site where repeat applications of the same treatments were made to plots treated in 1995/96. Table 2 shows data from a similar set of experiments conducted at another site that had a much lower infestation of purple nutsedge. Counts of nutsedge plants present when the halosulfuron treatments were applied (16.12.96 and 12.11.96 in Tables 1 and 2, respectively) show that in the trial area receiving treatments for the first time, there was a reasonably even spread of plants over all plots but in the trial receiving repeat treatments there was a carry over effect from the previous year's application of halosulfuron.

Within a week of treatment with halosulfuron, a gradual yellowing of the nutsedge foliage was evident which was assessed through the vigour scores (Tables 1 and 2). New growth on the treated plants became chlorotic, but the old leaves remained green for several weeks. The plants did not increase much in size and most withered eventually. Increasing level of shading from the maize crop also appeared to assist in limiting the weed growth as the phytotoxic effects of the herbicide disappeared. All halosulfuron treatments caused a large and significant reduction in nutsedge populations for the duration of the season. This is reflected in lower plant counts and lower tuber numbers (Tables 1 and 2). However, this reduction was greater in the trials with repeat treatments where the use of halosulfuron over two seasons had an additive effect, especially at site 1 (Table 1) where the initial weed population was higher. With the repeat application the overall level of control was improved, particularly by the low rate (32.5 g ai/ha). One reason for this could be the partial recovery of weed populations during the season in the case of a single application. This recovery is reflected in the tuber numbers where there was no significant rate effect, with all rates reducing tuber numbers to about half of the base treatment. The repeat treatments further reduced the tuber numbers to 10 - 20% of the base treatment.

Table 1 Plant and tuber numbers and vigour scores of purple nutsedge from efficacy trials in maize at Site 1.

Herbicide (g ai/ha)	No. of plants/m^2			Vigour score[b]		Tubers/m^2
	0 DAT	70 DAT	140 DAT	23 DAT	140 DAT	150 DAT
1996/97 Trial (First time application)						
acetochlor + atrazine[a]	366	871	387	0.2	0.6	2527
+ halosulfuron 32.5	349	349	156	1.7	2.0	1320
+ halosulfuron 65	301	212	172	2.2	3.0	1320
+ halosulfuron 130	392	177	125	2.5	2.9	1403
LSD (5%)	107	84	118	0.6	0.7	714
1996/97 Trial (Repeat application on 95/96 plots)						
acetochlor + atrazine[a]	270	643	104	0.3	0.4	2545
+ halosulfuron 32.5	108	79	42	2.0	2.3	764
+ halosulfuron 65	79	47	35	2.6	3.3	764
+ halosulfuron 130	79	27	27	2.6	3.5	453
LSD (5%)	64	69	47	0.8	0.6	470

[a] Pre-emergence acetochlor + atrazine (2.5 + 1.5 kg ai/ha) were applied to every plot in the trial. Halosulfuron was applied on 16.12.96. DAT = Days after treatment.

[b] On a 0-5 scale: 0 = No damage, full vigour, healthy; 5.0 = All foliage showing damage symptoms.

Table 2 Plant numbers and vigour scores of purple nutsedge from efficacy trials in maize at Site 2.

Herbicide (g ai/ha)	No. of plants/m^2			Vigour score[b]	
	0 DAT	65 DAT	105 DAT	35 DAT	105 DAT
1996/97 Trial (First time application)					
acetochlor + atrazine[a]	21	157	89	0	0.2
+ halosulfuron 32.5	30	60	45	1.2	1.5
+ halosulfuron 65	25	10	24	2.0	2.2
+ halosulfuron 130	24	16	11	1.9	2.2
LSD (5%)	13	27	23	0.8	0.8
1996/97 Trial (Repeat application on 95/96 plots)					
acetochlor + atrazine[a]	26	202	135	0.2	0.4
+ halosulfuron 32.5	17	19	30	1.9	2.0
+ halosulfuron 65	12	19	10	3.3	3.0
+ halosulfuron 130	10	5	14	3.9	3.2
LSD (5%)	6	13	27	0.9	0.6

[a] Pre-emergence acetochlor + atrazine (2.5 + 1.5 kg ai/ha) were applied to every plot in the trial. Halosulfuron was applied on 12.11.96. DAT = Days after treatment.

[b] On a 0-5 scale: 0 = No damage, full vigour, healthy; 5.0 = All foliage showing damage symptoms.

Plant counts at regular intervals showed a late season partial recovery of the nutsedge populations treated with halosulfuron, which indicates that repeat annual applications will be required to achieve good control of this problem weed. At site 1, where the weed population was high, repeat applications of 32.5 g ai/ha rate reduced the number of plants and tubers considerably more than a single application of halosulfuron (Table 1). Although similar trends are apparent from the results at site 2 (Table 2), which had a much lower weed population, the benefits of repeat treatments were not as marked.

Crop tolerance trials in maize

Observations of the maize plants made soon after treatment with halosulfuron showed that within 3 days of application, the plants began to show symptoms of chlorosis. These comprised a pale green to yellow blotching of the leaves at the point of emergence from the whorl. Within a week after treatment,

many of the treated leaves and the whole of the newly emerging leaf became chlorotic. Visual assessments showed this damage was rate related (Table 3) and was quite marked at the highest rate of 260 g ai/ha, which is 4 times the likely commercial rate of 65 g ai/ha. Regular visual assessments suggested that damage to the crop reached maximum levels 10-14 days after treatment. Plant height measurements around a fortnight after treatment showed that the chlorosis damage also resulted in significant stunting of the plant, which was more obvious in plots treated with the 260 g ai/ha rate. Both the extent of chlorosis and the speed at which it developed varied between trials and seasons and appeared to be related to the rate of crop growth. As the tolerance of maize to halosulfuron comes from the rapid metabolism of the herbicide in the plant, a plant that is growing more vigorously will metabolise the herbicide more efficiently and hence suffer less damage as well as overcome the damage more quickly.

Table 3 Damage, height and grain yield of maize from crop tolerance trials.

Herbicide [a] (g ai/ha)	Chlorosis (%)		Height (cm)	Grain moisture (%)	Grain yield (t/ha)
			1995/96 Trial		
Halosulfuron 9.12.95	6 DAT	14 DAT	14 DAT	150 DAT	150 DAT
acetochlor + atrazine	0	0	105.8	23.9	10.7
+ halosulfuron 65	10	3	95.0	23.9	11.5
+ halosulfuron 130	15	7	92.5	24.0	11.3
+ halosulfuron 260	20	8	88.3	23.7	11.6
LSD (5%)	6	4	5.1	0.6	0.8
			1996/97 Trial		
halosulfuron 5.12.96	4 DAT	7 DAT	14 DAT	160 DAT	160 DAT
acetochlor + atrazine	0	0	78.5	19.7	11.1
+ halosulfuron 65	4	2	69.3	19.8	11.1
+ halosulfuron 130	5	5	66.3	19.9	10.6
+ halosulfuron 260	8	15	64.3	20.0	10.5
LSD (5%)	3	7	4.9	NS	0.8

[a] Pre-emergence acetochlor + atrazine (2.5 + 1.5 kg ai/ha) were applied to every plot in the trial. Halosulfuron was applied on 9.12.95 and 5.12.96 in the two trials, respectively.

Within 3-4 weeks after treatment, the proportions of plants showing chlorosis had decreased considerably as new healthy leaves were produced, leaving any chlorotic leaves at the base of a now rapidly growing and apparently healthy plant. A month after treatment the previously damaged plants could only be identified by careful inspection of the old leaves at the base of the plants. The stunting effect also appeared to be temporary suggesting that halosulfuron does not affect all aspects of plant development and overall growth appears to be less affected than the initial plant height. By late January the crop had tasselled and produced silks with no obvious treatment effects evident. Grain yield and moisture data showed that there was no yield suppression or delayed development of the crop (which would have been reflected in higher grain moisture) from any halosulfuron treatment (Table 3).

Herbicide efficacy trials in asparagus

Twenty different herbicide treatments applied either before start of harvest or at close-up were evaluated over two growing seasons (1993-95) but many exhibited low phytotoxicity to purple nutsedge and therefore the results are not presented here. The terbuthylazine/diuron mixture which showed very little effect on this weed is used in Table 4 for comparative purposes as the treatment that provided the least control. Norflurazon, which gave satisfactory control of yellow nutsedge (*cyperus esculentus*) in asparagus (Agamalian, 1995) reduced the population of purple nutsedge by only about 50%, with ground cover reverting back to 100% towards the end of both growing seasons (Table 4). When applied in mixture with glyphosate at close-up, it also did not provide long term control (data not tabulated). Bromacil as a pre-emergence treatment showed a good level of suppressive activity against purple nutsedge during the season, with the highest rate of 4.0 kg ai/ha providing the best results overall.

Control of nutsedge by bromacil was augmented with the post emergence use of glyphosate at close-up (Table 4).

Table 4 Ground cover of purple nutsedge in the two growing seasons and the number of tubers from soil samples.

Treatment	Rate	Nutsedge ground cover (%) First season		Second season		Tubers/m^2
(Pre-E)	(Kg ai/ha)	110 DAT	210 DAT	105 DAT	190 DAT	270 DAT
terbuthylazine + diuron	2.6 + 2.6	86	100	94	100	4980
norflurazon	4.0	55	98	73	100	2490
EPTC	6.0	38	100	70	100	4103
bromacil + diuron	2.4 + 2.4	45	76	40	68	2688
bromacil	1.6	25	45	40	75	2066
bromacil	4.0	28	35	17	16	1839
bromacil + glyphosate[a]	1.6 + 2.16	8	38	26	15	1302
bromacil + imazapyr[a]	1.6 + 0.25	15	23	25	1	1669
SED		10	15	10	11	930

[a]Treatment applied at close-up in December. All other treatments applied early September.

Another trial in 1996/97 evaluated the efficacy of halosulfuron alone or in combination with glyphosate applied at close-up in December. These treatments in Table 5 were preceded by a pre-emergence application of bromacil + diuron (2.4 + 2.4 kg ai/ha) in early September. Regular assessments showed that halosulfuron treatments alone did not kill all nutsedge plants present at the time of treatment and many new plants also continued to emerge. However, all halosulfuron treatments caused some chlorosis of nutsedge foliage on treated and newly emerging plants. Data on tubers collected in May 1997 followed a trend very similar to that recorded for number of plants during the season. Addition of glyphosate to halosulfuron improved the level of nutsedge control but the efficacy of the combination was not much better than glyphosate alone. Data on number of plants at the end of season (30.4.97) showed that 2.16 kg ai/ha of glyphosate was considerably more effective than 1.44 kg ai/ha rate (Table 5).

Table 5 Data on purple nutsedge from the 1996/97 efficacy trial in asparagus

Treatment[a]	Rate kg ai/ha	Ground cover %	Plants/m^2		Tubers No/m^2	Tubers Dry wt g/m^2
		0 DAT	0 DAT	150 DAT	150 DAT	
halosulfuron	32.5	51	391	162	597	176
halosulfuron	65	52	368	125	1224	140
halosulfuron	130	30	274	99	777	115
halosulfuron + glyphosate	32.5+ 1.44	12	108	69	567	116
halosulfuron + glyphosate	65 + 1.44	12	78	39	747	95
halosulfuron + glyphosate	130 + 1.44	6	49	20	687	83
glyphosate	1.44	17	114	102	777	123
glyphosate	2.16	14	108	28	269	42
LSD (5%)		16	79	58	423	

[a] All plots also received a pre-emergence application of bromacil + diuron (2.4 + 2.4 kg ai/ha) before harvest started in early September. Halosulfuron and glyphosate applied 6.12.96.

Herbicide tolerance trials in asparagus

Data from the two tolerance trials showed no significant differences between the treatments listed in Table 5 in either the spear number or the spear yield and therefore are not presented here. Visual assessments of spears and ferns showed no apparent damage from halosulfuron treatments. However, the treatments containing glyphosate caused a slightly greater incidence of bent stems in the first two weeks. At the end of the season the fern stem counts and the fresh weights also did not show any significant differences between treatments.

Conclusions

Based on the results of these trials, halosulfuron appears to have good potential for selective control of purple nutsedge in maize crops. Repeat annual applications of halosulfuron would be necessary to reduce the number of tubers to low levels. It may be possible to use lower rates in the second and subsequent seasons. Halosulfuron caused chlorosis symptoms in maize plants within 2 - 3 days after spraying and it also resulted in a stunting of the crop after about 2 weeks. The plants grew out of all damage symptoms, however, and the final grain yields or the maturity of the crop were not affected. Results from trials in asparagus showed good tolerance of this crop to halosulfuron applied at close-up in December. However, the control of purple nutsedge from halosulfuron was not as good in asparagus as that recorded in maize crops where the more competitive maize crop contributes to weed suppression. Glyphosate applied at close-up appears to be the most effective treatment for purple nutsedge in asparagus.

Acknowledgements

We are grateful to Judy Mellsop and John Gow who assisted with the field work and to Dr John Waller who performed the statistical analyses.

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SOIL SOLARIZATION AND GLYPHOSATE FOR PURPLE NUTSEDGE (*CYPERUS ROTUNDUS*) CONTROL

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Abstract: Dormant propagules of purple nutsedge (*Cyperus rotundus* L.) are the principal reason for nutsedge persistence and survival. Soil solarization has been shown to release purple nutsedge dormancy and synchronize purple nutsedge sprouting. Our objective was to determine whether soil solarization pretreatment could enhance glyphosate control of purple nutsedge. A field infested with purple nutsedge was rotary-cultivated and irrigated, followed by covering with clear polyethylene for 24 days. Eighteen days after polyethylene removal, solarized and non-solarized purple nutsedge were treated with glyphosate at 2, 4 and 6 kg/ha. Purple nutsedge shoot density and percent tuber sprouting in the soil were determined to assess the effect of soil solarization and glyphosate applications. Soil solarization increased purple nutsedge shoot density from 258 to 473 per m^2 and tuber sprouting from 39 to 78% of the tuber population in the uppermost 15 cm of soil. Glyphosate at 2, 4, and 6 kg/ha killed all emerged purple nutsedge foliage. However, emergence of new purple nutsedge shoots 10 days after treatment was reduced about 80% when previously soil solarized. The nutsedge shoot and inter-connected tuber system treated with glyphosate was excavated from the soil to a depth of 15 cm; parent tubers, corms, and new tubers were moist-incubated at 31/21 C for 8 weeks to assess for live tubers. At 4 and 6 kg/ha, 0% of the new tubers, 0 to 1% of the corms, and 1 to 4 % of the parent tubers sprouted. Glyphosate at 2 kg/ha was less effective as 19% of the corms sprouted when nutsedge was solarized before treatment. The enhanced purple nutsedge control was attributed to solarization causing earlier sprouting of a greater population of purple nutsedge prior to the glyphosate application. Soil solarization followed by glyphosate may be a tool for purple nutsedge management.

Key words: tuber dormancy, tuber sprouting

Introduction

Various degrees of tuber dormancy cause irregular emergence of purple nutsedge (*Cyperus rotundus* L.), contributing greatly toward its persistence and adding significant cost to current management strategies. Effective herbicides such as glyphosate provide control of emerged purple nutsedge (Chase and Appleby, 1979; Doll and Piedrahita, 1977; Terry, 1985; Zandstra and Nishimoto, 1975, 1977), but dormant tubers of purple nutsedge that sprout after glyphosate application can quickly reinvade the site. If management strategies can be developed to synchronize the sprouting process prior to glyphosate application, the resulting purple nutsedge population may be significantly reduced.

An alternating temperature regime of 35/25 C (12/12h) caused 100% sprouting of purple nutsedge tubers within 4 weeks (Miles *et al.*, 1996), thus the ability to release all propagules from dormancy exists. At the mean constant temperature (30 C), only 72% sprouting occurred (Miles *et al.*, 1996). Both the budbreak and shoot elongation processes were regulated by temperature; most purple nutsedge tubers produce budbreak at constant temperature, and only a short (30 min) high temperature pulse caused budbreak in the remainder of the tubers (Sun and Nishimoto, 1997). Once budbreak occurs, little shoot elongation occurred at constant temperatures, but shoot elongation was greatly stimulated by diurnally alternating temperatures (Nishimoto *et al.*, 1995; Sun and Nishimoto, 1999).

Miles (1991) showed that soil solarization increases temperature fluctuation in the soil. He found that the mean daily soil temperature at 15 cm depth ranges from 22 to 27 C at a sea level location in Hawaii, and the daily difference between minimum and maximum was less than 2 C; single tubers were planted in nylon mesh bags, and about 70% of the tubers sprouted under these conditions. Under soil solarization, the mean daily soil temperature at the 15 cm depth increased from 5 to 9 C, and the difference between minimum and maximum was 4 to 5 C, which typically caused 97 to 100% of the single tubers planted in nylon mesh bags to emerge.

Another factor influencing tuber dormancy is apical dominance. Apical dominance occurs within a tuber and in a chain of tubers (Muzik and Cruzado, 1953, Smith and Fick, 1937). Apical

dominance within a tuber chain can be broken by severing the chains (Smith and Fick, 1937). Furthermore, the tuber chain greatly reduces the alternating temperature stimulation of purple nutsedge shoot elongation (Kawabata and Nishimoto, 1999). Thus, management practices such as soil tillage to sever tuber chains may also assist in synchronizing tuber sprouting.

The concept of synchronizing tuber sprouting followed by glyphosate may provide a new management scheme to control purple nutsedge. Our objective was to determine whether soil solarization following soil rotary-cultivation influenced purple nutsedge control by glyphosate.

Materials and Methods

The field experiment was conducted at the University of Hawaii's Waimanalo Research Station on Oahu, Hawaii. The Station is on very fine, kaolinitic, isohyperthermic Vertic Haplustolls. A field heavily infested with purple nutsedge was rotary-cultivated twice to a depth of 15 cm to prepare a smooth seedbed. Atrazine was applied at 2.8 kg/ha to control weeds other than purple nutsedge. The field was irrigated by overhead sprinklers. Two days later, on March 1, 1991, half of the main plots were covered with 0.025 mm thick polyethylene to an area of 2.4 by 14.7 m (solarized plot), and half were left bare (non-solarized plot). The field was overhead irrigated twice weekly with 15 to 20 mm of water if rainfall was inadequate to sustain purple nutsedge sprouting and growth. The polyethylene cover was removed after 24 days, and the number of purple nutsedge shoots per 0.093 m^2 sample area was determined. During the solarization period, the mean maximum air temperature was 23.7 C and the mean minimum was 19.1 C. In addition, all tubers within the sample area to a depth of 15 cm were excavated and counted to provide an estimate of percent tuber sprouting. No tubers below 15 cm sprouted at that time. Tubers in the uppermost 15 cm of soil represented 90% of the tuber population (Siriwardana and Nishimoto, 1978). Seventeen days later, glyphosate (Roundup 360 g a.e./l) at 0, 2, 4 and 6 kg/ha was applied in 237 L/ha water to 1.5 by 3 m subplots within each solarized or non-solarized main plot. Purple nutsedge in the non-solarized plots had 3 to 9 leaves, were 5 to 13 cm tall, and covered approximately 25% of the soil. Nutsedge in the solarized plots had 3 to 12 leaves, were 5 to 20 cm tall, and covered approximately 90% of the soil. Approximately 5% of the nutsedge were flowering in the solarized and non-solarized plots. Each treatment was replicated four times in a randomized complete block design. Ten days after glyphosate application, live and dead purple nutsedge shoot counts were made on 0.186 sq m plots. Counts of live purple nutsedge shoots were also made at 19, 28 and 38 days after glyphosate application. In addition, at the 10 day sampling, the interconnected network of corms, rhizomes, parent tubers and new tubers to each dead purple nutsedge shoot in a 30 by 30 cm to a depth of 15 cm were collected. Similar untreated control samples of live shoots were collected. The corms, parent tubers and new tubers were separated and moist-incubated at 31/21 C (12/12h) for 8 weeks to determine the effect of glyphosate on tubers connected to glyphosate-treated shoots.

The effects of solarization on the number of shoots, tubers, and tuber sprouting at the end of thhe solarization treatment were subjected to the t-test. Chi-square tests were used to test for the increases in the number of sprouted tubers, corms, parent tubers, and dead shoots due to glyphosate with or without solarization. Shoot numbers from 10 to 38 days were regressed on glyphosate level, with or without solarization, time after glyphosate application, and their interactions. The SAS general linear model procedure (SAS Institute, 1990) was used for all analyses of variance.

Results and Discussion

Soil solarization for 24 days increased purple nutsedge shoot density from 258 to 473 per m^2 while tuber population remained the same (Table 1). This resulted in an increase of percent tuber sprouted in the uppermost 15 cm of soil from 39 to 78%. It was interesting to note that some solarized tubers had multiple shoots while all non-solarized tubers had a single shoot. While the solarization effect is substantial, the extent of tuber sprouting with solarization in our study is considerably lower than the 97% obtained with Miles (1991) when he planted single tubers in nylon mesh bags at a depth of 15 cm in the field. With a natural field infestation, a significant portion of the tubers are connected in chains (Siriwardana and Nishimoto, 1987), and the apical dominance effect (Muzik and Cruzado, 1953; Smith and Fick, 1937) likely had an important influence in suppressing emergence of purple nutsedge, despite soil solarization. In further studies, we showed that while alternating temperature caused nearly all shoots of single tubers to elongate readily, less than half of the tubers on four-tuber chains had shoots that

Table 1 Purple nutsedge shoot emergence and sprouting following 24 days of soil solarization.

Treatment	No. tubers/m^2/15 cm depth	No. shoots/m^2	Tubers sprouted (%)
Non-solarized	662	258	39
Solarized	549	473	78
	P[a] = 0.71	P = 0.17	P < 0.01

[a]Probability that the means are different by the t test.

elongated (Kawabata and Nishimoto, 1999). Thus, strategies to sever tuber chains in the field prior to solarization may result in more effective early tuber sprouting.

Glyphosate at 2, 4 and 6 kg/ha killed all nutsedge shoots that were emerged at application (visual observation; data not presented). In addition, glyphosate at 4 and 6 kg/ha killed all new tubers, 99 to 100% of the corms, and 96 to 99 % of the parent tubers that were connected to foliar growth. (Table 2). Glyphosate at 2 kg/ha was less effective on controlling corms when previously solarized, as 19% of the solarized corms sprouted while only 6% of non-solarized corms sprouted (Table 2). Thus, at the 4 and 6 kg/ha glyphosate rate, virtually all nutsedge emerging after the glyphosate treatment would be expected to arise from previously dormant tubers.

Table 2 Effect of glyphosate on sprouting of new tubers, corms, and parent tubers connected to nusedge plants that were killed, and on live/dead purple nutsedge shoots 10 days after treatment. Tubers were removed from plants 10 days after glyphosate application and incubated at 31/21 C (12/12h) for 8 weeks.

Treatment		Tubers sprouted (%)			Dead shoots (%)
Glyphosate rate (kg/ha) ± solarization		New tubers	Corms	Parent tubers	
0	non-solarized	100	97	96	0
0	solarized	95	98	93	0
2	non-solarized	0	6	4	63
2	solarized	1	21*[a]	4	95*
4	non-solarized	0	0	3	67
4	solarized	0	0	1	90*
6	non-solarized	0	0	4	71
6	solarized	0	1	1	97*

[a]Solarized versus non-solarized within the same glyphosate rate was significantly different at the 5% level by chi-square analysis.

Without solarization, only 63 to 71% of the nutsedge shoots were dead 10 days after glyphosate treatment, and with solarization 90 to 97% of the nutsedge shoots were dead (Table 2). Ten days after glyphosate treatment, live nutsedge shoot numbers in the solarized plots were reduced about 80% when compared with the non-solarized plots (data not shown). Thus, solarization greatly reduced the nutsedge population that emerged after the glyphosate application. Soil solarization resulted in markedly higher nutsedge shoot densities prior to the glyphosate treatment and in the nontreated plots shortly after

glyphosate was applied (Fig. 1). By shifting a greater proportion of the nutsedge population to emerge earlier and to be treated with glyphosate, the solarization pretreatment greatly reduced the number of nutsedge shoots that emerged after the glyphosate treatments, but with time the nutsedge population rapidly increased. (Fig. 1).

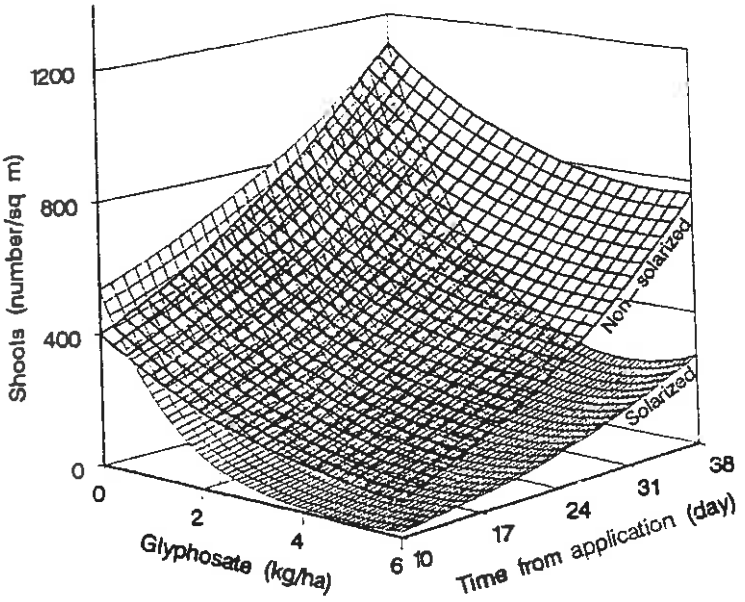


Fig. 1 Purple nutsedge population following glyphosate application that was pretreated with soil solarization. Shoot number = $(16.7 + 3.73xS - 2.92xG + 0.188xGxG - 5.51xSxG + 0.667xSxGxG + 0.366xD + 0.00209xDxD - 0.112xSxD + 0.0223xGxD - 0.00871xSxGxD)^2$ where S, solarization (0 for non-solarized, 1 for solarized); G, glyphosate level; D, days from glyphosate application.

The enhanced purple nutsedge control was attributed to solarization causing earlier sprouting of a greater proportion of the native purple nutsedge population prior to glyphosate application. The greatly reduced nutsedge population which resulted from solarization plus glyphosate as compared to glyphosate alone would be expected to significantly improve yield of vegetable crops (William and Warren, 1975). Further studies to refine this technique by appropriate solarization techniques, glyphosate timing, and methods to sever tuber chains may enhance the level of nutsedge control.

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STATUS OF WEED MANAGEMENT RESEARCH IN INTERCROPPING IN INDIA-AN OVERVIEW

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Abstract : Intercropping is the most common and prevalent cropping system in Indian Agriculture. Research works were undertaken during 1970s at ICRISAT to study the weed problems and developing their management technology in intercropping systems for semi-arid tropical farmers. Further, weed management research was initiated under different agroclimatic conditions in the country when All India Coordinated Research Programme on weed control came into operation during 1978 at different centres and some useful results have been achieved. Identification of competitive periods, evaluation of intercrops under different planting patterns and screening of safe and effective herbicides are the main components of the programme. Information available on critical period of weed competition, weed suppression ability of short duration and quick growing intercrops with wide spaced, long duration and tall growing crops and thereby saving in weeding requirement and herbicidal recommendations for important intercropping systems have been highlighted in this paper. Scanning of the literature revealed that inadequate research work on weed management in intercropping systems have been carried out in this country and more research work is needed in every aspects of weed management in intercropping systems. Priority for future research strategies in intercropping is also suggested.

Key words: Weed management, Intercropping, Herbicides

Introduction

Intercropping systems (i.e. sowing of two or more than two crops in distinct but proximate rows) designed on principles of scientific base in crop production hold a great promise in increasing the land productivity under Indian conditions (Saxena, 1972). Intercropping results in more efficient use of solar energy and harnessing benefits of positve interaction in crop associations. These advantages are, in general, more pronounced in wide spaced crops under stress environments.

Since intercropping is practicised intensively under rainfed and irrigated conditions in this country and weeds are one of the major factors determining the success of an improved cropping system, research information in developing a sound and strategic weed management programme for each intercropping system prevailing in different agro-climatic zones of the country are of great significance.

Critical period of crop-weed competition

Considerable research works have been done in this country to identify the critical period of weed competition in sole cropping but little information are available in intercropping systems. It has been experimentally proved that the critical period of weed competition in intercropping was considerably longer than in sole crops, so that weeding operations had to be continued for a longer period. This is quite evident from the work of Shetty (1979) who reported that sole cropped sorghum needed to be maintained weed free for only the first 4-5 weeks of crop growth whereas in sorghum + pigeonpea intercropping, the weed free period had to be maintained upto 7 weeks after sowing. The critical periods of crop weed competition in important intercropping systems have been detailed in table1.

Table 1 : Critical period of weed competition in important intercropping systems.

Intercropping systems	Periods	Locations	Scientists
Sorghum + Pigeonpea	7 WAS	Hydrabad	Shetty, 1979
Sorghum + Pigeonpea	8 WAS	Kanpur	Ali, 1994
Pigeonpea + blackgram	2-8 WAS	Kanpur	Tewari *et al.*, 1989
Groundnut + pigeonpea	2-8 WAS	Kanpur	Tewari *et al.*, 1989
Maize + blackgram	4-5 WAS	Palampur	Sharma & Nayital 1991
Pigeonpea + sesame	15-45 DAS	Varanasi	Singh *et al.*, 1993
Chickpea + mustard	8 WAS	Kanpur	Ali, 1994

Effect of intercrops on weed suppression

Intercropping systems have also been found to suppress weeds through formation of good canopies due to competitive planting pattern and thus provided an opportunity to utilize cropping systems as a tool of weed management (Rao and Shetty, 1976). The suppression of weed growth in intercropping system is mainly due to increased leaf area index and light interception. Importance of short duration and quick growing intercrops with wide spaced long duration and tall growing crops toward weed suppression and resulting in saving of weeding requirement in base crops have been well recognised and documented.

Pigeonpea

It is slow growing, wide spaced and usually intercropped with short duration crops like sorghum, greengram, blackgram, cowpea, sesame etc. under rainfed situation. Sorghum + pigeonpea intercropping system is extensively practicised in Karnataka, Maharastra and Andhra Pradesh and is known to reduce weed intensity apart from efficient utilization of land space. At Delhi, inclusion of two rows of soybean in between two rows of pigeonpea registered a reduction in weed growth to the extent of 45-50 percent (Ahlawat *et al.*, 1982). A marked reduction in the density and dry matter accumulation of weeds have been observed in intercropping of cowpea with pigeonpea. (Shetty and Rao 1981; Venkateshwarlu and Ahlawat 1986). Inclusion of three rows of each urdbean and mungbean and one row of cowpea in between the two rows of pigeonpea suppressed the growth of weeds to the extent of 33, 31, 39 per cent, respectively, in irrigated pigeonpea at Kanpur. In fact, inclusion of intercrops in the rows of pigeonpea played dual role. Weed suppression on the one hand and additional or bonus yield of intercrops on the other hand without reducing the yield of pigeonpea. Manual weeding once during critical period of weed competition was found adequate for obtaining economic yield in all the intercropping systems. The labour requirement in intercropping could be reduced from 35 to 20 labours per hectare. (Tewari, 1989). Short duration and close growing legumes, (cowpea, urdbean and mung bean) intercropped with pigeonpea suppressed weed flora by 20-45 percent over sole pigeonpea and proved more productive under rainfed conditions. (Ali, 1994.) Intercropping of greengram, pearlmillet and sesame with rainfed pigeonpea led to weed suppression to the extent of 36.9, 50.8 and 36.6 per cent, respectively, at Kanpur (Table 2).

Table 2 : Weed dry weight under unweded plot (Tewari and Rathi, 1997)

Cropping systems	Weed dry weight (kg/ha)	Weed smothering efficiency (%)
Pigeonpea sole	2672	–
Pigeonpea + greengram (1: 2)	1684	36.9
Pigenopea + pearlmillet (1: 2)	1314	50.8
Pigenopea + sesame (1: 2)	1694	36.6

The results further revealed that pigeonpea equivalent yield obtained under pigeonpea + greengram intercropping raised under unweeded conditions was comparable (1064 Kg/ha) to the yield of sole pigeonpea with a single hand weeding (1072 Kg/ha). Similarly, supplementing a single hand weeding in the pigeonpea + greengram intercropping resulted in a substantially higher pigeonpea

equivalent yield (1507 Kg/ha) than the sole cropping of pigeonpea yield with two hand weedings (1311 Kg/ha). Thus, merely by inclusion of greengram as an intercrop with pigeonpea, one hand weeding could be saved (Table 3).

Table 3 : Pigeonpea equivalent yield (Kg/ha) (Pooled data of two years) (Tewari and Rathi, 1997)

Cropping systems	No weeding	Manual weeding once	Manual weeding twice	Pendimethalin (1.0 kg/ha)	Mean
Pigeonpea sole	794	1072	1311	1111	1072
Pigeonpea + greengram	1064	1507	1882	1339	1448
Pigeonpea + pearlmillet	697	949	1173	951	942
Pigeonpea + sesame	832	1181	1452	920	1096
Mean	847	1177	1454	1080	

LSD at 5%
Cropping System (C) = 108 Weed control (W) = 108 C x W = 215

Mishra *et al.* (1998) reported that paired row planting of pigeonpea with three rows of soybean (2:3) and pigeonpea + soybean (1:2) recorded significantly higher harvest index and less weed biomass/m^2 than the sole pigeonpea and soybean planting. Tewari *et al.* (1999) found a reduction of 24.52 percent in weed weight due to differed sowing of pigeonpea and groundnut intercropping compared to their simultaneous sowing.

Cotton

It is slow growing, wide spaced and long duration crop. At Fedrick Institute of Plant Protection and Toxicology, Padappai (Tamilnadu), result indicated that intercropping of sesame and soybean resulted weed suppression in cotton to the extent of 32.8 and 45.6 per cent, respectively. The seed cotton yield obtained from cotton + soybean intercropping system under unweeded condition was similar (724 Kg/ha) to the yield of cotton supplemented with single hand weeding alone (732 Kg/ha). Similarly, single hand weeding operating in cotton + soybean cropping system resulted in a substantially higher seed cotton yield (1086 Kg/ha) than the yield of sole cotton crop supplemented with two hand weedings (837 Kg/ha). So the adoption of soybean as an intecrop in rainfed cotton is an effective method for reducing the weed competition, enhancing yield potential and eventually reducing one hand weeding. Similar results were also achieved in cotton + sesame intercropping system (Gnanasambandan and Balakrishnamurthy , 1998).

Sorghum

Sorghum is poor competitor against weeds during the seedling stage. Intercropping sorghum with low growing crops like mungbean, urdbean, cowpea, soybean is quite popular under rainfed and semiarid areas. Intercropping of sorghum with cowpea and greengram smothered weeds and reduced weeding requirement (Table 4).

Table 4 : Grain yield of sorghum equivalent yield and weed weight at harvest (Rao and Shetty, 1981).

Cropping systems	Grain Yield (Kg/ha)	Dry weed weight (Kg/ha)
Sorghum + 1 hand weeding	3652	78.7
Sorghum + 2 hand weeding	5264	17.0
Sorghum + cowpea 1 HW	4895	8.3
Sorghum + greengram 2 HW	4952	14.7
C.D. at 5%	391	7.72

Maize

Growing mungbean, cowpea, soybean and groundnut as an intercrop with maize crop is very popular in northern India. Inclusion of soybean as an intercrop reduced 14, 38 and 23 per cent grassy weeds at 20, 40 and 60 days of crop growth stages, respectively, in comparison to sole maize whereas inclusion of groundnut as an intercrop the corresponding reductions in grassy weed population were 18, 30 and 17 per cent (Prusty, 1988). Weed suppression was recorded higher in maize + groundnut intercropping as compared to maize + soybean resulting in 35% and 68% more equivalent yield than maize + soybean intercropping and sole maize, respectively (Singh and Patel, 1991). Growing three rows of blackgram in paired row of maize had reduced the weed population (78, 38, 37/0.50 m^2) and dry matter production of weeds (49, 68 and 49 g/m^2) to the lowest where as solid maize paired planting systems recorded highest weed population (130, 59, 51/0.50 m^2) and dry matter production (74, 98, 65 g/m^2) at 30, 60 and 90 days after planting, respectively. Maximum values for maize yield (25.7 q/ha), maize equivalent yield (35.3 q/ha), stover yield (53.9 q/ha), total N uptake (71.7 kg/ha), LAI (4.6) and light interception (92) were recorded in paired planting of maize with three rows of blackgram (Singh & Garpalapandu, 1999). Weed suppression ability of soybean, groundnut, blackgram and pigeonpea with maize was found to be 15.4, 33.7, 17.3 and 16.4 percent resulting in greater maize equivalent yield than sole maize in table 5.

Table 5 : Effect of intercropping on weed suppression and yield of maize (Mishra and Gautam, 1995)

Cropping systems	Dry weight of weeds (Kg/ha)	Maize equivalent yield (Kg/ha)	Weed suppression ability(%)
Maize sole	2274	2111	–
Maize + soybean	1923	2750	15.4
Maize + groundnut	1508	4215	33.7
Maize + blackgram	1880	2358	17.3
Maize + pigeonpea	1990	2483	16.4

Sugarcane

Short duration coupled with short statured crops like potato, wheat, mustard, pea, chickpea, lentil, coriander, etc. with autumn planted and blackgram, greengram, cowpea, onion, lady finger, with spring planted cane are usually rasied as an intercrop in northern India. Intercropping of blackgram with sugarcane significantly reduced weed infestations and gave additional seed yield without adversely affecting the sugarcane yield (Dhillon and Kler, 1981).

Chilli

Intercropping of coriander in chilli (1:1) effectively checked the weeds and finally reduced weed dry matter than that of chilli + onion system intercropping. (Muthusankaranarayanan *et al.*, 1997).

Banana

High planting density (4440 - 6950/ha) of banana coupled with intercropping of cowpea, drastically reduced weed growth, resulted in substantially higher yield (Chacko and Reddy, 1981). Growing cowpea as an intercrop in banana resulted in the development of a dense canopy covering the entire ground area and suppressed weed growth completely for a period of 70 days. Weed growth was checked for a further period of two months by mulching the soil with uprooted cowpea plants.

Coconut

Intercropping of banana with coconut is widely adopted practice in Kerala. Intercropping of cowpea could check the weed growth for about 3 months only. Intercropping of banana reduced weed growth in young coconut garden (Savithri *et al.*, 1994).

Use of herbicides in intercropping

Based on the research work done at different centres under All India Coordinated Research Programme on Weed Control scheme and other research institutes, following herbicides have been found selective, effective and economical in different intercropping systems.

Pigeonpea based intercropping

At Bhopal, fluchloralin (1.5 Kg/ha) followed by interculture at 40 days after sowing registered highest weed control and productivity (83%), more net income (Rs. 6936/ha) over unweeded in pigeonpea + soybean intercropping (Nimje, 1993). Fluchloralin (0.5 Kg/ha) and metolachlor (0.75 Kg/ha) each followed by intercultivation at 35 days after sowing registered greater yield of sorghum and pigeonpea intercropping over untreated at Jhansi (Gangwar, 1993). In pigeonpea + cowpea, fluchloralin (0.75 Kg/ha) and pendimethalin (1.0 Kg/ha) were as effective as weed free treatments in reducing the weed growth and thereby improved pigeonpea yield significantly (Thomas *et al.*, 1994). Pendimethalin (1 Kg/ha) was found effective and profitable in pigeonpea + greengram intercropping (Tewari and Rathi, 1997). Pendimethalin (1.25 Kg/ha) and metribuzine (0.5 Kg/ha) each followed by post emergence of fluazifop butyl (0.5 Kg/ha) provided efficient control of associated weeds including *Sorghum halepense* in pigeonpea + soybean intercropping at Kanpur (Tewari *et al.* 1997). In sorghum intercropped with pigeonpea, pendimethalin (1.25 Kg/ha), metribuzine (0.5 Kg/ha), oxyfluorfen (0.10 Kg/ha) and metolachlor (1.5 Kg/ha) demonstrated effective control of associated weeds upto 30-35 days after sowing and thereafter *Phyllanthus niruri* and other weeds began emerging These herbicides registered 63.1%, 71.9%, 52.8% and 80.0% greater pigeonpea equivalent yield, respectively than unweeded at Kanpur (Tewari *et al.* 1997). In pigeonpea + soybean (2:4), metolachlor (1 kg/ha) coupled with one intercultivation and hand weeding ensured weed free condition resulting in higher seed yield and net returns at Dharwad (Hiramath and Agasimani, 1999). Alachlor (1 kg/ha) or metolachlor (1.5 kg/ha) followed by one hand weeding proved an alternative of two hand weedings in rainfed sorghum + pigeonpea intercropping at Coimbatore (Kandasamy *et al.*, 1999).

Ground nut based intercropping

In groundnut intercropped with sunflower, pendimethalin (1 Kg/ha), metolachlor (1 Kg/ha), imazethapyr (0.10 Kg/ha) and oxyfluorfen (0.15 Kg/ha) each followed by fluazifop butyl (0.25 Kg/ha) at 21 days after sowing or hand weeding at 30 days after sowing were found effective in preventing weed competition at Hyderabad (Venkat Reddy *et al.*, 1993). In groundnut + pigeonpea intercropping, pendimethalin (1.0 Kg/ha) menifested excellent control of associated weeds including *Trianthema monogyna* but was ineffective against *Commelina benghalensis*. Integration of single hand weeding with pendimethalin (1.0 Kg/ha) realized 544 Kg/ha (28.30%) more groundnut equivalent yield than its sole application and was at par with two manual weedings at Kanpur (Tewari and Rathi, 1995). Pendimethalin (1.0 Kg/ha) and fluchloralin (1.0 Kg/ha) each followed by one hand weeding at 30-40 days after sowing were found next to hand weeding and hoeing twice at Palem (Vijay Kumar *et al.* 1995). Alachlor, pendimethalin and trifluralin supplemented with hand weeding at 30 days after sowing recorded lower dry weight of weeds compared to herbicide alone in groundnut + sunflower intercropping. Oxadiazon (0.5 kg/ha) coupled with one intercultivation at 30 days after sowing and one hand weeding at 40 days after sowing was found quite effective in controlling weeds and recorded higher productivity in ground nut + chilli (4:2) intercropping at Dharwad.

Greengram/blackgram based intercropping

Pendimethalin (1 Kg/ha) prevented weed competition particularly from *T. monogyna* and resulted at par greengram equivalent yield (849 Kg/ha) with manual weeding twice (842 Kg/ha) in greengram + pearlmillet intercropping at Kanpur. In blackgram intercropped with sesame, pendimethalin (1.25 Kg/ha) and metolachlor (1.5 Kg/ha) registered 79.9% and 59.7% weed control efficiency and resulted in 55.8% and 58.1% in blackgram, 60.7% and 66.6% in sesame and 52.1% and 58.2% in blackgram equivalent yield more than unweeded and proved at par with manual weeding twice at Kanpur (Tewari *et al.* 1993).

Maize based intercropping

Alachlor (1.0 Kg/ha) menifested efficient control of annual grasses and broadleaved weeds resulted in 132% of maize and 169% of blackgram yield greater than unweeded in maize + blackgram intercropping at Kanpur (Rathi and Tewari 1982). At Palampur, Tripathi and Singh 1987 found control of weeds to the threshold level by alachlor (2.5 Kg/ha) in maize + soybean intercropping. In maize + groundnut/soybean intercropping, simazine (1 Kg/ha) as preemergence followed by mechanical weeding at 40 days after sowing was found most effective for reducing weed infestation and increasing yield in maize + groundnut intercropping but it was toxic to soybean (Singh and Patel, 1991). Metolachlor (1 Kg/ha), pendimethalin (1 Kg/ha), thiobencarb (2 Kg/ha) and oxadiazon (0.5 Kg/ha) were found effective alternative to hand weeding and hoeing in maize + blackgram intercropping in mid hills sub humid zone of Himachal Pradesh (Sharma and Nayital, 1993). Pendimethalin (1.5 Kg/ha) followed by one hand weeding significantly increased maize equivalent yield (3266 Kg/ha) than alachlor (2 Kg/ha) + one hand weeding (2095 Kg/ha) and mechanically weeded (1984 Kg/ha) in maize based cropping system (Porwal, 1993). Metolachlor (1.25 kg/ha) has been found most efficient and economic for controlling weeds in rainfed maize based blackgram/soybean/horsegram intercropping under mid hill conditions of Bajaura (Thakur, 1994).

Potato Based intercropping

At Kanpur, in potato + wheat intercropping, isoproturon (0.75 Kg/ha) and pendimethalin (0.75 Kg/ha) demonstrated 51.19% and 44.42% weed control efficiency resulted in 26.88% and 22.94% more potato equivalent yield and Rs. 8406/ha and Rs. 2479/ha greater net income than untreated (Tewari and Singh 1993). In potato intercropped with linseed, isoproturon (1.0 Kg/ha) and pendimethalin (1.0 Kg/ha) as pre-emergence brought about effective control of weeds (73.18% and 68.53%, respectively) and resulted more potato equivalent yield (26.07% and 25.62%, respectively), than unweeded and proved at par to manual weeding twice at Kanpur. Oxyfluorfen (0.10 Kg/ha) and pendimethalin (1.0 Kg/ha) registered 33.45 and 26.17 per cent more potato equivalent yield and Rs. 11659 and Rs. 7986 per hectare greater net income than unweeded in potato + mustard intercropping. However metribuzin was found toxic to mustard crop (Tewari *et al.* 1998).

Sugarcane based intercropping

In sugarcane intercropped with potato, metribuzin (1.0 Kg/ha) proved effective in providing weed free condition and resulted in comparable yield of millable cane obtained under weed free manualiy at Kanpur (Rathi and Tewari 1982). Isoproturon at (0.75-1.0 Kg/ha) was found effective against winter annual broadleaved weeds and *Phalaris minor* and proved selective in sugarcane + mustard intercropping. This treatment gave 65.1% to 90.6% and 44.8% to 45.3% mean increase in yield of sugarcane and intercropped mustard (Mehra *et al*, 1989). The higher yield of cane (86.9 t/ha), seed yield of mustard (1.58 t/ha) and cane equivalent yield (115.8 t/ha) were recorded with the application of oxyfluorfen (0.23 Kg/ha) at Udaipur (Singh *et al.* 1997).

Wheat based Intercropping

At Kanpur, isoproturon (1.0 Kg/ha) proved safe, effective and economical in wheat based mustard/chickpea/linseed intercroping as it fetched more net return (Rs. 1072/ha) than no application of isoproturon (Tewari *et al.*, 1989). In wheat intercropped with *raya* and lentil, isoproturon (1.0 Kg/ha) and pendimethalin (1.5 Kg/ha) were found effective and safe at Palampur, (Singh, 1985). Isoproturon (0.94

Kg/ha) as pre-emergence was found promising herbicide in wheat + mustard intercropping (Sindu *et al.*, 1988). In wheat + pea intercropping, isoproturon (1 Kg/ha) demonstrated effective control of weeds except *Lolium temulentum* at Palampur (Rana and Angires, 1994).

Chickpea /pea/ lentil based intercropping

In chickpea and *raya* intercropping at Hissar, pendimethalin (1.0 Kg/ha), fluchloralin (1.0 Kg/ha) and oxyfluorfen (0.20 Kg/ha) controlled weeds effectively and recorded significantly greater yield of component crops without any phytotoxic effect on either crops (Panwar *et al.*, 1985). At Kanpur, in chickpea + linseed intercropping, pendimethalin (1.0 Kg/ha) recorded 68.18%, 15.70% and 49.35% increased yield of chickpea, linseed and chickpea equivalent yield over unweeded and was at par to manual weeding twice (Tewari *et al.*, 1994). In pea + mustard intercropping at Kanpur, pendimethalin (1.25 Kg/ha) prevented the emergence of *P. minor* and brought about greater weed control efficiency (78.7%), more pea equivalent yield (60.3%) and greater net return (Rs. 7429/ha) than unweeded (Tewari *et al.*, 1998). In lentil intercropped with linseed, pendimethalin (1 Kg/ha) demonstrated excellent mortality of *C. album*, *P. minor* and *A. arvensis* resulting in 63.75% weed control efficiency, 51.94% increased lentil equivalent yield and Rs. 4031/ha higher net return over unweeded (Tewari *et al.*, 1997).

Cotton based intercropping

In cotton + black gram intercropping, fluchloralin (1 Kg/ha) was found selective and effective and gave higher returns than cotton pure or intercropped with onion. Fluchloralin (0.5 Kg/ha) supplemented with one hoeing or manual weeding at 6 weeks after sowing was found to be economical preposition. In another study, butachlor (1 Kg/ha) was found effective and economical method of weed control in cotton + blackgram intercropping under rainfed condition at Kovilpatti, (Muthu Sankaranarayanan *et al.*, 1988). In labour scarce situation, fluchloralin (0.90 Kg/ha) could be used as an alternative in cotton+soybean intercropping in Tamilnadu (Gnanasambandan and Balakrishnamurthy, 1998). In chilli + cotton intercropping, diuron (1.2 kg/ha) followed by inter cultivations at 20 and 45 days after sowing and one hand weeding was found effective in controlling weeds resulting in comparable yield to weed free at Dharwad.

Paddy based intercropping

In paddy + groundnut intercropping, sowing of alternate rows or paired rows of groundnut alongwith pre-emergence application of pendimethalin at 1 - 1.5 Kg/ha followed by hoeing gave comparable yield to two manual weedings at Kharagpur. In rice intercropped with greengram/ soybean/ cowpea, the lowest weed weight was recorded in case of cowpea intercropping, however, the highest rice equivalent yield was recorded with soybean intercropping at Jorhat. Pendimethialin (1 kg/ha) + one hand weeding proved effective and safe in all intercropping. Butachlor (1 kg/ha) + one intercultivation at 30 days after sowing and pendimethelin (1 kg/ha) + one intercultivation at 30 days were found effective against associated weeds in rice + pigeonpea intercropping at Ranchi.

Coconut based intercropping

Diuron (1.5 Kg/ha) and oxyfluorfen (0.20 Kg/ha) checked the weeds emergence upto 3 months and thereafter weeds were effectively controlled through paraquat (0.40 Kg/ha) or glyphosate (0.4 Kg/ha).

Future research strategies

Following research strategies are suggested while formulating research programmes on weed management in intercropping :

- Evaluation of new crop cultivars as means of enhancing competitiveness with the weed flora has not been fully exploited. This can be manipulated to provide a competitive advantage.
- Various agronomic approaches *viz.*, time and methods of sowing, row arrangements, plant density, fertilizer application etc. towards minimizing weed growth must be evaluated.
- Little attention has been paid to evaluate the weeds as an intercrop as most of the weeds are utilised as medicines, vegetables and fodder purposes and also to enrich soil fertility.

- There is good scope of reducing weeding requirement by combining sowing of intercrops and weeding of main crops. Research work should be initiated in this direction.
- The critical period of weed competition must be identified for the promising inctercropping systems prevailing in different agroclimatic zones.
- Meagre research work has been done on weed management in intercropping raised under rainfed situation.
- Evaluation of herbicides for different crop combinations, interactions with different agronomic factors viz time and method of sowing, fertilizer and irrigation management etc. must be undertaken for study under different edaphic and climatic conditions.
- Testing of impliments and weeding tools in intercropping systems deserve due attention.
- Studies related to allelopathic/smothering effects of crops on weeds growth and vice varsa are the need of hour.

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STUDIES ON SOME BIOLOGICAL CHARACTERISTICS OF PURPLE NUTSEDGE AND ITS CONTROL IN COTTON FIELDS

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Abstract: The present series of experiments was conducted to investigate the behavior of purple nutsedge on both field and laboratory conditions. The results showed that one tuber could grow out 1.9 1.7 or 2.7 sprouts in average at 10~15℃, 27℃ or 35℃ respectively. and most tubers grow out one or two sprouts at both 10~15℃ and 27℃; and at 35℃, 26.4% of tubers could grow out three sprouts. Broken tubers could grow out more sprouts than intact ones. Tillage to break tubers mechanically might result in more density of nutsedge stands in the cotton fields. The lengths of tuber sprouts being 80.9% or 9.5% of total sprouts were 10~20 cm or 20~25 cm respectively and the maximum length of the other ones was 29 cm growing in darkness. Depth of tuber burial markedly affected emergence. Emergence was only optimal at a depth of 10 cm or less. Emergence progressively declined at depth below 10 cm until emergence was completely inhibited at 20 cm. The tubers placed under -3℃ condition for 5 hours might be killed at 100%. Tubers dried to a water loss of fresh weight at 39% lose their sprouting ability. About 92.9% of tubers were distributed in the soil layer at the depth of less than 10 cm, If tillage occurred to depth of 10~20 cm, most tubers would be plowed out sufficiently to expose to the open air being killed by freezing in winter and then by drying in drought spring. In deep-plowed cotton fields where the winter temperature had decreased to -7℃, the density of nutsedge plants would be reduced to 85.9% and the density of tubers decreased at 73.2% in comparison with un-deep plowed plots. In field trials, soil incorporation with dymron at 6 kg a.i./ha or 12 kg a.i /ha, the density of tubers was reduced at 82.3% or 97.6% in comparison with check plots, respectively.

Key words: purple nutsedge, biological characteristics, control in cotton field

Introduction

Purple nutsedge (*Cyperus rotundus* L.) is the most important weed infesting heavily the dry farmland crops in the temperate and subtropical zones. Cotton growing in the fields of one cropping system in the state farms with high level mechanization located in some littoral and lake areas at the middle and lower reaches of Changjiang River (Yangtse River) is damaged by purple nutsedge and reduced heavily in its yields. For exploring integrated weed management, the authors approached some biological characteristics of purple nutsedge and its control in the cotton fields. This study was conducted both in cotton field and laboratory conditions for recent years.

Materials and Methods

The tubers of purple nutsedge were collected from the fields after cotton harvesting in the main

cotton growing region at Jin Shan county at the middle reaches of Changjiang River and stored in the refrigerator at 0~5℃ for usage.

The studies were conducted in laboratory and in cotton field including: sprouting ability of tubers; depth of sowing related to emergence; length of tuber sprouts in darkness; tuber susceptible to cold and dryness; tuber distributed at different depth of soil layer; effect of deep plowing in winter on nutsedge emergence; and effect of dymron incorporated in soil to the density of nutsedge stands and tubers.

Tuber sprouting ability test

1. The tubers were placed in glass dishes buried in fine sand then moisturized with top water to keep saturated moist and put under 10~15℃, 27℃ or 35℃ condition seperately allowed to sprouting. The tubers were taken out and then the sprouts of each tuber were counted after 30 days,
2. The tubers weighed up at a range of 400~450 g were used, each tuber was cut by cross-cut or lengthwise-cut into two pieces, crisscross-cut into four pieces and un-cut intact ones as a check, the pieces of cut tuber were buried in fine sand placed in the glass dishes, then watered to saturated moist, and put under 27℃ condition allowed to sprout, every 30 tubers for each treatment with 3 duplications, the sprouts of each tuber were counted. after 30 days

Relation between sowing depth and nutsedge emergence test

Every 20 tubers per square meter were sown in loamy clay soil at the depth of 5, 10, 20 or 30 cm in field plots in cotton seeding time, each treatment with 3 replications. After 30 days, the nutsedge stands were counted.

Length of various sprouts of tuber in darkness

The tubers were placed in the dark cabinet keeping saturated moist at 27℃ for sprouting. after 20 days, the length of sprouts was measured.

Tuber susceptible to cold and dryness test

1. The tuber were placed under –3℃ condition for 1, 2, 5, or 10 hours, after treated the tubers were put into glass dishes keeping saturated moist at 35℃ for sprouting. After 20 days, The sprouting tubers and rotten ones were counted.
2. each tuber weighed up at 0.450 g was chosen to be used, the tubers were scattered on enamel trays for air-drying, after a certain period the tubers were weighed continuously, the tubers air-dried to a certain weight were picked upon and put into glass dishes keeping saturated moist at 30℃ for sprouting. After 20 days, The sprouting tubers and rotten ones were counted.

Distribution of tuber at different depth of soil layer

The overwinter tubers distributed in the soil layer at different depth in cotton field were dug out before cotton seeding, and the tubers dug up from the soil layer at different depth in a same plot were separately counted as a number per square meter. Sampling in plots was replicated 3 times.

Effect of deep plowing in winter to nutsedge emergence;

Deep plowing to a depth of more than 20 cm was carried out in cotton fields in large scale where the minimum temperature in winter might be -7℃. The deep plowing was practiced before the minimum temperature coming for about one month, and the un-plowing plots in the cotton fields were retained as the check. Random sampling for counting nutsedge plants and digging out the tubers from plots were carried on August when the cotton plants had formed crop canopy.

Effect of dymron incorporated in soil on the densities of nutsedge stands and tubers

After plowing and harrowing, the field plots by 5m×3m were incorporated with dymron just before cotton seeding, According to the application rate, 40% dymron wettable powder diluted with

required volume of water was sprayed onto the soil surface by knapsack sprayer, then the plots were harrowed twice with spike-tooth harrow. The tubers at the rate of 75/m^2 were planted in the plots. Every treatment was duplicated three times. After 23 day or 127 days, the nutsedge stands or the dug out tubers were counted respectively.

Results and Discussion

Table 1. Sprouting ability of tubers under different temperature.

Number of sprouts per tuber	Number of tubers sprouted			Number of sprouts			Tubers sprouted (%)		
	10-15℃	27℃	35℃	10-15℃	27℃	35℃	10-15℃	27℃	35℃
1	823	44	56	823	44	56	42.4	48.9	21.1
2	625	35	68	1250	70	136	32.2	38.9	25.7
3	332	9	70	996	27	210	17.1	10.0	26.4
4	121	2	48	484	8	192	6.2	2.0	18.1
5	28	0	17	140	0	85	1.4	0.0	6.4
6	10	0	4	60	0	24	0.5	0.0	1.5
7	1	0	2	7	0	14	0.1	0.0	0.8
total	1940	90	265	3760	149	717	100.0	100.0	100.0
Sprouts/tuber				1.9a	1.7a	2.7b			

The results showed that the tubers placed under 10~15℃, 27℃ or 35℃ conditions, one tuber could grow out 1.9, 1.7 or 2.7 sprouts in average, respectively; but under 10~15℃ and 27℃ conditions, most tubers could grow out only one or two sprouts; but 26.4% of tubers could grow out three sprouts at 35℃ (Table 1). This means higher the temperature might enhance the tuber to grow out more sprouts.

Table 2. Spouting ability of the pieces of cut tuber in comparison with intact ones.

Tuber cut in pieces	Average sprouts / per tuber	T- value
Crisscross-cut into four pieces	2.67 ± 0.16 a	4.9016
Lengthwise-cut into two pieces	1.70 ± 0.04 b	2.4495
Cross-cut into two pieces	1.73 ± 0.05 b	2.5980
Non-cut as check	1.30 ± 0.10 c	——

The cut tuber into pieces would grow out more sprouts than the intact ones in average at 27℃. The tuber crisscross-cut into four pieces might grow more sprouts than that the tuber lengthwise-cut or cross-cut into two pieces significantly, but there was not different between length-cut and cross-cut tubers (Table 2). This explains that in the fields, tillage to break up the overwinter tubers mechanically might

result in increasing density of nutsedge plants.

Table 3. Relation between the depth of tuber sowing and nutsedge emergence.

Sowing depth (cm)	Number of seedling in average Days after sowing			Emergence % in average Days after sowing		
	7	21	30	7	21	30
10	0.0	7.5	8.5	0.0	42.9	34.7
20	0.0	3.5	6.0	0.0	18.0	30.5
30	0.0	0.0	0.0	0.0	0.0	0.0
5 (as check)	9.5	17.5	29.5	100.0	100.0	100.0

Through the studies on relation between tuber sown at the depth of soil layer and nutsedge emergence, the results showed that emergence was only optimal at a depth of about 5 cm or less than 10 cm, emergence progressively declined at the depth of more than 10 cm until emergence was completely inhibited at 30 cm (Table 3).

Table 4. Length of the sprouts for different tubers in darkness.

Length of sprouts (cm)	Number of sprouts	Number of sprouts (%)
9 ~ 10	4	6.4
11 ~ 15	29	46.0
16 ~ 20	22	34.9
21 ~ 25	6	9.5
26 ~ 29	2	3.2
Total	63	100.0

In darkness, 80.9% of the tuber sprouts was within a range of 10~20 cm; only 9.5% of them was within 20~25 cm; the maximum length of the sprout reached 29 cm, this means the tuber buried below the depth at 30 cm could not emerge (Table 4).

Table 5. Tubers susceptible to cold at −3℃ after different period.

cooling period (hour)	Number of tubers treated	Number of sprouting tubers	sprouting tuber (%)
1	50	32	64.0
2	50	7	14.0
5	50	0	0.0
10	50	0	0.0
Untreated	200	127	63.5

The tubers placed under the cool condition at −3℃ for 5 hours, 100% of the tubers was frozen to death (Table 5).

Table 6. Tuber susceptible to the water loss of its fresh weight.

Weight of tuber (g)	Reduced weight of tuber (g)	Number of sprouted tuber	Sprouted tuber (%)
0.360	20	26	86.7
0.300	33	18	60.0
0.273	39	0	0.0
0.450 (as check)	0	30	100.0

Tubers dried to a water loss of fresh weight at 39% lost their sprouting ability and then died to be rotten (Table 6).

Table 7 Distribution of tubers at different depth of soil layer.

Depth in soil layer (cm)	Number of tubers	Number of tubers (%)
0 ~ 5	621	67.0
5 ~ 10	240	25.9
10 ~ 20	66	7.1
20 ~ 30	0	0.0
Total	927	100.0

Field trials showed that overwinter tubers were distributed in the field soil layer at the different depth, about 92.9% of tubers was distributed within the soil layer at the depth of less than 10 cm, most them could be favorable to emerge, otherwise, they would be difficult to emerge (Table 7).

Table 8. Effect of deep plowing in winter to nutsedge emergence and density of tubers.

Treatment	Density		Density reduction (%)	
	Stands / m^2	Tubers / m^2	Stands	Tubers
Winter deep plowed	58.5	166.5	85.9	73.2
Unplowed	414.0	621.0	—	—

In deep plowed cotton fields, most overwinter tubers might be turned up to expose to the open air, when the winter temperature had decreased to −7℃, the tubers would be killed by freezing in winter or be killed by drying in drought spring. The results showed that the density of nutsedge plants would be reduced at 85.9% in deep plowed cotton fields and the density of tubers decreased at 73.2% in comparison with un-deep-plowed plots (Table 8).

Table 9. Effect of dymron incorporated in soil on the density of nutsedge stands and tubers.

Rate (g a.i. / ha)	Density		Density reduction (%)	
	Stands / m^2 After 23 days	Tubers / m^2 After 127 days	Stands After 23 days	Tubers After 127 days
6000	23.6	26.3	43.5	82.3
12000	8.9	3.6	78.7	97.6
Untreated	41.8	149.0	—	—

The field trials showed that before cotton planting, soil incorporation with dymron at 6 kg a.i./ha or 12 kg a.i./ha reduced nutsedge plants at 43.5% or 78.7% after cotton seedling stage; but the density of tubers in soil layer was reduced at 82.3% or 97.6% in comparison with check plots, respectively (Table 9)

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SULPHOSATE, PARAQUAT, AND COMBINATION OF PARAQUAT/DIURON HERBICIDES FOR LAND PREPARATION IN NO-TILLAGE UPLAND RICE (*Oryza sativa*)

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Abstract: Field experiments were conducted to evaluate effectiveness of: three formulations of sulphosate (480g/lt and 240 g/lt. formulations each at 360, 720, and 1080 g/ha; and 145 g/lt. formulation at 290, 580, and 870 g/ha); paraquat and combination of paraquat/diuron each at 300, 600, and 900 g/ha, as a substitute for land preparation in controlling weeds in no-tillage upland rice (*Oryza sativa* L.). Treatments were arranged in a completely randomized block design with 3 replicates. Herbicides were applied two weeks before planting (WBP) using a back sprayer with 400 lt./ha application volume. Results showed that sulphosate at 580, 720, 870, and 1080 g/ha of any formulation and paraquat at 900 g./ha as well as combination paraquat/diuron at 600 and 900 g/ha could be used as substitutes for land preparation based on the suppression of weed coverage and weed dry weight in herbicide treated no-tillage plots compared to full-tillage plots at planting time up to 3 weeks after planting (WAP) or 5 weeks after application (WAA). There was no differences in rice germinating rate at 2 WAP, plant height and number of tillers up to 6 WAP between plants from no-tillage+herbicide plots and that from full-tillage plots, except in plots with the lowest sulphosate and paraquat levels. However, the number of productive tillers was greatly reduced in no-tillage+herbicides as well as in full-tillage plots if weeds were not controlled. It could be concluded that sulphosate, paraquat or combination of paraquat/diuron at the right dosages were suitable for substituting land preparation in no-tillage upland rice without detrimental effects on the plants. However, as in full-tillage system, weeding was required in no-tillage+herbicides system at 3 or 4 WAP to avoid yield loss from weeds.

Key words: sulphosate, paraquat, paraquat/diuron, no-tillage, upland rice

Introduction

The shift of upland rice production areas in Indonesia from Java island to the drier areas outside Java is a logical decision to maintain rice self-sufficiency since areas in Java, especially irrigated areas, are limited. However, several constraints are faced in developing upland rice outside Java including high labor cost, especially for land preparation, limited labor and water supply. On the other hand, full-tillage in dry areas may cause several negative effects such as increasing soil erosion, decreasing soil organic-C and total-N contents, and reducing soil moisture level (Utomo, 1995). Based on the these reasons, conservation or minimum tillage including no-tillage is a logical choice because this technique may maintain soil productivity by preventing the negative effects of full-tillage, therefore it can be employed as a part of sustainable agriculture approaches. Probably, the most important development of limited tillage techniques in rice take place in humid tropics where farmers are small, water control is poor with monsoonal flooding, and where equipment limitations are most severe (Watson and Allen, 1985).

Conservation tillage, especially no-tillage, is dependent on the use of herbicides to control the initial weeds or crop raton from previous season which usually are controlled during soil preparation process. The role of herbicides is difficult to replace by other methods because of practical, effectiveness, and economic reasons. In addition, herbicides may speed up the planting time so that farmers may increase planting index, and consequently saving labor and money. Around the world, herbicide-assisted limited tillage has been used in corn, soybeans, cotton, potato, sugarbeet, several small grains, and rice (Watson and Allen, 1985), and its use dated back in the 60s and 70s. Preplant application of paraquat at 0.56 to 1.12 kg as a precultivation treatment was already used by farmers in Japan, Srilanka and Malaysia, and it could minimize time and water required for land preparation, decreased labor, animals, and machinery requirements (Mittra and Pieris, 1968 and Seth *et al*., 1971).

In Indonesia nowadays, the only herbicide registered for no-till lowland rice is glyphosate (as Polaris 240 AS), while paraquat and combination paraquat/diuron (as Gramoxone and Paracol) are

registered for tidal swamp rice. For noncrop land, both glyphosate (as Polaris 240 AS and Spark 160 AS) and sulphosate (as Touchdown 480 AS) are registered (Indonesia Pesticide Committee, 1997). Since the need for conservation tillage, especially in dry area, is evident, while the type of herbicides available for rice are still limited, there is a room for introducing other appropriate herbicides used in no-till upland rice. This study was to evaluate introduction of 3 groups of herbicides: paraquat, paraquat/diuron, and sulphosate applied before planting, as substitute for land preparation in controlling weeds.

Materials and Methods

The study consisted of two separate field experiments conducted at the same time (from October 1998 to February 1999) in the same place (Taman Bogo area, Central Lampung, Indonesia). In the first experiment, there were 10 treatments tested: no-tillage + paraquat each at 300, 600, and 900 g/ha (as Gamoxone at 1.5, 3.0, and 4.5 lt./ha), no-tillage + combination of paraquat/diuron each at 300/300, 600/600, and 900/900 g/ha (as Paracol 1.5, 3.0, and 4.5 lt./ha). In the second experiment, 13 treatments were tested: no-tillage + sulphosate 48% (480 g/lt.) each at 360, 720, and 1080 g/ha (as Touchdown 480 AS at 0.75, 1.5, and 2.25 lt./ha), no-tillage + sulphosate 24% (240 g/lt.) each at 360, 720, and 1080 g/ha (as Toupan 240 AS at 1.5, 3.0, and 4.5 lt./ha), and sulphosate 14.5% (145 g/lt.) each at 290, 580, and 870 g/ha (as Banish 145 AS at 2.0, 4.0, and 6.0 lt./ha). As a standard comparison for both experiments, glyphosate at 720 g/ha (as Polaris 3 lt./ha), weeded and unweeded full-tillage, and unweeded no-tillage were used Treatments were arranged in a completely randomized block design with 3 replicates.

Herbicides were applied two weeks before planting (WBP) using a back pack sprayer with 400 lt./ha application volume. Full-tillage treatment plots were mechanically plowed twice. Rice seeds were planted directly with 5-8 seeds per hole in 3m x 5m experimental plots. Standard fertilizers were applied: 30 kg N, 45 kg P_2O_5, and 45 kg KCl per ha at planting time, the second and third N application was at 3 weeks after planting (WAP) and at flower initiation stage, respectively. For maintenance, insecticide Furadan, fungicide Fongorene, and preemergence herbicide Ronstar were applied to all plots.

Variables observed in this study were weed coverage at planting time, weed dry weight per species at planting time, 4 WAP, 7 WAP, and harvest time using quadratic methods, as well as rice germination rate at 2 WAP, number of rice tillers, plant height, and rice phytotoxicity at 2, 4, and 6 WAP, and number of productive tillers at harvest time (17 WAP). Data were subjected to analysis of variance and treatment means were separated using Fisher Protected LSD at p=0.05.

Results and Discussion

Weed control

The level of weed suppression at planting time is a very important variable to consider in deciding whether a particular herbicide can be used in no-tillage system, because the use of herbicides in no-tillage upland rice system is mainly to control the initial weeds usually eliminated during land preparation. Paraquat and combination of paraquat/diuron at 300, 600, and 900 gr./ha suppressed weed coverage 86-98% as well as weed dry weight 58-97% at planting time compared to control plot. The suppression level was equal to full tillage plot if medium and high dosages of paraquat/diuron and high dosage of paraquat were applied (Table 1). Suppression of weed dry weight was still observed until 3 WAP, however, started at 6 WAP the effects of the herbicides applied 2 weeks before planting (WBP) were not apparent, because weed regrowth had already taken place.

For sulphosate herbicide, similar pattern was observed. All sulphosate formulations, except sulphosate 14.5% at 290 gr./ha, suppressed weed coverage considerably at planting time (21-79%). Weed dry weights at planting time (2 WAA) were in general lower compared to those at 3 WAP (5WAA). At 6 WAP (8 WAA), however, weed regrowth was apparent (Table 2). These data suggested that the time needed for sulphosate to show its peak performance was relatively long in this condition. It also means that if sulphosate is to be used in no-till system, it should be applied at least 2 WBP up to 4 WBP to achieve the best weed suppression level, and there is still 3-4 weeks after planting to benefit from the effects of herbicide before weed control is needed. Fortunately, it is also the time when farmers do their usual mechanical weeding. From these data, it is reasonable to conclude that the use of herbicides in no-till system does not eliminate the need for postplanting weed control. Watson and Allen (1985) also noted that in general works on limited tillage in lowland rice indicated that preplanting weed control using herbicides must be combined with other practices such as cultivation or several days of flooding, and the

technique is unlikely to be extended to upland rice until a good postplanting herbicides selective for grass become available. With the availability of paraquat, paraquat/diuron, and sulphosate, it is believed that the limitation is eliminated.

Table 1. Weed coverage and dry weight in upland rice planted in no-tillage combined with paraquat and combination paraquat/diuron herbicides and full-tillage systems.

Treatments	Weed Coverage at Planting Time (%)	Total Weed Dry Weight (g/0.25 m2)			
		Planting Time (2 WAA)	3 WAP (5 WAA)	6 WAP (8 WAA)	Harvest Time (19 WAA)
NO-TILL + Paraquat 300 g/ha	13.3	6.93	25.3	104	381
NO-TILL + Paraquat 600 g/ha	10.7	9.20	13.8	81.1	275
NO-TILL + Paraquat 900 g/ha	2.00	3.13	12.5	50.0	352
NO-TILL + Par./diuron 300 g/ha	8.33	18.0	14.2	67.5	221
NO-TILL + Par./diuron 600 g/ha	5.00	7.63	11.1	42.2	344
NO-TILL + Par./diuron 900 g/ha	3.67	4.20	9.57	48.5	304
NO-TILL + Glyphosate 720 g/ha	21.7	22.9	24.1	42.6	196
FULL-TILL; weeded	1.33	0.93	1.10	2.47	53.5
FULL-TILL; unweeded	1.00	0.33	7.17	65.2	279
NO-TILL; unweeded	97.7	43.6	54.4	89.8	422
LSD p=0.05	*6.64*	*7.49*	*15.0*	*53.8*	*32.5*

Note : numbers in the same column followed by same letters are not significantly different according to LSD test at p=0.05; WAP = weeks after planting; WAA = weeks after application

Table 2. Weed coverage and dry weight in upland rice planted in no-tillage combined with sulphosate herbicides and full-tillage systems.

Treatments	Weed Coverage at Planting Time (%)	Total Weed Dry Weight (g/0.25 m2)			
		Planting Time (2 WAA)	3 WAP (5 WAA)	6 WAP (8 WAA)	Harvest Time (19 WAA)
NO-TILL + Sulphosate 48% 360 g/ha	76.7	42.8	20.5	71.5	423
NO-TILL + Sulphosate 48% 720 g/ha	45.0	21.1	22.4	29.9	335
NO-TILL + Sulphosate 48% 1080 g/ha	21.7	26.0	13.1	35.2	281
NO-TILL + Sulphosate 24% 360 g/ha	53.3	31.8	34.5	51.7	352
NO-TILL + Sulphosate 24% 720 g/ha	23.3	29.2	15.1	44.1	259
NO-TILL + Sulphosate 24% 1080 g/ha	20.0	12.7	10.6	23.5	164
NO-TILL + Sulphosate 14.5% 290 g/ha	90.0	40.7	19.0	38.8	313
NO-TILL + Sulphosate 14.5% 580 g/ha	30.0	31.0	11.6	23.2	302
NO-TILL + Sulphosate 14.5% 870 g/ha	31.7	30.6	11.6	13.1	206
NO-TILL + Glyphosate 24% 720 g/ha	33.3	47.7	9.29	26.6	213
FULL-TILL; weeded	2.33	0.0	0.0	1.34	21.4
FULL-TILL; unweeded	1.00	0.17	2.96	26.8	138
NO-TILL; unweeded	97.3	56.4	62.3	86.5	287
LSD p=0.05	*12.0*	*27.9*	*19.5*	*33.4*	*116*

Note : numbers in the same column followed by same letters are not significantly different according to LSD test at p=0.05; WAP = weeks after planting; WAA = weeks after application

Weed dominance

Data in Table 1 and 2 show that weed coverage at planting time in control plots was quite high (>97%), comprised of very much same species between experiment 1 and experiment 2: *Acalypha rhomboidea, Amaranthus blitoides, Axonopus compressus, Brachiaria sp. (B. distachya, B. eruciformis, B. mutica, B. paspaloides), Calopogonium mucunoides, Cynodon dactylon, Eragrostis spectabilis, Galinsoga parviflora, Imperata cylindrica, Ischaemum timorense, Ludwigia prostata, Mimosa pudica, Opismenus composines, Paspalum conjugatum, Parietaria pensylvanica, Phyllanthus niruri, Sida acuta,* and *Themeda arguens.* Out of the 18 species in no-tillage+paraquat plots, *Brachiaria sp., C. mucunoides,* and *P. conjugatum* were the dominant species, while in no-tillage+sulphosate plots *A. compressus, Brachiaria sp., and C. mucunoides were the dominant species.* In general, *C. mucunoides* was the longest to suppress if paraquat or paraquat/diuron were applied, while *Brachiaria and P. conjugatum* were suppressed up to 3 WAP. When sulphosates were applied, *A. compressus, Brachiaria sp., and C. mucunoides* could be suppressed up to 6 WAP, except at the lowest dosages of each formulation.

Rice growth

Rice plants did not exhibit phytotoxicity symptom because of paraquat, paraquat/diuron, or sulphosate application. The absence of phytotoxicity was reflected by the absence of differences in germination rate, plant height, and number of tillers at 2 WAP between plants in herbicides treated plots and full tillage plots. However, the germination of plants in plots with paraquat 600 gr./ha, paraquat/diuron 300 gr./ha, sulphosate 48% at 360 gr./ha, and sulphosate 14.5% at all levels was lower than those from full tillage plots (Tables 3 to 6). Plant height and number of tillers up to 6 WAP in no-tillage with paraquat or paraquat/diuron, as well as no-tillage with medium and high dosages of sulphosate, were still the same as those from weeded full tillage, but at harvest time the number of productive tillers was totally suppressed in no-tillage+herbicides plots (Tables 3 to 6). We believe this suppression of the number of productive tillers at harvest time was not caused by the direct negative effects of herbicides, but rather by uncontrolled weed regrowth after 6 WAP.

From these data we conclude that paraquat and paraquat/diuron at 600 and 900 gr./ha could be used for preplant application in no-tillage upland rice because the herbicides could suppress the initial weeds without any detrimental effects on rice plants. Similarly, sulphosate 48% and 24% each at 720 and 1080 gr./ha, as well as sulphosate 14.5% at 870 gr./ha could also be used. We suggest that paraquat or paraquat/diuron be applied at 1-2 WBP, while sulphosate at 2-4 WBP. However, it is important to note that as in full tillage system, post planting weeding is required in no-tillage+herbicides system to avoid yield loss due to weeds. Weeding could be done at 3-4 WAP.

Table 3. Germination rate and plant height of upland rice planted in no-tillage combined with paraquat and combination paraquat/diuron herbicides and full-tillage systems.

Treatments	Germination Rate (%)	Plant Height (cm)		
		2 WAP (4 WAA)	4 WAP (6 WAA)	6 WAP (8 WAA)
NO-TILL + Paraquat 300 g/ha	46.7	11.3	19.5	19.2
NO-TILL + Paraquat 600 g/ha	26.7	12.0	21.3	25.9
NO-TILL + Paraquat 900 g/ha	43.3	10.6	24.4	30.7
NO-TILL + Par /diuron 300 g/ha	21.1	10.7	20.9	20.1
NO-TILL + Par./diuron 600 g/ha	36.1	10.9	24.3	28.0
NO-TILL + Par./diuron 900 g/ha	40.0	11.2	24.1	27.0
NO-TILL + Glyphosate 720 g/ha	21.1	7.79	17.8	15.7
FULL-TILL; weeded	55.6	8.86	21.9	32.2
FULL-TILL; unweeded	56.7	8.75	18.7	24.7
NO-TILL; unweeded	6.67	0.40	12.6	5.56
LSD p=0.05	***24.5***	***2.43***	***4.70***	***7.04***

Note : numbers in the same column followed by same letters are not significantly different according to LSD test at p=0.05; WAP = weeks after planting; WAA = weeks after application

Table 4. Number of tillers and productive tillers of upland rice planted in no-tillage combined with paraquat and combination paraquat/diuron herbicides and full-tillage systems.

Treatments	Number of Tillers			Number of Productive Tillers
	2 WAP (4 WAA)	4 WAP (6 WAA)	6 WAP (8 WAA)	
NO-TILL + Paraquat 300 g/ha	3.69	4.25	6.00	0.00
NO-TILL + Paraquat 600 g/ha	4.97	4.44	6.03	0.25
NO-TILL + Paraquat 900 g/ha	4.11	4.08	6.09	0.05
NO-TILL + Par./diuron 300 g/ha	4.00	3.78	4.78	0.19
NO-TILL + Par./diuron 600 g/ha	4.75	5.67	6.70	0.22
NO-TILL + Par./diuron 900 g/ha	4.14	6.08	7.33	0.38
NO-TILL + Glyphosate 720 g/ha	4.86	3.11	3.75	0.00
FULL-TILL; weeded	3.44	5.53	7.31	12.6
FULL-TILL; unweeded	3.41	8.30	9.42	0.52
NO-TILL; unweeded	0.74	1.53	0.94	0.00
LSD p=0.05	*1.45*	*2.65*	*3.20*	*1.14*

Note : numbers in the same column followed by same letters are not significantly different according to LSD test at p=0.05; WAP = weeks after planting; WAA = weeks after application

Table 5. Germination rate and plant height of upland rice planted in no-tillage combined with sulphosate herbicides and full-tillage systems.

Treatments	Germination Rate (%)	Plant Height (cm)		
		2 WAP (4 WAA)	4 WAP (6 WAA)	6 WAP (8 WAA)
NO-TILL + Sulphosate 48% 360 g/ha	25.0	6.53	16.6	20.0
NO-TILL + Sulphosate 48% 720 g/ha	64.4	9.22	17.7	22.1
NO-TILL + Sulphosate 48% 1080 g/ha	78.9	9.25	20.6	23.8
NO-TILL + Sulphosate 24% 360 g/ha	65.0	7.58	15.9	16.7
NO-TILL + Sulphosate 24% 720 g/ha	56.7	6.00	16.3	19.7
NO-TILL + Sulphosate 24% 1080 g/ha	60.6	7.31	20.8	23.5
NO-TILL + Sulphosate 14.5% 290 g/ha	11.1	4.97	11.5	14.6
NO-TILL + Sulphosate 14.5% 580 g/ha	43.3	7.39	14.9	22.0
NO-TILL + Sulphosate 14.5% 870 g/ha	53.3	7.95	14.6	19.4
NO-TILL + Glyphosate 24% 720 g/ha	71.7	10.4	21.4	25.4
FULL-TILL; weeded	85.0	9.33	20.4	34.1
FULL-TILL; unweeded	94.5	11.5	24.4	30.8
NO-TILL; unweeded	9.45	1.72	4.30	6.20
LSD p=0.05	*25.4*	*5.44*	*8.43*	*9.99*

Note : numbers in the same column followed by same letters are not significantly different according to LSD test at p=0.05; WAP = weeks after planting; WAA = weeks after application

Table 6. Number of tillers and productive tillers of upland rice planted in no-tillage combined with sulphosate herbicides and full-tillage systems.

Treatments	Number of Tillers			Number of Productive Tillers
	2 WAP (4 WAA)	4 WAP (6 WAA)	6 WAP (8 WAA)	
NO-TILL + Sulphosate 48% 360 g/ha	3.22	5.00	6.14	0.08
NO-TILL + Sulphosate 48% 720 g/ha	4.17	5.22	6.07	0.33
NO-TILL + Sulphosate 48% 1080 g/ha	4.69	5.11	6.41	0.08
NO-TILL + Sulphosate 24% 360 g/ha	2.97	4.11	5.81	0.19
NO-TILL + Sulphosate 24% 720 g/ha	3.11	4.58	5.67	0.47
NO-TILL + Sulphosate 24% 1080 g/ha	3.75	5.14	6.42	0.36
NO-TILL + Sulphosate 14.5% 290 g/ha	2.53	3.83	4.67	0.11
NO-TILL + Sulphosate 14.5% 580 g/ha	3.64	4.44	6.67	1.03
NO-TILL + Sulphosate 14.5% 870 g/ha	3.86	4.39	5.53	0.50
NO-TILL + Glyphosate 24% 720 g/ha	4.72	5.83	7.66	0.69
FULL-TILL; weeded	4.33	5.89	7.72	11.0
FULL-TILL; unweeded	5.36	7.17	8.67	0.50
NO-TILL; unweeded	1.03	1.25	2.41	0.00
LSD p=0.05	***2.98***	***2.94***	***3.58***	***1.62***

Note : numbers in the same column followed by same letters are not significantly different according to LSD test at p=0.05; WAP = weeks after planting; WAA = weeks after application

Acknowledgements:

The author is grateful to PT Zeneca Agri Products Indonesia for supporting this study, to the staffs of Taman Bogo Research Station for their technical assistance and facilities, to the weed science group in University of Lampung for their support, and to Manaek Winner and Supriyanto for their hard work.

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THE TECHNIQUES OF WEED CHEMICAL CONTROL IN FIELDS SEEDED ON UNFALLOWING WHEAT FIELDS

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Abstract: The techniques of weed chemical control wee studied in corn and soybean fields seeded on unfallowing wheat fields. And these experiments employed a randomized block design. Results showed that the treatments that included mixed Roundup and preemergence herbicides have very significant control effects for weeds which amount to 15. families, 27 species in the unfallowing wheat fields. The treatments were carried out before the emergence of weed seeding. Then it not only restrains the emergence of some weeds seedling, but also limit the growth of some weeds. Therefore, it is very effective to prevent the crops from weed injury. Moreover it can control effectively the weeds that emerge in later period of crop growing season. All treatments were safe to corn and soybean.

Key words: Corn; soybean; Seeding on unfallowing fields; Chemical weed control; Herbicide.

Introduction

Food problem is the most critical problem facing world agriculture. In China, a country having a huge population and comparatively less land, improving land efficiency is of special strategic significance. Multiply cropping is one way of better utilizing land. But, to fully make use of the precious light and heat resources after wheat harvest in summer, multiply cropping are often conducted on unfallowing fields. Thus, weeds in wheat field are left uncontrolled. Also this situation creates suitable condition for the emergence of new weeds. It is very difficult to control these weeds, which may easily lead to weed hazard and reduction of yield. Fu Kailian once made research on the chemical weed control on wheat-corn rotation fields. But in that case, summer corn is seeded after soil tillage which means after wheat harvest, weeds have been cleared. By far, the main techniques of chemical weed control have all been gained on the basis of fields with soil tillage. Not much reports on the techniques of chemical weed control on unfallowing fields have been made. With respect to this particular subject, this paper focus on the techniques of chemical weed control on unfallowing fields. The experiments aim to determine and provide feasible technique programs for production. Through experimentation, the author discovered that post emergence herbicide couldn't effectively control weeds on unfallowing field, while preemergence herbicide resulted in good efficient control of weeds. The results of the experiments are reported as following.

Materials and methods

Crop subjects used in this experiment are multiply cropping corn variety, Ji Cheng Dan 3 and soybean variety JinDa 61, supplied by Crop Genetic Breeding Research Room in Shanxi

Agricultural University: Herbicides used are 41% Round up WS and 90% Harness Emulsifiable concentrate Provided by Monsante in the United States, 72% Propisscochlor EC supplied by Weed Science Research Institution of China Agricultural University, 50% Sumisoya wettable powder provided by Sunitomo Chemical Co, LTD. 56% MCPA DP, a product of Fushun Chemical factory; JNH-2 and JNH-3, supplied by Agricultural Chemical Control Center of Shanxi Agricultural University.

The experiments were conducted in the testing fields of Shanxi Agricultural University during 1997-1998. The soil type is loamy soil, and the level of organic material is 1.07%. Wheat were harvested by combine harvesting machine. Without soil preparation, corn and soybean were planted directly by planting machine on unfallowing fields. Herbicides were applied on the second day. The volume of liquids is 750 l/hm^2. Experimental fields were designed as randomized blocks, with 3 repetition, 9 treatments. The area of each plot was 33.34m^2; Demonstration fields adopted complete randomized blocks with 4 repetition, 6 treatments, each plot has an area of 333.3m^2. the chemical were diluted twice and sprayed with hand-holding compressing sprayer along ridge on experimental fields. On demonstration fields, chemicals were sprayed with Model 16 knapsack sprayer .

After 25days and 70 days, weeds in fields were investigated. First, in each field, 10 representative spots ,each is as large as 1m2, were selected in order to find out the species of weeds. Then, three sample spots , each has a area of 0.25 m2 were selected in each plot to investigate the types of weeds, number of weeds, weight in order to calculate weed prevention rate through statistic analysis. Degree of crop injury was also observed.

Results and discussion

The overall control effects of weeds in experimental fields

On unfallowed fields, there were both weeds left from previous crop and newly emerged weeds. After investigation, it was found that weeds on unfallowed fields included 15 families, 27 species, among which, grassy weed, as major weeds. These weeds were not growing uniformly. Weeds left from previous crop-wheat had grown up into reproductive development, while weeds emerged during summer time were still in vegetation development. Some just emerged. It was very difficult to kill these weeds with manpower which would involve high cost and result in bad effects. Only through chemical weed control, could these weeds be controlled effectively.

Variance analysis of table 1 showed that, After multiply crop was planted on unfallowed fields, the effects of applying pre-emergence soil applicant on weeds could reach significant degree. The investigation conducted on the 25 days after planting have found that the effect of each treatment on the green weight of Gramineae weeds could reach 86.7%, and the effect on number of grass could reach 82.4%. The effects on green weight of broad leave weeds could reach 90.2%. Crop injury caused by weeds often occur in seedling stage, especially in summer time, rainy season. Pre-emergence soil herbicide could have a good control of weeds during crop's seedling period. The investigation made on the 70th day revealed that , except for the treatment which apply Roundup only, the combined treatment with Roundup and other herbicide all had good effects in controlling the green weight of weeds. To Gramineae weeds, the effect reach 81.4%. to broad leave weeds that could reach 80.1%. All these indicated that the combined use of Roundup and other pre-emergence could not only ensure that there were no weeds during seedling period, but also effectively control

weeds during the overall growth period of crops. In particular, JNH-3 showed a very good control on Gramineae and broad leave weeds. It was observed that crop seedlings in CK were weak and not uniform while crop seedlings with treatment grow uniformly and strenuously. The investigation on yields have shown that the average yield increase of corn was 21.2% during the two years, and that of soybean was 14.5%. No chemical harm was observed and detected.

Table 1 The effect of experiment with Herbicide used in multiply cropping on unfallowing fields (1997-1998)

treatment (ml,g/hm^2)	Check after 25 days				Check after 70 days			
	Grassy weeds		Broadleaf weeds		Grassy weeds		Broadleaf weeds	
	Effect on number of weeds	Effect on green weight	Effect on number of weed	Effect on green weight	Effect on number of weeds	Effect on green weight	Effect on number of weeds	Effect on green weight
Round up and Harness (3000+1500)	92.6	98.9	97.8	98.1	80.7	96.2	67.9	80.1
JNH-2	93.7	98.5	99.1	99.4	81.2	93.9	81.5	95.3
JNH-3	95.9	99.2	99.8	99.9	81.2	94.8	94.8	98.6
Round up & Propiscochlor(3000+750)	86.7	88.6	85.6	92.3	73.1	81.4	63.3	79.5
Round up & Propiscochlar (3000+1500)	93.7	96.3	97.3	98.1	81.2	92.7	72.7	80.9
Round & Propiscochlar (3000+2250)	97.7	99.3	98.2	99.6	88.7	93.5	88.6	88.7
Round up & Propiscochlar & Harness (3000+750+750)	99.2	99.3	98.9	99.9	89.9	94.7	89.4	91.4
Round up(3000)	82.4	86.7	83.7	90.2	70.7	77.3	62.2	76.6
CK(stemg/m^2)	(86.4)	(327.0)	(20.1)	(98.8)	(97.6)	(2177.2)	(27.3)	(1293.6)

Table 2 The yield increasing effect of different treatment (%)

Treatment	Soybean	Corn
N+H	13.6	14.6
JNH-2	15.4	21.7
JNH-3	17.7	25.2
N+P5	12.1	20.8
N+P10	12.6	25.0
N+P15	16.8	26.1
N+P5+H5	16.3	19.3
N	11.2	16.8

Prevention and control of major weeds in experimental fields

The effects of herbicide on different types of seeds were also investigated and analyzed. The preventing effects of 4 major, severe weeds were shown on the following diagram. We could see from the diagrams, the effects of different treatments on controling major weeds all reached significant level. The effect of JNH-2 on preventing broad leave weeds was better than its effect on grassy weeds. JNH-3 could effectively control all major weeds with the best overall effects.

The controlling effect of weeds on demonstrated fields

Figure 2 showed that, on unfallowed wheat field, 56%MCPA had a good control over broad leave weeds, but it couldn't control grassy weeds. The combined use of Harness with Propiscochlor and with MCPA didn't show a significantly improved controlling effects compared with applying MCPA only. The combined application of Roundup with Harness and/or with Propiscochlor gained an apparent effective control on weeds.

Conclusion

Seeding crops on unfallowing wheat field is proved to be a good way of better making use of land in that it can save time and extend the growth period of succession crop. But the large population and diverse types of weeds easily lead to weed hazard and may greatly affect the quality and quantity of after reap crops. The application of JNH-2, JNH-3 and the combined application of Roundup and other preemergence could effectively kill weeds already existed and prevent those weeds which haven't emerged. In particular, JNH-3 not only have a better overall effect but have a longer functioning period. But all treatment can't effectively prevent wheat seedlings. Apart from that, after wheat is harvested, be sure to distribute wheat straw evenly in the fields, otherwise, the spraying and effects of weed control will be affected.

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USE OF SOME CULTIVATION METHODS ON THE MILPA EXCLUDING SOME WEED SPECIES

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Abstract : In Vietnam, 75% of to natural land are hilly and moutainous. So, agriculture in the uplands (mostly slopping land agriculture) accounts for considerably large proportion in national GDP. Severe soil erosion and degradation due to deforestation, in addition to weed damage are the main reasons causing fast yield decrease. In these areas, the agroecologycal conditions are getting worse and worse. Research for appropriate cultivation methods, in which weed control is an unavoidable pant, is urgent. This study deals with research and control of weeds in slopping fields.

Keywords : milpa, slopping land, upland, cultivation

Introduction

Weeds is one of major problems in slopping fields. If uncontrolled, weeds may complementary depress the crop growth and lead to zero harvest. The survey on weeds is the first and very important step to promote control practices. But so far, the result of this field is still limited. Initially, we've just found the major weeds in some important upland crops and listed them as a basis for getting out the methods to control them. Rice is one of the most important crops. The yield is averaging around 1,2 ton/ha. The yield of upland rice is low because of problems such as lack of suitable cultivars, erratic water supply and poor weed control. Weed competition and corresponding yield losses are usually greater in upland rice than in other rice production systems (Moody,. 1983). The limited data available show that production losses can reach 30-40% for fields that are poorly weeded (Anon,.1988). Yield losses can be almost total if there has been no weed control. Elliot and Moody (1987) reported that an additional weeding within 8 weeks after crop emergence resulted in yield increases of 43-80%. It also happened to other plants like lemon and orange... We are really interested in applying the traditional cultivation method for weed control. These methods are accepted easily by the farmers because of their economic benefit and the practices are not difficult. However, herbicide application is still the important method for weed control, specially in upland fields. Research for rational combination of all weed control practices may play an important role in facilitating agricultural production in upland area.

Materials and methods

Field survey, review, PRA (Rapid Rural Aprisal)

Results and discussions

1. Major weeds in some important crops in upland field in Vietnam

In the upland fields of rice, 35 species of weeds were found, of which, 14 are the major ones (Nguyen Hong Son *et al.* 1997).

Scientific name	Family
- Degitaria timorensis (K) Bal	Poaceae
- Eleusine indica (Linn) Gaent	"
- Cyrtococcum patens (Linn) A.Camus	"
- Panicum incomtum Trin	

- Sporobolus elongatus R. Br	Poaceae
- Eragrotis unioloides (Retz) Nees	"
- Sacchrum officinarum L.	"
- Cyperus rotondus Linn	Cyperaceae
- Cyperus cerotinus Rott	"
- Leucas aspera Spreng	Lamiaceae
- Leucas zeylanica R. Br	"
- Cudrania cochinchineusis (Lour) Kudo et Matsam	Moraceae
- Ageratum conizoydes Linn	Asteraceae
- Mimosa invisa Mart	Mimisaceae

On the upland field of orange (Citrus sinensis Osbeck), 27 species of weeds were found. of which 12 are most important.

Scientific name	Family
- Paspalum conjugatum Berg	Poaceae
- Imperata cylindrica Beauv	"
- Panicum repens Linn	"
- Chloris barbata Sw.	"
- Ischaneum ciliare L.	"
- Cyperus rotondus Linn	Cyperaceae
- Cyperus imbricatus Retz	"
- Leucas zeylanica R. Br	Lamiaceae
- Amaranthus viridis Linn	Amaranthaceae
- Biodens pilosa L.	Asteraceae
- Ageratum conizoides Linn	"
- Mimosa invisa Mart	Mimisaceae

2. Traditional weed control methods in upland crop areas.

At present, these methods are being applied widely in moutainous areas. Most of them are applied for weed control in generaly and some applied for selective control.

* Land preparation : This work is really important and easy that farmer can implement for weed control. Preparing soil usually starts at the beginning of rainy season.

- Ploughing soil made one month before planting. To avoid land erosion, ploughing must follow the contour lines. First time, farmers plough as turn up the soil and keep this around 2 weeks under the sunshine. By this way, soil becomes heaty and soft. Roots and tubers taken over the surface are dead, diseases are also limited. However, ploughing turns over the dry seeds from the deep stage which germinate strongly when it's raining. So the second time ploughing is really necessary for killing germinat weeds. The next work is loading dry weed and burning.

- Burning is applied for eliminating weeds on ploughed virgin soil and also on the milpa under cultivation. Burning is the simple and economical way. Weeds which are in the process of germinating or have already germinated are killed by fire. Most dry seeds, however, are more tolerant to high temperature than are plant tissues and often require prolonged exposure to kill them (Schlesselman *et al.*, 1985). November is the harvest time of upland rice. From November to the next season (April) is fallow period. Because of burning, soil becomes fertile and softer, weed propagation is limited. In this condition, farmers can minimise tillage and start sowing immediately after burning. So labour force needed for preparing soil is reduced. Minimised tillage is very important for soil protection from erosion.

- Mulching the milpa surface by plant materials is applied widely on the rice milpa. After harvesting, whole the milpa surface is covered by thatch which limit weed development and keep the soil humid during the fallow time.

* Manure application : before application to the field, manure is kept in a big hole. Heating inside the hole is the cause to limit diseases, pests and weed seed germination.

* Hand weeding : In fact in moutainous area of Vietnam, the labour source is abundant and very cheap, so hand weeding have been applied widely. It seems that they don't care about the effectiveness, even hand weeding takes times and labours. Anyway, in small cultivation areas, hand weeding is the effective method of selective excluding weed. Simple tools like hoe for digging are used for this work. Orange is mulched, dredged twice a year and some weeds with shallow roots are directly eliminated.

* In well irrigated areas or gravity irrigation gions, farmers create the step fields for growing rice. On these fields, water is kept during the time to the next season to eleminate weeds.

In addition, the facility of water supply is good condition to practice 2-3 crops a year or rotation. By this way, soil is covered whole the year by different crops, so condition for weed growing is limited.

* Mix crop cultivation : In Vietnam, mix crop cultivation is known not only for improving environment but also applied by farmers for increasing their incomes. However, mix crop cultivation is effective method for weed control and it is interested to research and improve by the Scientists.

In Cao Bang province (North Vietnam), *Vigna umbellata* (common name : Nho nhe bean) is mixing with spring corn. Bean is sowed when corn start flowering. So that after the ear harvest, corn stems can serve as support for the bean to climb over. Bean plants develop very fast and can reach 2 - 2,5m in height. And therefore, in August - September (rainy season), the milpa surface can be totally covered by their stems and leaves. In this model, soil can be protected from erosion caused by rainfall and condition for weed growing is limited.

In Muong La district - Son La province (North West Vietnam), *Leucaena leucocephala* propagated to enrich soil fertility and protect soil from erosion. *Leucaena leucocephala* is mixing with maize in last season before the fallow period. After 12 months, whole the surface covered by their canopy and the fallow period will be shortened. In this case, it is very important to limit weed growing during the fallow period. Many other legumes like *Mucuna pueraria*... can be very good tools to control weeds.

To increase the effectiveness of weed control, all the cultivation methods should be implemented so as to complement for each other.

However at present, herbicide application is still popular because of its economic efficiency such as : labour force reduced, good form of the products and its efficiency in weed control. It is remaining difficulties in Vietnam's agricultural production which effects to quality of the products, environment pollution and specilly water resource.

3. Herbicide application :

Table 1. The herbicide use in period of 1991 - 1995 in Vietnam
(Nguyen Hong Son *et al.*, 1997)

	Product value (1.000 ton)					Percentage (%)				
	1991	1992	1993	1994	1995	1991	1992	1993	1994	1995
Total	20,7	24,4	25,5	23,2	19,6	100	100	100	100	100
Of which: Herbicide	0,9	2,6	3,0	3,5	3,6	4,3	10,6	11,8	15,1	18,1
Others	19,8	21,8	22,5	19,7	16,0	95,7	89,4	88,2	84,9	81,9

Nguyen Hong Son *et al.* (1997) also estimated that herbicides are used increasingly, which 60 - 70% of the total is used for paddy rice (mostly used in Mekong delta river where broadcasting is most

dominant). 30 - 40% of the total is used for upland crops and mostly are applied for tea, orchard, soybean, maize and upland direct seeding rice.

The most promising herbicide now is Glyphosate with various commercial name like : Nurfarmglyphosate, Lyphoxim, Roundupfarm.

Table 2. Some effective herbicides uplied on upland rice

Name of herbicide	Quantity (l/ha)	Applied time
Dual 720EC	1	Spray 3 days before sowing
Lyphoxym	2,5	Spray 3 days before sowing
Nabu 25EC	1,5	Spray when plant in 3cm height

On upland field of Citrus sinensis Osbeck, applying herbicides of Glyphosate activity in combination with dredging have increased efficiency of herbicides.

Acknowlegement : The auther are gratefully thank Mr. Nguyen Hong Son, researcher in National Institute of Plant Protection; Mr. Le Quoc Doanh, Head of Department of Research Planning and International Cooperation - Vietnam Agricultural Science Institute; Mr. Nguyen Dinh Tuan, researcher in Vietnam Agricultural Science Institute, for help to complete the presentation.

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UTILISATION AND MANAGEMENT OF ORCHARD GROUND COVER IN THE MEKONG DELTA, VIETNAM

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Summary: Quite a lot of weed species reported by fruit farmers in the Mekong Delta, Vietnam, are lowland weeds as most orchards are converted paddy fields. Fruit farmers have extensive knowledge about weeds which are important, meaning directly useful or harmful. This determines the level of taxonomic differentiation. Weeds which are traditionally used as vegetables such as *Alternanthera sessilis*, *Amaranthus viridis* and *Ipomoea batatas* are described up to species level. *Cyperus rotundus*, the most noxious sedge is described by a specific name, *co cu*, while all the other sedges are grouped under one common name, *co lac*. More recently farmers have learnt about other beneficial characteristics of weeds, especially about their role as mulch. The most frequently mentioned weed *Commelina nudiflora*, which is also known to have medicinal properties, is conserved by farmers to retain soil humidity and suppress other more harmful weeds. Hand weeding and mulching are most important weed management techniques. Less than one third of the farmers applied herbicides, spraying on average twice a year with one product only. More than 80% of the farmers who apply herbicides used glyphosate, whereas paraquat and 2,4-D were applied by less than 20% of the farmers. Farmers had no knowledge about the role of weeds in conserving natural enemies such as predatory mites. IPM training programs should include training of farmers to recognize weeds such as *Ageratum conyzoides, Blumea glandulosa, Eclipta prostrata, Synedrella nodiflora* as beneficial weeds. Sediments of canals, that are dug between the planting beds, are commonly spread over the planting beds one to two months before the end of the dry season. Consequently weeds are completely covered, temporary depriving beneficial organisms from food and refuge. Slight adaptions of this existing technique of canal clearing are discussed in order to make it more compatible with an IPM program.

keywords: farmers' knowledge, weeds, citrus, longan, durian, mango, IPM, Vietnam.

INTRODUCTION

The Mekong Delta, in the south of Vietnam, has an area of 39,000 km^2, about 12% of the country's total area. This region currently produces 16 million tons of rice, supplying more than 50% of the annual national rice production (5). After the Vietnemese war, in 1976, about 50,000 to 60,000 ha were planted with fruit trees. Since the *Doi moi* or policy reform in 1986, government policies have increasingly emphasized diversification of agricultural production into higher value crops. One of the direct observed consequences thereof was and still is the conversion of paddy fields into fruit orchards. Fruit growing area in the Mekong Delta has since increased from 92,000 to 176,000 ha in 1995 and is still increasing. Major fruit crops grown are sweet orange (*Citrus sinensis*), Tieu mandarin (*C. reticulata*), longan (*Dimocarpus longan*), mango (*Mangifera indica*) and durian (*Durio zibethinus*).

Traditionally, fruit trees were grown in home gardens which consisted of of a mixture of different fruit trees, annual crops and integrated animals such as chicken, duck or fish. The rapid population growth (2.2%) in Vietnam, however, has increasingly put pressure on the food supply, prompting the government to stimulate the use of chemical inputs. Along this line, farmers tend to shift from the home garden system to commercial orchards. Newly established commercial orchards, mainly Tieu mandarin and longan are all predestined monoculture.

Since only little information is available on weeds in orchards in the tropics, and more particularly in Asia (4, 7, 12), one can ask himself the question whether they do pose a real problem in this type of agro-ecosystem. In the traditional home garden system in Malaysia, weeds and undergrowth are present all the time and do not affect the productivity of trees such as durian (10). In Thailand, weeds often form the ground vegetation under tall fruit trees and are only cleared during the fruiting season. Weeds are extremely good competitors and pose serious problems during the early years of orchard establishment. Once the trees reach maturity, however, their competitive ability is usually sufficient to keep weeds down, especially around the base of the plants. Optimum spacing of trees is therefore very important. Perennial weeds tend to become more dominant in established older orchards, since there is minimal soil disturbance. Proper choice and rotation of control methods is important to avoid the build-up of noxious perennial weeds. Methods to control weed infestation in orchards include cultural, biological and chemical methods. Throughout history, each of these different methods has received periodically more attention than the other.

In the Mekong Delta, three different stages of knowledge development can be distinguished related to weed management by fruit farmers throughout history (Figure 1). Initially, farmers had no extensive knowledge about weeds, except for those weeds traditionally used as vegetables or as a source of medicines. All weeds were weeded by hand or traditional tools. In a second phase, with the wide-scale introduction of herbicides on the market, farmers have shifted away from traditional hand weeding practices and excessively applied broad-spectrum herbicides. Due to recent extension efforts, farmers in the Mekong Delta have learnt about the beneficial effects of weeds, especially about their role as mulch in conserving soil humidity and reducing erosion.

Major beneficial effects of weeds include prevention of soil erosion during heavy rains, retention of soil humidity during the dry season, contribution of organic matter to the soil, provision of food or refuge for beneficial organisms such as predatory mites, spiders, etc., and provision of a source of vegetables or medicines (1). In the following paper an overview is given on how Vietnamese fruit farmers suppress and utilise weeds. Special attention is paid to possible improvements of the current weed management practices as part of the development of an integrated pest management (IPM) program, as well as to some constraints inherent to the currently dominating weed flora.

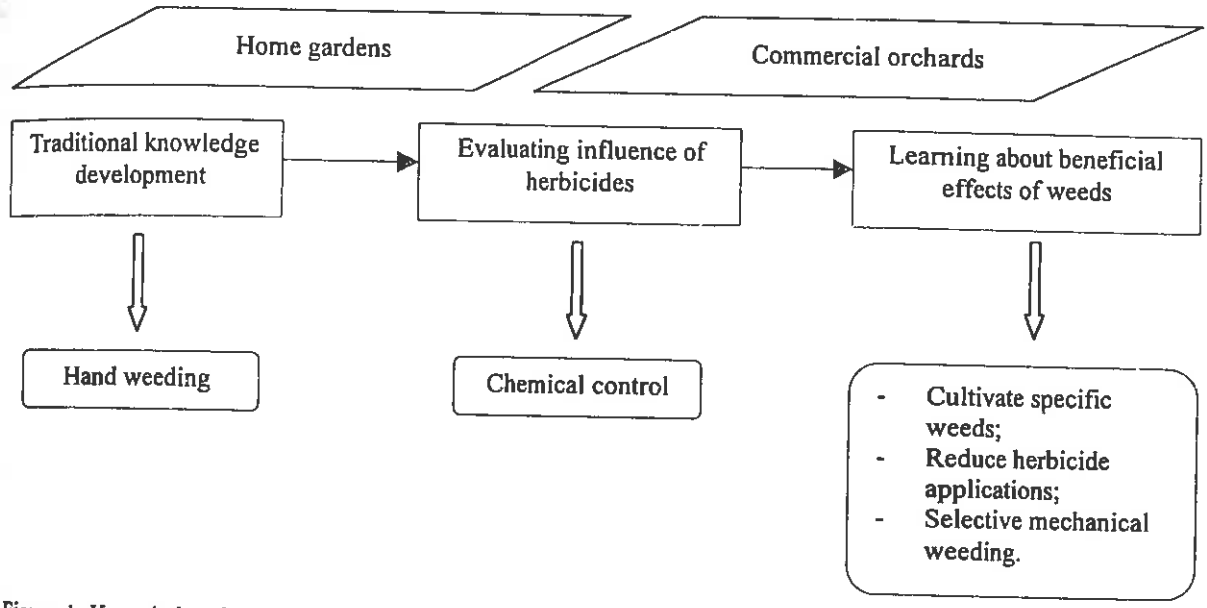


Figure 1. Knowledge development stages related to weed management in orchards in the Mekong Delta.

MATERIALS AND METHODS

Study Site: Three major fruit growing provinces were covered in this study, namely Can Tho, Dong Thap and Tien Giang. Mean annual rainfall in the study area ranges from 1,300 mm to 1,600 mm. The dry season generally occurs from November/December to April/May. Average elevation of the Mekong Delta is about 0.8 m a.s.l. and large areas are exposed to flooding during some periods of the year. Most soils of the fruit producing areas in the Mekong Delta are alluvial soils, with a high natural fertility.

Survey: An extensive survey was conducted from 1997 to 1998 in the main production areas of the five major fruit crops, namely sweet orange, Tieu mandarin, longan, mango and durian. Production and orchard characteristics are given in Table 1. In this table, no distinction has been made between sweet orange and Tieu mandarin, because no separate statistical figures are available and general characteristics for both crops are very similar. A total of 465 farmers with commercial orchards in production were selected and interviewed about their knowledge on weeds and their weed management practices. A combination of structured and semi-structured open questions was used. Full details about the survey techniques has been described elsewhere (16). Staff of the Plant Protection Department, Cantho University, conducted the surveys. Survey data were encoded and analyzed, using spreadsheet and statistical software programs. Information from field observations is presented as unquantified statements.

Table1. Characteristics of surveyed orchards, Mekong Delta, 1997-1998.

	Citrus	Longan	Durian	Mango
Production area (ha)	38,000	28,600	1,900	12,700
No. of farmers interviewed	165	171	36	93
Mean orchard size (ha)	0.6	0.5	0.5	0.6
Mean age (y)	7.7	7.6	13.9	11.4
Mean crop density (trees/ha)	1098	653	209	401
Mean estimated yield (ton/ha)	21.9	35.3	14.2	38.9
Converted paddy field (%)	91.5	63.7	86.1	82.8

RESULTS AND DISCUSSION

Farmers' utilisation of weeds

Initially in the home garden system, farmers had no extensive knowledge about beneficial aspects of weeds, except for those traditionally used as vegetable or as a source of medicine (Table 2). More recently farmers have learnt about other beneficial characteristics of weeds, especially about their role as mulch.

Upland weeds: Some weeds such as *Alternanthera sessilis*, *Amaranthus viridis* and *Ipomoea batatas* are used as fresh vegetables or in soups. Some plants have medicinal applications, *Commelina nudiflora* is used as a diuretic and against dysentry among other diseases. Freshly grinded plant material can be applied on the inflammatory areas of bone joints. Leaves of *I. batatas* are used as a laxative. Besides the direct benefits to humans, herbs are also consumed by animals such as chickens or duck.

Table 2. Utilisation of weeds by fruit farmers, Mekong Delta, 1997-1998.

Scientific name	Mulch	Vegetable	Medicinal use	Other
Commelina nudiflora	*		*	
Ischaemum spp.	*			
Brachiaria mutica	*			
Sacciolepis interrupta	*			*
Oryza spp.	*			
Eichornia crassipes		*		
Alternanthera sessilis		*		*
Amaranthus viridis		*	*	
Ipomoea batatas		*	*	
Corchorus capsularis			*	
Portulaca oleracea			*	
Centella asiatica				

Aquatic weeds: Common rice field weeds sometimes infest the canals between the planting beds of orchards. Some of these weeds serve both as food and anima' feed (15). The waterspinach, *Ipomoea aquatica*, is consumed by humans or is offered as green forage to pigs, ducks or chickens. Another aquatic weed, *Monochoria vaginalis*, is favorite green forage for ducks. Likewise, the floating fern, *Pistia stratiotes*, is often supplemented as green forage to pigs and ducks. The idea behind the vernacular name, namely duck weed, can therefore be easily traced back. For pigs, duck weed is often cooked with broken rice to prevent throat irritation. For plant propagation in nurseries or on-farm, the roots of *Eichornia crassipes* are used as a rooting substrate for marcotting branches of trees such as citrus, longan, durian and sapodilla (*Manilkara zapota*). This technique is especially important in places where the water table is too high and propagation by cuttings is difficult.

Farmers' knowledge of the weed flora

Most of the orchards, citrus in particular, are converted paddy fields (Table 1). Besides, most fruit farmers have, apart from their orchard, a paddy field. The weed flora, as reported by farmers, therefore mainly consists of rice weeds (Table 2). A long history of rice cultivation has created a typical rice weed seed bank on the one hand, while creating an empirical knowledge of these weeds on the other hand. Generally, farmers have good knowledge about easily observable and important objects (3). Weeds can be categorised as easily observable. Whether a weed is 'important' as

meaning 'of perceived value or harm to the local people' determines the level of taxonomic differentiation and unique classes of knowledge. Weeds with immediate importance as food or medicine were always described up to the species level by farmers. As differentiating up to species level for grasses used as mulch is less important, farmers had for instance one name to describe the different *Ischaemum* spp. (*co mom*). *Cyperus rotundus*, the most noxious sedge is described as *co cu*, while all the other sedges are grouped under one common name, *co lac*. Weeds with no direct importance to farmers were described in very general morphological terms such as waxy leave plant or rough leave weed.

The most frequently mentioned weed was *Commelina nudiflora* with an overall frequency of 54% (Table 2). This weed is actually conserved by farmers to retain soil humidity in the dry season, reduce soil erosion in the rainy season, and to suppress other more harmful weed species. It is also used as medicine as described above. That this weed is not harmful in orchards has long ago been described (11). Majority of the weeds mentioned are grasses, probably a heritage from the year after year rice cultivation prior to conversion into orchards. The most frequently noted species are vegetatively propagating perennials.

Table 2. Major weeds (percentage frequency) as mentioned by fruit farmers, Mekong Delta, 1997-1998.

Scientific name	Family	Type[1]	Sweet orange	Tieu mandarin	Longan	Durian	Mango	IRRI[2]
Commelina nudiflora	Commelinaceae	P (v)	53	68	56	25	47	LOW
Ischaemum spp.	Poaceae	A	49	34	9	6	22	
Leersia hexandra	Poaceae	P (s/v)	16	12	14	28	26	LOW
Ruellia tuberosa	Acanthaceae	P (v)	28	32	12	6	16	UPL
Cyperus rotundus	Cyperaceae	P (v)	11	12	25	3	8	UPL
Ageratum conyzoides	Asteraceae	A	33	6	10	11	15	UPL
Imperata cylindrica	Poaceae	P (v)	5	13	15	8	13	UPL
Brachiaria mutica	Poaceae	A	19	26	8	-	5	LOW
Apluda mutica	Poaceae	A	4	18	9	14	9	
Cynodon dactylon	Poaceae	P (v)	5	12	13	8	4	UPL
Panicum repens	Poaceae	P (v)	11	7	8	3	13	UPL
Eleusine indica	Poaceae	A/P (s)	5	5	15	6	3	UPL
Echinochloa crus-galli	Poaceae	A	4	6	12	8	9	LOW
Alternanthera sessilis	Amaranthaceae	A	-	9	9	8	3	LOW
Ludwigia erecta	Onagraceae	A	4	7	9	3	4	LOW
Blumea glandulosa	Asteraceae	A	-	6	2	11	6	
Echinochloa colona	Poaceae	A	2	6	4	6	5	UPL
Paspalum conjugatum	Poaceae	P (v)	4	4	3	3	4	UPL
Oryza spp.	Poaceae	A	21	1	1	-	-	LOW
Amaranthus viridis	Amaranthaceae	A	2	-	5	-	1	UPL
Eclipta prostrata	Asteraceae	A	-	7	2	-	2	UPL
Leptochloa chinensis	Poaceae	A	-	1	5	3	1	UPL
Ipomoea/Merremia spp.	Convolvulaceae	A/P (v)	-	7	2	-	1	UPL
Sacciolepis interrupta	Poaceae	P (v)	14	-	1	-	-	LOW
Fimbristilis miliacea	Cyperaceae	A/P (s)	2	1	4	-	-	LOW
Cayratia trifolia	Vitaceae	A	-	5	1	-	2	
Chromolaena odorata	Asteraceae	P (s)	-	-	2	-	1	UPL
Heliotropium indicum	Boraginaceae	A	-	1	2	3	-	UPL
Portulaca oleracea	Portulacaceae	A	-	-	2	-	-	UPL

[1] A = annual, P = perennial, s = propagation by seed, v = vegetative propagation.
[2] According to Moody (1989): LOW = lowland weed, UPL = upland weed.

Quite a lot of weed species described in orchards are lowland weeds (Table 2). This illustrates the general prevailing moist soil regimes. Differences in occurrence of weeds partly reflect the differences in soil type. Tieu mandarin for instance is cultivated on soils with a slightly higher elevation and better drainage than sweet orange, due to its high susceptibility for root rot disease. Longan is mainly cultivated on more sandy soils. Therefore, uplands weeds such as *Cynodon dactylon* and *Imperata cylindrica* are more important in Tieu mandarin and longan. Typical lowland grasses such as *Leersia hexandra*, *Oryza* spp. and *Sacciolepis interrupta* were more mentioned by farmers growing sweet orange, durian and mango. *Chromolaena odorata*, a weed which is extremely noxious in plantation crops in Southeast

Asia (20), has not really manifested itself yet in the Mekong Delta. Probably the soils are not well enough drained for this weed to become widely distributed.

Management

Major weed management practice is hand weeding, applied by about 50% to 90% of the farmers (Table 3). It is done by slashing the weeds with a *phan*, by digging up the roots with a machete-like *dao*, or by hand pulling. As the closed canopy of fully grown durian trees outcompete most weeds for light, weeds are less problematic in this crop. Mulching was the second most important weed management technique being practiced in about 70% of the citrus orchards, 40% in longan and about 25% in durian and mango orchards. Herbicides were used by less than one third of the farmers, being highest for longan, mango and Tieu mandarin. In these crops also insecticide and fungicide use was highest (18).

Table 3. Weed management practices of fruit farmers, Mekong Delta, 1997-1998.

	Sweet orange	Tieu mandarin	Longan	Durian	Mango
Hand weeding (%)	89.4	73.2	59.1	47.2	65.6
Mulching (%)	68.4	65.9	42.1	27.8	23.7
Rotary cutter (%)	5.3	2.4	5.8	0.0	1.1
Herbicides (%)	21.0	30.5	33.9	13.9	31.2
Mean no. of sprays	2.0	2.2	2.4	2.5	2.0
Mean no. of products	1.1	1.2	1.4	1.2	1.4

Farmers applying herbicides spray on average twice a year and mainly use one product only. More than 80% of the farmers who apply herbicides use the non-selective, translocated herbicide glyphosate against both annuals and perennials (Figure 2). Paraquat against annuals and 2,4-D against both annual and perennial broadleaves are applied by less than 20% of the farmers. To avoid herbicide resistance, herbicides should not be used year after year, preferably herbicide mixtures should be used and herbicides should be applied in rotation (1, 7).

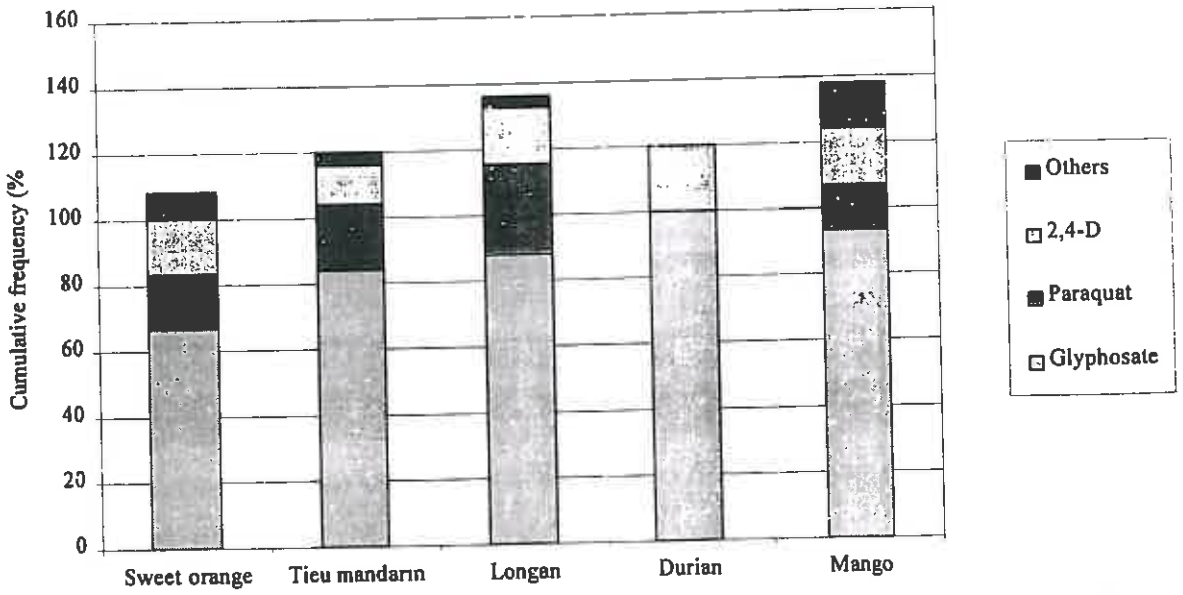


Figure 2. Major active ingredients used (%) by those farmers applying herbicides, Mekong Delta, 1997-1998.

Mulching is primarily done by cutting the weeds in the orchard and leaving them *in situ*, or by cutting or collecting weeds growing near or in the canals and bringing these to the orchard (Table 4). Some of the weeds are even intentionally grown by farmers as a source of mulch. These weeds are all monocotyledonous plants with a superficial root system. Rice straw and husks are used in some cases only, despite its high availability in the region. Many different applications of these natural resources make them more difficult to purchase (15). Experiments with different mulches in guava orchards in India indicated that rice husks suppressed weeds most efficiently, resulting in higher yields (4). Mulching with rice straw or slashed weeds is common practice to reduce annual weeds in Thai orchards (13), while geese are often used to graze *C. rotundus*. In the Mekong Delta of Vietnam, only few farmers mentioned chickens and duck to graze in their orchard. In a pineapple intercrop under coconut in Sri Lanka, mulching with coconut coir dust significantly suppressed *Ageratum conyzoides* and *C. rotundus*, while the incidence of *C. nudiflora* was enhanced (14).

A common practice of fruit farmers in the Mekong Delta is to remove the sediments of canals one to two months before the end of the dry season. This might be done every year or every second year, depending on the amount of sediment deposited. As such, the level of the planting beds is maintained over the years and the canals are kept clean for irrigation or fish culture. The alluvial sediments are spread over the planting beds and consequently weeds are completely covered. It is surprising that only a few farmers described this as a type of mulch. This practice of canal clearing has both its positive and negative aspects. Firstly, a lot of organic matter consisting of the complete weed biomass is incorporated which increases soil stability. Besides, with the sediments a lot of nutrients are provided to the soil and consequently the trees develop new roots in the upper soil layer.

Table 4. Major types of mulch used by fruit farmers, Mekong Delta, 1997-1998.

	Sweet orange	Tieu mandarin	Longan	Durian [c]	Mango
Weeds	84.6	83.3	75.0	70.0	86.4
Water hyacinth	5.1	1.9	13.2	-	-
Rice straw	-	13.0	10.3	30.0	4.5
Rice husks	2.6	1.9	-	-	-
Leaves of trees	-	-	4.4	-	-
Canal sediments	2.6	1.9	4.4	-	-
Animal manure	10.3	-	-	-	-

However, nutrients are not the only substances. Research in Thailand showed that insecticide residues are always present in the sediments of the canals, even when the farmer himself does not use any pesticides (DelVecchio, personnal communication). This can be regarded as one of the global effects of pollution. Residues not only kill ground dwelling arthropods; they also disturb the equilibrity between different microorganisms. The latter not only play an important role in nutrient cycling, but also in the natural defense against pathogenic root fungi. This negative effect on the fauna of the orchard ecosystem is enhanced by the fact that the mud layer often covers the planting beds as a film and therefore probably creates a chemically reduced environment depriving organisms temporary from oxygen. And last but not least, the complete weed flora is destroyed during a period that might be crucial for many beneficial insects, mites and spiders. After all, this practice is a way of clean cultivation that drastically reduces biodiversity and deprives beneficials from refuge and food.

Potential for incorporating weed management practices in IPM program

Traditionally, citrus farmers in the Mekong Delta use the weaver ant *Oecophylla smaragdina* as a biological agent to control several major insect pests. Farmers taking care of these ants apply significantly less insecticides and fungicides (17). No difference was observed regarding their weed management practices, probably because these ants have their nests in tree canopies and patrol the orchard by making use of artificial 'ant highways'. These consist of bamboo poles or ropes connecting different trees with one another. Both citrus and mango farmers in the Mekong Delta have no knowledge about beneficial organisms such as predatory mites (16, 17). Predatory mites are normally present in abundant numbers to keep populations of phytoseid mites under control. However, the use of broad-spectrum insecticides has destroyed this natural balance and triggered the outbreak of mite pests. Over the past years, the importance of orchard ground cover, in particular the availability of Asteraceae weeds as a rich source of pollen and nectar, has received more and more emphasis (6, 8, 19). IPM training programs should include training of farmers to recognize Asteraceae weeds such as *Ageratum conyzoides, Blumea glandulosa, Eclipta prostrata* and *Synedrella nodiflora* as beneficial weeds.

Some minor changes could make the practice of canal clearing a more compatible and even beneficial practice within an IPM program. One alternative might be that farmers apply the sediments only around the tree base, leaving the rest of the weeds untouched, a similar approach as with ring weeding. If weeds do become a problem, mechanical weeding or hand weeding could be practiced preferably in blocks or alternate rows. It should be borne in mind always to conserve part of the ground vegetation. Cut weeds can serve as mulch, as is already being practiced now. Another alternative would be that farmers clear their canals annually and apply the sediments on alternate planting beds every other year. As such, the level of the beds is maintained over the years, and weeds are available to natural enemies during the whole year.

A total herbicide treatment of weeds in the orchard has the same negative effect on biodiversity as clean cultivation. Besides, the soil is left bare and prone to erosion. If herbicides have to used, better would be to use products such as fenoxaprop (Whip's) and thiobencarb (Saturn), which are more selective against grassy weeds and are less harmful to Asteraceae weeds (2).

ACKNOWLEDGEMENTS

Current studies have been conducted within the VL.I.R. Project 'IPM in Fruit Production' at Cantho University, Vietnam in cooperation with the K.U. Leuven, Belgium. This Project has been funded by the Belgian Agency for Development Cooperation (B.A.D.C.). The authors would like to thank the Cantho University staff who assisted during the survey, as well as all the participating farmers and government officials. H. Eelen is kindly acknowledged for reviewing this manuscript.

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Weed Control Efficacy and Soil Persistence of New Pendimethalin Formulations

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Abstract: Pendimethalin is a selective dinitroaniline herbicide, which is widely used for controlling annual and biennial weeds in Korea. Pendimethalin is currently registered as an emulsifiable concentrate (EC) formulation. Recently, formulations other than EC type, such as water-dispersible granule (WG) and capsule suspension (CS), have been developed by the American Cyanamid Company to enhance safety for users and the environment through the use of safer formulation ingredients. To compare weed control efficacy and soil persistence between the three formulation (EC, WG and CS), trials were conducted in red pepper fields and weed development and soil residues were determined at 10 day intervals for 50 days after application. All three formulations effectively controlled most annual weeds in the trials and there were no significant differences in weed control efficacy between the three formulations. The analytical method for pendimethalin residues was successfully validated with a mean recovery of 99.6±7.1% (n=6) and detection limit of 0.005 mg/kg. Soil residue analyses showed that there were no statistical differences in half-lives between the formulations tested. These data indicate that the WG and CS formulations could successfully substitute the current EC formulation in Korea.

INTRODUCTION

Pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine], is a selective dinitroaniline, pre-emergent herbicide which controls a wide range of annual and biennial weeds in many crops. Pendimethalin, like other dinitroaniline herbicides, has the characteristics of low water solubility, medium to high volatility, and strong absorption to soil.

In Korea, pendimethalin is currently registered by American Cyanamid Company. The emulsifiable concentrate (EC) is the most predominantly used formulation. Recently, water-dispersible granule (WG) and capsule suspension (CS) formulations have been developed by American Cyanamid, to enhance safety for users and the environment by elimination of organic solvents.

Three different pendimethalin formulations (EC, WG and CS), were evaluated in red pepper fields to compare weed control efficacy and soil persistence with a view to replacing the currently registered EC formulation with the WG and CS.

MATERIALS AND METHODS

Site preparation and chemical treatment

Pendimethalin formulations were provided by the American Cyanamid Company. Red pepper seedlings were

propagated in a greenhouse until the eight leaf stage. The plants were then transplanted into field plots at a spacing of 60x80cm at Youngnam University Agricultural Research Farm, Korea. Each experimental plot was $10m^2$ and treatments were made in a complete randomized block design with four replications. Pendimethalin applications were made at 4 days after transplanting using a portable power sprayer fitted with a 20mm screened TZ nozzle at the rates given in Table 1 using a water volume of 2 l/ha.

Table 1. Application rates of three pendimethalin formulations

Formulation (% a.i.)	Application rate (a.i. g/ha)
Water Dispersible Granule (60% w/w)	2,000 g/ha (900 g a.i./ha)
Capsule Suspension (45% w/v)	1,500 ml/ha (900 g a.i./ha)
Emulsifiable Concentrate (31.7% w/w)	3,000 ml/ha (951 g a.i./ha)
Untreated control	--

Weed sampling

Weed species and numbers were monitored from two 1 m^2 subplots of each plot at 10 day intervals for 50 days after application (DAA). At 50 DAA, weeds were harvested and separated into individual species. Dry weights were determined after drying at 70°C for 48 hours.

Soil sampling

At one DAA soil samples were taken from 10 random cores to a depth of 10 cm from each plot using a soil auger and analysed for pendimethalin residues. Subsequent soil samples were taken at 10 day intervals up to 50 DAA. Immediately after collection, soil samples were transferred to the laboratory, mixed, air-dried, and passed through a 2mm sieve. These prepared soil samples were used for determination of the physicochemical characteristics of the soil (Table 2), and pendimethalin residue analyses from each replicated treatment.

Table 2. Physicochemical properties of soil used in this study

pH	org. matter (%)	CEC cmol(+)/kg soil	sand	silt	clay (%)	texture
5.6	1.5	12.8	21.8	38.0	40.2	clay

Extraction and cleanup of pendimethalin in soil

Twenty grams of dry soil was moistened with 20 mL distilled water for 10 min and extracted with 100 mL acetone for one hour on a flask shaker. The extract was suction-filtered through filter paper and the residue was rinsed with 50mL acetone. The filtrate was quantitatively transferred to a separating funnel, and then 450mL distilled water, 50mL saturated NaCl, and 100mL *n*-hexane, sequentially added. After vigorous shaking for 1 min, the upper hexane phase was dried over 10g anhydrous sodium sulfate and evaporated just to dryness under vacuum at 40°C. The residue was dissolved in 10mL *n*-hexane and subjected to Florisil column chromatography (11mm i.d. × 40 cm, dry packed with 5g Florisil, 60~100mesh, activated for more than 5 h at 130 °C, and topped with *ca.* 2cm layer of anhydrous sodium

sulfate). The hexane extract 5 mLwas poured into the column. When the liquid drained to sodium sulfate layer, the column was eluted with 50mL dicholromethane/*n*-hexane mixture (20/80, v/v), and the fraction discarded. The column was then eluted with 50mL dichloromethane/acetonitrile/*n*-hexane mixture (50/0.35/49.65, v/v/v), and the fraction collected, concentrated to dryness, and the residue was reconstituted with 10mL *n*-hexane for GLC determination.

Gas-liquid chromatography (GLC)

GLC was performed using a Hewlett Packard 5890 Series II GC equipped with electron capture detector. Operating parameters are shown in Table 3. Under these conditions, retention time and minimum detectable quantity of pendimethalin were 4.7min and 0.01 ng, respectively.

Table 3. Gas-liquid chromatograph operating condition for analysis of pendimethalin

Column:	SPB-5 fused silica capillary column, 0.53 mm i.d × 30 m, 0.5 film Thickness (Supelco, USA)
Temperature (°C):	Column oven 180; Detector block 300; Injection port 270
Gas flow rate:	Carrier, He 20 mL/min; Make-up, N_2 60 mL/min

RESULTS AND DISCUSSION

Pendimethalin efficacy

At 50 DAA the key weed species in the untreated control were: *Echinocholoa crus-galli, Digitaria sanguinalis, Acalypha australis, Capsella bursa-pastoris* and *Chenopdium album*. Based on dry weight, weed control efficacy of pendimethalin were 84.5% for barnyardgrass (*Echinochloa crus-galli*), 80.6 % for crabgrass (*Digitaria sanguinalis*), 92.8% for Virginia copperleaf (*Acalypha australis*), 97.3% for Goosefoot (*Chenopodium album*), and 83.7% for Shepherd's-purse (*Capsella bursa-pastoris*), when averaged across the three formulations (Table 4). There was no statistically significant difference in weed control performance between the three formulations. No crop injury was observed in any of the treatments.

Table 4. Weed control efficacy of different pendimethalin formulations based on dry weight at 50 DAA.

	ECHOR		DIGSA		ACAAU		CAPBP		CHEAR		total	
	dw*	%**	dw	%	dw	%	dw	%	dw	%	dw	%
[illegible]WG	3.9	93.5	12.2	78.5	1.2	88.5	1.2	85.3	0.0	100.0	21.9	85.5
[illegible]GS	15.5	74.1	12.9	77.4	0.2	98.5	1.9	77.4	0.0	100.0	32.4	78.6
[illegible]GC	8.3	86.1	8.1	85.8	0.9	91.3	1.0	88.4	0.8	91.9	24.1	84.1
Control	57.9	-	56.9	-	10.8	-	8.2	-	9.7	-	151.4	-

* dry weight expressed as g/m^2, ** % weed control.

ECHOR: *Echinochloa crus-galli*, DIGSA: *Digitaria sanguinalis*, ACAAU: *Acalypha australis*, CAPBP *Capsella bursa-pastoris*, CHEAR: *Chenopodium album.*

The weed density of four of the key species are shown in Fig. 1. Clearly all three formulations were capable of controlling the key weeds for the duration of the experiment, compared to the high weed density in the untreated control plots.

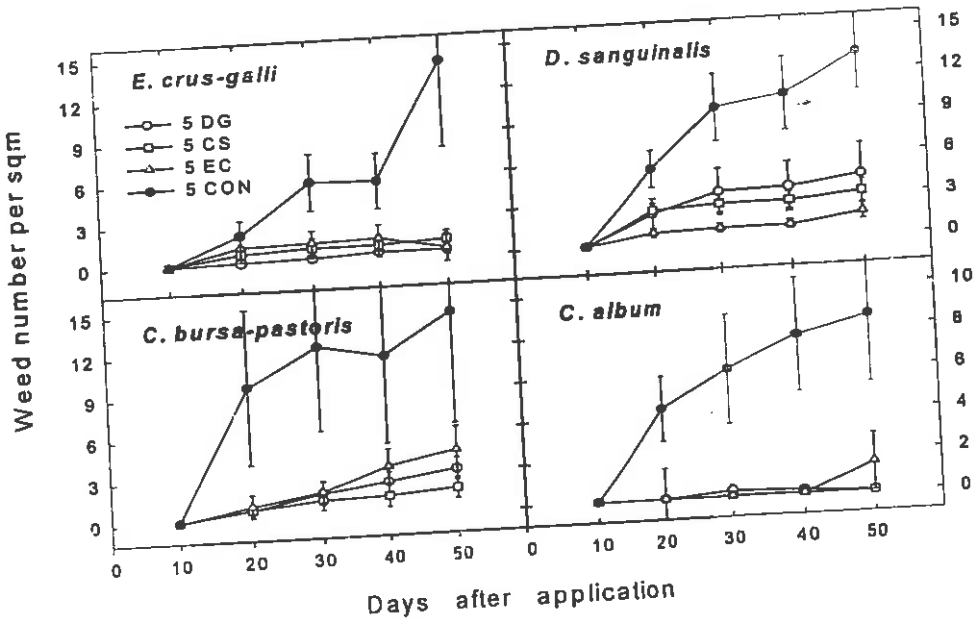


Fig. 1 Change of weed number after application of three different formulations of pendimethalin in redpepper field. WG: water-dispersible granule, CS; capsule suspension, EC; emulsifiable concentrate. Number were the means of four replications and were expressed as number per square meter. Error bars indicated standard deviations.

Soil persistence

The analytical method for pendimethalin residues in soil was successfully validated as measured by mean recovery of 99.6 ± 7.1% (n=6) and detection limit of 0.005mg/kg (data not shown).

The soil persistence of pendimethalin from each of the three formulations is shown in Fig. 2. Each formulation had similar half-lives of 18.1, 18.8 and 17.7 days for the WG, CS and EC respectively. In agreement with our results, Kim *et.al.* (1997) also reported similar half-lives of different formulations of fenitrothion, fenarimol and tricyclazole when applied to crop. Gasper *et.al.* (1994) compared a granular formulation with that of a wettable powder and reported that dissipation of pendimethalin in soil were not greatly dependent on formulation. Our results of the formulations tested indicated that the duration of weed control efficacy were similar, regardless of formulation. This agreed with the pattern of weed development shown in Fig. 1. Statistical differences were not significant for half-lives between formulations.

Our result showed that the WG, CS and EC formulations had similar weed control efficacy and soil persistence. Therefore it is concluded that the new formulations of pendimethalin WG and CS could successfully replace the current commercial EC formulation.

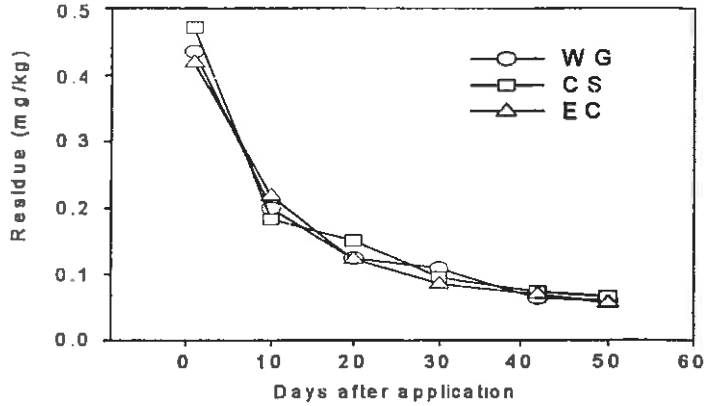


Fig. 2. Soil persistence of three formulations of pendimethalin in redpepper field. Values were the means of triplicates.

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WEED MANAGEMENT STRATEGIES IN ONION GROWN AFTER RICE

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Abstract: Studies were conducted in farmer's fields in Nueva Ecija, Philippines during the 1997 and 1998 dry seasons to evaluate the effect of various agronomic practices on weed growth and crop yield in transplanted bulb and shallot onion (*Allium cepa* L.), a major vegetable crop grown after rice (*Oryza sativa* L.) in rainfed rice-based cropping systems. Treatments ranged from a single cultural practice to a maximum of two herbicides plus two handweedings. Regardless of cultivar, one herbicide plus one handweeding controlled weeds and yielded comparably with two herbicides and two handweedings. This reduced costs of weed control inputs by 15 to 70% of total production costs without reducing weed control efficacy or crop yields. In most cases, a second herbicide was not necessary because it was not effective on the dominant weed, reflecting the importance of farmer awareness of the weed spectrum of a particular herbicide. Rice straw mulch and rice hull burning also suppressed weed growth and reduced the amount of labor needed for manual weeding or the number of herbicide applications to a minimum. Although yields were highest with two handweedings, it was more expensive than one herbicide plus one handweeding when weed pressures were high. These results indicate that weed infestations can be suppressed adequately using a minimum of chemical inputs combined with cultural inputs in integrated agroecological approaches to managing weeds in rice-onion systems.

Keywords: rice-onion systems, weed management, cultural control, chemical control

Introduction

Onion, a leading export crop in the Philippines, is grown after flooded rice, a traditional rotation system dictated by the annual rainfall cycle of distinct dry and wet seasons. At any one growing season, about 25 weed species, at a wide range of densities, grow with each crop (Baltazar et al, 1998). In onion, the most dominant weeds are purple nutsedge (*Cyperus rotundus* L.), horse purslane (*Trianthema portulacastrum* L.), and the grasses junglerice (*Echinochloa colona* (L.) Link) and goosegrass (*Eleusine indica* (L.) Gaertn). Some of these weeds also now grow in flooded rice (Baltazar et al, 1998). After the rice crop, these weeds are carried over into the onion crop, sprout into new plants, and add to the already high infestations in onion. Onion growers face two problems: 1) onion is a poor competitor against weeds, thus requiring high inputs for weed control; and 2) its most dominant weeds are difficult to control selectively with postplant methods other than tedious and/or expensive manual or mechanical weeding. Weed control inputs can reach a maximum of US$300/ha in weeding labor and herbicides, which is about 20% of total production costs.

The objective of the IPM-CRSP weed research program is to develop weed management strategies that will reduce dependence on herbicide use and production costs due to weed control in rice-onion systems. The initial phase focuses on addressing immediate weed problems in onion, specifically, to develop agronomic approaches which will provide immediate solutions to these problems. This includes determination of the best combination of cultural and chemical methods which will provide adequate to maximum efficacy at minimum input costs. This paper reports the results of studies evaluating the efficacy of single or various combinations of rice straw mulch, rice hull burning, tillage, handweeding, and herbicides for control of weeds in onion grown after rice. For herbicides, single or combined applications, and rates and timings were evaluated, with or without a cultural practice. The cost effectiveness of all these methods were considered.

Materials and Methods

Site description and general procedures

Studies were conducted from November to March during the 1996-97 and 1997-98 dry seasons in several farmer fields located in two villages in San Jose and one village in Bongabon in the province of Nueva Ecija, Philippines. The average monthly rainfall is 350 mm during the rainy months (June to

September) and 30 mm during the dry months (November to April). Monthly average night and day temperatures range between 20°C and 32°C. Soils in the area are Inceptisols (Eutropepts with Dystropepts) ranging from clay loam to sandy loam. Shallot (cv Tanduyong) and bulb onion (cv Yellow Granex) were grown according to farmer's practices in the area. Except in one field in Palestina in 1997, shallot onions were grown with rice straw mulch in tilled or untilled sunken plots that were used as rice paddies in the preceding season. Seedlings were established in October or November. Thirty to 45-day old seedlings were dibbled into mulched plots at 10 cm within rows and 20-30 cm between rows following rice harvest in November to December. Bulb onions were grown with (Palestina, 1997) or without (Bongabon 1997, 1998) rice hull burning. Fields were plowed twice and harrowed thrice. Thirty to 45-day old seedlings were transplanted into sunken plots (San Jose) or raised furrows (Bongabon) at 10 cm within furrows and 20-30 cm between each furrow. Fields were irrigated with deep-well pumps at transplanting and later, as needed. Agronomic practices, fertilizer and pest management were done according to prevailing local practices or as recommended by the Department of Agriculture. Herbicides were applied with a hydraulic knapsack sprayer calibrated to deliver 500 L/ha using 8002 Teejet flat fan nozzles. The herbicides used were glyphosate [*N-(phosphonomethyl)glycine*], fluazifop *[(+2-[4-[5-(trifluoromethyl)-2-pyridinyl] oxy] phenoxy] propanoic acid)]*, oxyfluorfen [*2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4- trifluoromethyl) benzene]*, and oxadiazon *[3- [2,4- dichloro-5-(1-methylethoxy) phenyl]-5- (1,1-dimethylethyl)-1 ,3, 4- oxadiazol-2-(3H)-one]*. The recommended rates for each herbicide, indicated on the labels, were used: 0.9 kg ai/ha for glyphosate, 0.8 kg ai/ha for fluazifop, 0.06 kg ai/ha for oxyfluorfen and 0.6 kg ai/ha for oxadiazon. Unless otherwise indicated, weed counts and weed weights by species were taken from a 1 by 1 m quadrat at 45 days after transplanting (DAT) and at harvest. Yield was taken from a 2 by 5 m area at the center of each plot and expressed in t/ha. The treatments were laid out in Randomized Complete Block Design (RCBD) with four replications. Individual plot size was 4 m by 5 m. Data in each study were subjected to analysis of variance using the General Linear Models Procedure (SAS). Treatment means were compared using Duncan's New Multiple Range Test at 5% level of significance. Data were not combined across years or locations because the treatments, weed pressure, proportion of dominant weeds, cultivars, and other factors varied among fields and between years.

Specific studies

Rice straw mulch. The study was conducted in three farmers' fields in San Jose (Santo Tomas, 1997). The fields were either tilled (plowed and harrowed once or twice), or if not tilled, were sprayed with glyphosate to kill weeds that grew during the fallow period. At one week after the last harrowing or after glyphosate treatment, approximately 10 to 12 cm of rice straw mulch was laid out in the field. An adjacent area was not mulched. Treatments, consisting of 4 x 5 m^2 of mulched and unmulched plots, were superimposed into the farmers' fields. In each field, there were two mulched and two unmulched plots, making a total of 6 replications. Following irrigation, shallot onion (cv. Tanduyong) was dibbled into the plots. Weed counts and weights were taken from a 1 x 1 m^2 area marked off at the end of each plot. To ensure that only the effect of rice straw mulch was being measured, this area was not treated with herbicides nor handweeded. Weeds were counted by species and dry weights were recorded at 7 to 15 and 30 to 45 DAT and at harvest.

Rice hull burning. The study was conducted in two farmers' fields in San Jose (Palestina, 1997). Prior to transplanting, approximately 12 cm deep of rice hull was laid out in the seedbed/field and burned for 24 to 48 hours. The burned ash was plowed and incorporated into the soil and the field was harrowed twice. An adjacent area was not burned. There were two burned and two unburned 4 x 5 m^2 plots in each field, making a total of four replications. Following irrigation, bulb onion (cv Yellow Granex) was transplanted into the burned and unburned plots. The burned and unburned plots were separated by a 1 m area as a buffer zone and were superimposed into the farmers' fields. Weed counts and weights were taken from a 1 x 1 m^2 area marked off at the end of each plot. To ensure that only the rice hull burning effect was being measured, this marked area was not treated with herbicides nor handweeded. Weeds were counted by species and dry weights recorded at 7 to 15 and at 30 to 45 DAT and at harvest.

Rice straw mulch, herbicides and handweeding. Three studies were conducted in two sites, Palestina (1997) and Santo Tomas (1997, 1998). Shallot onion cv. Tanduyong was used. The fields were not tilled, except for Santo Tomas in 1998. Rice straw mulch was laid out and seedlings dibbled into the mulch. Treatments in each of the fields are in Table 1. In Palestina, oxyfluorfen and fluazifop were

applied alone or in sequential treatments at 19 DAT when weeds were 2 to 6 cm tall with two to four leaves. Handweeding was done 15 and/or 35 days after the herbicides were applied (30 and/or 50 DAT).

Tillage, herbicides, and handweeding. Three studies were conducted in two sites, Palestina (1997) and Bongabon (1997, 1998). The fields were plowed twice and harrowed three times. No mulching or rice hull burning was done. Shallot onion cv Tanduyong was used in Palestina and bulb onion cv. Yellow Granex was used in Bongabon. Treatments in each of the field are in Table 1. Herbicides were applied in single or sequential treatments at 9 to 12 DAT, when weeds were 2 to 8 cm tall with two to four leaves. Handweeding was done 20 and/or 40 days after the herbicides were applied (30 and/or 50 DAT).

Results and Discussion

Cultural practices: rice straw mulch and rice hull burning: Weed growth in unmulched plots was greater by about 60% than in mulched plots at early and late season (Figure 1a), except in one farm where the dominant weed was *C. viscosa*. This tall, bush-like weed grew through the mulch, resulting in similar weed densities in mulched and unmulched plots at mid-season. Averaged across farms however, yields in mulched plots were 70% higher than yields in unmulched plots. The wide spacing required in onions to enhance maximum bulb development also enhances luxuriant weed growth between and within rows, since onion has no canopy to shade out weeds. The rice straw mulch makes up for the lack of canopy by preventing sunlight penetration into the soil, thus suppressing weed germination and growth

With rice hull burning, weed growth in unburned plots was about 55% greater than in burned plots (Figure 1b). Greatest weed growth, which was 70% higher than in burned plots, occurred at mid-season. Yields in burned plots were 64% greater than those in unburned plots. Rice hull burning reduced weed populations by killing or destroying weeds and weed propagules. Our studies showed exceptionally high yields of 40 to 60 t/ha in plots where rice hull was burned, mainly because of adequate weed growth suppression in addition to suppression of soil-borne pests and diseases. This practice, however, is limited to farms far from roadsides or residential areas. Also, if not available for free, a 12 cm depth costs about $290/ha, which is as expensive as two herbicides and two handweedings (22% of total production costs.)

Rice straw mulch, herbicides and handweeding. Palestina, 1997: Weed growth and yields in plots which received single applications of either fluazifop or oxyfluorfen plus one handweeding were similar to those in plots which received sequential applications of both herbicides plus two handweedings (Table 1). Rice straw mulch in this field helped suppress weed populations, and a single herbicide treatment of either oxyfluorfen or fluazifop plus one handweeding controlled weeds adequately. Thus, there was no need for an additional herbicide treatment or another handweeding operation. Because grass weeds were dominant in this field, fluazifop was more effective than oxyfluorfen.

Santo Tomas, 1997-1998: In both years, a single preplant application of glyphosate followed by one handweeding controlled weeds and yielded comparably to treatments consisting of two handweedings alone or to treatments using a maximum of two herbicides (preplant glyphosate followed by postplant fluazifop) plus two handweedings (Table 1). Because the dominant weed in this farm was the broadleaf weed, *C. viscosa*, fluazifop applied alone yielded 30% lower than when it was combined with glyphosate, even when followed by one handweeding. This indicates that applying fluazifop alone or as follow-up to glyphosate was not necessary in cases where broadleaf weeds are dominant. Tillage apparently did not affect glyphosate efficacy, as reflected in similar weed growth and yields when glyphosate was applied into no-till plants in 1997 or when it was applied into tilled plants before or after land preparation in 1998.

Combinations of tillage, herbicides, and handweeding. Palestina, 1997: A single application of oxyfluorfen plus one handweeding controlled weeds better than did a single application of fluazifop plus one handweeding (Table 1). Both treatments, however, yielded comparably with those of plots which received sequential treatments of both herbicides plus two handweedings. Thus, a single application of either herbicide followed by one handweeding provided adequate weed control. A second herbicide application or a second handweeding was not necessary. Because the dominant species in this field were sedges and broadleaf weeds, oxyfluorfen was more effective than fluazifop.

Bongabon, 1997-1998: In 1997, a single application of either oxyfluorfen, oxadiazon, or fluazifop, each followed by one handweeding, provided comparable weed control and yields with sequential applications of any two of these herbicides plus two handweedings (Table 1). In 1998, plots which received a single application of fluazifop plus one handweeding controlled weeds and yielded as well as those which received sequential applications of oxyfluorfen and fluazifop and two handweedings, confirming the results obtained in 1997 (Table 1). These treatments also yielded as well as plots which were handweeded twice. Single treatments of glyphosate applied at 14 to 21 days before planting either before or after land preparation did not control weeds as adequately as did the oxyfluorfen or fluazifop treatments (Table 1). Applying glyphosate at 14 to 21 days before planting to avoid injury to onions was apparently too early in the season to control subsequent weed flushes at mid-season, thus adequate season-long control was not obtained since there was no mulch to provide additional weed suppression. Oxyfluorfen and fluazifop were applied at 7 to 15 days after transplanting and weed flushes at these stages were controlled.

In 1998 in Santo Tomas and Palestina, yields in unweeded plots were reduced by 70 to 98% of handweeded plots, confirming the poor competitive ability of onion against weeds.

Total weed control costs from two herbicides plus two handweedings was about $130/ha in mulched fields where weed densities were low and about $308/ha in unmulched fields where weed densities were high. Assuming total production costs of about $1,300/ha (Gaskell, 1994) the cost of two herbicides plus two handweedings is 10% of total production costs at low weed densities and 24% at high weed densities. If weed control treatments are reduced to one herbicide plus one handweeding, the total costs for weed control in mulched fields (low weed densities) is reduced from 10% to 3% (oxyfluorfen), 4% (glyphosate), and 8% (fluazifop), of total production costs. Handweeding twice in mulched fields is 5% of total production costs. Thus, in mulched fields, greatest reduction (70%) occurred with oxyfluorfen, followed by glyphosate (60%) and two handweedings (50%) and least reduction (20%) with fluazifop (Table 1). In unmulched fields (high weed densities), the total cost for two herbicides and two handweedings, which is 24% of production costs, is reduced to 10 to 14% of production costs if this is reduced to only one herbicide and one handweeding; Because of high weed pressure, two handweedings alone, even without herbicides, was more expensive because it took 62 to 120 man-days/ha for one or two handweedings and cost 18% of total production costs. Thus, greatest reduction occurred with oxyfluorfen, oxadiazon or glyphosate (56%) followed by fluazifop (29%), and least reduction with two handweedings (19%) (Table 1).

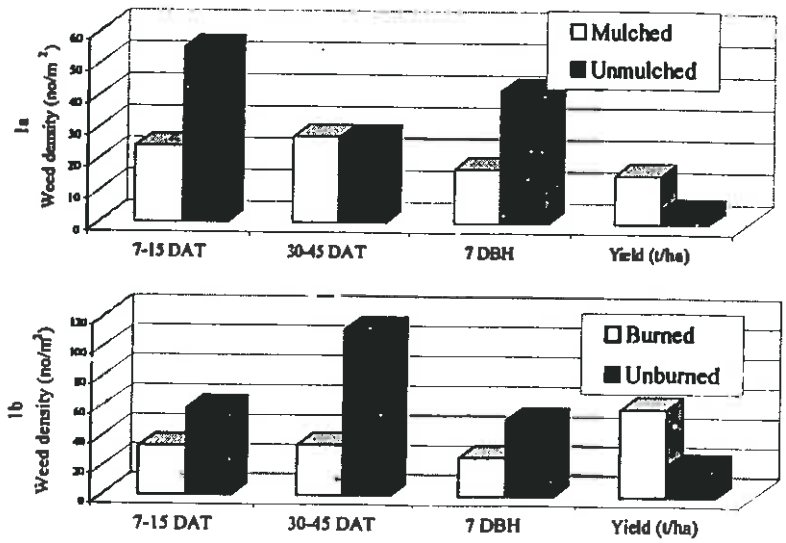


Figure 1. Weed density and yield in mulched and unmulched shallot onion (1a) and in rice hull burned and unburned plots of bulb onion (1b) in San Jose, Nueva Ecija during the 1997 dry season; DAT = days after transplanting; DBH = days before harvest.

Various agroecological practices, ranging from a single cultural practice of rice straw mulching or rice hull burning to a maximum combination of two herbicides plus two handweedings, were evaluated. Of these approaches, one herbicide plus one handweeding provided adequate season-long control with least weed control costs, regardless of the onion cultivar grown. Except for glyphosate which is applied preplant, none of the three herbicides currently used postplant in onion in the country are effective on all the four major weed species. Thus, the choice of a herbicide depends on the dominant species in a particular field. Oxyfluorfen and oxadiazon are best suited where broadleaf weeds are dominant and fluazifop where grasses are dominant. These are applied within one to four weeks of transplanting. Subsequent weed regrowths or escapes are controlled with a follow-up handweeding. Thus, it is important that farmers are aware of: 1) what their major weeds are, and 2) which herbicide is effective on which weed. Perhaps the reason why often farmers use two herbicides is that they are not aware of which herbicide to use on which weed. Our studies showed that fluazifop was not needed when broadleaf weeds were dominant. Similarly, oxyfluorfen or oxadiazon were not needed when grasses were dominant. By reducing treatments from two herbicides and two handweedings to one herbicide and one handweeding, the total costs for weed control were reduced from10% (low weed pressure) or 24% (high weed pressure) to 5% to 10% of total production costs. This cuts down total weed control costs by an average of 50% to 70%.

Data from our two-year studies show that weed control inputs in transplanted shallot and bulb onions can be reduced to a single herbicide followed by one handweeding, decreasing weed control costs by as much as 70% with no reduction in weed control efficacy and yields. Our results can serve as basis for comparison with studies in countries like the U.S. where herbicide-based control approaches are now being shifted to cultural-based strategies in response to increasing environmental, political and economic concerns of increasing herbicide use and increasing cases of herbicide resistance (Swanton and Wiese, 1991). In tropical Asia, manual or mechanical weeding following herbicide treatment is believed to contribute greatly to delay or prevent the development of herbicide-resistant weeds (Gressel and Baltazar, 1996). Results of our studies can provide interesting comparison (and contrast) with those in temperate countries and contribute to the generation of knowledge that are vital in developing IWM approaches that reduce weed infestations through integration of agroecological approaches using reduced chemical inputs combined with cultural inputs.

Acknowledgements:

This project was supported by IPM-CRSP (Collaborative Research Support Program) funded by USAID Global Bureau Grant No. LAG 4196-G-00-3053-00, with Virginia Tech as lead institution and Philippine Rice Research Institute, University of the Philippines Los Baños, and International Rice Research Institute as collaborating institutions.

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Table 1. Weed density, yield, cost of weed control inputs and amount reduced in bulb and shallot onion treated with various weed control methods in San Jose and Bongabon, Nueva Ecija during the 1997 and 1998 dry seasons.

Treatment[1]	Weed Density[1] (no/m^2)	Yield[1] (t/ha)	Handweeding Cost[2] (man-day/ ha)	(P/ha)	Herbicide[3] (P/ha)	Total (P/ha)	% Total Prod'n. Cost	Amt. Reduced[4] (%)
Rice Straw Mulch, Herbicides, and Handweeding								
Palestina, 1997								
Oxy+Flua+2 HW	10 a	10.7 a	13.5	945	3049	3994	7.9	0
Oxy+1 HW	14 a	11.0 a	9.9	693	505	1198	2.4	70
Flua+1 HW	11 a	10.5 a	11.2	784	2684	3468	6.9	13
Santo Tomas, 1997								
Gly+Flua+2 HW	12 a	21.2 ab	14.6	1022	3479	4501	9.0	0
Gly+1 HW	14 a	23.8 a	13.0	910	935	1845	3.7	59
Flua+1 HW	16 a	15.2 b	15.6	1092	2684	3776	7.5	16
Santo Tomas, 1998								
Gly+Flua+2 HW	26 ab	20.1 a	28.7	2009	3479	5488	11.0	0
Gly(A)+1 HW	52 a	20.2 a	15.1	1057	935	1992	4.0	64
Gly(B)+1 HW	27 ab	17.3 a	19.8	1386	935	2321	4.6	58
Handweeding 2 x	27 ab	22.9 a	34.9	2443	0	2443	4.9	55
Unweeded Control	33 a	4.9 b	0	0	0	0	0	0
Tillage, Herbicides, and Handweeding								
Palestina, 1997								
Oxy+Flua+2 HW	101 a	19.4 a	18.8	1316	3049	4365	8.7	0
Oxy+1 HW	64 b	18.3 a	15.1	1057	505	1562	3.1	64
Flua+1 HW	192 a	17.9 a	17.7	1239	2684	3923	7.8	10
Bongabon, 1997								
Oxy+Flua+2 HW	82 ab	23.4 a	121.9	8533	3049	11582	23.2	0
Oxa+Flua+2 HW	79 ab	20.2 a	124.5	8715	3944	12659	25.3	0
Flua+1 HW	89 ab	22.4 a	61.5	4305	2684	6989	14.0	42
Oxy+1 HW	106 a	21.1 a	64.6	4522	505	5027	10.0	58
Oxa+1 HW	107 a	21.4 a	60.9	4263	1400	5663	11.3	52
Bongabon, 1998								
OxyFlua+2 HW	54 cd	13.8 a	110.4	7728	3049	10777	21.5	0
Flua+1 HW	57 cd	13.2 ab	60.9	4263	2684	6947	13.9	36
Gly (B)+1 HW	108 ab	12.5 ab	60.2	4214	935	5149	10.3	52
Gly (A)+1 HW	81 bc	9.6 b	58.9	4123	935	5058	10.1	53
Handweeding 2 x	4 d	14.1 a	125.3	8771	0	8771	17.5	19
Unweeded Control	151 a	0.3 c	0	0	0	0	0	0

[1]Means followed by the same letter are not significantly different at 5% level of DMRT. Average of 4 replications; oxy = oxyfluorfen; flua=fluazifop; oxa=oxadiazon; gly=glyphosate; HW=handweeding.
[2]8 hr/man-day at P70/man-day
[3]Includes 2 man-days (P140/ha) spraying labor; oxyfluorfen – P365/ha, fluazifop – P2544/ha, oxadiazon – P1260/ha, glyphosate – P795/ha at recommended rates; 1 US$ = P38.
[4]Amount reduced compared with two herbicides and two handweedings; total production costs in onion = $50,000/ha ($1,300/ha) (Gaskell, 1994).

4. Herbicides

4.1 Application Techniques

DRIZZLE HERBICIDE APPLICATIONS FOR VEGETATION MANAGEMENT ON FOREST TRAILS IN HAWAII

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Abstract: The State of Hawaii created the Na Ala Hele Trail System as its part of the National Trail System for the enjoyment of residents and tourists alike. However the comfort and safety of hikers and the protection of forests required that the Division of Forestry and Wildlife of the Department of Land and Natural Resources, State of Hawaii, manage weeds that may block trails or injure hikers or colonize the forest interiors. The logistical inconvenience of conventional spraying which requires the portage of large volumes of water over remote and rough terrain resulted in the reliance on manual methods of vegetation management. However, high labor costs and transient vegetation suppression proved manual methods were unsustainable. Not only were weeds dominating the trails, but the excessive amount of labor devoted to vegetation management meant less labor was available for other management tasks such as litter collection, trail repair, and maintenance of native plants in forests. The drizzle herbicide application method, a very-low volume method (15 L/ha), proved very labor efficient; a trail could be treated at 3 km/hr. After a pilot project proved the drizzle method effective and efficient, it was adopted for trail maintenance. Data collected and compared to that of the former manual control system proved the drizzle method accomplished excellent weed suppression at as low as 3% the cost of manual methods per treatment and required fewer treatments per year.

Key words: drizzle herbicide application, forest weed control, triclopyr, glyphosate, hexazinone.

Introduction

In recent years eco-tourism, hiking, boating, and horseback riding to view natural areas and wildlife, has become an increasingly important part of the tourism industry. To accommodate this increasing interest in the natural environment, the State of Hawaii has established the Na Ala Hele Trail System, its part of the National Trail System. The increased traffic on trails required more effective and efficient trail maintenance by the State of Hawaii Department of Land and Natural Resources, Division of Forestry and Wildlife (DOFAW), especially vegetation management, in order to ensure the safety and comfort of hikers. Weeds on trails can block passage. Weeds armed with spines and burs can injure hikers. On cliff side trails weeds can force hikers dangerously close to the edge of the trail or obscure the edge of the trail. Trails also serve as arteries for invasive weeds into the interior of forests. Seeds on the shoes and clothing of hikers from all over the world may establish a foothold on trails and be spread by other hikers and animals. Thus DOFAW must exercise diligent vegetation management on their trails. Because of the large amount of water that must be portaged over often rough and remote trails, conventional herbicide application has not been favored by DOFAW. Instead, they had been relying on manual methods, principally string cutters, to suppress weeds. However, the high labor costs and temporal vegetation suppression resulted in poor vegetation management and a backlog of trails needing weed control. Where at least two manual clearings per year were required on each trail, often one or less was made. This in turn resulted in greater weed problems. A highly efficient method to suppress weeds on remote and rough trails would help keep trails safe and pleasant and release forest workers to do other forest management tasks.

The very-low volume drizzle herbicide method is a very labor efficient method that was developed by Shigeo Uyeda of the McBryde Sugar Company of Kauai, Hawaii (Motooka *et al.*, 1983). The method basically required two inexpensive components to convert any knapsack sprayer into a drizzle unit: an orifice plate (0.5 mm diameter orifice used in studies reported herein) and a 100 or 200 mesh strainer to keep the orifice clear. Under pressure, a fine jet stream of a concentrated herbicide mixture, 10% or higher depending on desired herbicide rate, is ejected. When the wand is waved, the stream breaks up in

the air and drizzles onto the weeds. The wand may also be aimed for a precise directed application. The application volume rate may be altered by changing the disc size, spray swath, walking speed and pressure. A 0.5 mm orifice at 1.44 kP, a swath of 7 m wide, and a walking speed of 0.3 m/sec delivers a spray volume of 15 l/ha. A trail 2.6 m wide can be treated at 3 km/hr. The efficiency of the drizzle method is derived from its very–low volume, which means fewer porters will be needed, especially on dry trails, and there will be less frequent reloading stops. Additionally, conventional spraying with atomizing nozzles require treatment of one side of the trail at a time. The drizzle unit has a reach of 5 m which means both sides of a trail can be treated in a single pass. Furthermore, there are built-in inefficiencies in working in remote areas. Workers must travel to and from the work site which may take half the work day or be transported by helicopter. Reducing the number of workers and visits to the work site eliminates much non-productive travel time and expenses. In a pilot project to demonstrate the efficacy and efficiency of the drizzle method, a three mile segment of Koaie Trail in the Waimea Canyon on Kauai was treated with 1 kg a.e. triclopyr (Garlon 4, 44.3% a.e.) + 1 kg a.e. glyphosate (Roundup, 41% a.e.)/ha applied with the drizzle method (Motooka *et al.*, 1998). Six months after the second annual application the trail was clear. Trail mileage markers, obscured by weeds and not seen since installation, were visible. The cost of clearing by the drizzle method was 3% the cost of mechanical methods and 10% the estimated cost of conventional spraying. The Koaie Trail ran along a stream so access to water was no greater than 0.8 km away. On dry trails, conventional herbicide applications would require more labor for the portage of water so the cost advantage of the drizzle method would be even greater.

A further advantage of the drizzle method is that the very-low volume applications made the use of crop oil carriers affordable. Thus weed species that were tolerant to emulsifiable herbicides (e.g. triclopyr ester) applied in water may be susceptible to the herbicide applied in a crop oil carrier as a foliar application (e.g. sisal [*Agave sisalana* Perrine]) or as a basal bark application (e.g. strawberry guava [*Psidium cattleianum* Sabine]), though the later was effective only on plants with thin barks (Motooka *et al.*, 1999).

Materials and Methods

To document the efficacy and economy of the drizzle herbicide method for vegetation management on trails, several trails in different climatic zones were maintained by the drizzle method and where possible, the costs were compared to the manual methods previously employed. In one case, the Lahaina Pali Trail, a trial was conducted to determine the feasibility of using the drizzle to apply a liquid formulation of hexazinone and tebuthiuron pellets for preemergence weed control. The trails were:

Nualolo Trail.

Nualolo trail ran along part of the Napali Coast of the island of Kauai. This is a high rainfall area which nevertheless did not have running streams when it was not actually raining. There were many weed species on this trail, the most problematical were lantana (*Lantana camara* L.) and highbush blackberry (*Rubus argutus* Link), both of which were armed with spines, and vaseygrass (*Paspalum urvillei* Steud.).This trail is a popular trail and so is a high priority for DOFAW. Mechanical control of weeds along this trail required 24 man-days at a total cost of $6,365. Two mechanical operations a year would be required for ideal maintenance, though this goal was not always met. A 2.8 km segment of this trail was treated twice with drizzle applications in 8 months. The first application was with glyphosate at 0.5 or 1 kg a.e./ha, the rate was increased by increasing the volume rate from 15 l/ha to 30 l/ha. The second application was with triclopyr at 0.72 kg a.e./ha and glyphosate as in the first treatment. The herbicides were applied separately by two applicators. Triclopyr was applied to broadleaf weeds except lantana; glyphosate to grasses and to lantana, a dicot more sensitive to glyphosate than to triclopyr.

Alakai Swamp Trail.

This 5 km trail cuts through the Alakai Swamp on the top of Mount Waialeale, the wettest spot on earth in some years. To prevent damage to the swamp, DOFAW constructed a boardwalk for hiking. Vasey grass grew on high ground along the boardwalk, evidence that it was carried in by hikers. The Alakai Swamp Trail is very popular and is a high priority trail to DOFAW. Mechanical weed control required 41 man days per year at a cost of $4,848. Two applications of glyphosate at 0.5 kg a.e./ha were made 6 months apart.

Lahaina Pali Trail.

The 8 km Lahaina Pali Trail on the leeward side of the island of Maui is dry with no water sources. Winter storms triggers vigorous but short lived weed growth mostly of orchardgrass (*Dactylis glomerata* L.). Ordinarily, the flush of growth would quickly dry up. In prolonged wet weather however, the grass can grow as tall as a person, thus making hiking extremely unpleasant. DOFAW expended 50 man-days at a cost of $4,426 to clear the trail twice in a typical year. Occasionally one or three clearings a year are necessary. More importantly, unchecked weed growth becomes tinder dry in the long dry season which then poses a fire hazard. This trail was closed for several weeks in 1998 because of a large brush fire which also closed the only highway to Lahaina isolating that resort area for two days. For that reason DOFAW has considered making the trail a firebreak to contain wild fires. Preemergence herbicides will be required to do this. A trial was conducted on the Lahaina Pali Trail to evaluate the preemergence activity of tebuthiuron pellets (Spike 20P, 20% a.i.) and hexazinone (Velpar L, 25% a.i.) applied with the drizzle applicator, each at 2 kg a.i./ha, to plots 30 m by 5 m in four randomized complete blocks. The trial was evaluated at 5 MAT.

Boundary Trail.

Boundary trail is high on the slopes of Haleakala on Maui. It is a moist area with a major problem in Mysore raspberry (*Rubus niveus* Thunb.) which grew along side the trail in brambles at about 3 km from the trail head. Mysore raspberry encroached on the trail with spiny canes that reached out 5 m into the trail from both sides thus posing severe discomfort to hikers and an onerous maintenance problem for DOFAW. Although the infestation was relatively small, affecting 50 meters of trail, it appeared to be spreading. DOFAW expended 5 man-days per year on mechanical clearing of this Mysore raspberry infestation at a total cost of $443. Mysore raspberry was treated by foliar applications of triclopyr at 1 kg a.e./ha in crop oil or by basal stem applications in which four streaks were made on the basal stems with the drizzle applicator.

Results and Discussion

Nualolo Trail.

Eight months after the first treatment with glyphosate, lantana and blackberry were still severely suppressed. However, vaseygrass was recovering vigorously on parts of the trail without tree cover. Until longer-term control of vaseygrass is achieved, re-application may be required every six to nine months. The objective was to reduce weed management operations to annual intervals. Nevertheless, two annual applications are still only about 20% the cost of one manual control operation and much more effective (Table 1). Herbicide use increased in the second application because a greater effort was made to control noxious weeds previously ignored.

Table 1. Costs of manual methods and drizzle herbicide applications for vegetation management on Nualolo Trail (2.8 km), Kauai.

Method	Labor (man-days)	Labor ($)	Helicopter ($)	Food[1] ($)	Herbicide ($)	Total ($)
Manual	24	2,850	2,990	525	0	6,365
Drizzle[2]	1.5	179	585	0	18[3]	781
Drizzle[4]	1.5	179	585	0	41[5]	804

[1]Employer required to provide food for overnight outings. Eight man crew stayed at a base camp and were flown to and from trail daily. [2]06/17/98, 3 men, 0.5 day. [3]1200 ml glyphosate. [4]02/04/99, 3 men, 0.5 day. [5]600 ml glyphosate, 800 ml triclopyr applied separately.

Alakai Swamp Trail.

Six months after the first application of glyphosate, there was very little vaseygrass reinfestation. The second treatment was unnecessary. The Alakai Swamp is cold and enveloped in clouds much of the time. This weather apparently retarded vaseygrass growth so that only 14 ml of glyphosate product was used in the second application (Table 2). Only four man-days were required to make the two treatments

at a cost of $1,668/km. The cost advantage of the drizzle method was only 75% because of helicopter costs; the applicators flew to the end of the trail and worked their way out whereas the manual crew walked in and out, concentrating on the head of the trail. With the drizzle method, this trail should be treated no more than once annually.

Table 2. Costs of manual control and drizzle herbicide applications on the Alakai Swamp Trail (4.8 km), Kauai.

Method	Labor (man-days)	Labor ($)	Helicopter ($)	Herbicide ($)	Total Cost ($)
Manual[1]	41.0	4,848	0	0	4,848
Drizzle (08/07/98)	1.5	179	650	12.00[2]	841
Drizzle (02/24/99)	1.5	179	650	0.49[3]	829

[1]Three treatments per year. [2]800 ml glyphosate. [3]15 ml glyphosate, 10 ml triclopyr.

Lahaina Pali Trail.

By 5 months after treatment (MAT), there was a brief rainy period in which weeds had flushed and dried up. Tebuthiuron had reduced vegetation on the trail by 47% and hexazinone virtually prevented weed growth entirely (Table 3). Because of the dry climate, hexazinone may provide weed suppression for three or more years. Hexazinone provided 3.5 years suppression in a roadside test in Napoopoo, a similarly arid area on the island of Hawaii (Unpublished data, University of Hawaii). Alternatively, the trail can be treated with drizzle applications of glyphosate after each rain at a cost of $218 per application.

Table 3. Efficacy of tebuthiuron and hexazinone, each at 2 kg a.i./ha, for preemergence weed control on the Lahaina Pali Trail, Maui, 5 MAT.

Herbicide	Weed Cover[1] (%)
Check	68
Tebuthiuron	32
Hexazinone	6

[1]F = 26 (arcsin transf.) ***

Table 4. Annual costs of manual methods and drizzle herbicide applications to control Mysore raspberry along Boundary Trail, Maui.

Method	Labor (Man-days)	Total Cost ($)
Manual	5	443
Drizzle	0.75	101

Boundary Trail.

Mysore raspberry treated with triclopy ester in crop oil carrier was almost completely controlled by either foliar treatment or by very-low volume basal stem treatments. However, the very tall and thick stands made complete treatment of trailside brambles impossible. It is anticipated that periodic treatments including manual clearing of the dead vegetation will eventually allow access to the interior of the weed stands. As an alternative, drizzle applications with an extended wand will be evaluated for covering the entire bramble. The manpower to treat the short segment of this trail was 8 man-hours, most of this just to drive and hike to and from the Mysore raspberry infestation (Table 4).

The above results led to the adoption of the drizzle method for other trails. Cost data on these trails indicate an average reduction of 93% in weed management costs from manual methods (Table 5). It is anticipated that no more than two annual applications will be required on high rainfall trails and one or less on trails in mesic and arid areas. Of course, mechanical control methods cannot be totally eliminated. Mowing of turf areas along some segments of prime trails will continue. Conventional spraying may continue along forest roads and on parts of trails close to vehicular access where the drizzle is not as effective as conventional spraying or in cases in which the drizzle does not work, e.g. application of wettable powders. Nevertheless, the widespread use of the drizzle method will reduce the

overall manpower requirements for vegetation management thus releasing more than 95% the manpower for more labor-intensive vegetation management and other tasks such as litter collection, trail repair and protection of native plants. For example, on Kauai alone, DOFAW expended nearly 12,000 man hours on vegetation management on trails. Drizzle application could release over 11,500 man hours to other tasks. Furthermore, the efficacy and convenience of the drizzle method should result in more timely control which will reduce herbicide use. On Koaie Trail for example, herbicide use was reduced by 59% in the second annual application over the first (Motooka *et al.*, 1998), and by 75% by the fourth annual application (Unpublished data, University of Hawaii).

Table 5. Annual manpower and costs of manual and drizzle herbicide vegetation management on other forest trails.

Trail	Manual, Labor (Man-days)	Manual, Total Cost ($)	Drizzle, Labor (Man-days)	Drizzle, Total Cost ($)	Driz.,Cost Advantage (%)
Kawaikoi	54	2,281	1	64	97
Kuilau	37	1,317	1	71	95
Pihea	43	1,532	3	267	83
Waihee	75	6,639	1	127	98

Conclusions

The drizzle application method reduced vegetation management costs by reducing the labor requirements in herbicide applications. Indeed, the efficacy and efficiency of the drizzle method made vegetation management on trails possible. The drizzle method will not replace other methods of weed management entirely but can be used in the majority of applications, especially in remote sites, and its use will release manpower for more labor-intensive vegetation management and other tasks.

Acknowledgement:

The work reported herein was supported in part by a grant from the United States Department of the Interior, Fish and Wildlife Service.

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FIELD EVALUATION OF A FORMULATON OF IMAZAPYR/GLYPHOSATE FOR WEED CONTROL IN RUBBER PLANTATIONS IN THAILAND

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Abstract: Field trials to evaluate the performance of a co-formulation of imazapyr/glyphosate 75/180 g/l AS (tradename: TACKLE*) for general weed control in rubber plantations were carried out in southern Thailand, during July to November 1998. Rubber trees were 2 - 3 years of age in the trial plantations. Imazapyr/glyphosate at rates ranging from 75/180 to 187.5/450 g ai/ha were applied to the inter-rows of rubber trees with a knapsack sprayer fitted with a fan-type nozzle (Jacto x-15). The results showed that imazapyr/glyphosate at the rate of 112.5/270 g ai/ha gave good control of total weeds with long residual effect up to 3 months after application. Residual control was >80% at 1.5 months after application, equal to or better than the commercial standards. At 3 months after application, imazapyr/glyphosate was significantly superior to most of the standards in the trials. Imazapyr/glyphosate up to the maximum rate tested of 187.5/450 g ai/ha did not cause any adverse effects on rubber trees at least two years of age.

Key words: imazapic/glyphosate, rubber plantation, general weeds.

Introduction

Weeds are a major problem in rubber plantation. Competition from weeds affects the growth of the tree, particularly in the early years of establishment, and they also interfere with cultural practices such as tree pruning and fertilizer application. Hand weeding used to be the common weed management practice for rubber growers. However, due to the increasing trend of farm labor shortage and increasing wages in Thailand, herbicide application has in recent years become the most cost effective and efficient tool for controlling weeds. In 1998, field evaluation of the weed control performance of a co-formulation of imazapyr/glyphosate was carried out to determine its utility for use in rubber plantations in southern Thailand. The results are reported in this paper.

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Materials and Methods

Field trials were conducted using a randomized complete block design (RCB) with 4-5 replications in three 2-3 year old rubber plantations, each with differing weed spectra, *viz*:

Trial I 3-year old rubber trees. Soil type: silty clay. Plantation shading approximately 15%. The poportion of grasses and broadleaved weeds (BLWs) was 60/40%. Key weed species were:

Grasses: *Panicum repens*, *Digitana adscendens*, *Cynodon dactylon*, *Rhynchelytrum repens*, *Pennisetum setosum*, *Imperata cylindrica* and *Axonopus compressus*

BLWs: *Stachytarpheta jamaicensis*, *Borreria alata*, *Mimosa pudica* and *Vernonia cinerea*.

Trial II 3-year old rubber trees. Soil type: loamy sand. Plantation shading approximately 15%. The proportion of grasses and BLWs was 20/80%. Key weed species were:

Grasses: *Ottochloa nodosa* and *Dactyloctenium aegyptium*.

BLWs: *Borreria alata*, *Croton hirtus*, *Asystasia intrusa*.

Trial III 2-year old rubber trees. Soil type: loam. Plantation shading approximately 10%. The proportion of grasses and BLWs was 60/40%. Key weed species were:

Grasses: *D. adscendens*, *P. setosum* and *I. Cylindrica*.

BLWs: *B. alata*, *C. hirtus*, *Scoparia dulsis* and *M pudica*.

An imazapyr/glyphosate 75/180 g/l AS formulation from the American Cyanamid Company was tested at rates ranging from 75/180 - 187.5/450 g ai/ha, and performance compared against five commercial standards: glyphosate/dicamba, glyphosate/picloram, glyphosate/2,4-D, paraquat and glyphosate. Plot sizes were 2.0 x 30.0 m. Herbicide application was made by knapsack sprayer fitted with a fan-type nozzle (Jacto x-15), using a spray volume of 312.5 l/ha. Visual rating of percent weed control of key weeds was assessed regularly upto 4 months after application.

Results and Discussions

Trial I

Summary weed control data are given in Table 1. At the optimum economic use rate of imazapyr/glyphosate (112.5/270 g ai/ha), total weed control was 81% at 49 days after application (DAA) and 41% at 93 DAA. This compares with 46, 52, 36, 30 and 50% at 49 DAA and 20, 24, 14, 9 and19%

at 93 DAA for the glyphosate/dicamba, glyphosate/picloram, glyphosate/2,4-D, paraquat and glyphosate treatments respectively.

Trial II

Summary weed control data are given in Table 2. Because the field was dominated by BLWs, especially *B. alata* which is difficult to control, the residual effect of all herbicides was shorter than that in Trial I. However, imazapyr/glyphosate at the rate of 150/360 g ai/ha out performed all the standards by the second month after application, with 51% weed control *vs.* 12-44% for the standards.

Trial III

Summary weed control data are given in Table 3. In this trial, imazapyr/glyphosate at 112.5/270 gai/ha performed similarly to the treatments of glyphosate/dicamba and glyphosate/picloram, but was superior to glyphosate/2,4-D and paraquat and glyphosate alone. Imazapyr/glyphosate at 150/360 gai/ha outperformed all of the commercial treatments.

Table 1. Control of general weeds in Trial I by imazapyr/glyphosate compared to commercial standards in a rubber plantation in Thailand, 1998.

Treatment[1]	Rate g ai/ha	% Weed Control (average of 5 replicates)					
		23	31	49	63	76	93DAA
Imazapyr/glyphosate	75/180	73	77	68	51	39	30
Imazapyr/glyphosate	112.5/270	79	80	81	61	49	41
Imazapyr/glyphosate	150/360	78	78	83	86	71	47
Imazapyr/glyphosate	187.5/450	86	87	87	77	64	48
Glyphosate/dicamba	582.75/285.75	68	66	46	35	27	20
Glyphosate/picloram	605/66.25	74	70	52	38	34	24
Glyphosate/2,4-D	600/300	71	57	36	22	18	14
Paraquat	690	62	53	30	21	11	9
Glyphosate	512.5	78	75	50	36	24	19
Untreated check	--	--	--	--	--	--	--

[1] Herbicides applied on 14 July 1998. DAA: days after application.

Table 2. Control of general weeds in Trial II by imazapyr/glyphosate compared to commercia standards in a rubber plantation in Thailand, 1998.

Treatment[1]	Rate g ai/ha	% Weed control (everage of 4 replicates)			
		13	27	45	59DAA
Imazapyr/glyphosate	75/180	35	40	49	35
Imazapyr/glyphosate	112.5/270	39	52	54	42
Imazapyr/glyphosate	150/360	46	67	67	51
Imazapyr/glyphosate	187.5/450	49	67	72	56
Glyphosate/dicamba	582.75/285.75	50	50	47	44
Glyphosate/picloram	605/66.25	52	47	47	41
Glyphosate/2,4-D	600/300	52	41	41	31
Paraquat	690	39	16	16	12
Glyphosate	512.5	40	25	20	21
Untreated check[2]	—	--	--	--	--

[1] Herbicides applied on 17 July 1998. DAA: days after application.

Borreria spp. are considered to be second only to *Imperata cylindrica* in adversely affecting the establishment of young rubber trees (Sunindyo, 1988). Glyphosate has been widely used to control key BLWs such as *Borreria* spp., and *Mikania* spp., but when used alone high use rates are required to effect adequate control (Arif, 1988). In recent years, where glyphosate has been widely used in rubber plantations in Thailand, there has been a shift in the weed spectrum towards increased populations of *Borreria* spp. Results from the trials reported here have clearly demonstrated that imazapyr/glyphosate can provide superior control of *Borreria* spp., than the standards glyphosate and paraquat and provide significantly longer residual control.

Table 3. Control of general weeds in Trial III by imazapyr/glyphosate compared to commercial standards in a rubber plantation in Thailand, 1998.

Treatment[1]	Rate g ai/ha	% Weed control (everage of 4 replicates)					
		15	31	45	60	75	95DAA
Imazapyr/glyphosate	75/180	63	74	76	60	42	31
Imazapyr/glyphosate	112.5/270	75	81	80	67	44	29
Imazapyr/glyphosate	150/360	72	83	87	80	59	38
Imazapyr/glyphosate	187.5/450	75	89	90	82	64	41
Glyphosate/dicamba	582.75/285.75	82	75	61	46	23	29
Glyphosate/picloram	605/66.25	85	92	88	71	54	32
Glyphosate/2,4-D	600/300	84	73	56	40	21	14
Paraquat	690	51	19	11	12	12	9
Glyphosate	512.5	64	55	42	42	34	22
Untreated check	—	--	--	--	--	--	--

[1] Herbicides applied on 31 July 1998. DAA: days after application.

Conclusions

A co-formulation of imazapyr/glyphosate 75/180 g/l AS at a proposed commercial rate of 112.5/270 g ai/ha gave good control of general weeds in rubber plantations. Residual control remained for up to 3 months after application. Weed control was significantly superior to most of the current commercial standards, against the major BLWs and *Borreria* spp in particular. Imazapyr/glyphosate can be used safely in rubber plantations. The use rate of up to 187.5/450 gai/ha showed no adverse effect on young rubber trees, two or more years old.

Acknowledgement:

We are most grateful to Dr. N. J. Armes of American Cyanamid Company for help in critical reading of the manuscript and valuable advise on the preparation of this paper.

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ORGANOSILICONE ADJUVANTS FOR AGROCHEMICAL APPLICATIONS

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Abstracts: Trisiloxane based surfactants have been actively used as a new generation of spray adjuvant for agriculture applications. To date, more than 536 references on organosilicone surfactants for agrochemical applications have been published, with over 80% publications specifically referencing Silwet® surfactants. Relative to conventional adjuvants, trisiloxane surfactants provide an extremely low aqueous surface tension (~21 mN/m). This coupled with a compact hydrophobe (trisiloxane portion of the molecule) makes these unique surfactants superspreaders. Therefore, almost any biological surface is easily wetted by the trisiloxane solutions, and the overall coverage on target plants is significantly increased. In addition, trisiloxane surfactant solutions have the ability to rapidly penetrate stomata. Active ingredients taken up into the plant via stomatal infiltration become immediately rainfast. Because trisiloxane surfactants are such powerful superspreaders, it is possible, to reduce conventional spray volumes, for a particular application, without compromising efficacy. Reducing spray volume will benefit the areas where water is either in short supply, and results in time effectiveness.

Key words: trisiloxanes, surfactants, surface tension, adjuvants, spreading, rainfastness, low volume sprays

History

Organosilicone surfactants, as a new generation of agrochemical adjuvants, have been actively used with different agrochemicals, especially with herbicides, in recent years. By June, 1999, more than 536 references on organosilicone surfactants for agrochemical applications have been published, with over 80% publications specifically referencing Silwet® surfactants (R.E. Gaskin, Forest Research Institute, Rotorua, NZ, personal communication).

In the past, adjuvants were not widely used because pesticides were simple, inexpensive products. Today, pesticides have become more complex and they now account for an important part of the farmer's budget. As a result, there is now more economic incentive for formulators and basic pesticide producers to consider the performance advantages of synergistic, activating, penetrating adjuvants. During this process, organosilicone compounds have played an important role in niche applications, when superspreading and rainfastening properties are desired

General Structure and Physical-Chemical Properties

To date, most of the commercially available organosilicone based adjuvants are trisiloxane alkoxylates (TSA). The general trisiloxane structure is shown in Figure 1. Due to the extremely low static surface tension (~21 mN/m) and the unique chemical structure of the trisiloxane hydrophobe, aqueous solutions of these silicone surfactants spread completely on most hydrophobic surfaces. This is illustrated in Table 1, where only the solution containing the trisiloxane alkoxylate Silwet L-77 ® surfactant dramatically increased the relative spread area of a droplet on polyester film (Murphy *et al.* 1991). The relative spread area of the solution containing Silwet L-77 was 172 times greater than that of water alone. This unique ability to enhance the coverage of an aqueous droplet is often referred to as superspreading. However a low aqueous surface tension alone is not sufficient to promote superspreading (Nickolov *et al.* 1997). Although the fluorocarbon based surfactant (FCS) provided the lowest surface tension (~16 mN/m), the relative spread area was not increased to the same degree as the trisiloxane alkoxylate, indicating that a small compact hydrophobe may be important in superspreading.

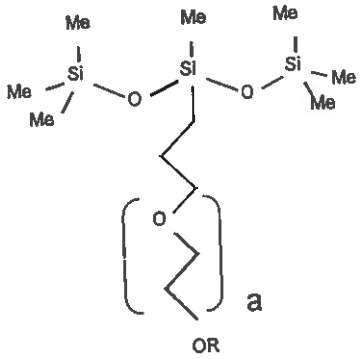


Figure 1. General trisiloxane alkoxylate structure
(Silwet L-77 surfactant: R=Me, Silwet® 408 surfactant: R=H)

Table 1 Surface Tension and Superspreading (0.1% wt%)

Surfactant	Surface Tension (mN/m)	Relative Spread Area
Silwet L-77® (TSA)	21.6	172
Tetrasiloxane	24.2	12
Polysiloxane	23.6	2
OP10*	31.8	4
FCS**	16.5	3

*OP 10: Octylphenol Ethoxylate (10EO)
** FCS: fluorocarbon based surfactant

When the spreading of glyphosate solutions was measured on the abaxial and adaxial surfaces of velvetgrass (*Holcus lanatus* L.), the spread area of the solution with Silwet L-77 surfactant was approximately 100 times greater than that of the glyphosate solution alone; other surfactant solutions also substantially enhanced droplet spread, but to a much lesser extent (Gaskin and Zabkiewicz, 1989).

Cosurfactants

Murphy *et al.* (1991) also found that when a cosurfactant was added with these organosilicone surfactants, the conventional surfactant competes with the silicone for the liquid/solid interface. Generally, if the cosurfactant contains a large hydrophobic group (> C_{10}), the spreading of the trisiloxane alkoxylate is impeded.

Most conventional surfactants, wetting agents, emulsifiers and dispersants compromise the performance of trisiloxane surfactants (reduction in spreading and rainfastening). Therefore, it is critical to consider the additives contained in pesticide formulations, when the formulators work with trisiloxane based adjuvants . Figure 2 compares the spreading properties of blends of Silwet L-77 with several cosurfactants. Here a 1:1 blend of Silwet L-77 with a conventional surfactant, an octylphenol ethoxylate (10EO,) illustrates the antagonism in spreading, when compared to L-77 alone. However, when the cosurfactant is based on a short hydrophobe, such as isodecyl alcohol ethoxylate (6EO), the spreading is significantly increased. The most favorable cosurfactants for trisiloxane alkoxylates are based on a C_6 to C_{10} hydrophobe, excluding branching (Murphy *et al.* 1993). Examples of favorable cosurfactants are isodecyl alcohol ethoxylate (DA-6), octyl alcohol ethoxylate (O4) and 2-Ethylhexyl sulfate.

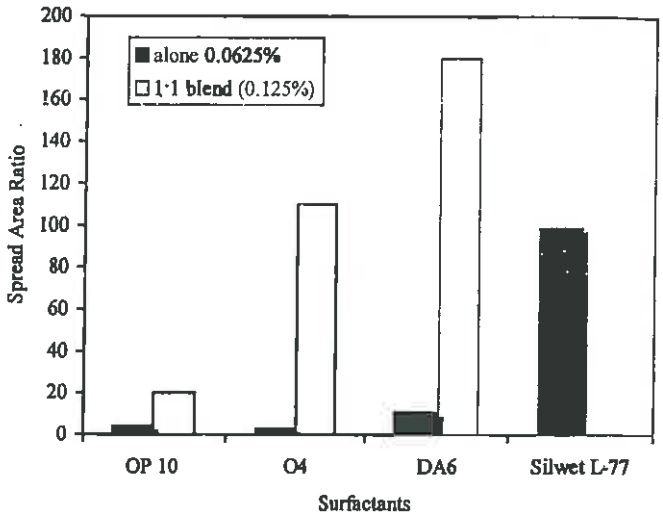


Figure 2. The effect of cosurfactants on Silwet L-77 surfactant spreading

Hydrolytic Stability

Although trisiloxane alkoxylates are used successfully as unique "tank-side" adjuvants, susceptibility to hydrolysis has limited their utility in aqueous "In-can" pesticide formulations. The organosilicone surfactant Silwet L-77 surfactant degrades in acidic (pH 2 to 6) and alkaline (≥pH 9) spray solutions. Changes in solution characteristic (turbid to clear), and increased surface tension of the spray solutions may be used as indicators of surfactant breakdown. Monitoring the spreading properties, of formulations containing a trisiloxane surfactant, is a quick and easy method for determining the degree of hydrolysis. For example, a 0.1% solution of L-77 at pH 3 shows a complete loss in superspreading within an hour after preparation (Table 2.)

Table 2 Effect of pH on Silwet L-77 surfactant Spreading

	Spread diameter (mm)		
Time (h)	pH 3	pH 5	pH 7
0.25	38	49	46
1	10	--	–
24	4	39	49
400	4	5	44

Resistance to hydrolysis can be overcome by buffering aqueous formulations to a pH between 6.0 and 7.5. Solutions buffered in this way show excellent long term shelf life stability. Figure 3 demonstrates that a 10 wt% dispersion of Silwet 408 surfactant, buffered to a pH within this range, maintains the desired superspreading properties for at least 1 year. Solutions of Silwet L-77 surfactant buffered to pH 7 have remained stable for greater then five years.

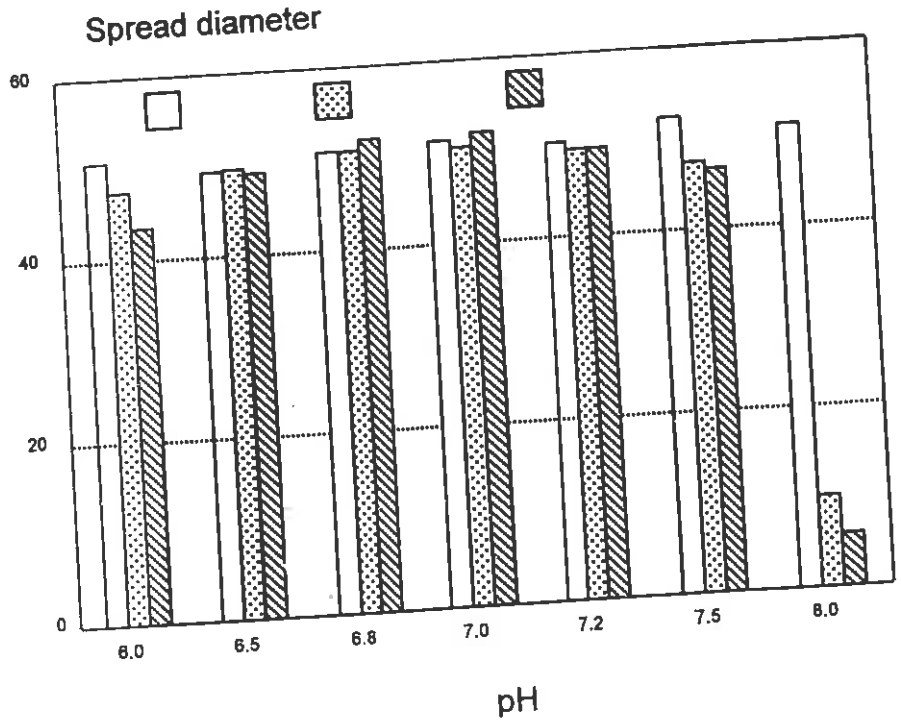


Figure 3. Effect of pH and Time on Silwet 408 Surfactant Spreading*
* Diluted to 0.1% for spread evaluation

Examples of agricultural application

Rainfastness

Numerous studies have shown that organosilicone surfactants improved the rainfastness of herbicides by inducing stomatal infiltration (Field and Bishop, 1987; Kudsk, 1992; Roggenbuck *et al.*, 1990, 1993). Simulated rainfall applied 2 h after spray application of glyphosate had no effect on the response of perennial ryegrass (*Lolium perenne* L.) in the presence of Silwet L-77 surfactant. However, in the absence of organosilicone surfactant, rain reduced herbicide effectiveness for up to 10 h after herbicide application (Field and Bishop, 1988a). Similar data were reported for glyphosate plus Silwet L-77 surfactant applied to quackgrass [*Elytrigia repens* (L.) Beauv.] (Thonke *et al.*, 1989) and for acifluorfen plus an organosilicone surfactant applied to velvetleaf (*Abutilon theophrasti* Medius) (Roggenbuck *et al.*, 1990).

Sun and Foy (1996) reported that when the critical rain-free period was 15 min after treatment, only primisulfuron at 40 g ai/ha in combination with Silwet 408 surfactant effective controlled velvetleaf (figure 4).

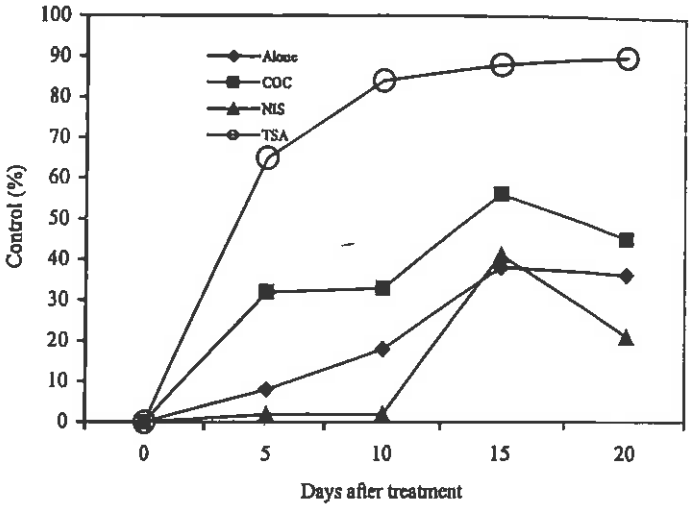


Figure 4. Efficacy of different adjuvants on primisulfuron in velvetleaf
(*COC: crop oil concentrate NIS: noionic surfactant)

When a herbicide solution is applied to a leaf surface, there are two pathways for the herbicide active ingredient to enter the plants. One is to penetrate the cuticular layer; in most situations this is the main pathway. Another way is to enter the stomatal cavity directly. According to Schonherr and Bukovac *et al.*, for stomatal infiltration to occur, the surface tension of the formulation must be equal to or less than the critical surface tension of the target surface (Greene and Bukovac, 1974; Schonherr and Bukovac, 1972). The critical surface tension of most leaf surfaces ranges from 20 with sugarbeet (*Beta vulgaris* L.) to about 30 mN/m with broccoli (*Brassica oleracea* var botrytis L.), or *Zebrina purposii* (Knoche and Bukovac, 1993; Schonherr and Bukovac, 1972). Since the surface tension of trisiloxane alkoxylate solutions is always below this range, herbicide uptake by stomatal infiltration was proposed by Field and Bishop (1988) and Stevens *et al.* (1991). The solution that enters into the substomatal cavity by stomatal infiltration should provide easier diffusion of the active ingredient into the adjacent cells, since the cuticle lining the substomatal cavity is thinner.

Study results showed that triclopyr ([3,5,6-trichloro-2-pyridinyl)oxy]acetic acid), glyphosate and deoxyglucose did enter through stomatal pores when Silwet L-77 surfactant was present by using fluorescent dye and electron microscopic techniques (Buick and Field, 1990; Field and Bishop, 1988; Stevens *et al.*, 1991).

The advantages of induced stomatal infiltration is that the active ingredient taken up in this manner is immediately rendered rainfast.

Reduce spray volume

Because trisiloxane surfactants are powerful superspreaders, it is possible, to reduce conventional spray volumes, for a particular application, without compromising efficacy. For example, in field trials where RoundUp was applied for chemical burndown of sugarcane (Saccharum spp.), the spray volume was reduced from 400 l/ha to 120 l/ha. The treatment using a spray volume of 120 l/ha containing RoundUp and Silwet L-77 surfactant surfactant (0.1%) provided control equivalent to the standard 400 l/ha treatment (without adjuvant), while a significant reduction in efficacy was observed for the corresponding treatment at 120 l/ha alone. Reducing spray volume will benefit the areas where water is in short supply.

Environment fate and registration

Stevens (1995) indicated that Silwet L-77 surfactant is quickly inactivated in soil and water, initially being rapidly adsorbed onto soil particles and subsequently degraded by hydrolysis. The adsorptive capacity of soil for this organosilicone adjuvant is substantial; therefore, the material is unlikely to contaminate groundwater.

When organosilicones (methylated silicones) are used as agrochemical adjuvants, they are considered to be "Inert" according to the US Environmental Protection Agency regulation 40CFR 180.1001(c): Chemicals that can be used in formulations for applying a pesticide to growing crops or raw agricultural commodities after harvest.

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OPTIMIZING HERBICIDE APPLICATION RATE IN SUMMER MAIZE (*Zea mays*)

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Abtract: Experiments were carried out in Beijing and Laiyang, China, to optimize application rate of a widely used mixture (propizochlor + atrazine) in summer maize in north China based on net profit. The experimental results showed that the intensity of weed interference affected optimal herbicide application rate. Maximum net profit was achieved when the mixture was applied at 1/3 – 1/4 of recommended rate in summer maize.

Key words: optimizing application rate, maize, atrazine, propizochlor, weed control

Introduction

Continuously applying herbicides at high rate results in high selection pressure that accelerates the evolution of weed resistance (Maxwell and Mortimer, 1994) and enhances environmental contamination. To minimize the risks of herbicide application and in the meantime to maximize benefit, we have to reduce application rate without sacrificing weed control. The recommended rate is chosen by the chemical company to minimize complaints of poor performance or crop damage and to provide the customer with the most reliable product possible (Cussans 1992). It is possible to reduce application rate without penalty in terms of control efficacy (Wilson *et al* 1974, Whiting *et al* 1991).

Maize is a staple food crop in China and its planting area is about 20 million hectares. The chemical weed control area was 5.62 million hectares in maize in 1995 and widely used herbicides were the mixture of atrazine plus amide herbicides (acetochlor, metolachlor, propizochlor)(Zhang and Huang 1999). Yufeng, a mixture of atrazine plus propizochlor [2-chlor-2'-methyl-6'-ethyl-N-(2-propoxy-methyl)-acetanilide], was newly development and marketed in China. The objective of this study was to optimize application rate of the mixture in north China.

Materials and Methods

The experiments were carried out at the Experimental Station of China Agricultural University, Beijing, and the Experimental Station of Laiyang Agricultural College, Laiyang, Shangdong, in summer maize fields during 1997-1998. The previous crop was winter wheat. The soil was sandy loam in both experimental fields. The fields were rotovated twice before sowing.

Yufeng 40% SE was applied at 150, 300, 450, 600, 750, 900, 1050, and 1200 (recommended dose) g a.i./ha with a backpack sprayer equipped with a flat fan nozzle. A weedy CK and weed-free (hand weeding) CK were included. Hand weeding was done three times. Spray volume was 450 L/ha. The experimental designs were randomized complete blocks with four replications in Beijing Experiment and with three replications in Laiyang Experiment. Plot size was 30 m^2.

In Beijing Experiment, maize was sown on July 28 and herbicides were immediately applied after sowing. Weed numbers were counted at 20 and 35 day after application (DAA). Reduction percentage of weed biomass in weeded plots was visually estimated compared with weedy and weed-free plots at 60 DAA. In Laiyang Experiment, maize was sown on July 23 and herbicides were applied at 3 day after sowing. Weed numbers were counted at 15 and 30 DAA. Fresh weed biomass above ground was weighed at 60 DAA. Five weed samples were taken from each plot. Quadrat size was 0.1 m^2. Maize grain yields were determined at maturity.

Results and Discussion

Weed Composition in Experimental Fields

Weed compositions in the experimental fields were listed in Table 1. Predominant weeds were *Digitaria sanguinalis* (L.) Scop, *Echinochloa crus-galli* (L.) Beauv., *Acalypha australis* L., *Amaranthus retroflexus* L., and *Portulaca oleracea* L. in Beijing experimental field and *D. sanguinalis*, *Eleusine indica* (L.) Gaertn., *E. crus-galli*, *A. retroflexus*, *A. australis*, *P. oleracea*, and *Cyperus rotundus* L. in Laiyang experimental field. Weed densities in weedy plots in Beijing and Laiyang experimental fields were 52-79 plants/m^2 and 85-113.4 plants/m^2, respectively.

Table 1 Weed Compositions of Beijing and Laiyang Experimental Fields

Weed Species	Abundance*	
	Beijing	Laiyang
Abutilon theophrasti Medik.	+	+
Acalypha australis L.	+++++	++
Amaranthus retroflexus L.	+++	+++
Chenopodium album L.	+	
Cirsium segetum Bge.	+	
Convolvulus arvensis L.		++
Cyperus rotundus L.	+++	++ ++
Digitaria sanguinalis (L.) Scop	+++	++
Echinochloa crus-galli (L.) Beauv.		+
Eclipta postrata L.	+	+++
Eleusine indica (L.) Gaertn.		+
Hibiscus trionum L.		+
Humulus scendensc (Lour.) Merr.		+
Pharbitis purpurea (L.) Voigt	+	
Polygonum hydropiper L.	+++	+++
Portulaca oleracea L.	+	+
Setaria viridis (L.) Beauv.	+	+
Xanthium sibiricum Patrin.		

*+++++: very abundance, ++++: rather abundance, +++: abundance, ++: few, +: very few

Effect of Application Rate of Yufeng on Weed Control Efficacy

Weed control efficacy increased with increasing application rate of Yufeng (Figure 1 and 2 and Table 2). At low application rate, weeds surviving the herbicide grew normally while at high application rate, the growth of the surviving weeds was seriously inhibited. Reduction in weed number was relatively low in treated plots in Beijing Experiment even at high rate because the very high population of *A. australis* which was tolerant to the herbicide. The plants of this weed were small size and its most leaves were eaten by an insect herbivore. Thus, like Laiyang Experiment, the reduction of biomass was still high at high application rates in Beijing Experiment at 60 DAA even though number reduction was rather low (Table 2).

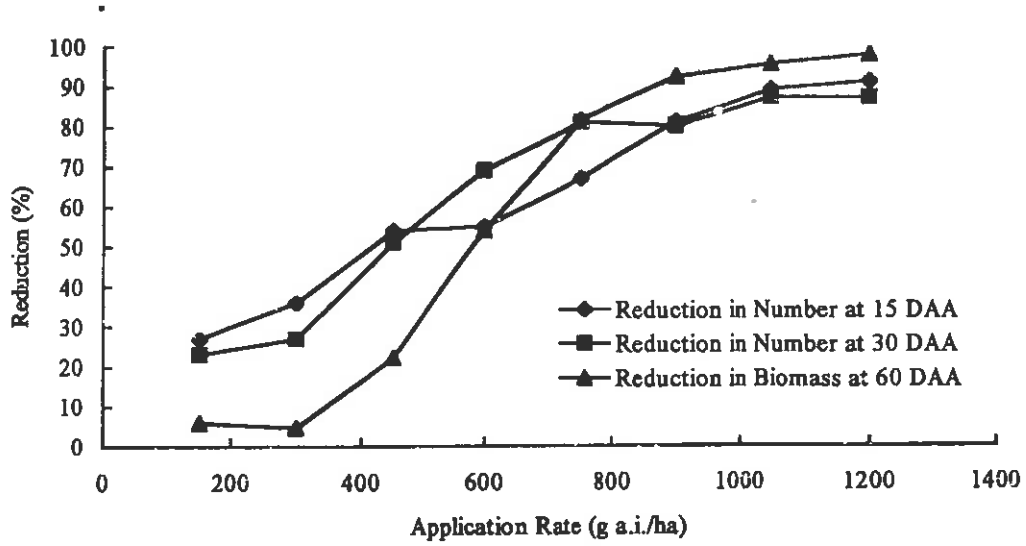


Figure 1. Effect of Application Dose of Yufeng SE (propizochlor + atrazine) on Weed Control Efficacy in Summer Maize in Laiyang. DAA = day after application

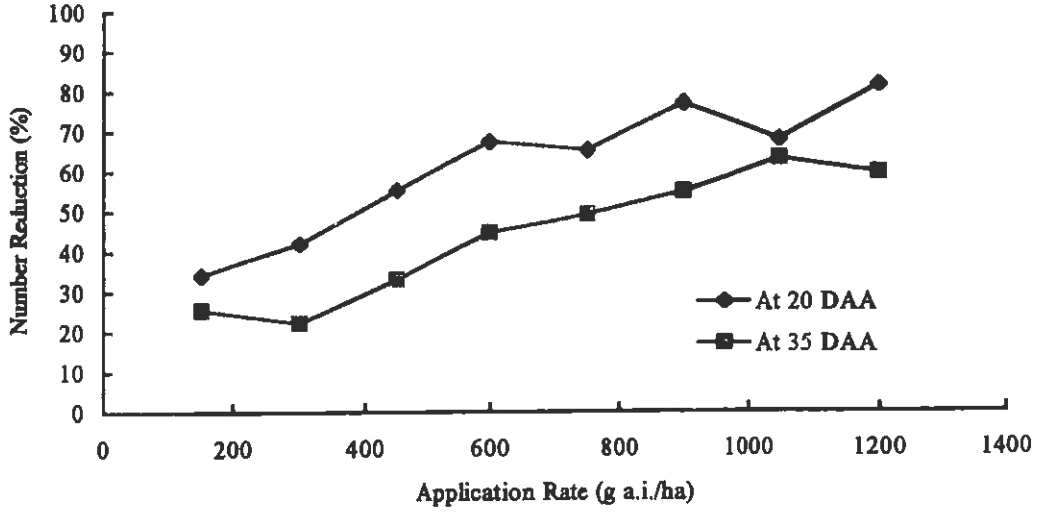


Figure 2. Effect of Application Dose of Yufeng SE (propizochlor + atrazine) on Weed Number Reduction in Summer Maize in Beijing. DAA = day after application

Table 2. Reduction of Weed Biomass at Different Application Rates of 40% Yufeng SE (propizochlor + atrazine) in Maize at 60 Day after Application (Beijing)

	Application Dose (g a.i./ha)								
	0	150	300	450	600	750	900	1050	1200
Scale*	7	7	7	5	4	2	1.5	1.5	1

*Scale 7: biomass as weedy CK; Scale 0: biomass as weed-free CK

Analysis of Profit and Determination of Optimal Application Rate

Grain yield of maize was lower in Beijing Experiment than in Laiyang Experiment. The average yields in plots of weed-free CK in the former and latter fields were 3054 and 6267 kg/ha, respectively. Grain yield loss was lower in Beijing Experiment than in Laiyang Experiment due to low weed biomass.

Because of low grain yield and low weed biomass, the profit of applying Yufeng was much lower in Beijing (Figure 3). In Figure 3, the profits (curve) was the product of increased grain yields of applying the herbicide multiplied by price of maize and the maximum net profits (line) of applying the herbicides at different rates were the increased profit of weed-free CK minus the herbicide cost. Optimal application rate should be the rate at which net profit of applying herbicides reached maximum. This rate was

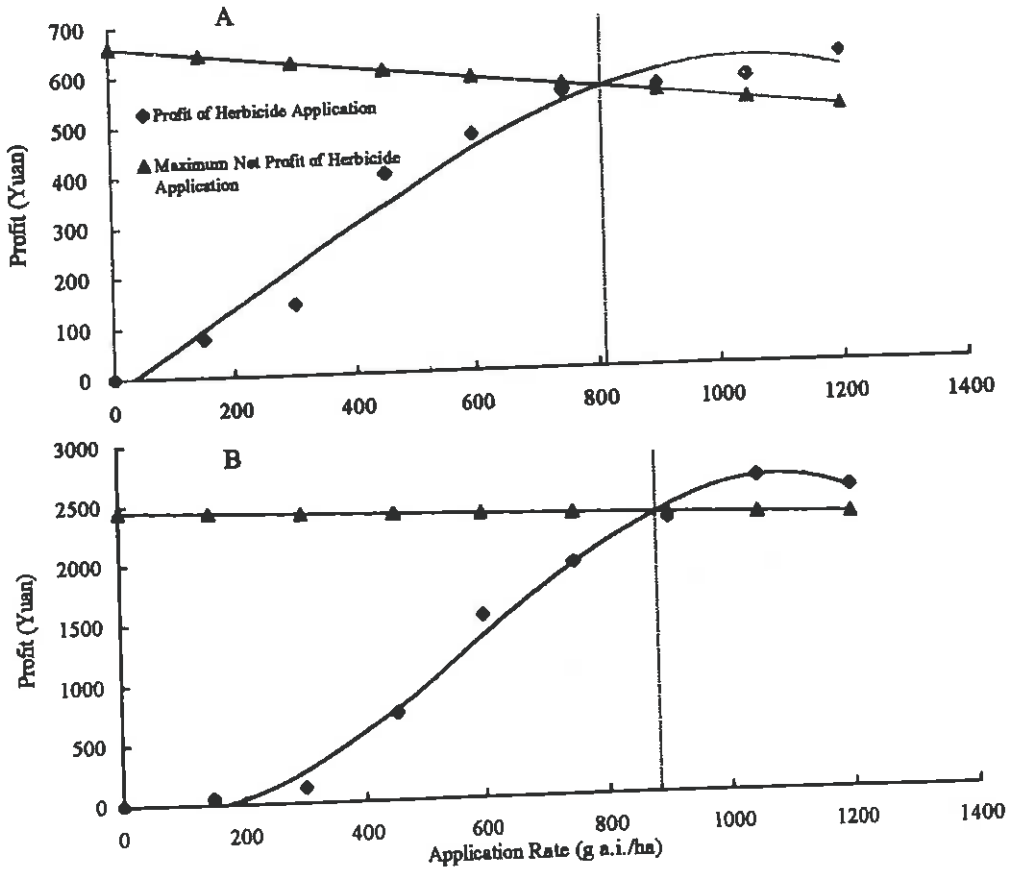


Figure 3. Analysis of Profit of Yufeng SE (propizochlor + atrazine) Application.
Figure A for Beijing; figure B for Laiyang.

corresponding to the intersection of the profit curve and the maximum net profit line. Increasing application rate could increase net profit below the optimal rate and in inverse beyond the optimal rate.

The experimental results showed that optimal application rate of herbicides varied with weed densities. Optimal application rates of Yufeng in Beijing and in Laiyang were 800 and 870 g a.i./ha, respectively. These optimal application rates were lower than recommended rate that was 1200 g a.i./ha.

The application rate of herbicides recommended by producers is not optimal rate and higher than optimal rate from the viewpoint of economics. The relationship between herbicide application rate and field performance is probabilistic and at high rates the performance had a little response to the rate (Cussans 1992). Profit from increased yields at high rates might not compensate increased herbicide cost. The recommended rate is chosen by the chemical company is the rate at which reliable weed control can be achieved even under worse environmental conditions. To most consumers, the recommended rate is not economical. In addition, we should consider the competitiveness of weeds surviving herbicide treatment is significantly reduced (Black and Dyson 1993).

However, we have to realize the risk of reducing application rate and to well understand the variation of herbicide performances under different conditions to reduce risk of poor performance (Cussans 1992). In addition, we have to consider the increase of weed population because surviving weeds can still reproduce seeds a lot when application rates is reduced (Bellinger *et al* 1994).

Acknowledgements:

This project was supported by Science and Technology Ministry of China. The project no: 96-005-01-05.

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SAFETY EVALUATION FOR HERBICIDES USED IN SOYBEANS

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Abstract : In China weeds can be seen in soybeans field for a lengthy time, using chemical herbicides accelerates weeds' population change, resultingly broadleaf weeds and tough weeds dominate. China's soybeans belt is geographically and climatically complex, and next crops vary depending on areas. Farmers plant soybeans in small scale and use rough farming technology. Herbicides applied to soybeans should emphasize its safety not only to soybeans but also to the following crops, meanwhile, the herbicides are expected to have broad weeding spectrum, simple application, as well as good efficacy when mixed with other herbicides.

Keywords : herbicides in soybeans, safety

1. WEEDS GROWTH

The land of China expands to a great extent with complex natural environment, many soybean varieties are planted with different farming methods, and various crops may be planted after soybeans' harvest. Many kinds of weeds can be found in soybeans fields, the most common weeds are numbered more than 20, sometimes weeds depress crop yield. These common weeds include annual grasses such as *Echinochloa crusgalli*, *Avena fatua*, *Setaria viridis*, *Setaria glauca*, *Digitaria sangunalis*, *Eleusis indica*; annual broadleaf weeds such as *Xanthium strumarium*, *Amaranthus retroflexus*, *Solanum nigrum*, *Commelina communis*, *Bidens tripartita*, *Abutilon theophrasti*, *Chenopodium album*, *Salsula collina*, *Polygonum bungeanum*, *Polygonum lapathifolium*, *Elsholtzia ciliata*, *Amethystea caerulea*, *Galium aparine*, *Acalypha australis*, *Portulaca oleracea*, *Rorippa palustris*, *Stellaria media*; parasitic weeds such as *Cuscuta chinensis*, *C. australis*; perennial weeds such as *Equisetum arvense*, *Cephalanoplos segetum*, *Cephalanoplos setosum*, *Sonchus brachyotus*,

Phragmites communis. In the north weeds can be seen in the fields from sowing season till the end of August, firstly weeds' growth is influenced by temperature, later influenced by rainfall and farming activities. In the south weeds' growth period is shorter than in the north. Chemical herbicides accelerate weeds' population change, broadleaf & tough weeds become out of control, especially some perennial weeds like *Polygonum convelvulus*, *Galeopsis bifida*, *Solanum nigrum*, *Xanthium strumarium*, *Chenopodium serotinum*, *Abutilon theophrasti*, *Commelina communis*, *Bidens tripartita*, *Avena fatua*, *Siegesbeckia pubescens*, *Equisetum arvense*, *Sonchus brachyotus*, *Cephalanoplos segetum*, *Cephalanoplos setosum*. Mixture of 2 or more herbicides provides good weeding control using several sprays, tough weeds require higher dose, however, safety is beyond all concerns.

2. SAFETY EVALUATION OF HERBICIDES USED IN SOYBEANS

2.1 Safety to soybeans

In the north low temperature, heavy rainfall & insect threat often reduce soybeans' ability of herbicide degradation, to avoid yeild decrease, safe herbicides are crucial. Based on years practice, with same weeding efficacy, safe herbicides provide higher soybeans yield. The yield varies depending on different herbicides and mixtures used, sometimes the difference may reach 450-750 kg/ha. In China more than 30 herbicides are used in soybeans, some are very safe, such as clomazone, vernolate, alachlor, metolachlor, propisochlor, thifensulfuron-ethyl, imazethapyr, flumioxazin, bentazone, flumiclorac-p-butyl, sethoxydim, quizalofop-p-ethyl, fluazifop-p-butyl, fenoxaprop-p-ethyl, clethodim, haloxyfop, haloxyfop-R-methyl, even under bad condition like low temperature, heavy rainfall, insect threat etc. Big scale promotion for trifluralin was held in 1978 since it controls *Avena fatua* effectively, however, it inhibits *Rhizobus*, and deteriorates Rhizoctonia root rot in soybeans. Vernolate is not an ideal herbicide for soybeans due to bad control on *Commelina communis* and yield decrease. In arid land there is no safe herbicide other than vernolate, mix lower rate of vernolate with others to prevent *Avena fatua*. In 70s and 80s most herbicides were not available yet, 2,4-D butylate was applied for early post emergence control on broadleaf weeds. The weeding effect shut down early, also soybeans stunt happened, Rhizoctonia root became very serious. If the temperature dropped with heavy rainfall,

the yielding reduced greatly. For postemergent broadleaf weeds control, mix 72% 2,4-D butylate EC 750 ml/ha with other herbicides, apply 3 days after soybeans sowed. In United States acetochlor with safener is registered in corn, not in soybeans due to the fact that it's not as safe as metolachlor, alachlor and propisochlor. At low temperature and heavy rainfall acetochlor causes serious soybeans stunt. In swamp at cold weather, 50% acetochlor EC decreases yield by 150-225 kg/ha comparing to metolachlor. 90% acetochlor EC is safer and with higher yield than 50% EC, metolachlor is safer than 90% EC, however, in dry condition the difference is diminished. Accordingly 90% acetochlor EC is a good substitute for 50% EC, adding safener to 90% EC may increase crop safety. Some soybeans varieties, like He Feng 25, Bei Feng species in Heilongjiang Province, are sensitive to metribuzine. It's recommended to conduct small scale test plot with new soybean variety to check sensitivity. Plant very sensitive variety may decrease yielding dramatically or even no yield. Metribuzine-acetochlor mixture injures crops and decreases yield in swamp with high moisture, comparing to flumioxazin, the mixture reduces crop yeild by 10% in hills, over 20% in swamp. Metribuzine can't be used in the soil with less than 0.5% organic matter, sandy soil and loam soil with less than 2% organic matter, however, applicable in hills and arid land in fall. Thifensulfuron-ethyl and chlorinuron can't be applied in swamp or the soil with less than 2% organic matter. In United States they are sprayed after soybeans emergence with good safety profile, however, due to different herbicide tolerance, thifensulfuron-ethyl and chlorimuron injure and kill soybeans at low temperature with heavy rainfall in China. Soybeans at or after 3 LS are sensitive to thifensulfuron-ethyl, between soybeans emergence stage to 1 LS soybeans are sensitive to chlorimuron. In soybeans pre-emergence stage thifensulfuron-ethyl can be used, the only drawback is short control period. Mixture of thifensulfuron-ethyl and flumioxazin or clomazone can prevent broadleaf weeds effectively. Comparing to thifensulfuron-ethyl, chlorimuron has narrower weeding spectrum and shorter application period, it has to be applied in 3 days before soybeans emergence. Comparing to clomazone, chlorimuron reduces yield and injures the following crop, therefore it's not recommended to use in soybeans. Clomazone has broad weeding spectrum with excellent control over perennial weeds, it can be applied before or after soybeans emergence. If the application rate is below 480 gm ai/ha, no injury happens in following crops. Clomazone is safe to soybeans, yield increases with spray rate. The drift may injure crops but crops recover shortly, and

the yield remains intact. Imazethapyr is safe to apply before or after soybeans are sowed or at early emergence stage, it has broad weeding spectrum and produces high soybeans yield, but inapplicable after 3 LS. Flumioxazin can be applied before or after soybeans are sowed, after spray gently till the surface of the soil or incoorperate the soil upon seeds to 2 cm depth. This step is to prevent soybean sprouts being contacted with contaminated raindrop in heavy rainfall, otherwise crop injury may occur. Spraying flumioxazin at soybeans emergence stage induces injury, crops recover slowly in cold weather. Contact herbicides such as lactofen, acifluofen, fomesafen and bentazon-acifluorfen mixture are likely to cause serious injury in bad condition like cold or hot weather, heavy rainfall or insect threat. Unlike injury caused by translocating herbicides, contact herbicides lead burnt spots on crop leaves, sometimes the whole leaves are burnt out. Nevertheless, the injury doesn't effect soybeans' growth and yield. Translocating herbicides bring in invisible injury, soybeans are severely damaged and hard to recover, the yield is depressed, in extreme cases no yield at all.

2.2 Safety to the Following Crops

Recently herbicides with long-lasting weeding effect are under active promotion in Heilongjiang Province, however, attention should be drawn to problems occurred, too. Herbicides are mainly degraded by microbes presenting in the soil, besides, soil texture and pH value also have influence on degradation. Microbes activities are effected by temperature and moisture, in the south herbicides are degraded fast, but slowly in the north, especially Heilongjiang Province and north Inner Mongolia. Imazethapyr is degraded slowly in acid soil, fast in alkali soil. In Heilongjiang Province, the pH value of soil is less than 7, if apply imazethapyr at the rate of 75-100 gm ai/ha, more residue is found in west and north area, less in east and south area. In west and north area soybeans and wheat can be planted 1 year after spray, but corn can't be planted due to crop stunt, when application rate is over 90 gm ai/ha, corn injury happens. In east and south area soybeans, wheat and corn can be planted 1 year after spray, on condition that standardized mechanical farming technique and even spray are applied. Rice, rapeseed, sugarbeet, flax and vegetables etc can't be the following crops, do not use soil sprayed by imazethapyr as rice's, sugarbeet's and vegetables' seedbed. Plant potato, Chinese cabbage, aubergine, chili pepper, Welsh

onion, tomato, watermelon, squash 36 months after application. Sugarbeet and flax are very sensitive, plant 40-48 months after application, plant rice 20 months after application.

In Heilongjiang Province it's recommended to mix clomazone less than 480 gm ai/ha with other herbicides for application. Wheat, rice, sugarbeet, potato, sunflower, pumpkin, tobacco etc can be the following crops. Two sprays may brown wheat sprouts slightly, but the crops soon recover and no yield reduction happens.

The recommended application rate for fomesafen in Heilongjiang Province is 250-325 gm ai/ha. Corn, wheat, flax, sorghum and sunflower can be planted the following year. Injury may happen in crops which are sowed after plow, like rapeseed, sugarbeet and Chinese cabbage, prevent the injury by deeply plowing the field and mixing low dosage fomesafen with other herbicides.

Chlorimuron is degraded fast in acid soil, slowly in alkali soil, inapplicable to soil with pH value over 7. In America chlorimuron 5.6 gm ai/ha is mixed with thifensulfuron-ethyl to spray. Plant grain crops and pasture crops can be planted 3 months after application; chlorimuron-tolerant corn 6 months after application; alfalfa, clover, cotton, cucumber, corn, green peas, pumpkin, rice, sorghum, sunflower, transplant tobacco, transplant tomato, watermelon 9 months after application; rapeseed, Chinese cabbage, flax, lentil, mustard, sweet corn 18 months after application; sugarbeet, carrot, potato and other crops 26 months after application. Mixture of chlorimuron-ethyl 34-52 gm ai/ha and sulfentrazone can be applied before soybeans emergence. Plant wheat 4 months after application; rice and corn 10 months after application; cotton 18 months after application; sugarbeet and rapeseed 30 months after application; alfalfa and sorghum 42 months after application. In Heilongjiang Province sugarbeet, flax, potato, sunflower, rice, sorghum, rapeseed, vegetables etc are sensitive to chlorimuron. Sugarbeet, flax and potato are very sensitive, plant 36 months after application. When chlorimuron is applied at the rate over 15 gm ai/ha, plant rice one year after application. When it's applied at the rate under 8 gm ai/ha, deeply plow the field, plant rice the following year. Injury may happen crops which are sowed after plow. Soil sprayed by chlorimuron can't be used as rice's, sugarbeet's and vegetables' seedbed.

Imazamox is degraded slowly in acid soil, fast in alkali soil. In America 44.8 gm ai/ha is used. Plant wheat 3 months after application; barley and rye 4 months after application; alfalfa, cauliflower, cabbage, carrot, corn, cotton. cucumber, sorghum, oat, green peas, onion, peanuts, chili pepper, potato, pumpkin, rice, sunflower, tobacco, tomato, radish and watermelon 9 months after application; flax 18 months after application. When pH value of the soil is over 6.2, plant sugarbeet 16 months after applicaiton. When pH value is under 6.2, plant sugarbeet 26 months after application.

Flumetsulam is degraded fast in alkali soil, slowly in acid soil. Sugarbeet, rapeseed, flax and cotton are sensitive to flumetsulam. In America, flax and sugarbeet can be planted 26 months after application; sorghum and sunflower 18 months after application; potato 12.5-18 months after application; cotton 22 months after application.

The recommended application rate for metribuzin is 420-1,120 gm ai/ha. In America alfalfa, asparagus, barley, corn, pasture crops, wheat, potato, sainfoin, tomato, sugarcane, soybeans can be planted 4 months after application; rice, cotton, green peas planted 8 months after application; any crops but root vegetables 12 months after application; onion, sugarbeet and root vegetables 18 months after application. In Heilongjiang Province the recommended application rate is 210-560 gm ai/ha. Metribuzin is generally safe to the following crops, except in arid land and soil with less organic matter, high pH value (over 7.5), where high dose may injure sugarbeet.

2.3 Application and Safety of Synergist

Adding synergists to post-emergence herbicides can improve weeds' absorption, achieve good and stable weeding control even in dry condition. Sethoxydim, fluazifop-p-butyl, fenoxaprop -p-ethyl, haloxyfop-R-methyl, clethodim, quizalofop-p-ethyl, imazethapyr with synergists Y2-901, AA-921 are safe to soybeans. Post emergence herbicides acifluorfen, fomesafen, lactofen, bentazone, bentazon+acifluorfen, imazamox with synergists Y2-901, AA-921 provide better weeding control but increase injury.

STUDY ON INFLUENCE OF THREE HERBICIDES TO CORN SEEDLING

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Abstract: The sensitivity of corn seedling to chlorimuron ethyl, imazethapyr and imazamox was determined with water culture methods in laboratory. The treatment concentrations were as follow: chlorimuron ethyl (Classic 25% DF) was at 0, 0.3125, 0.625, 1.25, 2.5, 5, 10 μg/kg. Imazethapyr (Pursuit 5SL, 5% a.i.) and imazamox (Jindou 4SL, 4% a.i.) were at 0, 3.125, 6.25, 12.5, 25, 50, 100, 200 μg/kg. The results showed that the sensitivities of corn seedling to chlorimuron ethyl, imazethapyr and imazamox were different. The orders of sensitivity from strong to weak were chlorimuron ethyl > imazethapyr > imazamox. The higher the herbicide concentration, the stronger the inhibition to corn seedling root. The regression analysis result showed that the inhibition rates of dry weight of corn seedling root were positive relation with the natural logarithm value of the herbicide concentration. The linear equations were $Y_{\text{chlorimuron ethyl}}$=35.3613+12.6298lnx, $Y_{\text{imazethapyr}}$= – 16.8200+12.9642lnx, Y_{imazamox}= – 21.3909+13.2512lnx. ED_{50} for chlorimuron ethyl, imazethapyr and imazamox were 3.1869μg/kg, 173.16μg/kg and 218.66μg/kg, respectively.

Key words: chlorimuron ethyl, imazethapyr, imazamox, corn seedling, sensitivity

Introduction

Chlorimuron ethyl is a member of the sulphonyl urea family of herbicides. Imazethapyr and imazamox herbicides are the members of the imidazolinone family. They are good herbicides of soybean and have soil residual activity (Su Shaoquan and Song Shunzu, 1996; Chen Tiebao et al., 1994; Hui Ding et al., 1989; Chen Tiebao et al., 1998). So they may injure the following crops (Yang Shaoyi et al., 1991). In order to probe the influences to corn seedling, the sensitivities of three herbicides to corn seedling were tried in laboratory.

Materials and Methods

Materials

Chlorimuron ethyl 25% DF was the product of Dupont, USA. Imazethapyr 5SL and imazamox 4SL provided by American Cyanamid Company.

Crop used in the experiment was corn (*Zea mayse*). The corn variety was cultivar Huangmo.

Chlorimuron ethyl concentrations were 0, 0.3125, 0.625, 1.25, 2.5, 5, 10 μg/kg. Imazethapyr and imazamox concentrations were 0, 3.125, 6.25, 12.5, 25, 50, 100, 200 μg/kg.

Methods

Weigh 1000 mg Chlorimuron ethyl 25% DF and plus water 250ml to make up 1000mg/kg Chlorimuron ethyl liquid. Absorb 2ml imazethapyr 5SL and imazamox 4SL, plus water 100ml and 80ml respectively to make up the herbicide liquid of concentration as 1000mg/kg for the experiment used. Then plusing different number of water to make the herbicide liquid that was used in the experiment.

Select 60 grains of corn seeds that were not disease or injured by insect and they were healthy. Put them in the herbicide liquid of different concentration. Soak the seeds 24 hours in 25±1 ℃ warmer before seed germination. Germinating seeds were used when the bud length was about 5mm.

Fill a beaker (size 100ml) with 80ml herbicide liquid, select 2 grains similar germination corn seeds

and hold on a piece of glass with a strip of filter paper. Then put them in the beakers, respectively. While the beakers were put in the warmer (25±1 ℃) 48 hours, they were taken out and let the seedling growth 10 days in the laboratory. Then survey the weight of seedlings and roots respectively.

Results and Discussion

Influence of different herbicides on corn seed germination and seedling growth

The different concentrations of chlorimuron ethyl, imazethapyr and imazamox liquid showed no significant influence on corn seed germination while corn seedling growth was affected. There were no significant inhibitory to corn seedling growth was observed when the liquid concentration of chlorimuron ethyl, imazethapyr and imazamox were below 1.25 μg/kg, 12.5 μg/kg and 25 μg/kg separately. At the concentrations of chlorimuron ethyl 2.5 μg/kg, imazethapyr 25 μg/kg and imazamox 50μg/kg, the seedling growth were markedly inhibitory. The treated seedlings were shorter than check ones. But the rate of inhibitory on above-ground dry weight of seedling were no regularity.

Influence of different herbicides on corn seedling root

The herbicides at the concentrations of chlorimuron ethyl 0.3125 μg/kg, imazethapyr 6.25 μg/kg and imazamox 12.5 μg/kg showed no significant inhibitory activity on seedling roots. The obvious inhibitory activity on seedling roots were observed at the concentrations of chlorimuron ethyl 0.625 μg/kg, imazethapyr 12.5 μg/kg and imazamox 25 μg/kg. Over these of herbicide liquid could reduced corn seedling root growth significantly. The higher the concentration of herbicide liquid, the shorter the root of corn seedling.

Regression analysis on the inhibition rates of dry weight of corn seedling root

The dry weight of corn seedling root reduced with the increase of inhibitory activity. The regression analysis result showed that the inhibition rates of dry weight of corn seedling root were positive related with the natural logarithm value of the herbicide concentration (Fig. 1, 2, 3). The linear equations were as follows.

$Y_{\text{chlorimuron ethyl}}$=35.3613+12.6298lnx±6.3647, r=0.9752**, S.D.=4.1518;

$Y_{\text{imazethapyr}}$= − 16.8200+12.9642lnx±7.1719, r=0.9748**, S.D.=4.8590;

Y_{imazamox}= − 21.3909+13.2512lnx±5.4986, r=0.9855**, S.D.=3.7253.

The Y(%) was the inhibition rate of dry weight of corn seedling root. The lnx was the natural logarithm value of the herbicide concentration. r values with two asterisks indicate that their linear correlation coefficients were statistically significant at 1%. The theory value of ED_{50} for chlorimuron ethyl, imazethapyr and imazamox were 3.1869 μg/kg, 173.16 μg/kg and 218.66 μg/kg, respectively.

Communality analysis and T test on the regression equations

The result of communality analysis showed that if the total regression equation (Y_{total}=20.8428+3.7390lnx) was used to express the correlation between the inhibitory rate of dry weight of corn seedling roots and the herbicide concentration, the remainder variance will be notably increased (F=91.29, $F_{0.01}$=5.03). This difference was caused by the correction average number (in equation it is constant a) difference of the regression equation of three herbicides (F=206.91, $F_{0.01}$=6.23). The linear regression coefficients (constant b in equation) were no marked difference (F=0.06, $F_{0.05}$=3.74).

T test showed that there were remarkable difference of correction average number between regression equations of chlorimuron ethyl and imazethapyr, chlorimuron ethyl and imazamox (t=6.1534 and t=7.4251, respectively). The t values > $t_{0.01}$=2.921. The a value of regression equation of imazethapyr and imazamox was no difference (t=1.6962 < $t_{0.05}$=2.120). This result illustrated that there were significant difference of the influence on corn seedling between family of sulphony urea and imidazolinone.

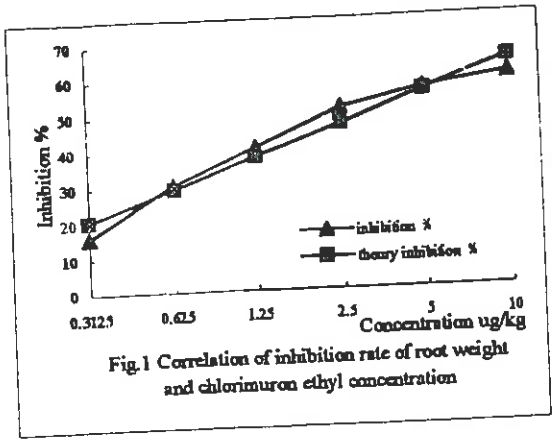


Fig.1 Correlation of inhibition rate of root weight and chlorimuron ethyl concentration

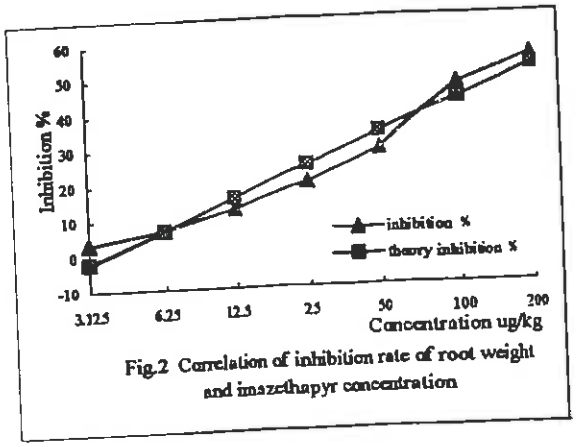


Fig.2 Correlation of inhibition rate of root weight and imazethapyr concentration

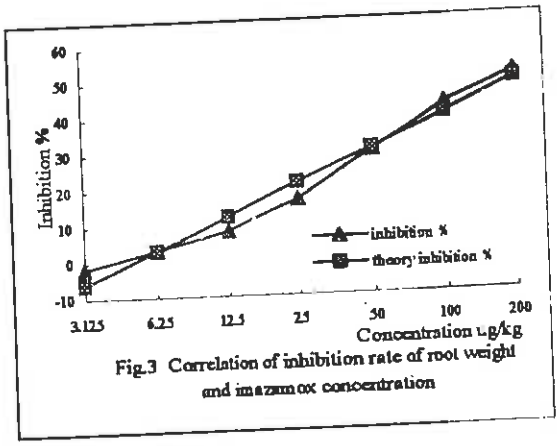


Fig.3 Correlation of inhibition rate of root weight and imazamox concentration

Acknowledgements

The authors are grateful to Professor Chen Tiebao of our Institute for his advice about the experimental design and this manuscript preparations.

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THE APPLICATION OF 2,4 – D SUSTAIN RELEASED IN CONTROLLING *HYDRILLA VERTICILLATA*

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Abstract: The 2,4 – D sustain released (SR) herbicide is a new formulated herbicide specially design to be used in water system to eradicate aquatic weeds. The sustain released formulation is referred to slow release of active ingredient (2,4 – dichlorophenoxyacetic acid) from the plastic film when is applied to water. Matured *Hydrilla* (215 days after planting) has been chosen for the laboratory test to control *Hydrilla* which has been rated to be one of the most noxious submerged weeds. *Hydrilla* colonies have been planted in small plastic pots and placed in plastic aquarium tanks with 12 l of water. Different concentrations of herbicides (0.2 % w/v, 0.4 % w/v, 0.6 % w/v and 0.8 % w/v) were applied to two sets of *Hydrilla* populations. A group of tested colonies was grown in flowing water and the other group was grown in stagnant water, in order to observe the performance of 2,4 – D in both conditions. The release rates of 2,4 – D and the percentage of dry weight reductions of *Hydrilla* after treatments were recorded. Overall, the treatments in flowing water showed higher percentage of dry weight reduction (59.7 %) when treated with 2,4 – D 0.6 % w/v compared to the one in stagnant water. In stagnant water, the highest reduction percentage recorded was 39.8 % after being treated with 0.8 % w/v of 2,4 – D. Both results showed that higher concentrations of 2,4 – D were more effective to reduce the biomass of *Hydrilla*. Release rate test showed that treatments in flowing water recorded higher value when compared to treatments in stagnant water. The highest release rate recorded in the study was 52.4 ppm/hrs whereas the lowest release rate was 35.8 ppm/hrs. Films with higher concentrations of 2,4 – D could release more 2,4 – D in both flowing and stagnant water conditions.

Key words: submerged aquatic weed, *Hydrilla verticillata*, herbicide, 2,4 – D, sustained release

Introduction

Submerged aquatic weeds have caused several major problems to aquatic ecosystems. *Hydrilla verticillata* is one of the most noxious submerged aquatic weeds which has spread all over the world particularly in tropical countries (Langeland, 1996b). High population densities are recorded from various habitats ranging from rivers, irrigation canals, ponds and lakes.

Lately, controlling the aquatic weeds become the main agenda to most authorities. Noxious weeds are generally difficult to control and manage. Chemical control using herbicide is the most popular method in managing aquatic weeds particularly in developed countries. This is because, herbicide is considered more economical and perhaps relatively compatible when apply to environment (Getsinger, 1998; Sahid, 1989; Ashton and Craft, 1981). One of the most popular herbicides is 2,4 – dichlorophenoxy acetic acid (2,4 – D).

According to Watanabe *et al.* (1997), in early 1970s 2,4 – D was the first herbicide which used in controlling broad leaves such as *Monocharia vaginalis*, *Ludwigia adscendes*, *Limnocharis flava*, sedges such as *Fimbrystylis miliaceae* and *Cyperus difformis*. Until now there are no report regarding the using of 2,4 – D in controlling *H. verticillata*.

This paper will describe the application of a new formulated herbicide 2,4 – D sustain released (SR) to control *H. verticillata*. Sustain released is referred to slow release of active ingredient, 2,4 – D from the film which was prepared using co-polymer polyhydroxy tri butyric acid as matrix.

Materials and methods

Culturing of *H. verticillata*

Fresh and healthy *Hydrilla* plants were collected from Sungai Batu Pond and cleaned from attached algae and debrises. Plants were cut from apical tips approximately 10 cm in length. Six plants were planted in each small pots (5.5 cm × 5.5 cm) containing 5 cm sand and subsequently placed in plastic aquariums (25 cm × 39 cm) with water 12.0 L. Water depth were 7.0 cm.

Hydrilla populations were prepared in six replicates and remained until 215 days after planting which is considered as a mature plant.

Preparation of 2,4 – D sustained release

Herbicides 2,4 – D sustained release (SR) were prepared in four different rates; 0.2 % w/v, 0.4 % w/v, 0.6 w/v and 0.8 % w/v.

Active ingredients, 2,4 – diclorophenoxyacetic acid (Fluka) were measured in 0.2 g, 0.4 g, 0.6 g and 0.8 g and were added with 1gram copolymer poly-hydroxy-3-butyric acid (Aldrich) respectively. These mixtures were diluted in chloroform and heated until all the substances dissolved. The solution being cooled and transferred to volumetric flask 100 ml followed by adding chloroform until 100 ml.

The solutions were transferred and distilled to eliminate chloroform by using rotary vapor until the remains volume is approximately 10 ml. Then the residues were poured into glass petry dishes and left at room temperature until it became a thin film. Finally films will be used for herbicide application on *H. verticillata*.

Treatment of 2,4 – D SR

The herbicides were tested on mature plants (215 DAP). The treatments were divided into two experiments, which were conducted in culture house for two weeks. The first experiment was conducted in flowing water whilst the second experiment was conducted in stagnant water.

The herbicide films with different concentrations 2,4 – D were added into five different aquarium tanks. Aquarium 1 (T1) was a control (without treatment), aquarium 2 (T2) was treated with 2,4 – D 0.2 % w/v, aquarium 3 (T3) was treated with 2,4 - D 0.4 % w/v, aquarium 4 (T4) was treated with 2,4 - D 0.6 % w/v and aquarium 5 (T5) was treated with 2,4 – D 0.8 % w/v.

At the interval of every six hours in the first week, water samples were collected in order to determine the release rate (dc/dt) of 2,4 – D in the water based on the concentrations over a two weeks period. The release rate were calculated based on method from Tinoco *et al.* (1995).

After two weeks, dry weights of *Hydrilla* were measured in order to calculate the percentage of dry weight reduction. Initial fresh weights were measured from several lengths of similar plants and the

data were used to calculate the initial weight of experimental plants. The remains of the plant were dried in oven at 60°C to measure dry weight. (Mansor *et al.*, 1988). Method used to estimate biomass based on dry weight (y variable) of *Hydrilla* which was modified from Pine *et al.* (1989) using linear regression equation with lengths of plant as variable x.

Result and discussion

Figure 1 showed that the mean dry weight of *Hydrilla* after being treated with 2,4 – D SR in flowing and stagnant water condition. In the flowing water, the minimum dry weight recorded was 131.9 mg, whereas the maximum dry weight recorded was 1077.3 mg. In stagnant water condition, the minimum dry weight recorded was 225.9 mg, whereas the maximum dry weight recorded was 1564.4 mg.

Table 1 showed that the percentage of dry weight reduction of *Hydrilla* after being treated with the herbicides in flowing water. The highest percentage recorded was 59.7 % after being treated with 0.6 % 2,4 – D SR with the rate of reduction was 2.2 mg/day, whereas the lowest percentage of dry weight reduction was 16.5 % with the rate 0.5 mg/day.

Table 2 showed that the percentage of dry weight reduction of *Hydrilla* after being treated with the herbicides in stagnant water. The highest percentage recorded were 39.8 % after being treated with 0.6 % 2,4 – D SR with the rate of reduction was 1.8 mg/day, whereas the lowest percentage of dry weight reduction was 0.9 % with the rate 0.2 mg/day.

Maximum release rate recorded in flowing water condition was 0.0524 g/l/hr released from 2,4 – D SR 0.8 % w/v. Conversely treatment in stagnant water condition showed the lower release rate which was 0.0472 g/l/hr with the same initial concentration of 2,4 – D (Table 3).

Result showed that the lowest percentage of dry weight was less than 1 %. In addition there was no 100 % reduction in dry weight. These indicated that no *Hydrilla* were totally killed. However 2,4 – D SR showed the effect to reduce the dry weight with higher concentration of herbicides. Treatment with 2,4 – D 0.6 % w/v in both water condition showed the dry weight reduction exceed 50 %. However with lower concentration, the herbicides didn't show the hormonal characteristic.

The resistance of matured *Hydrilla* to 2,4 – D was due to the formation of stolons, new developed buds with long and strong roots. In this stage, the dense growth of *Hydrilla* might interrupt the absorbance of herbicides through leaves. The top plant parts were easier to expose to herbicides when compared to lower plant parts.

As conclusion, although the sustain released formulation couldn't totally kill *Hydrilla*, but it can reduce the dry weight of treated plants. To increase the efficacy of 2,4 – D SR on *Hydrilla* application should be made on early stages.

Acknowledgements:

We express our appreciation to Dr. Md. Isa from National Poisson Centre, USM for the herbicides and also its formulation technique. To Mr. Ganesh, Mr. Amir and Mr. Bakar for helping us in collecting *Hydrilla* and other technical works are gratefully acknowledged. The project is partly sponsored by IRPA grant no 190/9601/3209.

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Table 1 Percentages of dry weight reduction and rate of *Hydrilla* reduction after being treated with different concentrations of 2,4 - D in flowing water conditon.

2,4 - D concentration (% w/v)	Percentage of reduction (%)	Rate of reduction (mg/day)
0	[144.3]	-
0.2	39.7	1
0.4	16.5	0.5
0.6	59.7	2.2
0.8	27.7	0.1

Table 2 Percentages of dry weight reduction and rate of *Hydrilla* reduction after being treated with different concentrations of 2,4 - D in stagnant water conditon.

2,4 - D concentration (% w/v)	Percentage of reduction (%)	Rate of reduction (mg/day)
0	[164.8]	-
0.2	18.3	0.6
0.4	15.5	0.4
0.6	0.9	0.2
0.8	39.8	1.8

Table 3 Release rate of 2,4 - D from 2,4 - D sustain released with different concentrations within 48 hrs of application in flowing water and stagnant water condition.

concentration of 2,4 - D	release rate (g/l/hr)	
	flowing water	stagnant water
2 (0.2 % w/v)	0.0443	0.0358
4 (0.4 % w/v)	0.0421	0.0435
6 (0.6 % w/v)	0.0384	0.0391
8 (0.8 % w/v)	0.0524	0.0472

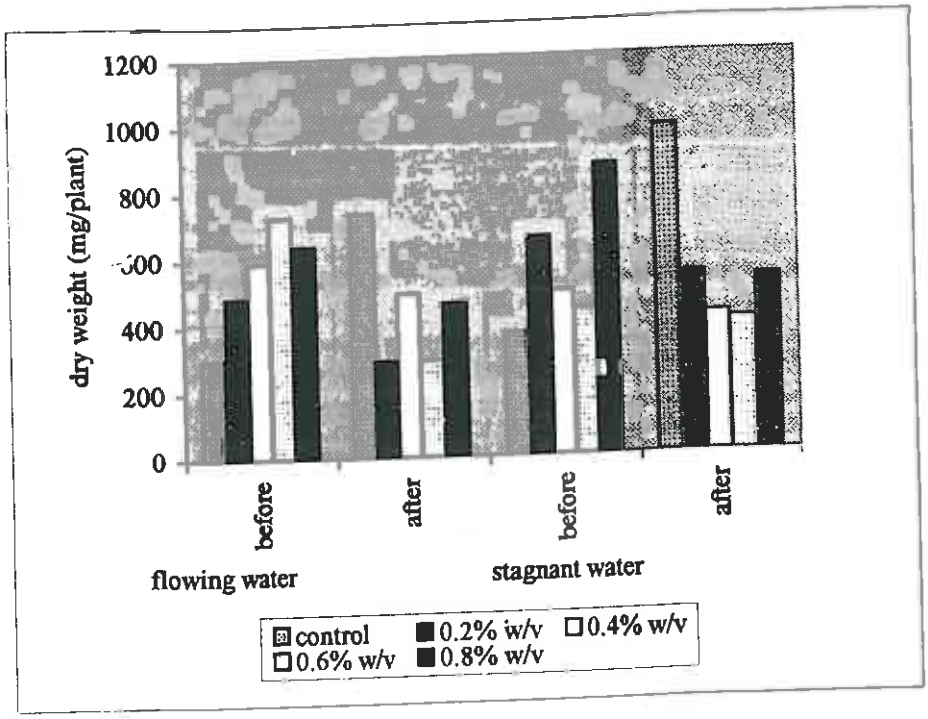


Fig. 1 Mean dry weight of *Hydrilla* after being treated with 2,4 - D sustain released in flowing and stagnant water conditions

WEED CONTROL EFFICACY OF GLYPHOSATE HERBICIDES WITH THE USE OF CONTROLLED DROPLET APPLICATION (CDA) SPRAYER

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Abstract: A series of field studies was conducted in low-grown tea [*Camellia sinensis* (L) O. Kuntz.] at Tea Research Institute, Ratnapura, Sri Lanka to investigate the weed control efficacy of two glyphosate formulations with the use of CDA sprayer in comparison with knapsack sprayer. Four different rates *i. e.* 198 g a. i. and 594 g a. i. of glyphosate (36% w/v) and 320 g a. i. and 640 g a. i. of glyphosate (16% w/v) were tested using both sprayers. Results showed that the efficacy of glyphosate sprayed by the CDA sprayer was greater than that with the knapsack sprayer. A greater injury % on weeds and a lower fresh weight of weeds were recorded with the CDA sprayer when compared with the knapsack sprayer.

Key words: Controlled Droplet Application (CDA), glyphosate (Spark, 16 % a.e.), Roundup, weed Control in tea.

Introduction

Weed management in tea plantation [*Camellia sinensis* (L) O. Kuntz.] is critically important particularly during young and post pruning phases since there is an inadequate ground cover. Weeds in tea fields interfere with its growth leading to a crop loss and some weeds interrupt the plucking operation as they overgrow the tea bush (Somaratne, 1988). It has been estimated that the yield loss due to weeds in high-grown young tea was 30% (Visser, 1961) and in low-grown mature tea was 5-15 % (Wettasinghe, 1971a, 1971b). Expenditure on weed management in tea accounts for about 10-14% of the cost of field operations which attributed to the high cost of chemicals and labour. Integrated approach that includes manual, chemical, cultural and some biological methods is practised at present in order to minimize the weed menace. Use of herbicides serves a major role, as it is more convenient and efficient. Glyphosate herbicides are commonly used in tea fields at present. However, the high cost of chemicals, some hazardous effects on tea and human particularly with the use of high dosages and scarcity of labour are the major obstacles faced by tea cultivators. Hence, more emphasis is to be given in order to find ways of reducing the cost of chemical weeding and some deleterious effects on the crop and the human. Use of a low volume of spray solution with a low rate of active ingredient of a given herbicide could be an answer to such difficulties partially. The knapsack sprayer, which is commonly used for herbicide application, requires 550 l of water to cover a one-hectare of tea land and 2 workers for spraying and carrying water. Whilst, the development of low volume sprayer nozzles has made it possible to apply herbicides in low water volumes to control weeds effectively (Breay, 1981; Njoroge, 1990; Kimemia & Njoroge, 1991). Further, it has been reported that Controlled Droplet Application (CDA) sprayer is more convenient and effective in weed control in oil palm and rubber lands in Malaysia (Monsanto, 1993). This sprayer requires only 25 l of water/ha and more appropriate for glyphosate herbicides. Therefore, a series of studies was carried out to investigate the weed control efficacy of glyphosate herbicides with the use of CDA sprayer in comparison with knapsack sprayer.

Materials and Methods

A field study was conducted from May until Dec. '98 at Hapugastenne estate, Ratnapura, Sri Lanka where the elevation is about 300 m amsl and soil is ultisol.

Plots each of 2 m x 2 m in size, were marked from an open area of a tea field where the ground was uniformly covered by weeds for the first study in May '98. Plots were also marked from an adjoining field in June '98 for the second study and repeat (third) application. Eight chemical treatments together with an untreated control as given below were accommodated in 27 plots with three replications in a Randomized Complete Block (RCB) design.

Treatments:

T1 Glyphosate (16% w/v)* @ 320 g a. i./550 l water/ ha (with Knapsack sprayer)
T2 Glyphosate (do) @ 640 g a. i./ -do-
T3 Glyphosate (36% w/v)+ @ 198 g a. i./ -do-
T4 Glyphosate (do) @ 594 g a. i./ -do-
T5 Glyphosate (16% w/v) @ 320 g a. i./25 l water/ ha (with CDA sprayer)
T6 Glyphosate (do) @ 640 g a. i./ -do-
T7 Glyphosate (36% w/v) @ 198 g a. i./ -do-
T8 Glyphosate (do) @ 594 g a. i./ -do-
T9 Untreated control

* Glyphosate (in the form of Isopropylamin salt) [Spark, 16% a.i]
+ Glyphosate (in the form of Isopropylamin salt) [Roundup, 36% a.i.]

First spray of the above herbicide was done in early May '98. Second round of application was done in mid June and the same treatments were repeated in late Nov. '98.

Assessments and data analyses:

The level of damage on weeds following herbicide application was visually scored in terms of injury percentage for each plot at 3 or 4 weeks after (WAS) each spraying. Fresh weight of live weeds was also recorded at 3, 10 and 4 WAS for the first, second and third spray rounds respectively. Quadrat (0.6 m x 0.6 m) samples were obtained from four randomly selected spots within each plot. The data were analyzed using Dunken's Multiple RangeTest (DMRT) at p=0.05 probability level using ANOVA.. Some data were subjected to transformation following homogeneity test.

Results

Study I:

The greatest injury % was recorded with glyphosate (16%) @ 640 g a. i./ha sprayed by the CDA sprayer at 3 WAS and this was comparable to the same sprayed by the knapsack, glyphosate (36%) @ 594 g a.i./ha sprayed by either CDA or knapsack sprayer and; glyphosate (16%) @ 320 g a.i./ha by CDA sprayer (Fig. 1.1). The lower dosages *i. e.* glyphosate (16%) @ 320 g a. i./ha sprayed by knapsack sprayer and glyphosate (36%) @ 198 g a. i. /ha sprayed by either CDA or knapsack sprayer had poorly damaged the weeds compared to the higher dosages.

All treated plots had a significantly ($p<0.05$) lower weed biomass yield when compared with the untreated control at 3 WAS. The lowest was recorded with glyphosate (36%) @ 594 g a. i./ha and glyphosate (16%) @ 640 g a. i./ha sprayed by the CDA sprayer. Although it was non-significant both herbicides sprayed by the knapsack had produced a greater weed biomass yield than that sprayed by the CDA sprayer. A greater difference between corresponding fresh weights of weeds for CDA and knapsack sprayers was recorded with the lower rates such as glyphosate (16%) @ 320 g a. i./ha and glyphosate (36%) @ 198 g a. i./ha than with the higher rates (Fig. 1.2).

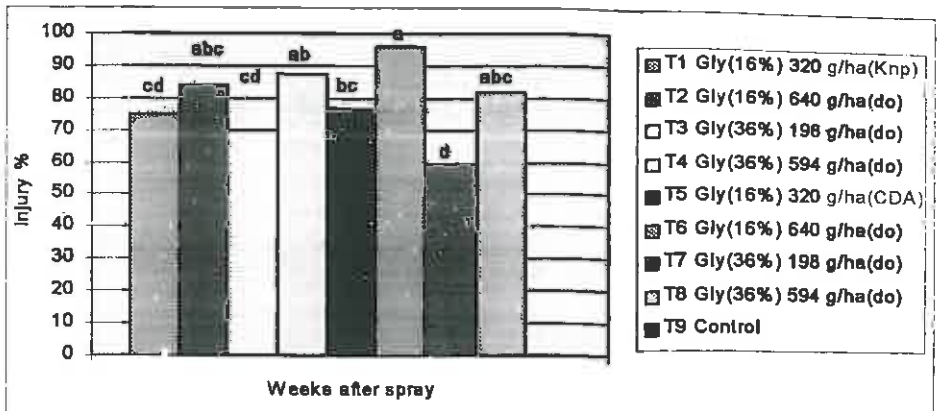


Fig. 1.2: Mean injury % on weeds 3 weeks after herbicide application

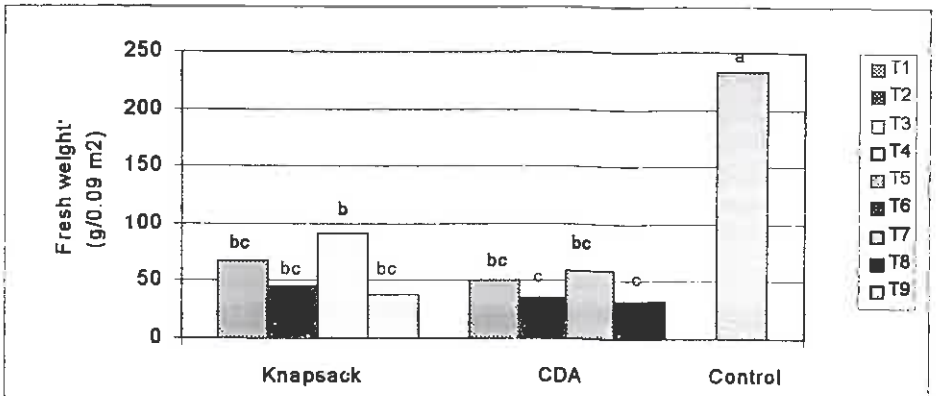


Fig 1.2: Mean weed biomass yield 3 weeks after herbicide application

(Means with a same letter are not significantly different at the 5% level)

Study II:

The greatest injury % was recorded with glyphosate (16%) @ 640 g a. i./ha and glyphosate (36%) @ 594 g a. i./ha sprayed by CDA sprayer at 3 and 4 WAS. Though there was a similar trend in these results, weed damage was relatively poor when compared with that of the study I, because of the bad weather prevailed 4-5 hours after herbicide application. The former sprayed by the knapsack occurred a significantly lower ($p<0.05$) damage on weeds at 3 WAS but comparable to the above at 4 WAS. The performance was inferior with lower dosages of both herbicides sprayed by either CDA or knapsack sprayer. However, though non-significant, performance was relatively greater only with glyphosate (36%) @) 198 g a.i./ha applied by CDA sprayer when compared with knapsack sprayer (Fig. 2.1).

There was a significant ($p<0.05$) reduction in weed biomass production in all treated plots even at 10 WAS when compared to the untreated control. The least fresh weight was recorded with glyphosate (16%) @ 640 g a i./ha sprayed by CDA sprayer followed by the same sprayed by knapsack (Fig.2.2). Although the results were non-significant, herbicides sprayed by knapsack sprayer always resulted in a greater weed fresh weight compared to that with CDA sprayer.

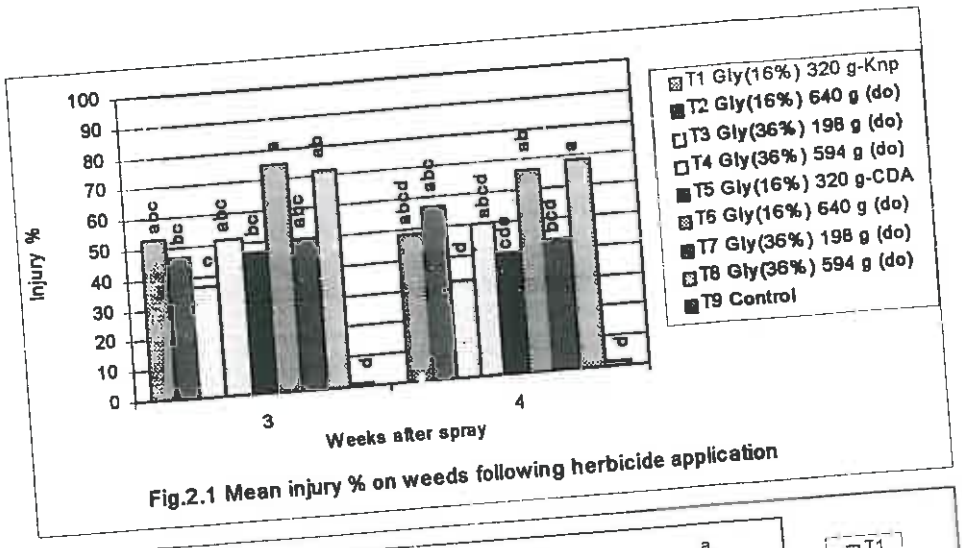


Fig.2.1 Mean injury % on weeds following herbicide application

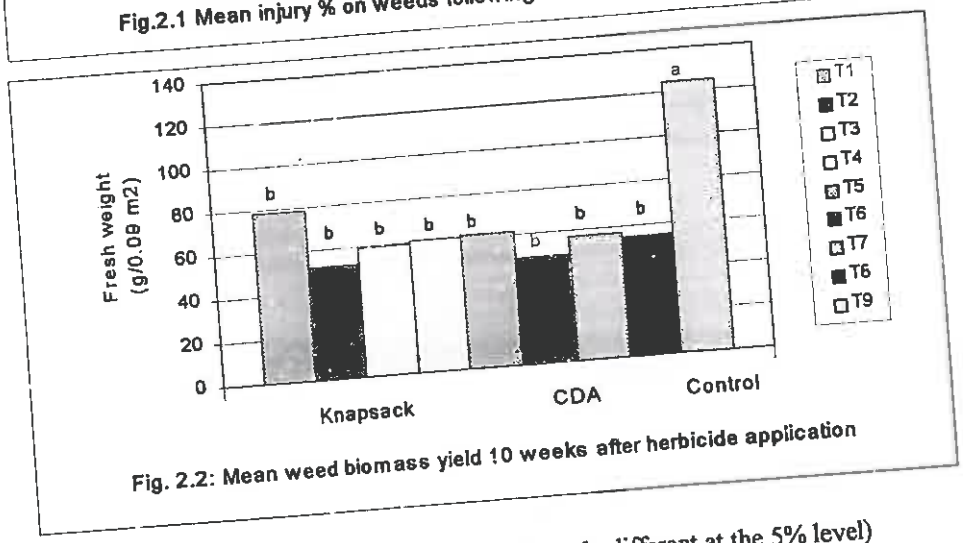


Fig. 2.2: Mean weed biomass yield 10 weeks after herbicide application

(Means with a same letter are not significantly different at the 5% level)

Repeat application test:

The visual observations made at 4 WAS further witnessed that the higher dosages performed better than the lower dosages in weed control irrespective of the type of sprayer. Though the results were non-significant, the injury % with CDA spraying was always greater than that with knapsack sprayer at both high and low dosages of herbicides (Fig. 3.1).

A very low biomass yield, prior to spray was recorded in plots to be treated with glyphosate (36%) @) 198 g a. i./ha and glyphosate (16%) @ 640 g a. i./ha sprayed by CDA sprayer. However, weed fresh weight was significantly reduced ($p<0.05$) in all chemically treated plots when compared to the untreated control. The sprayer-dependent or herbicide dosage-dependent response on weed control were not shown by the repeated application (Fig. 3.2).

Discussion

With all studies it was apparent that the higher the dosage the greater the damage on weeds. This may be true because, the glyphosate is known to be a dosage-dependent herbicide in its performance. The performance of herbicides with CDA sprayer was better than that with knapsack sprayer. Monsanto (1993) also reported that the average increase in the performance of glyphosate (Wallop, 22% a. i.)

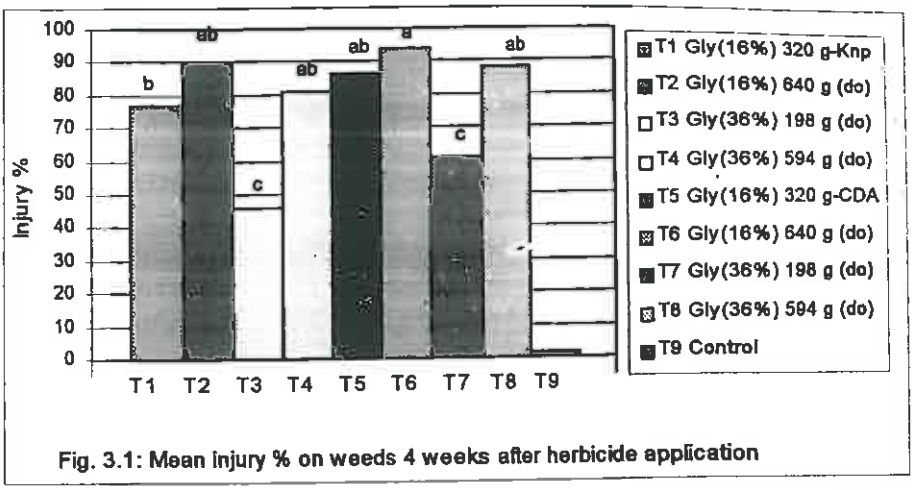


Fig. 3.1: Mean injury % on weeds 4 weeks after herbicide application

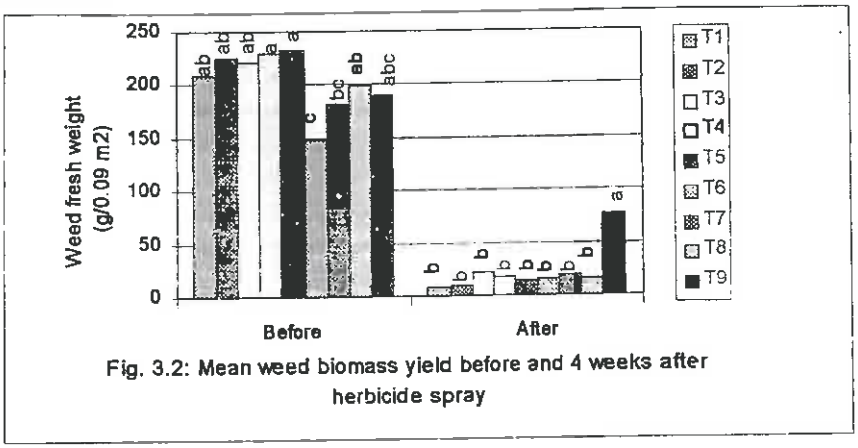


Fig. 3.2: Mean weed biomass yield before and 4 weeks after herbicide spray

(Means with a same letter are not significantly different at the 5% level)

herbicide sprayed by CDA sprayer over the knapsack was about 10%. Whilst, glyphosate (Wallop, 22% a. i.) and (Spark, 16% a. i.) sprayed by CDA sprayer at a range of 440-640 g a. i./ha gave a superior control of *Hedyotis auricularia* L. weed with a poor recovery (Prematilaka *et al* 1999). Glyphosate (Spark, 16% a.i.) at 640 g a.i./ha alone sprayed by the same also controlled the *Caladium bicolor* **vent.** weed effectively in tea fields (Prematilaka, 1999). Furthermore, the reduced cost of application resulted from 94 % saving of water and one third of man power requirement with the CDA sprayer compared to the knapsack sprayer have been reported under the field condition of rubber and oil palm, cocoa and orchard tree crops in Malaysia (Monsanto, 1993). Although the performances are only fairly better than the knapsack, its efficiency, simplicity in use should also be given a due consideration. Handling a CDA sprayer in tea lands is easy and more efficient particularly in vacant patches and uncultivated blocks. Besides, tea interrows with 1.2 m width can be treated with CDA sprayer. However, in mature tea fields with a good ground cover, moving with CDA sprayer is difficult and inefficient. Further investigations have been planned to appraise the application cost and efficacy of the CDA sprayer under varying field conditions of tea plantation.

Acknowledgements:

Authors are grateful to the Monsanto Co. (Pvt) Ltd., Sri Lanka for providing a CDA sprayer together with new herbicide.

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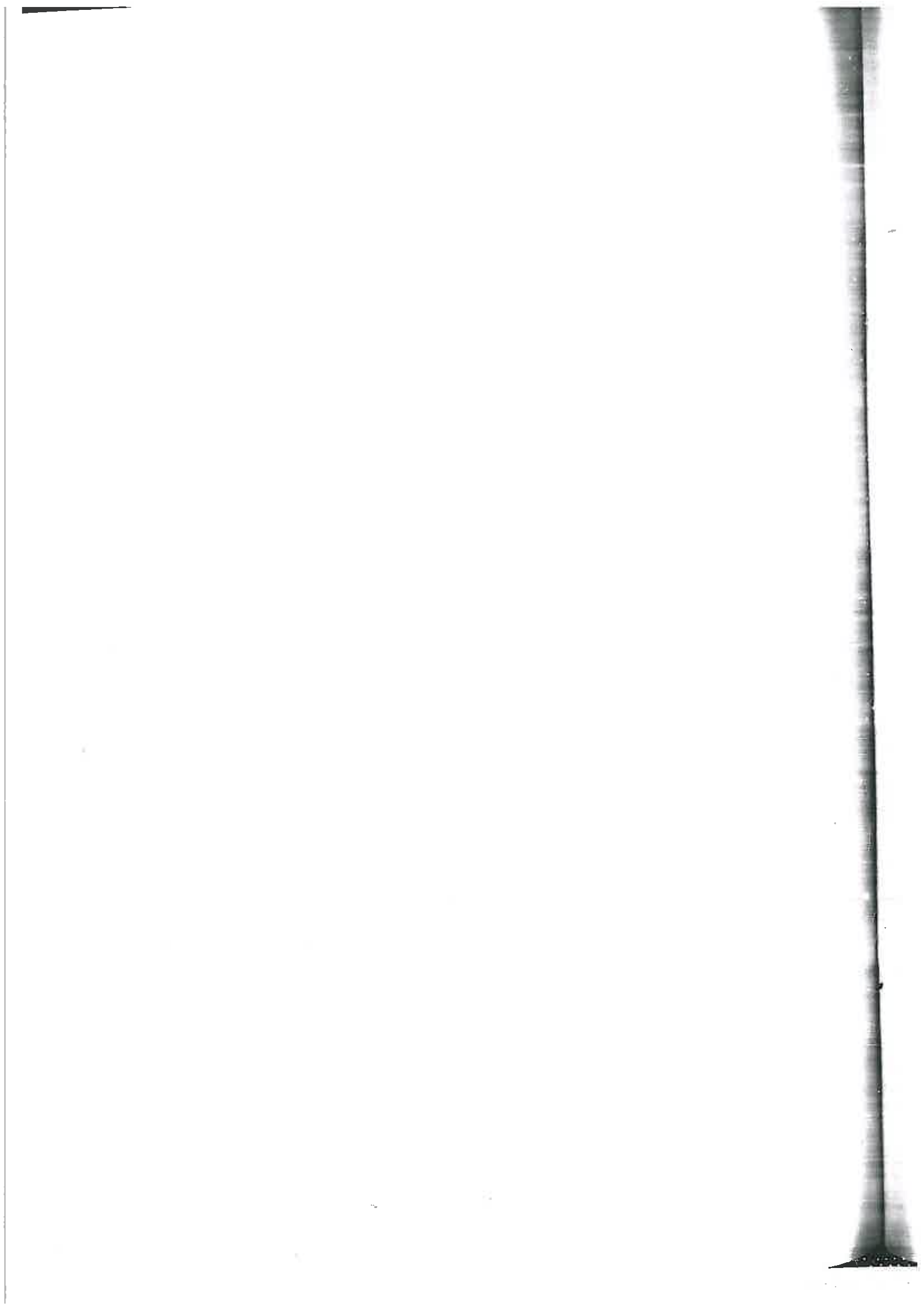
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4.2 Physiology and Biochemistry



EFFECT OF CARFENTRAZONE-ETHYL ON ABSORPTION AND TRANSLOCATION OF [^{14}C]GLYPHOSATE

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Abstract: Absorption and translocation of non-selective systemic herbicide glyphosate applied in combination with non-selective contact herbicide carfentrazone-ethyl were investigated. Absorption of [^{14}C]glyphosate alone applied to *Commelina communis* L. and *Echinochloa crus-galli* (L.) P. Beauv. increased rapidly by 4 days after application (DAA) and thereafter levelled off. However, the absorption was not greatly affected when carfentrazone-ethyl at 30 g a.i./ha was treated in mixture or one day before [^{14}C]glyphosate application. After absorption, rapid decrease of [^{14}C]glyphosate remained in the treated leaf *of C. communis* occurred, whereas most of [^{14}C]glyphosate was remained in the treated leaf of *E. crus-galli*. The translocation was not generally affected by carfentrazone-ethyl. Relative distribution of the absorbed [^{14}C]glyphosate 10 DAA in the various plant parts was different between the two weed species. The highest amount of [^{14}C]glyphosate was found in non-treated leaves of *C. communis*, whereas in *E. crus-galli* most of [^{14}C]glyphosate was remained in cuticle of the treated leaf. On the other hand, there was no great difference in the relative distribution between the treatments of [^{14}C]glyphosate with and without carfentrazone-ethyl.

Key words: glyphosate, carfentrazone-ethyl, absorption and translocation

Introduction

Carfentrazone-ethyl is a phenyl triazolinone herbicide currently being developed by the FMC Corporation. This compound is a low rate, non-residual, contact herbicide that effectively controls many important weeds in cereal culture (van Saun *et al.*, 1993). In Korea, carfentrazone-ethyl is being examined in orchards as an effective postemergence herbicide to control weeds.

Weed control in orchards has been mainly done with several non-selective herbicides. Use of the herbicides, however, often leaves specific weed species that show tolerance, resulting in inadequate weeding efficacy. Mixture application of different types of herbicides may be another alternative to manage such tolerant weeds. There have been various examples of herbicide mixtures, which provide synergistic or antagonistic action (Hatzios and Penner, 1985).

Because of reduced activity against grass weeds, carfentrazone-ethyl alone does not provide complete weed control in orchards. Combination of carfentrazone-ethyl with some postemergence herbicides such as glyphosate has enhanced activity on specific weed species over that obtained with the herbicides alone (Lee *et al.*, 1997). In spite of this advantage in their herbicidal performance, one might question whether absorption and translocation of the systemic herbicide glyphosate is inhibited by contact herbicide carfentrazone-ethyl. Since the primary target of carfentrazone-ethyl is known to be plastid protoporphyrinogen oxidase (Protox) (Dayan *et al.*, 1997), the competitive inhibition of Protox eventually leads to the massive accumulation of photosensitising protoporphyrin IX, which causes cellular leakage and ultimate cellular death in the presence of light and molecular oxygen (Matringe *et al.*, 1989; Becerril and Duke, 1989; Duke *et al.*, 1991). When applied in mixture, cellular damage caused by carfentrazone-ethyl may hinder absorption and translocation of glyphosate.

In the present study, we examined the absorption and translocation of [^{14}C]glyphosate as affected by carfentrazone-ethyl in *C. communis* and *E. crus-galli*. The weed species selected were comparatively tolerant to glyphosate and carfentrazone-ethyl, respectively. In addition, electrolyte leakage of *C. communis* leaf disks by carfentrazone-ethyl was also determined to find possible effect of the cellular damage on absorption and translocation of glyphosate.

Materials and Methods

Plant growth

Dormancy-broken seeds of *C. communis* and *E. crus-galli* were germinated in the greenhouse in plastic pots (15 x 25 cm) containing a silty clay loam soil with pH 5.3 and 2.4% organic matter. Before the seedlings reached 4-leaf stage (LS), they were transplanted into separate 50-ml styroform cups and allowed to grow further to 5-LS.

Absorption

Carfentrazone-ethyl was applied at 30 g a.i./ha to all plants of 5-LS each weed species 0 or 1 day prior to [^{14}C]glyphosate (specific activity, 2 GBq/mmole) application. Ten 2-µl droplets of [^{14}C]glyphosate (0.05 µCi) were uniformly spotted on the abaxial surface of the 3rd leaf. The treated plants were kept in a growth chamber at 125 µE m^{-2} s^{-1} at 25°C. At 1, 2, 4, 7, and 10 days after application (DAA) the treated leaf was detached, rinsed by placing it in water for 2 min and subsequently blotted dry. Radioactivity in the leaf wash was quantified by scintillation spectrometry (model TRI-CARB 300, Packard Co., Downers Grove, IL, USA). The amount of [^{14}C]glyphosate absorbed through the treated leaf was estimated by subtracting the fraction of [^{14}C]glyphosate recovered in the wash from the amount applied.

^{14}C remained in epicuticular wax and cuticle in the treated leaf was assayed essentially as described by Ricotta and Masiunas (1992). Total leaf area of the treated leaves was measured using a leaf area meter (model LI-3000, LI-COR, Lincoln, NE, USA). To remove epicuticular wax, the leaves of each weed species were individually submerged in 70 ml chloroform for 30 s and subsequently in 30 ml chloroform for 15 s. The chloroform washes were then combined. After surface wax removal, cuticle was isolated by digestion of the remaining leaf tissues in a solution consisting of $ZnCl_2$ and HCl in a ratio 1:1.7 (w/v) at room temperature for 2 h. Following digestion, cuticle was extracted from the remaining tissues with 50 ml methanol. Radioactivity in the chloroform and methanol washes for epicuticular wax and cuticle component, respectively was then determined using a liquid scintillation counter.

Translocation

A 20-µl solution containing 0.05 µCi [^{14}C]glyphosate was applied to the 3rd leaf of each species in 2-µl droplets. At 10 DAA, the plants were washed in running water and divided into the treated leaf, shoot and other leaves, and roots. The tissues were separately homogenized in a mortar and pestle with an aid of sea sand and then resuspended in 2 ml of distilled water. Following the centrifugation at 12,000 *g* for 5 min, the resulting supernatants were saved to measure radioactivity.

Autordiography

The plants treated with [^{14}C]glyphosate as in the translocation experiments were kept in a growth chamber at 125 µE m^{-2} s^{-1} at 25°C. At 1, 4 and 7 DAA, the samples were taken, washed with distilled water, blotted dry, and placed on X-ray film (Kodak) for 7 days. All treatments were triplicated, but results of autoradiographs were from the representative experiments.

Cellular leakage

Effect of carfentrazone-ethyl alone or in combination with glyphosate on cellular damage of *C. communis* was determined by detection of electrolyte leakage into the bathing medium with a conductivity meter (model 162, Orion Research Inc., Germany). Fully expanded leaves were punched into 8-mm diameter leaf disks using a cork borer and the disks (1 g fresh wt) were transferred into a 15-ml test tube containing 7 ml of distilled water. Following vacuum infiltration at about 400 mmHg for 20 min, the water was removed and replaced with 10 ml of 10-µM carfentrazone-ethyl alone or in combination with 10-µM glyphosate solution. The leaf disks were then incubated under light condition at 125 µE m^{-2} s^{-1} with agitation at 25°C. Because of differences in background conductivity of different treatment solutions, results were expressed as changes in conductivity from initial measurement.

Results and Discussion

Absorption

Penetration of [^{14}C]glyphosate in *C. communis* and *E. crus-galli* readily occurred after application

(Fig. 1). At 1 DAA, about 20 to 22% of the total applied [^{14}C]glyphosate was absorbed. Rapid increase in the absorption continued to 4 DAA and thereafter levelled off. Absorption of [^{14}C]glyphosate was not greatly changed in both weed species studied although carfentrazone-ethyl was applied 0 or 1 day prior to [^{14}C]glyphosate application. These results indicated that carfentrazone-ethyl did not greatly affect absorption of [^{14}C]glyphosate.

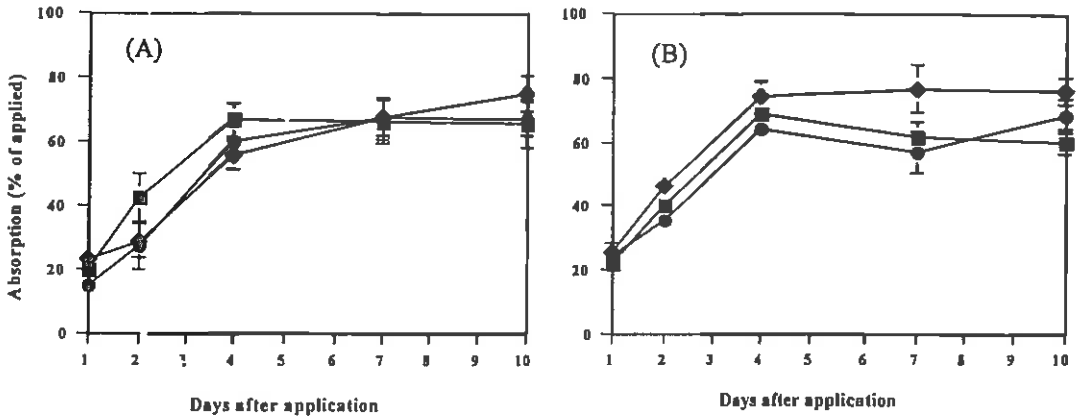


Fig. 1. Effect of carfentrazone-ethyl on total absorption of [^{14}C]glyphosate in *Commelina communis* (A) and *Echinochloa crus-galli* (B). Symbols are as follows: ■ [^{14}C]glyphosate alone; ◆ [^{14}C]glyphosate+carfentrazone-ethyl; ● carfentrazone-ethyl followed by [^{14}C]glyphosate.

After absorption, all [^{14}C]glyphosate was not translocated from the treated leaf to other plant tissues. A part of [^{14}C]glyphosate was remained in epicuticular wax and cuticle of the treated leaf (Table 1). The radiolabel from [^{14}C]glyphosate was remained less in epicuticular wax than in cuticle in both species and

Table 1. ^{14}C remained in the treated leaf of *Commelina communis* and *Echinochloa crus-galli* after application with [^{14}C]glyphosate alone or 0 and 1 day following application of 30 g a.i./ha carfentrazone-ethyl (Carf).

Treatment	^{14}C-recovered (% of applied) after application[1]					
	1 day		4 days		10 days	
	Epicuticular wax	Cuticle	Epicuticular wax	Cuticle	Epicuticular wax	Cuticle
	C. communis					
[^{14}C]glyphosate	0.5 b	2.3 a	0.5 a	7.0 b	0.8 a	12.4 a
Carf+[^{14}C]glyphosate 0-day sequence	1.3 a	2.4 a	0.9 a	6.3 b	0.7 a	10.9 a
Carf+[^{14}C]glyphosate 1-day sequence	0.5 b	2.6 a	0.4 a	11.3 a	1.0 a	13.4 a
	E. crus-galli					
[^{14}C]glyphosate	0.9 a	10.2 a	1.4 a	48.0 b	1.5 a	24.6 a
Carf+[^{14}C]glyphosate 0-day sequence	1.1 a	13.1 a	1.2 a	55.7 a	2.5 a	38.9 ab
Carf+[^{14}C]glyphosate 1-day sequence	1.5 a	11.6 a	2.7 a	47.1 b	3.5 a	33.0 b

[1]Means within columns for each weed species with the same letters are not significantly different at the 5% level by the LSD test.

the difference increased with increasing time. On the other hand, [^{14}C]glyphosate left in the treated leaf was much greater in *E. crus-galli* than in *C. communis*, indicating less translocation of the absorbed [^{14}C]glyphosate in the former. Epicuticular wax contents in the 5th leaf were similar in *E. crus-galli* and *C. communis*, but the *C. communis* leaf exhibited about 1.5-fold higher cuticle content than the *E. crus-galli* leaf (data not presented). In addition, there was no great difference in the amount of [^{14}C]glyphosate distributed in the treated leaf after translocation between applications of [^{14}C]glyphosate without and with carfentrazone-ethyl. These results suggested that the amount of [^{14}C]glyphosate remained in the treated leaf was not affected by the leaf surface characteristics and use of carfentrazone-ethyl.

Translocation

Autoradiographs of the [^{14}C]glyphosate-treated leaves of both species visualized that the radiolabel was readily translocated into other plant tissues (Figs. 2 and 3). At 1 DAA, [^{14}C]glyphosate treated to the 3rd leaf at 5-LS was acropetally and basipetally translocated, so that the radiolabel was detected in upper and lower leaves and roots. The translocation pattern was not greatly changed by 7 DAA. Moreover, the translocation of [^{14}C]glyphosate was not affected by carfentrazone-ethyl applied either in mixture or 1 day prior to [^{14}C]glyphosate.

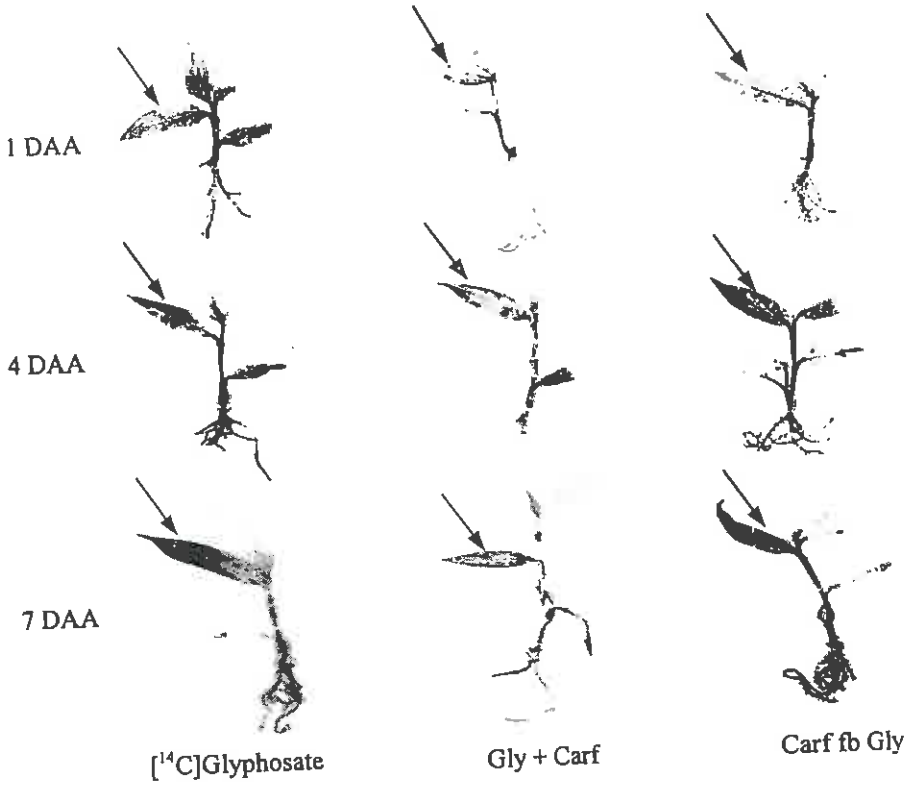


Fig. 2. Autoradiograms showing translocation pattern of [^{14}C]glyphosate (Gly) treated to 5-leaf stage of *commelina communis* as affected by carfentrazone-ethyl (Carf). (Gly+Carf; application of [^{14}C]glyphosate and carfentrazone-ethyl mixture, Carf fb Gly; application of carfentrazone-ethyl followed by [^{14}C]glyphosate). DAA=days after application. Arrows indicate the application sites of [^{14}C]glyphosate.

[^{14}C]Glyphosate translocated from the treated leaf to other plant tissues and roots was also determined 10 DAA (Table 2). In *C. communis* about 40 to 52% of the applied [^{14}C]glyphosate was tranlocated to non-treated leaves and roots, whereas less amount of [^{14}C]glyphosate in non-treated leaves and roots as compared with that in the treated leaf was found in *E. crus-galli*.

In both species studied, carfentrazone-ethyl did not affect the translocation of [^{14}C]glyphosate as applied in mixture. When carfentrazone-ethyl was applied 1 day prior to [^{14}C]glyphosate, however, the translocation occurred less in *C. communis*, but greater in *E. crus-galli* as compared with application of

[^{14}C]glyphosate alone or in combination with carfentrazone-ethyl. This was due probably to differences in sensitivity of both species to carfentrazone-ethyl. *C. communis* is relatively susceptible to carfentrazone-ethyl as compared with *E. crus-galli* (van Saun *et al.*, 1993; Lee *et al.*, 1997), so that more inhibition might occur in the former by carfentrazone-ethyl that applied 1 day prior to application of [^{14}C]glyphosate.

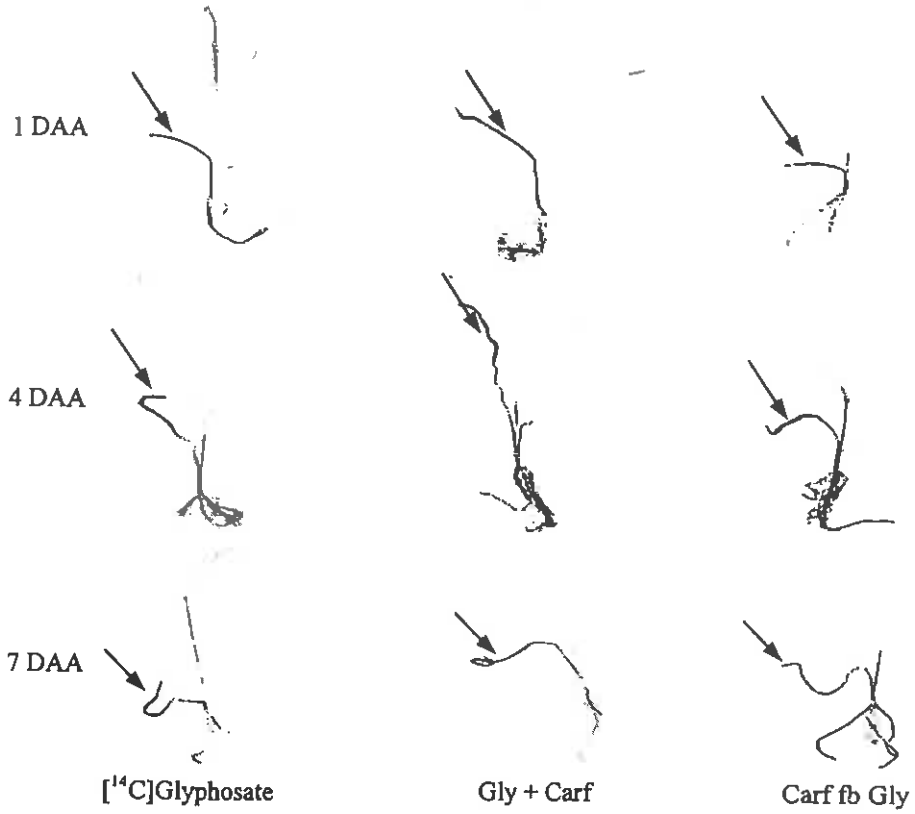


Fig. 3. Autoradiograms showing translocation pattern of [^{14}C]glyphosate (Gly) treated to 5-leaf stage of *Echinochloa crus-galli* as affected by carfentrazone-ethyl (Carf). (Gly+Carf; application of [^{14}C]glyphosate and carfentrazone-ethyl mixture, Carf fb Gly; application of carfentrazone-ethyl followed by [^{14}C]glyphosate). DAA=days after application. Arrows indicate the application sites of [^{14}C]glyphosate.

Cellular leakage

When *C. communis* leaf disks were incubated with carfentrazone-ethyl alone under light condition following 24 h dark incubation, significant electrolyte leakage from the tissues into the bathing medium did not occur for the first 24 h after treatment (HAT), but began to slightly increase during the second 24 HAT. (Fig. 4). Treatment of carfentrazone-ethyl in combination with glyphosate, however, caused significant increase in electrolyte leakage starting from 12 HAT. As applying carfentrazone-ethyl 1 day prior to glyphosate, greater change of the electrolyte leakage was obtained.

Our results obtained from these experiements reveal that total amount of [^{14}C]glyphosate absorbed does not greatly differ between the two weed species studied. However, there is a slight difference in translocation of [^{14}C]glyphosate after absorption. In *C. communis*, the absorbed [^{14}C]glyphosate was rapidly translocated from the treated leaf to other plant parts and roots, whereas most of [^{14}C]glyphosate was remained in cuticle of the treated leaf in *E. crus-galli*. Differential susceptibility of the two weed species to glyphosate may be partly attributed to difference in the translocation. On the other hand, absorption and translocation of [^{14}C]glyphosate were not greatly affected by the contact herbicide carfentrazone-ethyl that applied in mixture or 1 day prior to [^{14}C]glyphosate. In general, absorption and translocation of a systemic herbicide may be impaired by a contact herbicide when they are applied in mixture. This is due to cellular damage by the latter before absorption and translocation of the former oc-

Table 2. Translocation of ^{14}C in *Commelina communis* and *Echinochloa crus-galli* 10 days after application with [^{14}C]glyphosate alone or 0 and 1 day following application of 30 g a.i./ha carfentrazone-ethyl (Carf).

Treatment	^{14}C-recovered (% of applied)[1]		
	Treated leaf	Non-treated leaves	Roots
	C. communis		
[^{14}C]glyphosate	13.2 a	44.4 a	7.9 b
Carf+[^{14}C]glyphosate 0-day sequence	11.6 a	47.6 a	19.6 a
Carf+[^{14}C]glyphosate 1-day sequence	14.4 a	32.9 b	6.6 b
	E. crus-galli		
[^{14}C]glyphosate	26.1 b	7.5 b	5.1 b
Carf+[^{14}C]glyphosate 0-day sequence	41.4 a	12.8 b	4.0 b
Carf+[^{14}C]glyphosate 1-day sequence	36.5 a	20.7 a	10.9 a

[1]Means within columns for each weed species with the same letters are not significantly different at the 5% level by the LSD test.

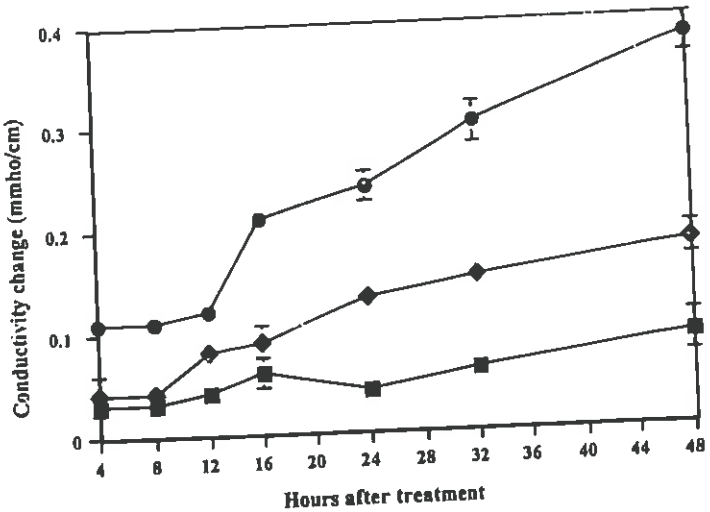


Fig. 4. Effect of carfentrazone-ethyl treated with glyphosate on cellular leakage from *C. communis* leaf disks. Symbols are as follows: ■ [^{14}C]glyphosate alone; ◆ [^{14}C]glyphosate+carfentrazone-ethyl; ● carfentrazone-ethyl followed by [^{14}C]glyphosate.

curs. As shown in Fig. 4, however, electrolyte leakage from *C. communis* leaf disks caused by carfentrazone-ethyl applied alone or in combination with glyphosate increased very slowly for 2 days after application. Therefore, cellular damage caused by carfentrazone-ethyl may not greatly affect absorption and translocation of glyphosate during this period.

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EFFECTIVENESS OF HERBICIDES AND SLASHING ON WEED CONTROL IN YOUNG RUBBER PLANTATIONS

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Abstract : Trials were conducted under young rubber of about three years old to evaluate the effectiveness of chemical weeding and slashing on weed control. In a trial along rubber planting strips, slashing with a motorised slasher required five rounds of weeding per year, while pre-mixed glyphosate (0.54 kg ae/ha) + dicamba (0.27 kg ae/ha) required four rounds per year and both glufosinate ammonium (0.5 kg ai/ha) and pre-mixed paraquat (0.6 kg ai/ha) + diuron (0.6 kg ai/ha) required six rounds per year. In a rubber forest plantation, evaluation of slashing versus application of glyphosate (2.16 kg ae/ha) + metsulfuron methyl (0.03 kg ai/ha) for about three years since planting as blanket treatment showed slashing resulted in higher mortality with rubber clones RRIM 623, PB 260 and RRIM 921. Slashing also resulted in smaller girth with all the three rubber clones compared with chemical weeding. In an another trial, karbutilate at 2.0, 3.2 and 4.8 kg ai/ha broadcasted in the planting circles provided effective control on general weeds and were not phytotoxic to the rubber trees. This herbicide was also effective on *Pennisetum polystachion* at 3.6 and 4.8 kg ai/ha. Evaluation of three glyphosate formulations at 1.08 and 2.16 kg ae/ha and imazapyr at 0.5 and 0.75 kg ae/ha showed that all treatments were effective on *P. polystachion*. Evaluation of herbicide and herbicide mixtures on mixed weeds showed that glyphosate (2.16 kg ae/ha) + metsulfuron methyl (0.03 kg ai/ha) was most effective compared to glyphosate (1.08 kg ae/ha) + metsulfuron methyl (0.03 kg ai/ha), paraquat (0.6 kg ai/ha) + metsulfuron methyl (0.03 kg ai/ha), pre-mixed paraquat (0.6 kg ai/ha) + diuron (0.6 kg ai/ha) and glufosinate ammonium (0.5 and 0.75 kg ai/ha).

Key words : rubber, herbicides, slashing, karbutilate, weed control

Introduction

Frequency of weeding is highest during the immature phase of rubber. This is due to the small canopy which allows abundant light to reach the ground and encourages abundant and luxuriant growth of weeds. Ineffective weed control will result in serious weed competition with the crop especially for nutrients and water. Serious weed competition retards growth and development of the crop and delays period to reach maturity. Weeds under rubber are generally controlled by herbicides as chemical weeding requires less labour and is generally more effective than manual weeding. Slashing of weeds is still practiced especially in rubber smallholdings. However, information on effectiveness of slashing on weed control, crop growth and development and weed succession is limited.

In rubber plantations, herbicides are applied by spraying. Application of granular herbicide by hand is not practiced in rubber plantations. Recently a granular herbicide karbutilate which can be broadcasted by hand was introduced for evaluation. This herbicide had been reported effective on some woody weeds (Scifres *et al.*, 1978; Young and Evans, 1978; Creager, 1990) and may have potential in rubber plantations. Advantages with hand application of herbicides include planters can do away with expensive spraying equipment and the herbicides can be applied together with fertilizers. However, this herbicide needs some soil moisture to be effective. Its potential on weed control under rubber should therefore be explored further as it may have potential in areas where water for spraying is a problem and also for spot treatment of weeds.

The herbicide mixture glyphosate + metsulfuron methyl has been reported effective on mixed weeds comprising of grasses and broad-leaves especially along planting strips (Chee,1989; Chung,1989; Faiz,1990). Information on tolerant weeds and comparison on effectiveness of this mixture compared with other herbicides and herbicide mixtures are, however, limited.

The objectives of the experiments were to determine the effectiveness of slashing versus herbicides on weed control and rubber growth; the effectiveness of karbutilate on mixed weeds and *P. polystachion*; and also to compare the efficacy of glyphosate plus metsulfuron methyl on mixed weeds.

Materials and Methods

Herbicides versus slashing

A trial was carried out under young rubber on sandy loam soil. Plot size was 100 m^2 and was unreplicated. The leguminous cover crops *Pueraria phaseoloides* and *Calopogonium caeruleum* were planted as mixtures prior to planting rubber. The treatments were slashing compared with pre-mixed paraquat (0.6 kg ai/ha) + diuron (0.6 kg ai/ha), glufosinate ammonium (0.5 kg ai/ha) and glyphosate (0.54 kg ae/ha) + dicamba (0.27 kg ae/ha). Visual assessment was carried out at periodic intervals on weed control and weed succession.

Another trial was carried out in a young rubber forest plantation in plots of 0.1 ha which contained about 100 trees per plot. The experimental design was a complete randomised block design with three replicates. The rubber trees comprised of clones PB 260, RRIM 623 and RRIM 921. Treatments were slashing compared with tank-mixed glyphostae (2.16 kg ae/ha) + metsulfuron methyl (0.03 kg ai/ha). Assessment was carried out after about three years from planting on tree survival and girth at 130 cm from soil surface.

Herbicides on weeds

Karbutilate on weeds

Two trials were carried out under young rubber of about three years old on sandy loam soil. The experimental design was a complete randomised design with three replicates. In the first trial, karbutilate was broadcasted in planting circles of 1.0 m diameter at rates of 2.0, 3.2 and 4.8 kg ai/ha. Periodic visual assessments were carried out on weed control and crop phytotoxicity.

In the second trial, karbutilate at 2.4, 3.6 and 4.8 kg ai/ha were hand broadcasted on to the soil in the interrows for controlling *P.polystachion*. The trial was conducted in plots of 10 m^2 with three replicates in a complete randomised design. Visual assessments were carried out at periodic intervals on weed control.

Glyphosate and imazapyr on P. polystachion

A trial was conducted in young rubber of about three years on sandy loam soil. Two commercial brands of glyphosate isopropylamine (Ecomax and Roundup) at 1.08 and 2.16 kg ae/ha, glyphosate trimesium at 1.08 and 2.16 kg ae/ha and imazapyr at 0.5 and 0.75 kg ae/ha were evaluated on *P. polystachion* in interrows. Plot size was 20 m^2 with three replicates arranged in a complete randomised design. Visual assessments on weed control were made at periodic intervals.

Herbicides/herbicide mixtures on mixed weeds

A trial was conducted in young rubber of about three years old on sandy loam soil. Glufosinate ammonium (0.5 and 0.75 kg ai/ha), glyphosate (1.08 kg ae/ha), pre-mixed paraquat (0.6 kg ai/ha) + diuron (0.6 kg ai/ha), tank-mixed paraquat (0.6 kg ai/ha) + metsulfuron methyl (0.03 kg ai/ha) and tank-mixed glyphosate (1.08 or 2.16 kg ae/ha) + metsulfuron methyl (0.03 kg ai/ha) were evaluated on control of mixed weeds in planting strips and interrows. Plot size was 100 m^2 arranged in a complete randomised design with two replicates. Periodic visual assessments on weed control and weed succession were carried out.

Results and Discussion

Herbicide versus slashing

In the first trial, frequency of weeding per year for the various treatments showed that slashing required five rounds while pre-mixed paraquat + diuron required six rounds, glufosinate ammonium five rounds and pre-mixed glyphosate + dicamba four rounds (Figure 1). High weeding frequency with pre-mixed paraquat + diuron was due to its contact mode of action which provided short term control. Glufosinate ammonium which is a contact herbicide, however, has some systemic activity (Kocher and Lotzsch, 1985) and probably

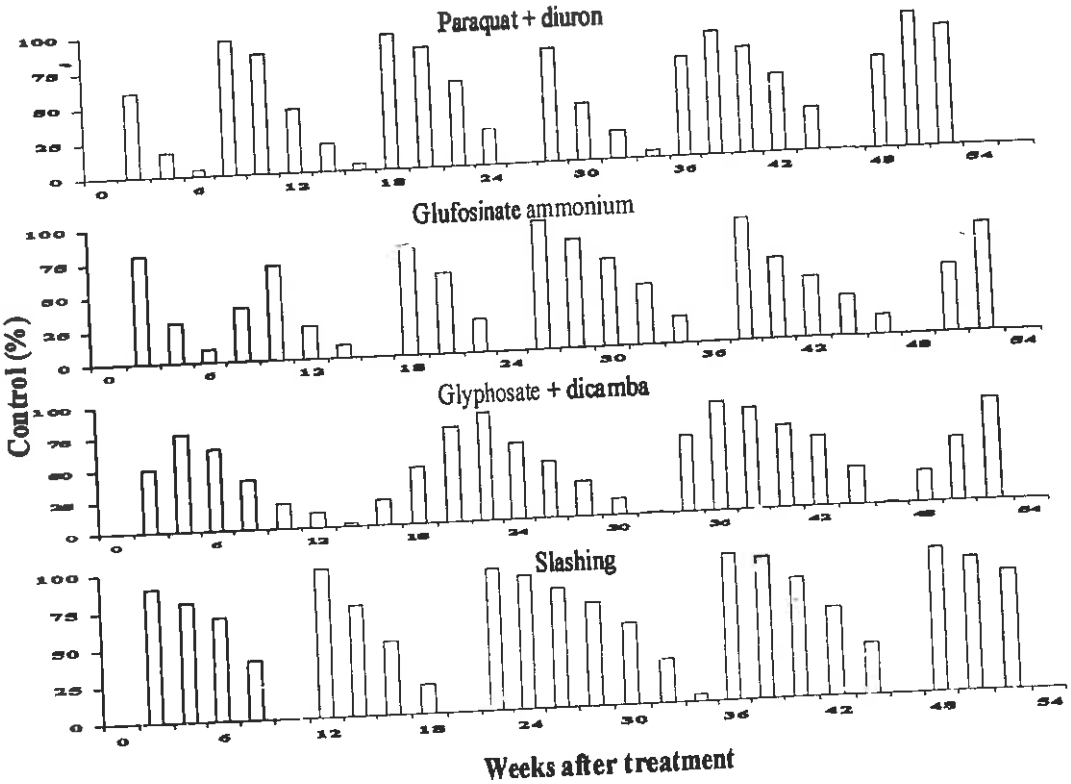


Figure 1. Effects of herbicides and slashing on weeding frequency under young rubber

contributed to the improved weed control. Slashing was comparable to glufosinate ammonium and was better than pre-mixed paraquat + diuron. Premixed glyphosate + dicamba which is systemic provided the most effective weed kill and the least number of weeding frequency. Effectiveness of pre-mixed glyphosate + dicamba on general weeds in young rubber agrees with other reports (Chee,1989; Chung,1989 and Faiz,1990, 1996).

Asystasia gangetica was the dominant weeds following these treatments. Some *Ottochloa nodosa* were also found in plots where the treatments were slashing, glufosinate ammonium and pre-mixed glyphosate + dicamba. Some legume covers were also present in the glyphosate + dicamba plots.

In the second trial, weed control by slashing or herbicide affected survival and girth of the rubber trees (Figure 2). Herbicide treatment resulted in higher survival and better girth of rubber trees compared to slashing . This was due to herbicides providing more effective weed control and hence allows better growth and development of the rubber trees in contrast with slashing.

Herbicides on weeds

Karbutilate on weeds

Broadcasting of karbutilate at 4.8 kg ai/ha in rubber planting circles provided complete control of weeds and effective control persisted for about three months. At 2.0 kg ai/ha it provided almost comparable control

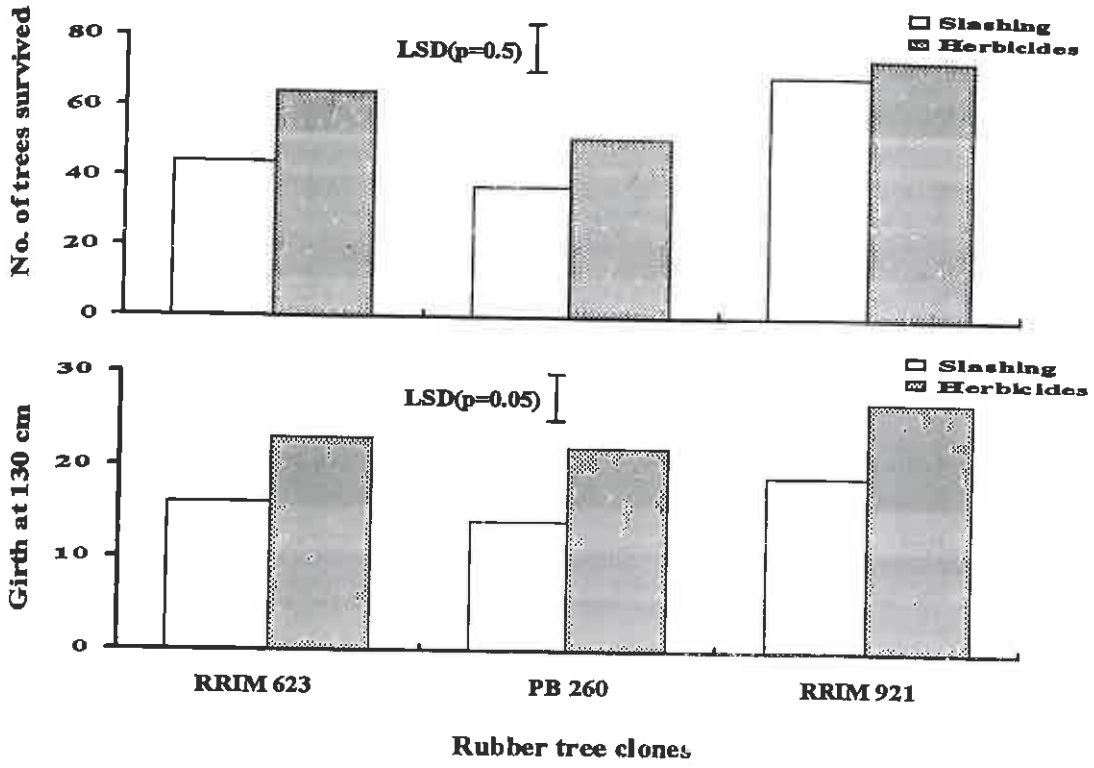


Figure 2. Effects of slashing and herbicides on survival and girth of rubber trees

as 3.2 kg ai/ha and good weed control persisted up to about two months. No phytoxicity effects were observed on the rubber trees.

P. polystachion was also susceptible to karbutilate and very effective control of the weed was obtained at 3.6 and 4.8 kg ai/ha. Complete aerial shoot kill persisted more than four months after treatment. Rate of 2.4 kg ai/ha was ineffective. Effectiveness of karbutilate on some woody shrubs have been reported (Scifres *et al.*, 1978; Young and Evans, 1978; Creager, 1990). Unlike spraying, hand broadcasting of herbicides can do away with expensive spraying equipment. However, some soil moisture is necessary for uptake of this herbicide by weeds and in dry areas or during a dry season this herbicide may not be effective.

Glyphosate and imazapyr on P. polystachion

Glyphosate isopropylamine, glyphosate trimesium and imazapyr gave complete control of the weed at 12 weeks after treatment at the rates tested. Imazapyr, however, showed slower initial kill compared with the glyphosate treatments. Effectiveness of glyphosate isopropylamine and imazapyr agrees with earlier reports (Faiz, 1994, 1996 and 1999). In the present study, lower rates of glyphosate at 1.08 kg ae/ha and imazapyr at 0.5 kg ae/ha were also very effective in controlling the weed probably due to the partial shade condition. No phytotoxicity symptoms of rubber trees were observed.

Table 1. Effects of herbicides and herbicide mixtures on weeds along planting strips

Treatment	Rate/ha	Mean % control			
		2 wks	6 wks	10 wks	14 wks
Glyphosate	1.08 kg ae	35	50	40	15
Glufosinate ammonium	0.5 kg ai	15	0	0	0
Glufosinate ammonium	0.75 kg ai	55	7	0	0
Paraquat + diuron	0.6 kg ai + 0.6 kg ai	60	20	5	0
Paraquat + metsulfuron methyl	1.08 kg ae + 0.03 kg ai	55	15	5	0
Glyphosate + metsulfuron methyl	1.08 kg ae + 0.03 kg ai	40	60	45	15
Glyphosate + metsulfuron methyl	2.16 kg ae + 0.03 kg ai	50	70	60	30
	LSD (p=0.05)	19.0	18.1	21.0	8.9

Herbicides/herbicide mixtures on mixed weeds

Glyphosate + metsulfuron provided more effective weed control than glufosinate ammonium, pre-mixed paraquat + diuron, tank-mixed paraquat + metsulfuron and glyphosate isopropylamine (Table 1). This mixture, however, was not effective on the ferns *Stenochlaena palustris* and *Nephrolepis biserrata* although slight effects on *Dicranopteris linearis* was observed. Poor effect of glyphosate on *S. palustris* had been reported (Faiz, 1991).

Conclusion

Pre-mixed glyphosate + dicamba required lower weeding frequency compared to slashing, glufosinate ammonium and pre-mixed paraquat + diuron. Tank-mixed glyphosate + metsulfuron methyl provided better weed control, less tree mortality and better girth compared with slashing in a rubber forest palntation. Karbutilate at 2.0, 3.2 and 4.8 kg ai/ha applied by hand broadcasting were effective on weeds in planting circles while at 3.6 and 4.8 kg ai/ha were effective on *P. polystachion* in the interrows. No phytotoxicity effect on the rubber trees was observed with these treatments. Glyphosate isopropylamine, glyphosate trimesium and imazapyr provided effective control of *P. polystachion*. Glyphosate + metsulfuron was effective on general weeds but not on the ferns *S. palustris* and *N. biserrata*.

Acknowledgements :

The author would like to thank Head of Crop Improvement and Protection Unit for editing the draft. Thanks are also due to En Zulkifly, En Segar and others who have assisted in one way or other for the success of the trials and also to MASTRA Corporation Sdn. Bhd. for providing karbutilate samples for evaluation.

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EFFICACY OF CLOMAZONE 36ME, SULFENTRAZONE 48SC AND SULFENTRAZONE 75DF IN DRY AND RAINY SEASON SOYBEAN *(Glycine max)*

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Abstract: The studies of efficacy of preemergence herbicides for weed control and soybean yield were carried out in Chiang Mai during December 1997-October 1998. The herbicides were applied as preemergence (1 day after crop seeding) with knapsack sprayer, flat nozzle in the spray volume of water 500 l/ha. It was found that clomazone 36ME [2-(2-chorophenyl)methyl-4,4-dimethyl-3-isoxazolinone] at the rate of 562.5-1,062.5 g ai/ha gave excellent control of annual grass weeds in dry and rainy season soybean. Annual broad-leaved weeds were moderately controlled by clomazone 36ME. Sulfentrazone 48SC or 75DF [N-(2,4-dichloro-5-(4-difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,3-triazol-1-yl)phenyl)methamesulfonamide] applied at the rate of 400-800 g ai/ha showed complete control of annual grass weeds broad-leaved weeds, and sedge during the first 45 days after application. The combination of sulfentrazone 48SC and clomazone 36ME could be used for general weed control. The application of sulfentrazone 48SC and 75DF provided excellent control of sedge but it caused some phytotoxicity to soybean. The use of clomazone 36ME, sulfentrazone 48 SC, and 75DF for preemergence weed control could increase yield of soybean compared to non weeded plot.

Key words: clomazone, sulfentrazone, soybean.

Introduction

Weed control in soybean production is the most important factor that can help increase yield. Weed competition significantly reduced yield of soybean. Vail and Lawrence (1993) reported that soybean yield reductions were 0 to 78% for densitities of 1 to 500 barnyard grass plants per meter of row. Application of herbicide for controlling weed is an essential method in soybean production. Both pre- and post-emergence herbicides have been recommended in soybean. Preemergence herbicides that have been used in Thailand are alachlor and imazethapyr (Tavee, et. al. 1996. Pornchai and Krisorn, 1995). Clomazone sulfentrazone in different formulation are the herbicides that have not been tested in thailand. The objectives of this research were to determine the efficacy of colomazone 36ME, sulfentrazone 48SC and 75DF in dry and rainy season soybean.

Material and Methods

Two field experiments were conducted in dry and rainy season soybean grown in Chiang Mai, Thailand during December 1997-October 1998. Soybeans (var. SJ.5 and CM60) were planted at the spacing 20×50 cm after soil preparation. A RCB design with 3 replications was used and plot size was 5×5 sq.m. Clomazone 36ME, sulfentrazone 48SC and 75DF were sprayed as preemergence at 1 day after planting to compare with alachlor and imazethapyr. All herbicides were applied with knapsack sprayer flat fan nozzle in the spray volume of water 500 l/ha. Weed control and phytotoxicity assessment were evaluated visually using the score 1-100%. Soybean yields were recorded at harvesting.

Results and Discussions

In experiment I (dry season soybean) major weeds found were *Echinochloa colona* (L.) Link., *Digitaria adscendens* H.B.K. Henr. *Eleusine indica* (L.) Gaertn *Ageratum conyzoides* L. and *Amaranthus spinosus* L. In experiment II (rainy season soybean), major weeds were *Eleusine indica* (L.) Gaertn *Digitaria adscendens* H.B.K. Henr., *Echinochloa colona* (L.) Link., *Ageratum conyzoides* L. *Amaranthus spinosus* L. and *Cyperus rotundus* L.

Herbicide efficacy

Weed control rating was evaluated by visual assessment at 15 30 and 45 days after application of herbicides. The results show in Table 1 and 2 indicate that the clomazone 36ME at the rate 562.5-1,062.5 g ai/ha gave excellent control of annual grass weeds and good control of broadleaf weed at 45 days after application. The use of sulfentrazone in the formulation 48SC or 75 DF at the rates 400-800 g ai/ha controlled 100% of both annual grass and broadleaf weeds. It was also found that the combination of sulfentrazone 48SC plus clomazone 36ME gave as good level as that of sulfentrazone applied alone.

Alachlor applied at the rate 1,500 g ai/ha had very good control of annual grass weeds at the first 15 days after application but it could slightly control annual broadleaf weeds. The use of imazethapyr resulted in more grass weeds than broadleaf weeds.

Table 3 and 4 indicate that weed dry weight per sq. m. at 30 days after apllication. It was found that the sulfentrazone 48SC or 75DF and sulfentrazone 48SC + clomazone 36ME could reduce 100% of both annual grass and broadleaf weeds, and sedge.

Crop injury

Phytotoxicity of soybean was evaluated at 7-30 days after herbicide application. The results are shown in Table 5 and 6. Clomazone 36ME 526.5-1,062.5 g ai/ha, alachlor 1,500 g ai/ha and imazethapyr 125 g ai/ha showed no injury to soybean during the first 30 days after treated. The results agree with reports of Tavee, et al (1996) and Mill and Witt (1989). Sulfentrazone in both formulations at the rate 400-800 g ai/ha caused some phytotoxicity to soybean at the first 30 days after application.

Yield of soybean

Table 5 summerized the results of soybean yield. The use of clomazone 36ME 526.5-1,062.5 g ai/ha for weed control in could produced yield 1,379.4- 1,490.6 kg/ha and 1,251.9-1,292.5 kg/ha in dry and rainy season, respectively. The application of sulfentrazone 48SC gave excellent control of general weed but it caused some phytotoxicity to soybean. It could producing soybean yield up to 1,451.9-1,470.6 kg/ha in dry season and 1,595.9 kg/ha in rainy season.

The use of sulfentrazone 75DF could increase yield up to 1,387.5-1,458.1 kg/ha and 1,66.8-1,756.9 kg/ha in dry and rainy season soybean respectively. The combination of sulfentrazone 48SC plus clomazone 36ME could produce more yield of soybean than clomazone 36ME used alone.

Summary

The studies of the application of preemergence herbicides in dry and rainy season soybean were carried out in Chiang Mai. Clomazone 36ME at 562.5-1,062.5 g ai/ha provided excellent control of annual grass weeds in both seasons but annual broadleaf weeds were moderately controlled by clomazone 36ME. Sulfentrazone 48SC and 75DF applied at 400-800 g ai/ha gave excellent control of annual grass weed, annual broadleaf weed and sedge but it caused some phytotoxicity to soybean after treated. The use of clomazone 36ME, sulfentrazone 48SC and 75 DF for general weed control in soybean gave similar yield to hand-weed plot.

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Table 1. Efficacy of preemergence herbicides for weed control in dry season soybean (Exp. I)

Herbicide	Rate	Control Rating[1/] Grass weed			Broadleaf weed		
	g ai/ha	15	30	45	15	30	45DAA[2/]
Clomazone 36 ME	526.5	10.0	9.8	9.3	8.2	8.2	7.6
Clomazone 36 ME	812.5	10.0	10.0	9.6	8.3	8.3	8.0
Clomazone 36 ME	1,062.5	10.0	10.0	9.7	8.3	8.4	8.0
Sulfentrazone 48SC	400	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 48SC	600	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 48SC	800	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 75DF	400	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 75DF	600	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 75DF	800	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 48SC+ Clomazone 36 ME	400+ 562.5	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 48SC+ Clomazone 36 ME	600+ 562.5	10.0	10.0	10.0	10.0	10.0	10.0
Alachlor	1,500	10.0	10.0	8.0	8.5	7.5	6.7
Imazethapyr	125	10.0	10.0	8.5	9.2	9.1	7.8
Hand weeding	-	-	-	-	-	-	-
Non weeding	-	-	-	-	-	-	-

[1/] Control Rating : 0 = No control, 10 = Completely control [2/] DAA : Days after application

Table 2. Efficacy of preemergence herbicides for weed control in rainy season soybean (Exp. II).

Herbicide	Rate	Control Rating[1/] Grass weed			Broadleaf weed		
	g ai/ha	15	30	45	15	30	45DAA[2/]
Clomazone 36 ME	526.5	10.0	9.9	9.9	6.3	6.0	5.3
Clomazone 36 ME	812.5	10.0	10.0	10.0	6.5	6.0	5.3
Clomazone 36 ME	1,062.5	10.0	10.0	10.0	7.0	6.21	5.3
Sulfentrazone 48SC	400	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 48SC	600	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 48SC	800	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 75DF	400	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 75DF	600	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 75DF	800	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 48SC+ Clomazone 36 ME	400+ 562.5	10.0	10.0	10.0	10.0	10.0	10.0
Sulfentrazone 48SC+ Clomazone 36 ME	600+ 562.5	10.0	10.0	10.0	10.0	10.0	10.0
Alachlor	1,500	10.0	8.7	8.0	6.4	6.5	5.5
Imazethapyr	125	10.0	9.5	8.5	9.0	8.2	7.2
Hand weeding	-	-	-	-	-	-	-
Non weeding	-	-	-	-	-	-	-

[1/] Control Rating : 0 = No control, 10 = Completely control [2/] DAA : Days after application

Table 3. Effect of preemergence herbicide on weed dry weigth (g/ 0.25m^2) at 30 days after application (Exp. I).

Herbicide	Rate g ai/ha	ECHCO	DIGAD	ELEIN	AGECO	AMASP
Clomazone 36 ME	526.5	0.3 c	0 c	2.7 c	5.8 b	12.4 bc
Clomazone 36 ME	812.5	0 c	0 c	1.3 c	6.0 b	12.7 b
Clomazone 36 ME	1,062.5	0 c	0 c	0 c	5.2 b	6.9 c
Sulfentrazone 48SC	400	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 48SC	600	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 48SC	800	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 75DF	400	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 75DF	600	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 75DF	800	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 48SC+ Clomazone 36 ME	400+ 562.5	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 48SC+ Clomazone 36 ME	600+ 562.5	0 c	0 c	0 c	0 c	0 c
Alachlor	1,500	1.7 b	3.7 b	7.9 b	7.1 b	12.5 bc
Imazethapyr	125	0 c	0 c	0 c	5.2 b	9.0b
Hand weeding	-	0 c	0 c	0 c	0 c	0 c
Non weeding	-	11.7 a	32.8 a	20.5 a	40.4 a	70.3 a
C.V.		41.54%	33.03%	83.36%	26.17%	41.91%

ECHCO : *Echinochloa colona* (L.) Link., DIGAD : *Digitaria adscendens* H.B.K. Henr.,
ELEIN : *Eleusine indica* (L.) Gaerth., AGECO : *Ageratum conyzoides* L.,
AMASP : *Amaranthus spinosus* L.

Table 4. Effect of preemergence herbicide on weed dry weigth (g/ 0.25m^2) at 30 days after application (Exp. II).

Herbicide	Rate g ai/ha	ELEIN	DIGAD	ECHCO	AMASP	AGECO	CYPRO
Clomazone 36 ME	526.5	0 c	0 c	0 c	23.8 c	25.7c	13.6 c
Clomazone 36 ME	812.5	0 c	0 c	0 c	19.2 c	27.1 c	18.4 c
Clomazone 36 ME	1,062.5	0 c	0 c	0 c	16.5 cd	25.3 c	13.5 c
Sulfentrazone 48SC	400	0 c	0 c	0 c	0 c	0c	0 d
Sulfentrazone 48SC	600	0 c	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 48SC	800	0 c	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 75DF	400	0 c	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 75DF	600	0 c	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 75DF	800	0 c	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 48SC+ Clomazone 36 ME	400+ 562.5	0 c	0 c	0 c	0 c	0 c	0 c
Sulfentrazone 48SC+ Clomazone 36 ME	600+ 562.5	0 c	0 c	0 c	0 c		0 c
Alachlor	1500	8.6 b	80.5 b	57.3 b	50.3b	76.8 b	20.6 b
Imazethapyr	125	0 c	0 c	0 c	6.0 de	8.8.d	0 d
Hand weeding	-	0 c	0 c	0 c	0 e	0 e	0 d
Non weeding	-	85.3 a	108.1 a	84.0 a	88.9 a	88.5 a	46.3 a
C.V.		21.17%	84.08%	88.63%	52.97%	31.04%	81.68%

ELEIN : *Eleusine indica* (L.) Gaertn., DIGAD : *Digitaria adscendens* H.B.K. Henr.,
ECHCO : *Echnochloa colona* (L.) Link., AMASP : *Amaranthus spinosus* L.
AGECO : *Ageratum conyzoides* L., CYPRO : *Cyperus rotundus L.*

Table 5. Effect of preemergence herbicide on phytotoxicity and yield of dry season soybean (Exp.I).

Herbicide	Rate g ai/ha	Phytotoxicity Rating[1/] 7	15	30 DAA[2/]	Yield Kg/ha
Clomazone 36 ME	526.5	0	0	0	1,379.4 b
Clomazone 36 ME	812.5	0	0	0	1,435.6 ab
Clomazone 36 ME	1,062.5	0	0	0	1,420.6 ab
Sulfentrazone 48SC	400	2.0	2.0	1.5	1,451.9 ab
Sulfentrazone 48SC	600	2.5	2.0	1.5	1,475.0 ab
Sulfentrazone 48SC	800	2.7	2.0	2.0	1,470.6 ab
Sulfentrazone 75DF	400	1.7	1.0	1.0	1,429.4 ab
Sulfentrazone 75DF	600	2.5	1.5	1.0	1,458.1 ab
Sulfentrazone 75DF	800	2.5	2.0	1.0	1,431.25 b
Sulfentrazone 48SC+	400+	1.7	1.5	1.0	1,387.5 b
Clomazone 36 ME	562.5				
Sulfentrazone 48SC+	600+	2.3	2.0	1.0	1,393.8 b
Clomazone 36 ME	562.5				
Alachlor	1,500	0	0	0	1,464.4 ab
Imazethapyr	125	0	0	0	1,443.8 ab
Hand weeding	-	-	-	-	1,551.9 a
Non weeding	-	-	-	-	583.1 c
C.V.					6.48%

[1/] Phytotoxicity Rating : 0 = No injury, 10 = Completely killed
[2/] DAA : Days after application.

Table 6. Effect of preemergence herbicide on phytotoxicity and yield of rainy season soybean (Exp.II).

Herbicide	Rate g ai/ha	Phytotoxicity Rating[1/] 7	15	30 DAA[2/]	Yield Kg/ha
Clomazone 36 ME	526.5	0	0	0	1,251,9 d
Clomazone 36 ME	812.5	0	0	0	1,296.9 d
Clomazone 36 ME	1,062.5	0	0	0	1,292.5 d
Sulfentrazone 48SC	400	2.2	2.0	1.5	1,595.6 bc
Sulfentrazone 48SC	600	2.3	2.2	1.5	1,658.1 bc
Sulfentrazone 48SC	800	2.5	2.8	1.7	1,666.9 bc
Sulfentrazone 75DF	400	2.2	2.3	1.3	1,666.8 c
Sulfentrazone 75DF	600	2.2	2.3	1.4	1,756.9 ab
Sulfentrazone 75DF	800	2.3	2.5	1.6	1,704.4 ab
Sulfentrazone 48SC+	400+	2.2	2.5	1.5	1,701.3 a-c
Clomazone 36 ME	562.5				
Sulfentrazone 48SC+	600+	2.3	2.0	1.7	1,603.1 bc
Clomazone 36 ME	562.5				
Alachlor	1,500	0	0	0	1,227.5 d
Imazethapyr	125	0	0	0	1,540.6 c
Hand weeding	-	-	-	-	1,853.7 a
Non weeding	-	-	-	-	602.5 c
C.V.					6.46%

[1/] Phytotoxicity Rating : 0 = No injury, 10 = Completely killed [2/] DAA : Days after application.

FIELD EVALUATION OF FLUFENACET FOR WEED CONTROL IN PHILIPPINE RICE PRODUCTION CONDITION

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Abstract: Flufenacet was evaluated during the 1997 wet season and 1998 dry and wet seasons, in two separate trials namely 1) Efficacy against weeds infesting irrigated lowland transplanted rice and 2) Efficacy against weeds infesting dry seeded rice. In the first experiment, the product at the rates of 75, 100 and 125 grams a.i./ha were tested in five(5) locations from 1997-1998, following split –plot experimental design with six treatments and four timings of application, while in the second experiment, the product was tested at the rates of 180, 240 and 300 grams a.i./ha following randomized complete block design. Results *of the first experiment showed that flufenacet* at the rate of 100-125 grams a.i./ha and applied at 2-4 DAT effectively controlled jungle rice (*Echinocloa colona, (L) Link), barnyard grass (Echinocloa crus-galli(l.) Beauv.), sprangletop (Leptochloa chinensis (l.) Nees)* smallflower umbrellaplant,*(Cyperus difformis L.), rice flatsedge (Cyperus iria L.)* , gooseweed (*Sphenoclea zeylanica* Gaertn.) and monochoria (*Monochoria vaginalis (Burm.f.)Presl)* infesting lowland transplanted rice and was comparable with butachlor . However under heavy monochoria infestation (>50%), the product provided marginal efficacy. Slight phytotoxicity was observed, however, seedlings recovered after 15 days after application (DAA). On yield, data showed that the plots treated with flufenacet at 100-125 grams a.i./ha provided better grain yield than Butachlor . Results of the second experiment showed that flufenacet at the rate of 180-300 grams a.i./ha and applied at 4 days after true wetness (DATW) was comparable with butachlor and oxadiazon for the control of jungle rice and smallplant umbrella plant No crop injury was observed in all plots treated with flufenacet as compared with the reference treatments. Yield obtained from plots treated with flufenacet at 240-300 grams a.i./ha was comparable with that of butachlor and oxadiazon.

Key words: flufenacet, butachlor, oxadiazon, dry seeded rice , phytotoxicity

Introduction

Weed infestations primarily constrain rice production by reducing grain yield. In the Philippines, yield reductions caused by uncontrolled weed growth throughout a crop season have been estimated to be from 44 to 96%, depending on the rice culture (IRRI, 1991). In general, almost all farmers practice weed control hence herbicides have become a component of rice production. Herbicides, therefore, which can offer broad spectrum of control offer great advantages to the rice farmer. In 1988, Bayer, developed a high technology herbicide which can economically control important grasses and small dicotyledonous weeds. The active ingredient, flufenacet , which belongs to oxyacetamide group of herbicides is selective in action and can be applied more than half the rates of the available standard herbicides. This study was conducted to determine efficacy of flufenacet against common weeds infesting lowland transplanted irrigated and dry seeded rice in the Philippines.

Materials and Methods

First experiment

The trial was conducted in lowland transplanted irrigated rice following split-plot design with four replication and four timings of application namely, 0, 2, 4 and 6 days after transplanting (DAT).Spray

volume used in the experiment was 160-300 l water/ha. The treatments used and respective rates of applications are as follows:

Treatments	Rate of application Grams a.i./ha
Flufenacet (Drago 60 WP, 60% a.i.)	75
Flufenacet (Drago 60 WP, 60 % a.i)	100
Flufenacet (Drago 60 WP, 60% a.i.)	125
Butachlor (Bolo 600 EC, 60 % a.i.)	600
Handweeding	20 and 40 DAT
Untreated	

Second experiment

The trial was conducted on dry seeded rice following randomized complete block design (RCBD) with four replications. The compounds were applied at four (4) days after true wetness (DATW) using a spray volume of 300 l water /ha. The treatments used are as follows:

Treatments	Rate of application Grams a.i./ha
Flufenacet (Drago 60 WP, 60% a.i.)	180
Flufenacet (Drago 60 WP, 60% a.i.)	240
Flufenacet Drago 60 WP, 60% a.i.)	300
Butachlor Bolo 600 EC, 60% a.i.	2000
Oxadiazon (Ronstar 250 EC, 25 % a.i.)	500
Handweeded	20 and 40 DATW
Untreated	

Results and Discussion

First experiment

Flufenacet, applied at 2-4 DAT timings at the rate of 100-125 g a.i./ha provided excellent control of jungle rice, barnyard grasss and spragletop, and was slightly better than the reference treatment, butachlor . The compound applied at 2-6 DAT at the above mentioned rates, likewise provided excellent control of the smallflower umbrella plant and rice flatsedge and was comparable with butachlor .For the control of gooseweeds, flufenacet applied at 4 and 6 DAT at the rate of 75-125 g a.i./ha performed better than butachlor. At 2 DAT, flufenacet applied 100-125 g a.i/ha was comparable with butachlor. Against monochoria, flufenacet applied at 100-125 g a a.i./ha at 4 DAT, provided excellent control and was comparable with the reference treatment. When applied at 2 DAT using the above rates, flufenacet provided satisfactory control of monochoria(Table 1). However, under heavy monochoria infestation (>50%) flufenacet provided very poor to poor control at 2 DAT but offered satisfactory control at 4 DAT timing of application

Slight phytotoxicity of flufenacet applied at 75-125 g a.i./ha was observed on dapog seedlings during the wet and dry season trials. However, seedlings recovered after 15 days after last application DAA). On wetbed, slight phyto was observed in one location during the wet season trials and symptoms were no longer visible at 15 DAA.

Yield data shows that plots treated with flufenacet at the rate of 100-125 g a.i./ha had better yield than butachlor. At the rate of 75 g a.i./ha, yield was comparable with the reference treatment

Second experiment

Flufenacet applied at 180, 240 and 300 grams a.i./ha provided good to very good control of jungle rice and excellent control of smallflower umbrellaplant when applied at 4 DATW and was comparable with butachlor and oxadiazon. Against long fruited primrose willow (*Ludwigia octovalvis* Jacq.) Raven), flufenacet provided good weed control but was slightly inferior to butachlor.

On phytotoxicity, plots treated with flufenacet at 180-300 grams a.i./ha did not exhibit phytotoxic symptoms at 3, 7 and 15 DAA observations. On the other hand, plots treated with butachlor and oxadiazon exhibited crop injury symptoms up to 7 and 15 DAA respectively.

Yield data shows that plots treated with flufenacet at 240-300 grams a.i./ha had comparable yield with the reference treatments.

Table 1. Percent weed control of flufenacet at different timings and rates of application on lowland transplanted irrigated rice and respective grain yield. 5 Registration Trials Philippines. August 1997-March 1998.

Treatment/Timing of application	Rate Grams a.i./ha	Yield Tons/na	% Efficacy at 45/50 DAA Evaluation			
0 DAT			*Echinoclon spp./ Leptochloa spp*	*Cyperus spp.*	*M.vaginalis*	*S. .zeylanica*
Flufenacet	75	4.48	82.3	76	75	84.56
Flufenacet	100	4.53	84	78	75	83.21
Flufenacet	125	4.61	90.25	84	75	85
Butachlor	600	4.86	95.35	98	94.25	85.56
Handweeded		4.89	96.5	98.6	97.25	96.3
Untreated (% Weed infest.)		1.51	14.-83.5%	1-15%	6-53%	11-25%
2 DAT						
Flufenacet	75	4.3	91.35	91	89	91
Flufenacet	100	4.58	94.75	97.15	93.2	94
Flufenacet	125	4.69	97.5	98	96	95
Butachlor	600	4.82	93.6	98	96	94
Handweeded		4.98	97.5	98	97.6	96
Untreated %Weed infest.)		1.65	16- 91.75%	1.5-16%	8-42%	15-32%
4 DAT						
Flufenacet	75	4.4	92.4	98	93.2	92.25
Flufenacet	100	4.9	96	98	96.4	94
Flufenacet	125	5.05	98	98	96.4	95
Butachlor	600	4.55	90.1	98	93.8	86.2
Handweeded		4.96	98	98	95.35	96
Untreated (% Weed infest.)		1.5	24-80%	1.6-1.8%	7-16%	15-34%
6 DAT						
Flufenacet	75	3.62	82.5	92	51.8	80
Flufenacet	100	4.24	87	96	78.8	88
Flufenacet	125	4.37	89	98	82.2	92
Butachlor	600	2.57	58	98	52.75	53
Handweeded		5.05	99	98	97.35	96
Untreated (% Weed infest.)		1.17	24-91.25%	9-18%	11-19%	12-37.5%

Table 2. Percent weed control of flufenacet at different dosages when applied at 4 DATW on dry seeded rice and respective grain yield. Philippines. 1998 Wet Season

Treatment	Rate Grams a.i./ha	Yield Tons/ha	% Efficacy at 45 DAA Evaluation		
			E. colona	*Cyperus spp.*	*L. octovalvis*
Flufenacet	180	2.92c	88.25d	93.75	85d
Flufenacet	240	3.24bc	90.5bcd	93.75	85d
Flufenacet	300	3.3bc	89.25cd	94.4	86.5d
Butachlor	2000	3.6abc	86d	95.63	91.25c
Oxadiazon	500	3.5abc	89.75bcd	93.75	100a
Handweeded		4.3a	100a	100	100a
Untreated(% weed infestation)		1.07	10.75%	3.5-12.5%	51.25%

Acknowledgement: Bayer Philippines Inc., wish to acknowledge the researchers and their respective staff for their outmost cooperation during the conduct of the trials.

Reference: IRRI, 1991
Moody et. al, 1984

INTERACTION BETWEEN A PROPANIL-CONTAINING HERBICIDE AND AN ORGANOPHOSPHATE INSECTICIDE ON RICE (*Oryza sativa* L)

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Abstract: The present study evaluated the interaction between a propanil-containing herbicide thiobencarb 400 g a.i./l + propanil 200 g a.i./l (Satunil EC, 60% a.i.) and an organophosphate (OP) insecticide dimethoate [O,O-dimethyl-S(N-methylcarbomoylmethyl) phosphorodithioate] on weed control efficacy, and growth and development and yield of lowland rice (*Oryza sativa* L).

During the first 50 days after sowing (DAS) rice, thiobencarb+propanil successfully controlled grasses such as *Echinochloa crus-galli*, but sedges such as *Cyperus iria* dominated the rice fields treated with the herbicide. The total weed biomass in the plots treated with the herbicide alone at 50 days after sowing was 70% low when compared to the un-weeded control. Application of dimethoate within 7 days before or after application of did not affect the weed control efficacy of the herbicide. Application of dimethoate on the same day, or 2 days prior or after application of thiobencarb+propanil resulted in a death of 6% of the rice plants. Scorching symptoms were observed in 28% of the plants but they recovered within 8-10 days. Mild phytotoxic symptoms were not observed when the OP insecticide was applied 4 days before or after application of the herbicide. The vegetative growth and yield of rice plant were significantly low ($p<0.05$) in the plots that received both pesticides on the same day. Plots treated only with thiobencarb+propanil recorded the highest yield, which was 180% higher than the un-weeded control. The results indicated that thiobencarb+propanil control grasses effectively, and thus increase rice yields. Application of OP insecticides should be avoided within 4 days before or after application of thiobencarb+propanil as it could be detrimental to rice plants.

Key words: Propanil-containing herbicide, Satunil, Dimethoate, interactions, rice, weed control

Introduction

Among the grass killers, propanil is widely used in lowland rice cultivation in Sri Lanka (Amarasinghe, 1986) due to its selective control of Barnyard grass (*Echinochloa crus-galli* L Beauv.) and usually causes no significant injurious effects to rice plant. However, Bowling and Flinchum (1968) reported that although rice is quite tolerant to propanil, the herbicide may severely injure the crop when certain carbamate or organophosphate insecticides are sprayed within 7 days of application. Smith and Tugwell (1975) reported that propanil and carbofuran (a carbamate insecticide) interacted adversely in rice causing chlorosis and necrosis when the insecticide was applied within 5 days after the herbicide. Khodayari *et al.* (1986) reported that carbamate and organophosphate insecticides could be phytotoxic to rice plants when they were applied two days before propanil.

A herbicide formulation containing thiobencarb 400 g a.i./l + propanil 200 g a.i./l (Satunil EC, 60% a.i., Kumiai Co. Ltd, Japan; Lankem (Ceylon) Ltd, Sri Lanka) is currently been used in Sri Lanka as an alternative to propanil to control *E. crus-galli* and several other weed species. However, due to presence of propanil, even at relatively low quantities when compared to other generally used propanil herbicides (36% w/v), this may also injure rice plants when applied with Organophosphate of Carbamate insecticides within short time intervals. Thus, prevention of any injury to rice as a result of interactions between herbicide and insecticides is considered to be important.

Therefore, the present study was conducted to determine the interactions of the herbicide formulation thiobencarb 400 g a.i./l + propanil 200 g a.i./l (Satunil EC, 60% a.i.) with an organophosphate insecticide on weed control and growth, development and yield of rice.

Materials and Methods

The experiment was conducted at the Research field of the University Unit, Mahailluppallama, Sri Lanka. The site is located in the North Dry Zone at 138 m above sea level. The rainfall during the study period was 125 mm and the mean temperature was 30.3°C (maximum). The soil was reddish brown loamy.

Rice (*Oryza sativa* L) variety BG 300 (3 month old) was sown at a rate of 140 kg/ha in plots at a size of 6*3 m². Mature seeds of *Echinochloa crus-galli* was broadcasted at a rate of 0.02 kg/plot. thiobencarb 400 g a.i./l + propanil 200 g a.i./l (Satunil EC, 60% a.i.) and dimethoate [O,O-dimethyl-S(N-methylcarbomoylmethyl) phosphorodithioate] supplied by the Lankem (Ceylon) Ltd., Colombo, Sri Lanka, were used as the propanil-containing herbicide and the Organophosphate (OP) insecticide, respectively. The herbicide was applied at the 3-leaf stage of *E. crus-galli* (*i.e.* 10 days after sowing rice - DAS) at a rate of 5 l/ha (spray volume 350 l/ha). The OP insecticide was applied at different time intervals ranging from 7 days before to 7 days after application of the herbicide at a rate of 550 ml/ha (spray volume 400 l/ha). The pesticides were applied using a knapsack sprayer. Plots without pesticide or weeding were maintained as controls. All the cultural practices were carried out as recommended by the Department of Agriculture, Sri Lanka, but MCPA was not applied at 21 days after sowing of rice as the herbicide formulation is expected to control all the weed species successfully (Anon, 1996).

The experiment was carried out in a randomized complete block design with three replicates. The outermost strip of 30 cm in each plot was considered as the border row. Sampling was done at 30, 50 and 70 DAS by using a 50*50 cm² quadrant. Weed biomass, and above ground dry weight, and yield of rice were recorded. Phytotoxicity symptoms were recorded according to the guidelines given by the Food and Agricultural Organization of United Nations (FAO, 1991) and modifications in leaf colour was considered as the index. The scale used in the experiment is given in Table 1. A separate area of 4 m² was harvested from the centre of each plot to measure the actual yield.

Table 1. Ranked scale for the assessment of phytotoxicity.

Percentage rating	Effects
0	non-evident
10	negligible discolouration
20	slight yellowing
30	moderate yellowing
40	fairly high yellowing
50	Substantial yellowing with symptoms of necrosis
60	Moderate necrosis
70	Substantial necrosis with less than 10% plant mortality
80	Severe necrosis with 10-20% plant mortality
90	Very heavy plant damage with 20-40% mortality
100	Complete kill of plants

Results and Discussion

Weed biomass

The dominant weed species in the un-weeded control were *Echinochloa crus-galli*, *Ischaemum rugosum* and *Leptochloa chinensis* (Grasses), *Cyperus iria* and *Fimbristylis miliacea* (Sedges), and *Ludwigia octovalvis* (Broadleaved weeds). The biomass of all grasses, sedges and broadleaves were reduced by 89%, 56% and 42%, respectively, with the application of herbicide alone when compared to the un-weeded control (Table 2). The efficacy of weed control of the thiobencarb+propanil formulation was not affected by application of dimethoate within 7 days before or after application of the herbicide.

Table 1. Weed biomass (g/m²) at 50 days after sowing rice.

Treatment	Grasses	Sedges	Broadleaves
Un-weeded control	36.6 a	34.8 a	6.9 a
Thiobencarb+propanil	3.9 b	15.3 b	4.0 b
Dimethoate			
7 days before herbicide	3.6 b	15.7 b	3.8 b
4 days before herbicide	2.8 b	14.8 b	4.5 b
2 days before herbicide	3.6 b	14.5 b	3.0 b
sameday with herbicide*	2.9 b	18.0 b	3.4 b
2 days after herbicide	2.9 b	16.2 b	3.1 b
4 days after herbicide	4.2 b	14.0 b	4.2 b
7 days after herbicide	3.8 b	16.7 b	3.0 b

* Dimethoate was applied soon after application of herbicide. Within each column, treatment means followed by same letter are not significantly different by the Duncan's New Multiple Range test at p=0.05.

Phytotoxic effects on rice

Phytotoxic symptoms were observed in rice plants when Dimethoate was applied on the same day, and 2 days before or after application of the herbicide. A plant mortality (ranked scale: cumulative from 70-100) of 11% was observed when both the insecticide and herbicide were applied on the same day while the mortality was 5-8% when the insecticide was applied 2 days before or after application of the herbicide (Fig. 1). It is well known that injury from the interaction between insecticides and propanil or propanil-containing herbicides is caused by the inhibition of the enzyme aryl-acylamidase in rice leaves that detoxifies propanil (Matsunaka, 1983). Chlorosis followed by necrosis and plant death is the characteristic symptom of propanil toxicity in susceptible plants (Floyd *et al.*, 1981). No plant mortality was observed in other treatments.

Symptoms of necrosis was recorded at the highest degree (ranked scale : cumulative from 50-90) in 28% of the plants when both pesticides were applied on the same day (Fig. 1). Mild symptoms were observed when the time difference between the application of the insecticide and herbicide was 4 days (ranked scale: cumulative from 10-30). The insecticide acted adversely when applied 2 days after application of the propanil-containing herbicide when compared to spraying 2 days before the herbicide resulting in resulting in 56% higher plant mortality than the latter. The plants that showed yellowing or necrosis recovered after 4-8 days (Fig. 2).

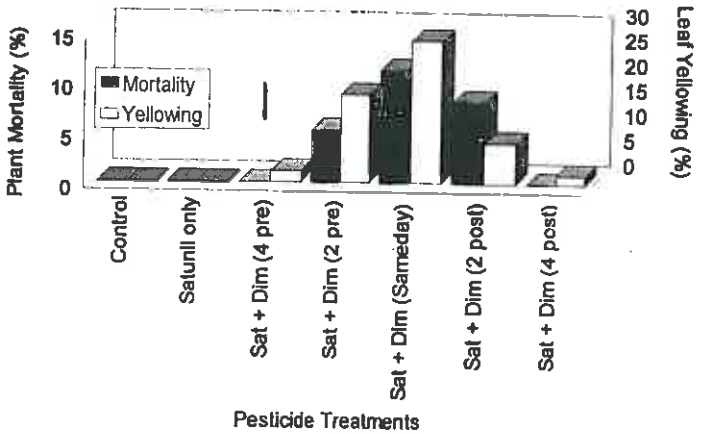


Figure 1. Phytotoxic symptoms on rice plant when the organophosphate insecticide was applied before (pre) or after (post) spraying the herbicide. Vertical bar indicate the least significant difference at p=0.05

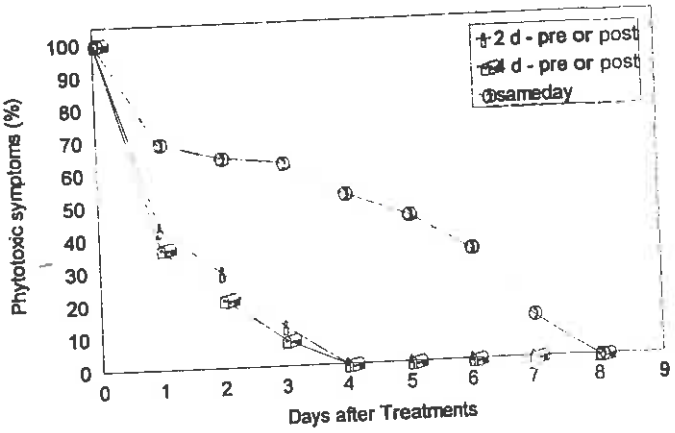


Figure 2. Recovery of plants that showed leaf yellowing as a result of the application of the organophosphate insecticide at different time intervals before (pre) or after (post) spraying the herbicide.

Above ground dry weight

The dry weight of above ground vegetative parts was the highest in plots treated only with thiobencarb + propanil (897 g/m²) which was 29% higher than that of the un-weeded control (Table 3). Decreasing time difference between application of pesticides significantly reduced the above ground dry weight. The lowest dry weight was recorded when both the pesticides were applied on the same day. In general application of dimethoate after the herbicide resulted in lower plant dry weight when compared to application before the herbicide.

Dry matter production in plants is highly correlated with the leaf area development (Matsushima, 1966). In agreement with previous studies, the low above ground dry matter observed in rice plants grown in plots where dimethoate was applied on the same day and, 2 days before or after thibencarb + propanil could be due to the low photosynthetically active leaf area, and the considerable phytotoxicity of the combination of pesticides.

Table 2. Above ground dry weight (g/m²) of rice.

Treatment	30 DAS	50 DAS	70 DAS
Un-weeded control	128 a	345 b	694 a
Thibencarb+propanil	167 a	400 a	897 a
Dimethoate			
7 days before herbicide	148 a	397 a	882 a
4 days before herbicide	130 ab	377 a	845 a
2 days before herbicide	102 c	272 c	700 c
sameday with herbicide*	71 d	191 d	453 d
2 days after herbicide	95 d	253 c	562 d
4 days after herbicide	120 b	330 b	812 b
7 days after herbicide	147 a	363 ab	865 a

* Dimethoate was applied soon after application of Satunil. Within each column, treatment means followed by the same letter are not significantly different by Duncan's New Multiple Range test at p=0.05.

Grain yield of rice

The grain yield was the lowest in un-weeded control (Fig. 3). The highest grain yield was observed in the plots treated only with the herbicide, which was 180% higher than that of the un-weeded

control. Application of Dimethoate on the same day with the herbicide resulted in a 61% decrease in grain yield when compared to plots treated only with the herbicide only. The phytotoxicity of the pesticide combination observed during the vegetative growth of rice may be attributable to the final yield losses of the crop (Velmurugu, 1980; Marambe and Sangakkara, 1996). Application of Dimethoate at 2 days prior or after thiobencarb+propanil gave statistically non-significant yield differences with the plots treated with both pesticides on the same day.

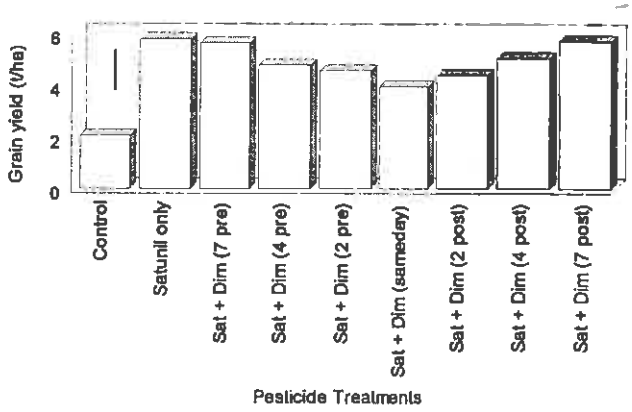


Figure 3. Grain yield of rice when the organophosphate insecticide was applied at different time intervals before (pre) or after (post) spraying the herbicide. Vertical bar indicate the least significant difference at p=0.05.

Conclusions

The results of the present experiment indicate that thiobencarb 400 g a.i./l + propanil 200 g a.i./l (Satunil EC, 60% a.i.) effectively controls grasses such as *Echinochloa crus-galli* in lowland rice cultivation but not the sedges and broadleaved weeds. Application of organophosphate insecticides such as dimethoate [O,O-dimethyl-S(N-methylcarbomoylmethyl) phosphorodithioate] between 2-4 days before or after spraying of the propanil-containing herbicide should be avoided due to detrimental effects of the combination of pesticides on rice plants.

Acknowledgements:

The author wishes to thank Messrs. Lankem (Ceylon) Limited for the supply of chemicals and financial assistance to carry out the research project. Assistance provided by Mr. Samantha Rosa is very much appreciated.

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INTERACTIONS OF METSULFURON-METHYL AND GLYPHOSATE APPLIED TO FOLIAGE OF WOODY BORRERIA (*Diodia ocimifolia*)

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Abstract: Greenhouse experiments were conducted to determine interactions of metsulfuron-methyl and glyphosate on *Diodia ocimifolia*. The percent growth inhibition of *Diodia* plants increased correspondingly with increasing dosages of metsulfuron-methyl and glyphosate. The inhibition dosage (ID_{50}) for metsulfuron-methyl and glyphosate on *Diodia* is estimated at around 7.5 g a.i./ha and 270 g a.i./ha respectively. The fresh weight data indicated that metsulfuron-methyl and glyphosate mixtures were more effective than each herbicide used alone. Metsulfuron-methyl at low dosages of 3.75, 7.5 and 15 g a.i./ha in the 1:36 metsulfuron-methyl and glyphosate mixture gave a synergistic interaction between the two herbicides. However, in the 1:72 mixtures, the interaction response analyzed using Colby's formula became additive. The same response was obtained with the 1:18 mixtures. This could be due to extremely high dosages where both herbicides may mutually restrict translocation and availability of metabolites, thus decreasing activity of the mixtures. The results indicate that the combination for optimum performance was the 1:36 mixture.

Key words: metsulfuron-methyl, *Diodia ocimifolia*, Colby's formula, synergistic, additive.

Introduction

Diodia ocimifolia is one of the noxious perennial weeds fast assuming importance in recent years in Malaysian plantations. The potential for greater spread and dominance is evident, given its high seedling capacity and density. Presently, herbicides are the only means of control. Metsulfuron-methyl (ALLY®), a sulfonylurea, was found to be effective for the control of this weed (Ong and Teo, 1990; Chee *et al*, 1993).

Application of two or more herbicides, simultaneously or sequentially, is a very common approach for weed management. The concept that optimum weed management systems could employ multiple herbicides, rather than a single herbicide, was a fundamental advance in use of these herbicides. This, in turn, has led to the concept of 'prescription weed control', where the actual components and amounts in a herbicide mixture are specifically tailored to the unique environment, weed population, and crop situation within a field. The simplest example of a herbicide mixture for prescription weed control is where a herbicide primarily effective against broadleaf (dicotyledonous) weeds is combined with an herbicide primarily effective against grass (graminaceous) weeds. The widely used combination of metsulfuron-methyl and glyphosate for broadleaf and grass weeds in oil palm plantation is an example of such a combination.

An important consideration for using herbicide mixtures is the reduced rates of the individual components used in a mixture in comparison of the rates required if only one herbicide is utilized to control the mixed weed population. Decreasing herbicide rates has the direct advantages of decreasing the danger of crop damage by the herbicide. Herbicide persistence in the environment, particularly the

soil, is a function of both the rate of herbicide degradation and the amount of herbicide applied. Persistence is a problem when herbicide residues in the soil injure successive sensitive crops. In addition, persistence of a herbicide in the soil increases the potential for contamination of surface and ground water. Reducing the rates of herbicides through the use of mixtures aids in management of both of these related problems.

Mixtures may also help prevent shifts in weed population associated with the use of a single herbicide. These shifts include both the emergence of weed species tolerant (not initially controlled) and resistant (initially controlled) to by a single herbicide.

Apparently, applying two or more herbicides is based on the assumption that herbicides would act independently when applied simultaneously or sequentially. However, it has been demonstrated that herbicides may interact before or after entering the plants and outcome of the interaction can be synergistic, antagonistic, or additive depending on whether the combined effect on the plants is greater, less than, or equal to the summed effect of herbicides applied alone (Hatzios and Penner, 1985).

The objective of this study was to determine interactions between metsulfuron-methyl and glyphosate in mixtures for the control of *Diodia ocimifolia* under glasshouse conditions.

Materials and Methods

Diodia ocimifolia seeds collected from oil palm plantation in Selangor were cleaned, air-dried and stored in a refrigerator before sowing. The seeds were sown in 38 cm x 28 cm trays containing soil mixture of sand and top soil at a ratio of 2:1. Two weeks after germination, seedlings were transplanted into 2-litre pots containing the same soil mixture with 1 plant per pot. Watering was carried out twice daily and compound fertilizer (15%N, 15%P and 15%K) was applied at 2 weeks after transplanting. Treatments were applied when *D. ocimifolia* seedlings attained 20-30 cm in height (6 weeks after transplanting).

The 8 week old plants were foliar sprayed with 1.87, 3.75, 7.5, 15, 30 or 60g a.i./ha of metsulfuron-methyl (ALLY® 20DF) and 33.75, 67.5, 135, 270, 540 or 1080 g a.i./ha of glyphosate. These herbicides were applied alone and in mixtures of metsulfuron-methyl and glyphosate at 1:18, 1:36 and 1:72 ratios. Spraying was carried out using a knapsack sprayer (PB Crossmark) fitted with Teejet XR11002 (yellow) flat fan nozzle. The nozzle was operated at a pressure of 2 bars delivering a spray volume of 200 litres/ha. The experiment consisted of a factorial combination of treatments arranged in a completely randomized design (CRD) with four replications.

The effect of treatments on *Diodia* were first determined by visual assessment using a scale of 0 to 100% where 0% represents no control and 100% represents total plant death at 28 days after spraying (DAS). The plants were then harvested and the above-ground fresh weight was determined. Visual assessment data were transformed to arce-sine $\sqrt{(x/100)}$ before analyses using SAS software. Treatment means were compared using Turkey's Studentized Range Test (HSD) at $P = 0.05$.

All fresh weights were expressed as percent of control prior to statistical anaiysis. Colby's (1967) formula was used to calculate the "expected response" (E) of the herbicide combination where,

x = weed growth as percent of control with herbicide A at p kg a.i./ha.
y = weed growth as percent of control with herbicide B at q kg a.i./ha
E = expected weed growth as percent of control with herbicides A + B at p + q kg a.i./ha

$$E = \frac{xy}{100}$$

The expected value was compared to observed percentage growth in the controls. The values obtained were statistically analyzed using the Chi-square test for synergistic (+ve) or antagonistic (-ve) response. Colby (1967) had noted that the above equation can only be an approximation, and that it will be most accurate if the x and y values are in a range of 20% - 80% since at this range the individual response curves are close to linear.

Results and Discussion

The percent growth inhibition of *Diodia* plants increased correspondingly with increasing dosages of metsulfuron-methyl. Metsulfuron-methyl applied at 7.5 g a.i./ha, reduced the percent growth to approximately 50% of untreated check. Thus the inhibition dosage (ID_{50}) for metsulfuron-methyl on *Diodia* is estimated at around 7.5 g a.i./ha. The dosage response of *Diodia* to metsulfuron-methyl is shown in Figure 1. Glyphosate at all tested dosage also significantly inhibited growth of *Diodia* plants. At 270 g a.i./ha, the percent growth inhibition was approximately 50% of untreated check. Thus, the ID_{50} for glyphosate on *Diodia* is estimated at 270 g a.i./ha. The dosage response of *Diodia* to glyphosate is shown in Figure 2. The visual assessment data showed a minimum dosage of 30 g a.i./ha metsulfuron-methyl and 1080 g a.i./ha glyphosate was required to give acceptable weed control (>90%) at 28 DAS (Table 1 and 2).

Fig.1 Dose response relationship with metsulfuron-methyl and *Diodia*.

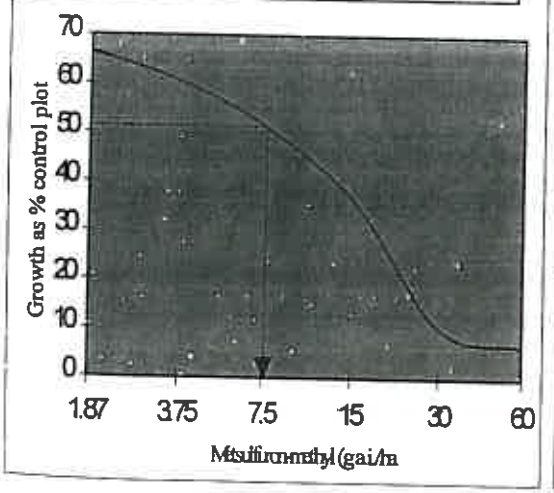


Fig. 2 Dose response relationship with glyphosate and *Diodia*.

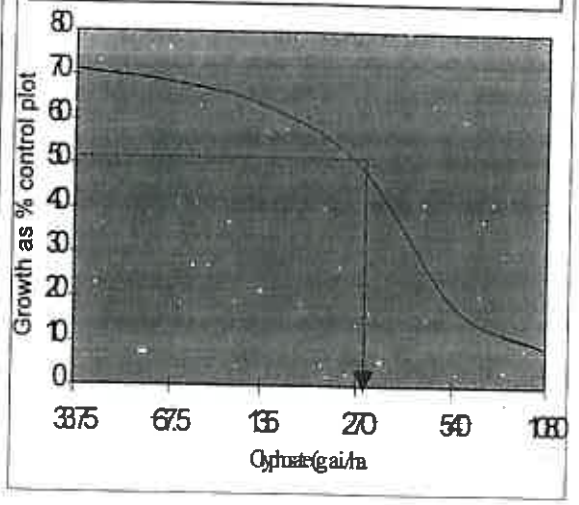


Table 1 Effect of metsulfuron-methyl on *Diodia* growth expressed as percent of control and visual assessment on percent control.

Treatment	Dosage (g a.i./ha)	Growth as % of check plot	Visual assessment on % control
1. Metsulfuron-methyl	1.87	63.41 ± 0.41 a	5.68 ± 0.62 e
2. Metsulfuron-methyl	3.75	57.48 ± 2.00 a	23.85 ± 2.31d
3. Metsulfuron-methyl	7.5	46.01 ± 1.36 b	38.35 ± 1.37 c
4. Metsulfuron-methyl	15	30.65 ± 0.76 c	60.17 ± 1.68 b
5. Metsulfuron-methyl	30	7.63 ± 0.70 d	93.43 ± 2.47 a
6. Metsulfuron-methyl	60	5.56 ± 0.27 d	96.42 ± 1.95 a

[1]Means within columns having the same letter are not significantly different at p = 0.05 (HSD).

Table 2 Effect of glyphosate on *Diodia* growth expressed as percent of control and visual assessment on percent control.

Treatment	Dosage (g a.i./ha)	Growth as % of check plot	Visual assessment on % control
1. Glyphosate	33.75	68.47 ± 0.74 a	4.52 ± 1.22 d
2. Glyphosate	67.5	66.26 ± 0.67 a	13.46 ± 0.86 d
3. Glyphosate	135	57.56 ± 0.71 ab	25.42 ± 2.18 c
4. Glyphosate	270	46.42 ± 0.56 b	36.25 ± 1.55 c
5. Glyphosate	540	16.61 ± 1.04 cd	72.66 +2.03 b
6. Glyphosate	1080	8.67 ± 0.72 d	92.38 ± 1.68 a

[1]Means within columns having the same letter are not significantly different at p = 0.05 (HSD).

The fresh weight data indicated that metsulfuron-methyl and glyphosate mixtures at all ratios were more effective than the herbicides used alone. Synergistic interactions were observed with treatments of 3.75, 7.5 and 15 g a.i./ha of metsulfuron-methyl plus 135, 270 and 540 g a.i./ha of glyphosate in the 1:36 metsulfuron-methyl + glyphosate mixtures (Table 3). However, the mixture of both herbicides at the lowest and highest rates showed additive and antagonistic interaction respectively. This may be attributed to the effect of one herbicide improving entry of the other by modifying leaf surface properties (Martin and Juniper, 1970). Lawrie and Clay (1992) had also reported that glyphosate + metsulfuron-methyl mixtures were more toxic than each herbicide alone for the control of *R. ponticum*.

All four metsulfuron-methyl + glyphosate combinations in the 1:72 mixture were not significantly different which means the interaction responses were all additive (Table 4). The same response was obtained with the 1:18 mixture except the highest rate combination where the interaction response was antagonistic (Table 5). Both glyphosate and metsulfuron-methyl inhibit amino acid synthesis. It is possible, therefore, that at extremely high dosages they may mutually restrict translocation and availability of metabolites, thus decreasing activity in mixtures.

Table 3 Interaction effects between metsulfuron-methyl (M) and glyphosate (G) in 1:36 mixtures.

Herbicides Dosages (g a.i./ha)	Mean Fresh Weight (as % of reduction from check)		χ^2 Value[b]	Interaction[c]
M G	Observed (O)	Expected (E)[a]		
1.87 + 67.5	47.83	45.54	0.12[ns]	A
3.75 + 135	31.29	38.59	1.38*	S
7.5 + 270	20.60	25.90	1.08*	S
15.0 + 540	8.38	12.22	1.16*	S
30.0 + 1080	5.04	2.08	4.21*	An

[a] E = expected Values by Colby's formula (1967)
[b] Probability : * - significant at p = 0.05; ns - non-significant
[c] Interaction effect : A - Additive; S - Synergistic; An - Antagonistic

Table 4 Interaction effects between metsulfuron-methyl (M) and glyphosate (G) in 1:72 mixtures.

Herbicides Dosages (g a.i./ha)	Mean Fresh Weight (as % of reduction from check)		χ^2 Value[b]	Interaction[c]
M G	Observed (O)	Expected (E)[a]		
1.87 + 135	43.40	42.00	0.05[ns]	A
3.75 + 270	33.18	30.48	0.24[ns]	A
7.5 + 540	18.66	17.44	0.08[ns]	A
15.0 + 1080	5.78	7.40	0.35[ns]	A

[a] E = expected Values by Colby's formula (1967)
[b] Probability : * - significant at p = 0.05; ns - non-significant
[c] Interaction effect : A - Additive; S - Synergistic; An - Antagonistic

Table 5 Interaction effects between metsulfuron-methyl (M) and glyphosate (G) in 1:18 mixtures.

Herbicides Dosages (g a.i./ha)	Mean Fresh Weight (as % of reduction from check)		χ^2 Value[b]	Interaction[c]
M G	Observed (O)	Expected (E)[a]		
1.87 + 33.75	49.40	47.18	0.13^{ns}	A
3.75 + 65.5	44.00	41.84	0.11^{ns}	A
7.5 + 135	28.12	32.79	0.66^{ns}	A
15.0 + 270	17.01	18.15	0.07^{ns}	A
30.0 + 540	4.91	3.43	0.64^{ns}	A
60.0 + 1080	3.97	1.32	1.77^{*}	An

[a] E = expected Values by Colby's formula (1967)
[b] Probability : * - significant at p = 0.05; ns - non-significant
[c] Interaction effect : A - Additive; S - Synergistic; An - Antagonistic

The results indicate that among the metsulfuron-methyl + glyphosate mixtures, the appropriate combination for optimum performance was the 1:36 mixture.

Acknowledgments:

The authors would like to thank DuPont Far East Inc. Malaysia for the permission to present and publish this paper.

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QUIZALOFOP-P-TEFURYL PLUS CERTAIN BROADLEAF HERBICIDES IN RAINY SEASON SOYBEAN (*Glycine max*)

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Abstract : Quizalofop-P-tefuryl [(R)-2-[4-(6-chloroquinoxalin-2- yloxy)phenoxy]propionic acid] applied alone and in combination with broadleaf herbicides ; fomesafen[5-(2-chloro-5-(trichloromethyl)phenoxy)-N-metsuthylphenoxy)-2-nitrobenzamide], acifluorfen[5[2-chloro-4 (trochloromethyl)phenoxy]-2-nitrobenzoic acid] and lactofen [(±)2-ethoxy-1-methyl-2-oxyethyl-5-[2-chloro-4-(trifluoromethyl)phenyl)phenoxy]-2-nitrobenzoatefomesafen] was evaluated for post-emmergence control of general weeds in soybean (var. S.J.5). The herbicides were applied ontop of weeds and soybean at 14 - 21 days after planting with knapsack sprayer delivering 325 l/ha. It was found that quizalofop-P-tefuryl alone at the rates of 60 g ai /ha gave excellent control of annual grass weeds; *Digitaria adscendens* H.B.K.Henr., *Eleusine indica*(L.) Gaertn., *Echinochloa colona* (L.)Link., *Echinochloa crus-galli* (L.)Beauv. Fomesafen, acifluorfen and lactofen alone at the rates 250, 240 and 125 g ai /ha respectively, showed completely control of annual broadleaved weeds; *Trianthema triquetra* L., *Ageratum conyzoides* L., *Amaranthus viridis* L. and *Amaranthus spinosus* L. The combination of quizalofop-P-tefuryl and fomesafen , acifluorfen and lactofen gave complete control of both annual grass and broadleaved weeds. The application of fomesafen, acifluorfen and lactofen alone or mixed with quizalofop-P-tefuryl cuased some phytotoxicity to soybean.The use of quizalofop-P-tefuryl alone or mixed with fomesafen, acifluorfen and lactofen for annual grass weed and broadleaved weed control could increase yield of soybean significantly compared to non weeded plot.

Key words: quizalofop-P-tefuryl, broadleaved herbicide,soybean, general weed.

Introduction

The cultivation of soybean in Thailand faces many limitations, in particular the damage caused by competition from weeds. Anusorn and Areeyan (1990) found that weeds affect yield, which could increase by not less than 23% if manually weeded. Therefore, weed control is considered the most essential factor in soybean production. The use of chemicals or herbicides to control weeds is one alternative to solve this problem; these herbicides fall into both the pre-emergence and post-emergence categories, with differing advantages and disadvantages. Pre-emergence herbicides that have been reported in use are alachlor, oxyfluorfen and oxadiazon (Tavee *et al*, 1996 a; Pornchai and Krisorn, 1995). Post-emergence herbicides that have been reported in use in soybean are fluazifop-butyl (Anusorn and Areeyan, 1990; Pornchai and Krisorn, 1995; Tavee *et al*, 1996 b), imazethapyr (Pornchai and Prisana, 1994; Anusorn and Areeyan, 1990), propaquizafop (Pradit *et al*, 1993), haloxyfop-R-methyl ester (Pornchai, 1995) and quizalofop-P-tefuryl (Pornchai and Suthep, 1996). These chemicals are selective herbicides and will kill grass weeds only, leaving broad-leaved weeds to flourish. Therefore, it may be necessary to add herbicides controlling broad-leaved weeds to extend control. Those already tested are fomesafen, aciflourfen and lactofen (Pornchai and Treeyanai, 1997). This research is to determine the efficacy of quizalofop-P-tefuryl, used alone and in combination with other selective herbicides for the control of broad-leaved weeds in soybean such as fomesafen, the results of which could be used as guidelines for future research as well as used in the planting of soybean.

Materials and Methods

Two fields were set up for trials, one in Amphur Hang Dong and the other in Amphur Muang, both in Chiang Mai province, during the rainy season of 1998. The variety of soybean used was S.J.5 and planted at distances of 20 x 50 cm on August 1 and 11, respectively, for fields 1 and 2. Each plot was 4 x 5 m and laid out according to randomized complete block design with 3 replicates. Single chemical treatments were quizalofop-P-tefuryl, fomesafen-S, aciflourfen and lactofen at the rates of 60, 250, 240 and 125 g ai/ha, respectively. Combination treatments were quizalofop-P-tefuryl mixed with fomesafen-S, aciflourfen and lactofen at rates of 60 + 250, 60 + 240 and 60 + 125 g ai/ha, respectively. They were to be compared to the treatments using fluazifop-butyl mixed with fomesafen-Z at the rate of 150 + 250 g ai/ha as well as to be compared to the manually weeded plots, at 15, 30 and 45 days after planting, and non-weeding plots. Application was by knapsack sprayer with impact spray nozzle delivering 350 l/ha of spray volume, at 14 and 20 days after planting in fields 1 and 2, respectively.

The herbicides used in this trial are quizalofop-P-tefuryl with the chemical name of (RS)-2-tetrahydrofuranylmethyl ?-2-[4-(6-chloro-2-quinoxalinyloxy) phenoxy] propionate and trade name of Pantera, fomesafen-S whose chemical name is 5-[2-chloro-4-(trifluoromethyl)phenoxy]-N-(methylsulfonyl)-2-nitrobenzamide and whose trade name is as yet to be introduced to Thailand, aciflourfen whose chemical name is 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid with the trade name of Blazer, lactofen with a chemical name of (±)-2-ethoxy-1-ethyl-2-oxoethyl 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoate and having the trade name of Cobra, fluazifop-butyl which is the butyl ester of (±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid with the trade name of Onecide-Super and finally fomesafen-S whose chemical name is 5-[2-chloro-4-(trifluoromethyl)phenoxy]-N-(methylsulfonyl)-2-nitrobenzamide with the trade name of Flex.

Results and Discussions

Weeds found in both fields were collected and the major species were identified as follows: -

Field No.1: annual grasses, *Digitaria adscendens* H.B.K.Henr., *Eleusine indica* (L.) Geart. and *Echinochloa colona* (L.) Link , annual broad-leaved weeds, *Trianthema triquetra* L. and *Ageratum conyzoides.* L. Field No. 2: annual grasses, *Digitaria adscendens* H.B.K.Henr. and *Echinochloa crus-galli* (L.) Beauv., annual broad-leaved weeds, *Amaranthus spinosus* L., *Amaranthus viridis* L.and *Trianthema triquetra* L.

Weed control efficacy

Trial results as shown in Tables 1 and 2 indicate that the use of quizalofop-P-tefuryl at the rate of 60 g ai/ha, either singly or in combination with other broad-leaved weed herbicides, gave excellent control of annual grass weeds at 21 days after application. The efficacy is similar to fluazifop-butyl, which is in keeping with reports of Pornchai and Suthep (1995). From Tables 5 and 6, the use of quizalofop-P-tefuryl, either singly or in combination with other broad-leaved weed herbicides, can completely control annual grasses. It was also found that fomesafen-S, acifluorfen and lactofen, either alone or in combination with quizalofop-P-tefuryl, can similarly control broad-leaved weeds completely, as indicated in Tables 2,3 and 7,8.

Phytotoxicity

Quizalofop-P-tefuryl at the rate of 60 g ai/ha is not phytotoxic to soybean. Fomesafen-S, aciflourfen and lactofen indicate slight phytotoxicity within 28 days after spraying, with lactofen showing more symptoms than the other two, as in Tables 9 and 10.

Growth and yield of soybean

Table 11 indicates that the height of soybean plants at 30 days after application of quizalofop-P-tefuryl, singly or in combinations with broad-leaved weed herbicides, and at harvest are near identical with those in hand weeded plots. In the treatments where broad-leaved weed herbicides were used, it could be seen that the growth and development of soybean was affected, particularly the treatments with single chemical application (Pornchai and Treeyanai, 1997). This is because these broad-leaved weed herbicides can not control the grass weeds resulting in competition with the principal crop, soybean. Furthermore, these herbicides were slightly phytotoxic to soybean as well. In the treatments using broad-leaved weed herbicides in combination with quizalofop-P-tefuryl, it was found that the soybean plants were taller than those treated with single chemicals. This is likely due to lessened competition from both types of weeds due to better control, even if there were phytotoxic symptoms after spraying.

Tables 12 and 13 indicate that the use of quizalofop-P-tefuryl singly, to control annual grasses, increase yield significantly when compared against plots with no weed control. Then again, the combination of quizalofop-P-tefuryl with other broad-leaved weed herbicides produce higher yields than straight quizalofop-P-tefuryl. Furthermore, the use of straight fomesafen-S, aciflourfen and lactofen will increase yields only slightly. This is because under the trial conditions, the main weeds were annual grasses, which continue to compete throughout the soybean season. It was found finally, that the use of quizalofop-P-tefuryl, either singly or in combination with fomesafen-S, aciflourfen and lactofen broad-leaved weed herbicides will increase yields of soybean to a level comparable to that of standard herbicide which is fluazifop-butyl, either singly or in combination with fomesafen-S.

Summary

The use of quizalofop-P-tefuryl singly to control annual grass weeds could increase significantlly yield of soybean when compared with unweeded plot. Yield will increase if used in combination with broad-leaved weed herbicides such as fomesafen-S, acifluorfen and lactofen. The use of broad-leaved weed herbicides singly or in combination with quizalofop-P-tefuryl herbicide indicate slight phytotoxicity within 28 days of spraying. The use of single broad-leaved weed herbicides will gives similar yield to non-weeded plots. The use of quizalofop-P-tefuryl, either singly or in combination with fomesafen-S, aciflourfen and lactofen broad-leaved weed herbicides gave similar weed control and yield when compared to the standard herbicide, fluazifop-butyl, used either singly or in combination with fomesafen-S.

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Table 1 Efficacy of herbicide for annual grass weed control in soybean (Location I).

Herbicide	Rate g ai/ha	Control Rating [1/] 7 DAA[2/]			21 DAA[2/]			35 DAA[2/]		
		ELEIN	DIGAD	ECHCR	ELEIN	DIGAD	ECHCR	ELEIN	DIGAD	ECHCR
Quizalofop	60	7.8	7.3	7.5	10.0	9.8	10.0	9.9	9.8	9.9
Fomesafen-S	250	0	0	0	0	0	0	0	0	0
Acifluorfen	240	0	0	0	0	0	0	0	0	0
Lactofen	125	0	0	0	0	0	0	0	0	0
Quizalofop+ Fomesafen-S	60+ 250	9.5	9.3	9.6	10.0	10.0	10.0	10.0	10.0	10.0
Quizalofop+ Acifluorfen	60+ 240	9.6	9.3	9.7	10.0	10.0	10.0	10.0	10.0	10.0
Quizalofop + Lactofen	60+ 125	9.3	9.0	9.0	10.0	9.6	9.7	10.0	9.3	9.5
Fluazifop+ Fomesafen-Z	150+ 250	9.0	9.0	9.5	10.0	10.0	10.0	10.0	10.0	10.0
Hand weeding	-	-	-	-	-	-	-	-	-	-
Non weeding	-	-	-	-	-	-	-	-	-	-

Annual grass weeds: ELEIN=*Eleusine indica*(L.)Gaertn., DIGAD=*Digitaria adscendens* H.B.K..Henr., ECHCR = *Echinochloa crus-galli*(L.)
[1/] Control Rating: 0=No control, 10= Completely control. [2/] DAA: Days after application.

Table 2 Efficacy of herbicide for annual grass weed control in soybean (Location II).

Herbicide	Rate g ai/ha	Control Rating [1/] 7 DAA[2/]			21 DAA[2/]			35 DAA[2/]		
		ECHCR	ECHCO	DIGAD	ECHCR	ECHCO	DIGAD	ECHCR	ECHCO	DIGAD
Quizalofop	60	8.0	7.3	7.8	10.0	9.8	10.0	9.8	9.9	9.9
Fomesafen-S	250	0	0	0	0	0	0	0	0	0
Acifluorfen	240	0	0	0	0	0	0	0	0	0
Lactofen	125	0	0	0	0	0	0	0	0	0
Quizalofop+ Fomesafen-S	60+ 250	9.5	9.3	9.6	10.0	10.0	10.0	10.0	10.0	10.0
Quizalofop+ Acifluorfen	60+ 240	9.6	9.3	9.7	10.0	10.0	10.0	10.0	10.0	10.0
Quizalofop + Lactofen	60+ 125	9 3	9.0	9.0	9.7	9.6	10.0	9 5	9.6	10.0
Fluazifop+ Fomesafen-Z	150+ 250	9.0	9.0	9.3	10.0	10.0	10.0	10.0	10.0	10.0
Hand weeding	-	-	-	-	-	-	-	-	-	-
Non weeding	-	-	-	-	-	-	-	-	-	-

Annual grass weeds: ECHCR = *Echinochloa crus-galli*(L.)Link.,
ECHCO = *Echinochloa colona*(L.), DIGAD =*Digitaria adscendens* H.B.K.Henr.
[1/] Control Rating: 0=No control, 10= Completely control. [2/] DAA: Days after application.

Table 3 Efficacy of herbicide for annual broadleaf weed control in soybean (Location I).

Herbicide	Rate	Control Rating [1/]					
		7 DAA[2/]		21 DAA[2/]		35 DAA[2/]	
	g ai/ha	AGECO	AMASP	AGECO	AMASP	AGECO	AMASP
Quizalofop	60	0	0	0	0	0	0
Fomesafen-S	250	10.0	10.0	10.0	10.0	10.0	10.0
Acifluorfen	240	10.0	10.0	10.0	10.0	10.0	10.0
Lactofen	125	10.0	10.0	10.0	10.0	10.0	10.0
Quizalofop+ Fomesafen-S	60+ 250	10.0	10.0	10.0	10.0	10.0	10.0
Quizalofop+ Acifluorfen	60+ 240	10.0	10.0	10.0	10.0	10.0	10.0
Quizalofop + Lactofen	60+ 125	10.0	10.0	10.0	10.0	10.0	10.0
Fluazifop+ Fomesafen-Z	150+ 250	10.0	10.0	10.0	10.0	10.0	10.0
Hand weeding	-	-	-	-	-	-	-
Non weeding	-	-	-	-	-	-	-

Annual broadleaf weeds: AGECO = *Ageratum conyzoides* L., AMASP = *Amarathus spinosus* L.
[1/] Control Rating: 0=No control, 10=Completely control. [2/] DAA: Days after application.

Table 4 Efficacy of herbicide for annual broadleaf weed control in soybean (Location II).

Herbicide	Rate	Control Rating [1/]					
		7 DAA[2/]		21 DAA[2/]		35 DAA[2/]	
	g ai/ha	AMAVI	TRITR	AMAVI	TRITR	AMAVI	TRITR
Quizalofop	60	0	0	0	0	0	0
Fomesafen-S	250	10.0	10.0	10.0	10.0	10.0	10.0
Acifluorfen	240	10.0	10.0	10.0	10.0	10.0	10.0
Lactofen	125	10.0	10.0	10.0	10.0	10.0	10.0
Quizalofop+ Fomesafen-S	60+ 250	10.0	10.0	10.0	10.0	10.0	10.0
Quizalofop+ Acifluorfen	60+ 240	10.0	10.0	10.0	10.0	10.0	10.0
Quizalofop + Lactofen	60+ 125	10.0	10.0	10.0	10.0	10.0	10.0
Fluazifop+ Fomesafen-Z	150+ 250	10.0	10.0	10.0	10.0	10.0	10.0
Hand weeding	-	-	-	-	-	-	-
Non weeding	-	-	-	-	-	-	-

Annual broadleaf weeds: AMAVI = *Amarathus viridis* L., TRITR = *Trianthema triquetra* L.
[1/] Control Rating: 0=No control, 10=Completely control. [2/] DAA: Days after application.

Table 5 Effect of herbicide on annual grass weed density and dry weight at 30 days after application (Location I).

Herbicide	Rate	No./ 0.25 m^2			gm/0.25m^2		
	g ai/ha	ELEIN	DIGAD	ECHCR	ELEIN	DIGAD	ECHCR
Quizalofop	60	0 b	0 c	0 c	0 c	0 b	0 b
Fomesafen-S	250	15.0 a	19.7 a	22.7 b	27.9 ab	23.5 a	28.9 a
Acifluorfen	240	14.3 a	13.0 b	23.0 ab	25.4 b	25.8 a	24.7 a
Lactofen	125	17.7 a	12.3 b	26.0 a	29.3 a	22.9 a	27.7 a
Quizalofop+ Fomesafen-S	60+ 250	0 b	0 c	0 c	0 c	0 b	0 b
Quizalofop+ Acifluorfen	60+ 240	0 b	0 c	0 c	0 c	0 b	0 b
Quizalofop + Lactofen	60+ 125	0 b	1.2 c	1.0 c	0 c	2.8 b	2.7 b
Fluazifop+ Fomesafen-Z	150+ 250	0 b	0 c	0 c	0 c	0 b	0 b
Hand weeding	-	0 b	0 c	0 c	0 c	0 b	0 b
Non weeding	-	17.7 a	18.7 a	25.3 ab	28.1 ab	22.3 a	24.5 a
	C.V.	23.97%	25.11%	9.78%	11.73%	25.67%	24.48%

Annual grass weeds: ELEIN = *Eleusine indica*(L.)Gaerth.,
DIGAD = *Digitaria adscendens* H.B.K.Henr., ECHCR = *Echinochloa crus-galli*(L.)

Table 6 Effect of herbicide on annual grass weed density and dry weight at 30 days after application (Location II).

Herbicide	Rate g ai/ha	No./ 0.25 m^2			Gm/0.25m^2		
		ECHCR	ECHCO	DIGAD	ECHCR	ECHCO	DIGAD
Quizalofop	60	0 c	0 b	0 b	0 b	0 b	0 c
Fomesafen-S	250	14.3 ab	22.3 a	15.3 a	28.3 a	44.8 a	29.2 a
Acifluorfen	240	15.0 ab	21.0 a	15.0 a	31.3 a	42.8 a	31.1 ab
Lactofen	125	15.7 a	20.7 a	14.7 a	27.7 a	41.8 a	32.8 ab
Quizalofop+	60+	0 c	0 b	0 b	0 b	0 b	0 c
Fomesafen-S	250						
Quizalofop+	60+	0 c	0 b	0 b	0 b	0 b	0 c
Acifluorfen	240						
Quizalofop +	60+	1.0 c	1.3 b	0 b	2.1 b	4.3 b	0 c
Lactofen	125						
Fluazifop+	150+	0 c	0 b	0 b	0 b	0 b	0 c
Fomesafen-Z	250						
Hand weeding	-	0 c	0 b	0 b	0 b	0 b	0 c
Non weeding	-	11.3 b	21.7 a	13.0 a	28.6 a	43.9 a	23.6 b
	C.V.	29.34%	23.00%	40.95%	16.80%	16.70%	31.80%

Annual grass weeds: ECHCR = *Echinochloa crus-galli*(L.)Link.,
ECHCO = *Echinochloa ccolona*(L.), DIGAD = *Digitaria adscendens* H.B.K.Henr.

Table 7 Effect of herbicide on annual broadleaf weed density and dry weight at 30 days after application (Location I).

Herbicide	Rate g ai/ha	No./ 0.25 m^2		gm/0.25m^2	
		AGECO	AMASP	AGECO	AMASP
Quizalofop	60	10.0 a	19.0 a	33.1 a	38.7 a
Fomesafen-S	250	0 c	0 c	0 c	0 c
Acifluorfen	240	0 c	0 c	0 c	0 c
Lactofen	125	0 c	0 c	0 c	0 c
Quizalofop+	60+	0 c	0 c	0 c	0 c
Fomesafen-S	250				
Quizalofop+	60+	0 c	0 c	0 c	0 c
Acifluorfen	240				
Quizalofop +	60+	0 c	0 c	0 c	0 c
Lactofen	125				
Fluazifop+	150+	0 c	0 c	0 c	0 c
Fomesafen-Z	250				
Hand weeding	-	0 c	0 c	0 c	0 c
Non weeding	-	7.3 b	6.0 b	24.8 b	21.1 b
	C.V.	48.00%	18.34%	20.55%	24.22%

Annual broadleaf weeds: AGECO = *Ageratum conyzoides* L.,
AMASP = *Amarathus spinosus* L.

Table 8 Effect of herbicide on annual broadleaf weed density and dry weight at 30 days after application (Location II).

Herbicide	Rate g ai/ha	No./ 0.25 m^2		Gm/0.25m^2	
		AMAVI	TRITR	AMAVI	TRITR
Quizalofop	60	14.7 a	5.0 a	35.8 a	17.3 a
Fomesafen-S	250	0 b	0 b	0 b	0 b
Acifluorfen	240	0 b	0 b	0 b	0 b
Lactofen	125	0 b	0 b	0 b	0 b
Quizalofop+	60+	0 b	0 b	0 b	0 b
Fomesafen-S	250				
Quizalofop+	60+	0 b	0 b	0 b	0 b
Acifluorfen	240				
Quizalofop +	60+	0 b	0 b	0 b	0 b
Lactofen	125				
Fluazifop+	150+	0 b	0 b	0 b	0 b
Fomesafen-Z	250				
Hand weeding	-	0 b	0 b	0 b	0 b
Non weeding	-	14.3 a	4.3 a	34.9 a	14.2 a
	C.V.	53.75%	56.55%	18.24%	90.85%

Annual broadleaf weeds: AMAVI = *Amarathus viridis* L.,
TRITR = *Trianthema triquetra* L.

Table 9 Effect of herbicide on phytotoxicity of soybean (Location I).

Herbicide	Rate g ai/ha	Phytotoxicity Rating[1/] 3	7	14	21	28	35 DAA[2/]
Quizalofop	60	0	0	0	0	0	0
Fomesafen-S	250	2.5	2.0	1.5	1.0	1.0	0
Acifluorfen	240	3.0	2.5	2.0	2.0	1.0	0
Lactofen	125	4.5	4.0	4.0	3.0	3.0	2.0
Quizalofop+ Fomesafen-S	60+ 250	3.5	3.0	2.0	2.0	2.0	0
Quizalofop+ Acifluorfen	60+ 240	3.5	3.0	2.0	2.0	2.0	1.0
Quizalofop + Lactofen	60+ 125	5.0	4.5	4.3	3.5	3.0	2.0
Fluazifop+ Fomesafen-Z	150+ 250	3.5	3.0	2.3	2.0	2.0	0
Hand weeding	-	-	-	-	-	-	-
Non weeding	-	-	-	-	-	-	-

[1/]Phytotoxicity Rating: 0 = No injury, 10 = Completely killed.
[2/]DAA: Days after application

Table 10 Efffect of herbicide on phytotoxicity of soybean (Location II).

Herbicide	Rate g ai/ha	Phytotoxicity Rating[1/] 3	7	14	21	28	35 DAA[2/]
Quizalofop	60	0	0	0	0	0	0
Fomesafen-S	250	2.5	2.0	1.5	1.0	1.0	0
Acifluorfen	240	2.5	2.5	2.0	2.0	1.0	0
Lactofen	125	4.5	4.5	4.0	3.0	3.0	2.0
Quizalofop+ Fomesafen-S	60+ 250	3.5	3.0	2.0	2.0	2.0	0
Quizalofop+ Acifluorfen	60+ 240	3.5	3.0	2.0	2.0	2.0	1.0
Quizalofop + Lactofen	60+ 125	4.8	4.5	4.3	4.3	4.0	3.0
Fluazifop+ Fomesafen-Z	150+ 250	3.5	3.0	2.3	2.0	2.0	0
Hand weeding	-	-	-	-	-	-	-
Non weeding	-	-	-	-	-	-	-

[1/]Phytotoxicity Rating: 0 = No injury, 10 = Completely killed.
[2/]DAA: Days after application.

Table 11 Effect of herbicide on crop height (Location I, II).

Herbicide	Rate g ai/ha	Location I (cm) 30 DAA[1/]	Harvesting	Location II (cm) 30 DAA[1/]	Harvesting
Quizalofop	60	29.3 ab	64.6 a	29.9 ab	65.9 ab
Fomesafen-S	250	22.7 d-f	42.7 cd	25.3 bc	57.6 a-d
Acifluorfen	240	22.4 ef	43.0 cd	25.4 bc	57.0 b-d
Lactofen	125	20.0 f	35.4 cd	21.0 bc	50.9 d
Quizalofop+ Fomesafen-S	60+ 250	27.0 bc	62.7 ab	30.9 cd	67.7 a
Quizalofop+ Acifluorfen	60+ 240	26.4 bc	57.4 ab	29.8 ab	64.8 d-c
Quizalofop + Lactofen	60+ 125	24.9 c-e	51.2 bc	26.9 ab	54.6 cd
Fluazifop+ Fomesafen-Z	150+ 250	25.7 cd	61.7 ab	30.7 ab	66.5 ab
Hand weeding	-	31.1 a	64.8 a	32.5 a	68.1 a
Non weeding	-	16.7 g	43.3 cd	18.4 d	49.0 d
	C.V.	5.21%	10.56%	9.05%	5.75%

[1/] Hand weeding at 15,30,45 days after planting. [2/] DAP: Days after planting.

Table 12 Effect of herbicide on yield of soybean (Location I).

Herbicide	Rate g ai/ha	Pod/ pl.	Seed/ pod	100 seed wt.(g)	Yield kg/ha
Quizalofop	60	20.8 d	1.8 b	13.7 bc	1,050.3 c
Fomesafen-S	250	12.5 e	1.2 cd	10.9 de	379.0 d
Acifluorfen	240	13.1 e	1.2 cd	10.7 de	324.7 de
Lactofen	125	8.9 f	1,.1 d	9.9 e	254.7 de
Quizalofop+	60+	36.8 a	2.6 a	16.2 a	1,609.7 a
Fomesafen-S	250				
Quizalofop+	60+	33.8 b	2.5 a	15.3 ab	1,497.7 ab
Acifluorfen	240				
Quizalofop +	60+	31.4 c	1.7 bc	12.2 cd	1,422.0 b
Lactofen	125				
Fluazifop+	150+	36.3 a	2.6 a	15.4 ab	1,459.3 ab
Fomesafen-Z	250				
Hand weeding	-	37.6 a	2.8 a	16.2 a	1,570.7 a
Non weeding	-	8.3 f	1.1 d	10.0 e	231.7 e
	C.V.	4.06%	10.42%	6.14%	5.69%

Table 13 Effect of herbicide on yield of soybean (Location II).

Herbicide	Rate g ai/ha	Pod/ pl.	Seed/ pod	100 seed wt.(g)	Yield kg/ha
Quizalofop	60	19.1 c	1.9 b-d	11.2 b	1,042.3 b
Fomesafen-S	250	13.7 de	1.1 e	9.6 bc	521.3 c
Acifluorfen	240	15.8 de	1.4 de	8.3 cd	456.0 c
Lactofen	125	9.8 ef	0.9 e	6.2 d	385.0 c
Quizalofop+	60+	33.1 a	2.2 a-c	14.8 a	1,578.0 a
Fomesafen-S	250				
Quizalofop+	60+	33.4 a	2.0 a-c	14.3 a	1,487.0 a
Acifluorfen	240				
Quizalofop +	60+	26.9 b	1.7 cd	10.1 bc	1,320.3 ab
Lactofen	125				
Fluazifop+	150+	35.9 a	2.3 ab	14.0 a	1,481.7 a
Fomesafen-Z	250				
Hand weeding	-	36.4 a	2.5 a	15.1 a	1,582.7 a
Non weeding	-	5.6 f	1.0 e	6.2 d	355.0 c
	C.V.	8.94%	15.08%	10.63%	11.82%

STRUCTURE-ACTIVITY RELATIONSHIPS OF NEW BENZENESULFONYLUREAS IN RICE (*Oryza sativa*) AND BARNYARDGRASS (*Echinochloa crus-galli* var. *oryzicola*)

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Abstract: Structure-activity relationships of 15 new benzenesulfonylurea derivatives on *in vitro* and *in vivo* acetolactate synthase (ALS) activities were investigated in rice (*Oryza sativa*) and barnyardgrass (*Echinochloa crus-galli* var. *oryzicola*). *In vitro* ALS activities of both rice and barnyardgrass were significantly inhibited by the compounds with decreasing of number of carbon atoms and α-fluorine substituents in the R radical. Among the stereoisomers, erythro form showed 10 times higher ALS inhibiting activity than threo form. There was good correlation between the *in vitro* ALS assay and the *in vivo* biological activities of the 15 compounds. However, the *in vitro* ALS assay did not account for the selectivity of rice and barnyardgrass to the compounds. The selectivity could rather be explained with the results of the *in vivo* ALS assay using an inhibitor of ketol-acid reductoisomerase, 1,1-cyclopropanedicarboxylic acid. Among the analogues tested, the compound K_8 was found to be the most potent ALS inhibitor *in vitro* having a good selectivity between rice and barnyardgrass *in vivo*.

Key words: acetolactate synthase (ALS), benzenesulfonylurea, 1,1-cyclopropanedicarboxylic acid(CPCA), structure-activity relationship (SAR)

Introduction

Sulfonylureas are well known as targeting the inhibition of acetolactate synthase (ALS), resulting in growth inhibition and eventual death of susceptible weeds. They are also known to be selective to a number of major crops including rice (Stidham, 1991). However, the most commercialized sulfonylurea herbicides are generally weak to control the most common problem weeds such as barnyardgrass (*Echinochloa* spp.) in paddy rice cultivation in Asia and appropriate partners have been required for obtaining the more satisfied spectrum. In paddy fields, Barnyardgrass is one of the most troblesome weeds worldwide and extremely competitive to rice. Its infestation causes severe yield loss and quality deterioration in rice culture. Therefore, rice growers have anxiously been waiting for the introduction of new potent herbicides which can effectively control not only annual weeds but also perennial weeds. Also, new sulfonylurea herbicides controlling problem weeds such as barnyardgrass in rice paddy fields are still needed.

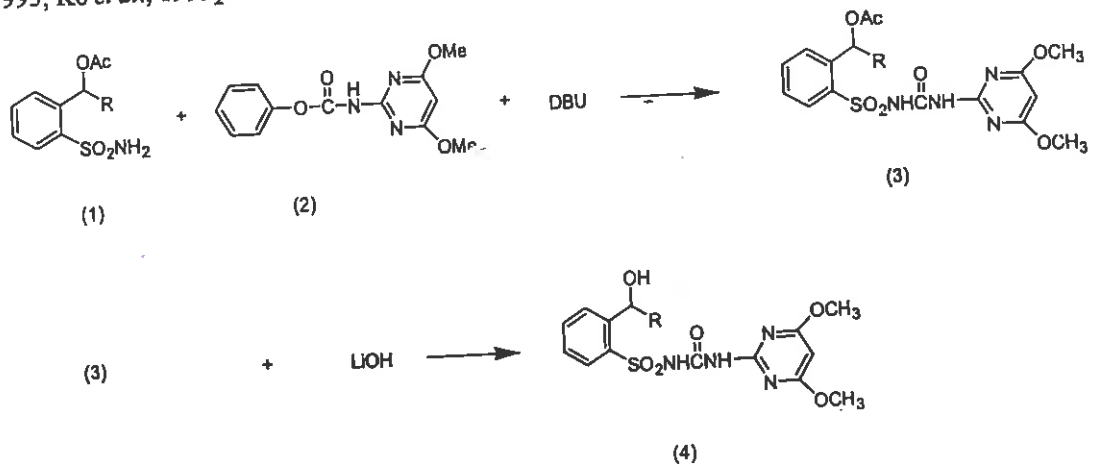
KRICT have recently found the new benzenesulfonylurea compounds, possessing α-hydroxyalkyl moiety, which have the good safety to rice and excellent controlling effects on major weeds including barnyardgrass in paddy fields (Hwang *et al.*, 1999). However, little information is available for the structure-activity relationship (SAR) to optimize the potency and selectivity between rice and barnyardgrass. In addition, the information on SAR varis with substitution patterns, target crops, and environmental conditions. In this paper, we reported the relationships of chemical structures of 15 new benzenesulfonylureas (Table 1) and biological activity using *in vitro* and *in vivo* ALS assay on rice and barnyardgrass leaf tissues.

Materials and Methods

Synthesis of benzenesulfonylureas

Benzenesulfonylurea derivatives **(4)** tested in this study were synthesized by a conventional coupling reaction of benzenesulfonamide **(1)** with carbamate **(2)**, followed by hydrolysis of acetyl group.

The corresponding benzensulfonamide (1) was prepared employing literature procedure (Kim *et al.*, 1995; Ko *et al.*, 1999).



(1) (2) (3)

(3) + LiOH → (4)

Table 1. Benzenesulfonylurea derivatives (K_1-K_{15}) with different R substituents examined in this study.

Code No	R	Code No	R
K_1	H	K_9	$CHFCH_3$ (Threo)
K_2	CH_3	K_{10}	$CF(CH_3)_2$
K_3	CH_2CH_3	K_{11}	$CHFCH_2CH_3$ (Erythro)
K_4	$CH(CH_3)_2$	K_{12}	$CHFCH_2CH_3$ (Threo)
K_5	CH_2F	K_{13}	CH_2CH_2Cl
K_6	CHF_2	K_{14}	$CH_2OCH_2OCH_3$
K_7	CF_3	K_{15}	$CH_2CH_2OCH_3$
K_8	$CHFCH_3$ (Erythro)		

ALS assay *in vitro*

All procedures were performed at 4°C unless otherwise noted. Fifty grams of plant shoots were pulverized in a prechilled mortar with a pestle using liquid nitrogen and homogenized in 100 mL of 0.1 M potassium phosphate buffer solution (pH 7.5) containing 5 mM $MgCl_2$ and 10 mM sodium pyruvate. The homogenates were filtered through a layer of cheesecloth and centrifuged at 20,000 *g* for rice and 15,000 *g* for barnyardgrass for 20 min. ALS in the supernatant was precipitated with ammonium sulfate. The enzyme was collected at 35% saturation with centrifugation at 20,000 g for 20 min. Resulting pellet was resuspended in the homogenization buffer and desalted through Sephadex G-25 (PD-10) preequilibrated with the same buffer. The desalted enzyme was immediately used for assay. ALS assay was conducted in a final volume of 2 mL of reaction mixture at 30 °C. The reaction mixture consisted of 1 mL of the desalted enzyme and 0.9 mL of 50 mM potassium phosphate buffer (pH 7.5) containing 10 mM sodium pyruvate, 0.1 mM thiamine pyrophosphate, 10 μM flavine adenine dinucleotide, and 10 mM $MgCl_2$. Herbicide stock solutions were prepared with acetone, and 0.1 ml was added in each reaction vial. Reaction was initiated by adding the pyruvate and terminated with 30 μL of 10 N H_2SO_4. ALS activity was determined as previously described by Westerfeld (1945). For decarboxylation, the acidified reaction mixture was heated at 60 °C for 15 min, and 0.5 mL of 0.5% (w/v) creatine and 5% (w/v) 1-naphtol dissolved in 10% NaOH was dissolved in 10% NaOH were added. The solution was then heated at 60 °C for an additional 15 min. After centrifugation at 3,000 g for 3 min, the absorbance at 530 nm of the supernatant was measured. Standard curve was constructed using acetoin which had been subjected to the same procedures of color development. Specific enzyme activity was calculated from the standard curve. Protein concentrations were determined by the method of Bradford (1976) with bovine serum albumin as a standard.

ALS *in vivo*

The amount of acetolactate accumulation *in vivo* was determined by the method of Simpson *et al.* (1995) with slight modifications. The spray of 1,1-cyclopropanedicarboxylic acid (CPCA) was conducted in a laboratory spray booth with a nozzle calibrated by 400 L/ha volume. A non-ionic surfactant (tween-20) at 0.25% (v/v) was included in all CPCA applications. Rice and barnyardgrass seeds were seeded on the paddy soil filled in plastic pots, and each pot was watered by 3 cm in depth. Herbicide applications were performed at a week after seeding by dropping each stock solution dissolved in 50% acetone on the water surface of pots. After the specified period of time, the youngest leaves were harvested and sliced 2- to 4-mm squares. The tissues of known amount were added to a test tube containing 6 mL of 0.25% tween-20 and homogenized for 20 s using a Polytron. The homogenate was filtered through a layer of cheesecloth to remove extracellular materials. For acetolactate decarboxylation, 50 µl of 6 N H_2SO_4 was added to a 3-ml homogenate aliquot, and incubated at 60°C for 20 min.. Then, a 1-mL of naphthol and creatine (0.09 and 0.009 g/mL) in 2.5 N NaOH was added to the extract and vortexed for 10 s. Following the incubation at 60 °C for 30 min., the aliquot was centrifuged at 10,000 g for 5 min and the absorbance at 530 nm of the supernatant was measured. Background absorbance was determined with untreated leaves as described previously.

Growth inhibition *in vivo*

Ten seeds each of rice and barnyardgrass were planted in agar plates containing various concentrations of compounds. The plants were grown in a growth chamber maintained at 28°C and 12/12 hr photoperiod. The shoots and roots were harvested at 10 days after seeding to measure plant height and root length. The negative logarithm of the concentrations of the compounds causing 50% growth inhibition (pI_{50}) were calculated. All experiments for each treatment were triplicated.

Results and Discussion

The compound K_1 with no carbon in the R radical had pI value of 7.0 *in vitro* ALS assay in rice and barnyardgrass (Table 2). The pI values of K_2, K_3, and K_4, each having 1, 2, and 3 carbon atoms in the R radical, on the ALS *in vitro* assay were 7.0, 6.7, and 4.3 for rice, respectively, and 7.0, 7.0, and 5.4 for barnyardgrass, respectively. K_{13}, K_{14}, and K_{15}, which were substituted with a relatively bulky group, had the pI value of each 7.2, 6.6, and 6.6 for rice, respectively, and 6.9, 6.4, and 6.3 for barnyardgrass, respectively. These results indicate that the *in vitro* ALS inhibition of the benzenesulfonylurea compounds is dependent on the size of the R radical (Table 2).

Table 2. pI values of the compounds on *in vitro* ALS inhibition for rice and barnyardgrass.

Compound	R	pI value	
		Rice	Barnyardgrass
K_1	H	7.0	7.0
K_2	CH_3	7.0	7.0
K_3	CH_2CH_3	6.7	7.0
K_4	$CH(CH_3)_2$	4.3	5.4
K_{13}	CH_2CH_2Cl	7.2	6.9
K_{14}	$CH_2OCH_2OCH_3$	6.6	6.4
K_{15}	$CHCH_3OCH_3$	6.6	6.3

The pI values of K_2, K_5, K_6, and K_7 were 7.0, 7.1, 6.7, and 6.0 for rice, respectively, and 7.0, 7.1, 6.5, and 5.8 for barnyardgrass, respectively, suggesting that the compound having a α-fluorine substituent

(K_5) gives the best ALS inhibition. In addition, the fact that pI values of K_3 and K_8, with a α-fluorine substituent at K_3, were 6.7 and 7.1 for rice, respectively, and 7.0 and 7.2 for barnyardgrass, respectively, could support the above result. The pI values of K_{11} (6.7 in both rice and barnyardgrass), with a α-fluorine substitution at *n*-propyl radical of the R, were much higher than those of K_4.

Among the stereoisomers, K_8 and K_{10} with erythro stereochemistry caused 10 times higher ALS inhibition than the corresponding threo isomers K_9 and K_{12} did (Table 3).

Table 3. pI values of the compounds on *in vitro* ALS inhibition for rice and barnyardgrass.

Compound	R	pI value	
		Rice	Barnyardgrass
K_2	CH_3	7.0	7.0
K_5	CH_2F	7.1	7.1
K_6	CHF_2	6.7	6.5
K_7	CF_3	6.0	5.8
K_8	$CHFCH_3$ (Erythro)	7.1	7.2
K_9	$CHFCH_3$ (Threo)	6.2	6.5
K_{10}	$CF(CH_3)_2$	5.4	5.5
K_{11}	$CHFCH_2CH_3$ (Erythro)	6.7	6.7
K_{12}	$CHFCH_2CH_3$ (Threo)	6.0	5.7

There was a good correlation in the results between *in vitro* ALS assay and *in vivo* biological activities of 15 compounds. However, the *in vitro* ALS assay did not account for the selectivity of rice and barnyardgrass to the compounds.

Among the compounds treated, K_8 induced significantly higher acetolactate accumulation in rice than in barnyardgrass (Fig. 1). The amount of acetolactate accumulation in the tissues, which was blocked at the next step in the branched-chain amino acid biosynthetic pathway of the plant, using an inhibitor of 1,1-cyclopropanedicarboxylic acid (CPCA) indicates a vitality of the plant which was treated with ALS inhibiting compounds. In addition, the K_8 showed the selectivity between rice and barnyardgrass in the greenhouse. The selectivity could rather be explained with the results of the *in vivo* ALS assay using CPCA. According to the *in vitro* and *in vivo* ALS assay, the selectivity between rice and barnyardgrass might be due to the differences of metabolism of the compound in each plant. Among the analogues tested, the compound K_8 was found to be the most potent ALS inhibitor *in vitro* having a good selectivity between rice and barnyardgrass *in vivo*.

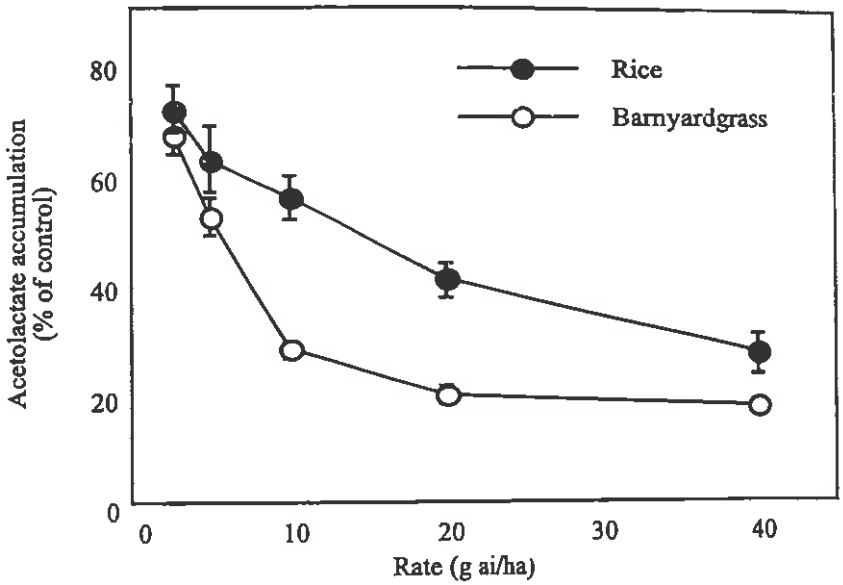


Fig. 1. Acetolactate accumulation in rice and barnyardgrass treated with the compound K_8 following 3 hr by CPCA application.

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STUDIES ON EFFECTIVE ACTION OF SETHOXYDIM-BENTAZON MIXTURE TO MONO-AND DICOTYLEDONOUS WEEDS

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Abstract: The studies were carried out in laboratory and greenhouse at CAAS during 1991-1992. Effective actions of Sethoxydim-Bentazon Mixture to barnyardgrass, crabgrass, redroot amaranth and dockleaved knotweed were assessed. Results indicated that tank mixture of sethoxydim and bentazon had significant antagonistic effect on barnyardgrass at one-leaf or two-leaf stage, and crabgrass at two-leaf or three-leaf stage. However, tank mixture of sethoxydim and bentazon had no antagonism on red root amaranth or dockleaved knotweed at two-leaf stage.

Key words: sethoxydim, bentazon, mixture, joint action.

Introduction

Herbicide tank mixture has many advantages such as: broaden the weed spectrum, reduce the rate of herbicides, reduce the cost of production, reduce the impacts of herbicide on environment etc.[Putnam and Penner 1974, Green 1987]. The results of tank mixture of herbicides could be synergism, independence, additive and antagonism[Gowing 1960, Nash 1981, Morse 1978].

Sethoxydim is a post emergence herbicide to control grasses in many dicotyleduous crops such as: soybean, peanut, flax ect.[Chandler 1980, Driver and Fran 1982, Harger et.al. 1980, Sciarappa 1982]. It has been applied to successfully control grasses in soybean, vegetable and peanut in China. Because sethoxydim can not control common broadleaf weeds such as: *chenopodium spp.*, *polygonum spp.*, *amaranths spp.* etc., it is necessary to mixed sethoxydim with other herbicides. Tank mixture of sethoxydim and bentazon is most popular one among them to control weeds in legume crops.

There are some documents on the interaction between sethoxydim and bentazon. The results are debatable. Many experiments in laboratory and field showed that the mixture of sethoxydim and bentazon had less effects on grasses than sethoxydim alone,[Banks et.al. 1989, Grichar 1991, Minton et.al. 1989, Parker and Thompson 1982,]. Many trials showed that the activity of sethoxydim were not affected by bentazon when sethoxydim mixed with bentazon [Compeil and Penner 1982, Grichar and Boswell 1987]. Some trials showed whether bentazon have antagonism on sethoxydim or not depended on the ratio and rate of sethoxydim in the mixture, there is antagonism of bentazon on sethoxydim if rate of sethoxydim in mixture is low, otherwise there is no interaction between them[Hartler and Foy 1983, Chermchy et.al. 1986, Rhodes and Coble 1984]. Some trials showed whether bentazon reduced the effect of sethoxydim in mixture depended on weed species, growth stage of weeds, and soil humidity[Parker et.al. 1986, Godley et.al. 1986, Holshouder 1990, Grichar and Boswell 1987].

Studies were conducted to identify the interaction between sethoxydim and bentazon, and the effects f

their mixture on mono-or dicotyleduous weeds. The interaction were evaluated with Isoble method [Tammes 1964, Chisaka 1989]. The synergism and antagonism were shown with Isoble.

Materials and Methods

A. Materials

1. **Herbicides:** sethoxydim technical product 96.3% in purity(from Nippon Soda Co., Ltd.)
   Nabu 20%EC (from Nippon Soda Co., Ltd.)
   Basagram 48% L. (BASF AG)
2. **Weeds:** *Echinochloa crus-galli var. mitris (pursh) Peterm,*
   Digitaria sanguinalis (L.) scop, .
   Polygonum lapathifolium L. var. salicifolium Sibth,
   Amaranths restroflexus L
3. **Soil:** cloam 17.41%, sand 5.58%, organic matter content 2.04%. the soil were wind dried and the water content is about 5%, through 30 meshed seize.

B. Method

The experiments were carried out in laboratory and greenhouse at CAAS during 1991-1992. temperature of growth chambers for seedlings is 25℃, light intensity is more than 6000Lux.

Cultivation of seedlings: weed seeds were pre-germinated in incubator at 37℃for 24hrs., then seeds were planted in plastic box in 9×9cm, 60 seeds were planted for each box, the seeds were covered with soil in the depth of 0.5cm. After 7-15 days, seedlings were treated with herbicides at needed leaf stage.

Herbicides were treated with Pot spray tower(made in Burkard) to seedlings, spray pressure is 10 p/inch^2, spray volume is 5ml. Precipitation of drops on vertical surface(X ± SE) is 168.16 ± 4.24 mg/100cm^2 . Accuracy(A) is 0.025.

5 to 6 concentrations of sethoxydim, bentazon and their mixtures were sprayed to barnyardgrass at either one or two leaf stage, and crabgrass either at two or three leaf stage, amaranth at two leaf stage or dockleaved knotweed at two leaf stage. Controls were sprayed with water. Each treatment replicates three times. All pots were arranged in completely randomized design. Responses were assessed 14 days after treatment. Dose-response curves were drawn, LC_{50} and LC_{90} were estimated. Isoble of 50% and 90% weed control were figured with method described by Tames(1964) and Akobundu(1981).

Result and Discussion

1. The effective action of sethoxydim and bentazon in mixture on barnyardgrass

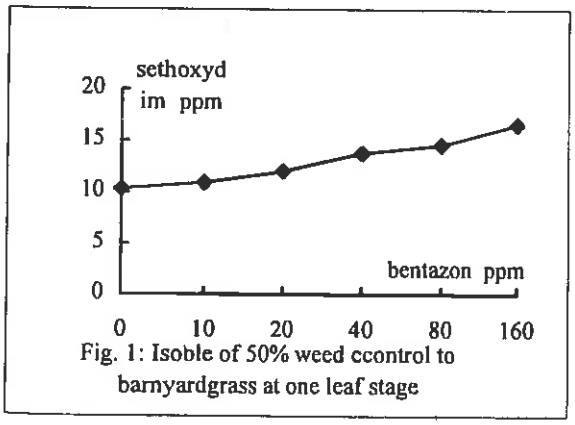


Fig. 1: Isoble of 50% weed ccontrol to barnyardgrass at one leaf stage

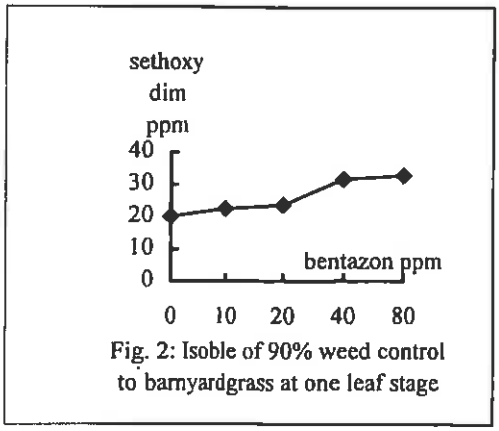


Fig. 2: Isoble of 90% weed control to barnyardgrass at one leaf stage

The LC_{50} of sethoxydim to barnyardgrass at one leaf stage was 10.1ppm. The LC_{90} of sethoxydim to barnyardgrass at one leaf stage was 20.1ppm. The Isoble of 50% and 90% weed control(Fig. 1, Fig. 2)) showed that bentazon had antagonistic action on activity of sethoxydim against one leaf stage barnyard grass.

The LC_{50} of sethoxydim to barnyardgrass at two leaf stage was 11.1ppm. The LC_{90} of sethoxydim to barnyardgrass at two leaf stage was 19.1ppm. The Isoble of 50% and 90% weed control(Fig. 3, Fig. 4) showed that high concentration of bentazon had antagonism on activity of sethoxydim against two leaf stage barnyardgrass.

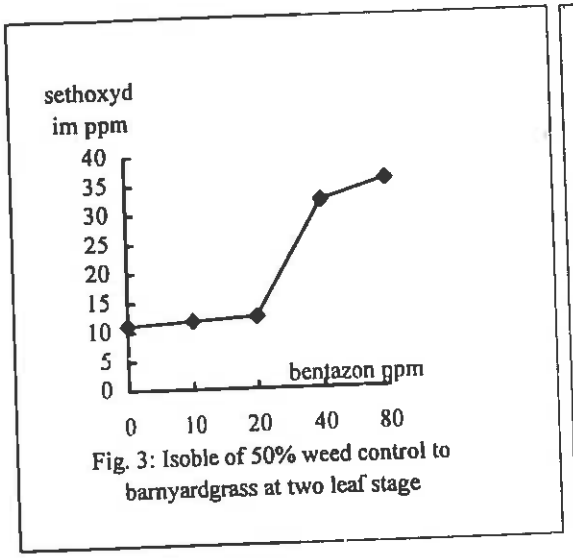


Fig. 3: Isoble of 50% weed control to barnyardgrass at two leaf stage

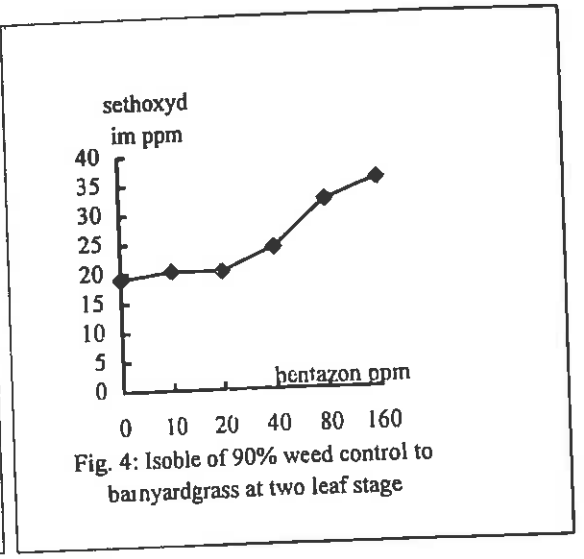


Fig. 4: Isoble of 90% weed control to barnyardgrass at two leaf stage

2. The effective action of sethoxydim and bentazon in mixture on crabgrass

The LC_{50} of sethoxydim to crabgrass at two leaf stage was 31.9ppm. The LC_{90} of sethoxydim to crabgrass at two leaf stage was 59.7ppm. The Isoble of 50% and 90% weed control(Fig. 5, Fig. 6) showed that bentazon had antagonism on activity of sethoxydim against two leaf stage crabgrass.

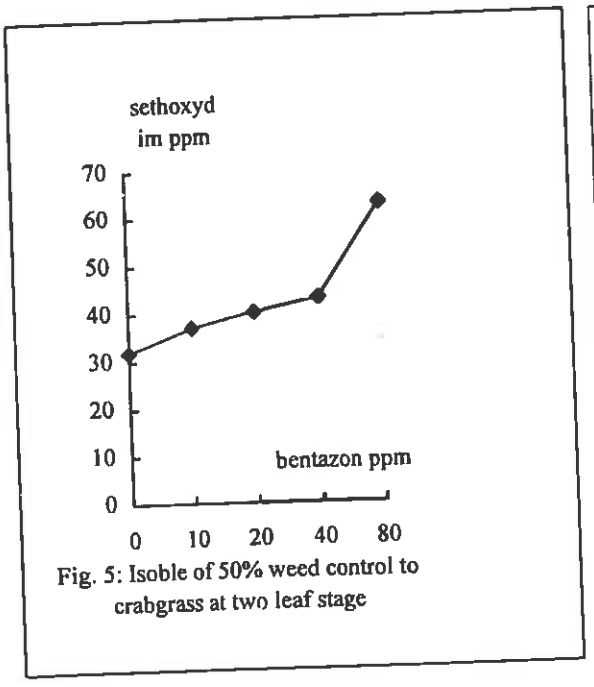


Fig. 5: Isoble of 50% weed control to crabgrass at two leaf stage

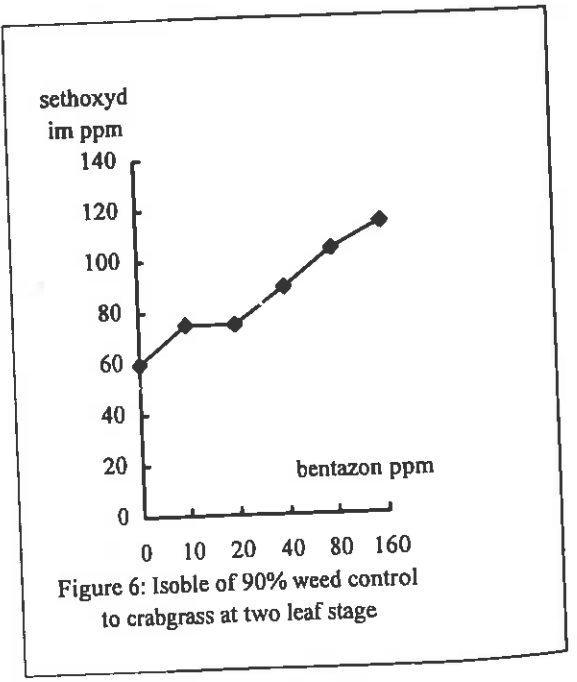


Figure 6: Isoble of 90% weed control to crabgrass at two leaf stage

The LC_{50} of sethoxydim to crabgrass at three leaf stage was 31.6 ppm. The LC_{90} of sethoxydim to crabgrass at three leaf stage was 64.2pm. The Isoble of 50% and 90% weed control(Fig. 7, Fig. 8) showed that bentazon had antagonism on activity of sethoxydim against three leaf stage crabgrass.

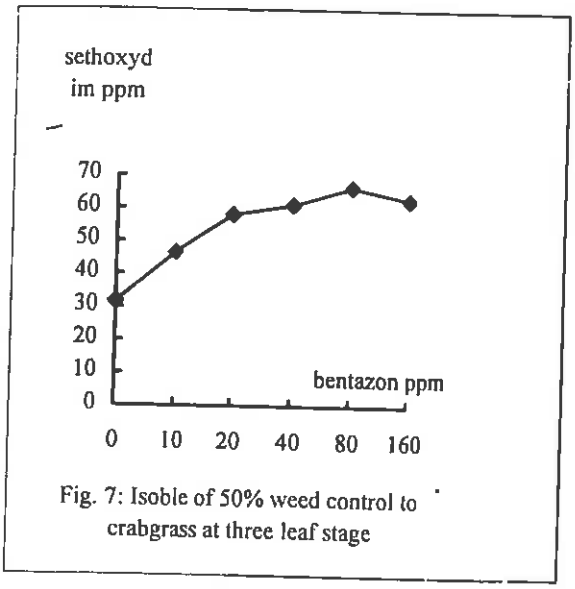


Fig. 7: Isoble of 50% weed control to crabgrass at three leaf stage

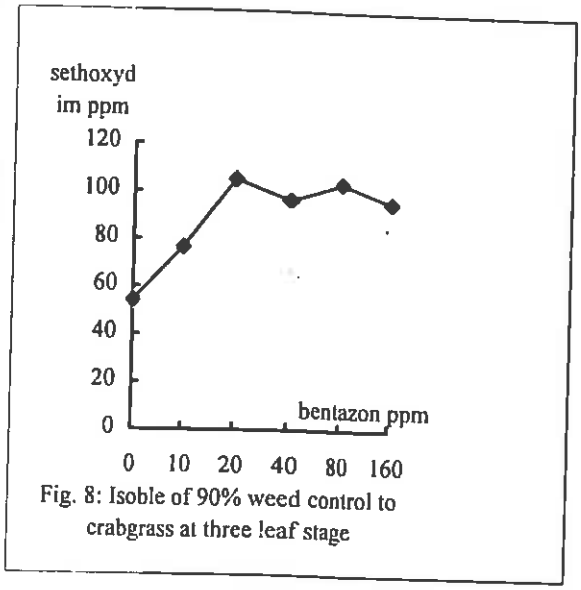


Fig. 8: Isoble of 90% weed control to crabgrass at three leaf stage

Chisaka(1989) pointed out: when Isoble method was used to evaluate the joint action of two herbicide, conclusion of joint action might have qualitative or quantitative difference if different weed growth stage or response level(50% or 90%) were used in experiments. Green(1989) also agreed that weed growth stage had quantitative and qualitative inffluence on antagonism between two herbicides. However, in this study, two growth stage and two response levels for each grass were tested, all Isobles from two leaf stages and two response levels showed that bentazon had antagonism on sethoxydim in the mixture.

Results above indicated: when mixture of sethoxydim and bentazon was applied to crabgrass or barnyardgrass, bentazon had obvious antagonism on activity of sethoxydim, and the antagonism didn't change when different weed species, different weed growth stages and different response levels were used. So, antagonism could be intrinsic joint action between sethoxydim and bentazon. Many reports showed: when tank mixture of sethoxydim and bentazon were used to control grasses, bentazon had antagonism on activity of sethoxydim against other grasses such as: *Panicum dichotomiflorum Michx, Brachiaria platyphlla(Griseb) Nash, Eleusine indica(L) Gaertn*[Rhodes and Coble, 1984];volunteer *Triticum aestirum L., Setaria italica(L) Beauv., Aven fatun L.*[Dexter and Nalervaja, 1987]; *Agropyron repens(L) Beauv.*[Wanamarta 1989]; *Panicum texanum Buckl.*[Grichar and Boswell, 1987]; *Sorghum halepensea(L) Pers.*[Retzinjer et.al., 1981]; *Setaria viridis var. majar(Guud) Posp.*[Whitwell and Walker, 1981], *Oryza sativa L.*[Minton et.al., 1987]. It was segggested that bentazon reduced activity of sethoxydim in mixture was universal.

3. The effective action of sethoxydim and bentazon in mixture on redroot amaranth.

The LC_{50} of bentazon to redroot amaranth at two leaf stage was 367 ppm. The LC_{90} of bentazon to redroot amaranth at two leaf stage was 1374ppm. The Isoble of 50% and 90% weed control(Fig. 9, Fig. 10) showed that bentazon had independent activity against two leaf stage redroot amaranth.

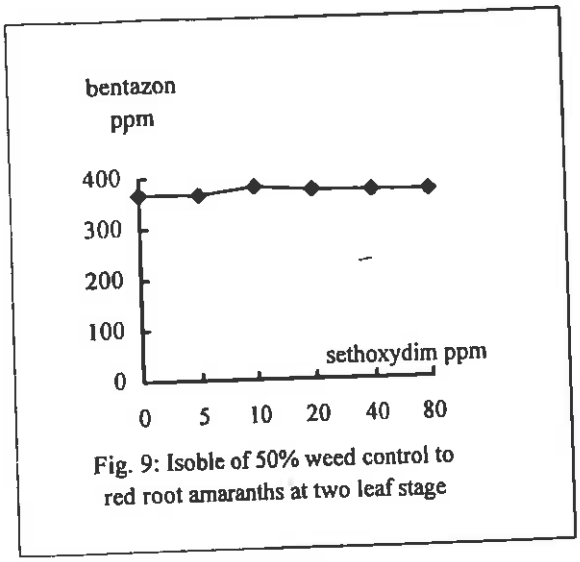


Fig. 9: Isoble of 50% weed control to red root amaranths at two leaf stage

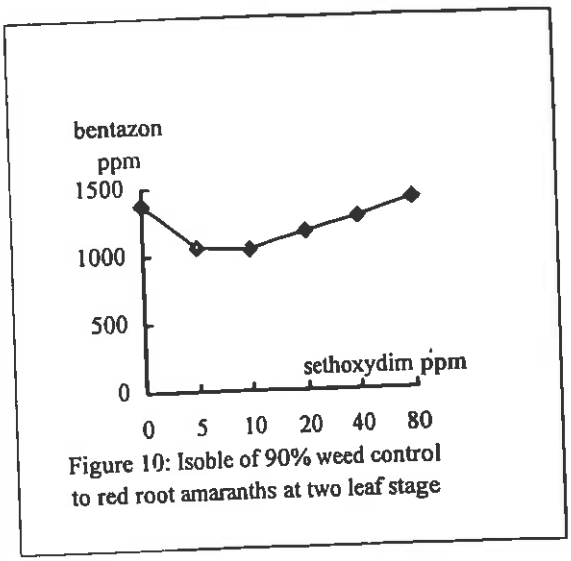


Figure 10: Isoble of 90% weed control to red root amaranths at two leaf stage

4. The effective action of sethoxydim and bentazon in mixture on dockleaved knotweed

The LC_{50} of bentazon to dockleaved knotweed at two leaf stage was 97 ppm. The LC_{90} of bentazon to dockleaved knotweed at two leaf stage was 159.1ppm. The Isoble of 50% and 90% weed control(Fig. 11, Fig. 12) showed that sethoxydim had slight antagonism on activity of bentazon against two leaf stage dockleaved knotweed.

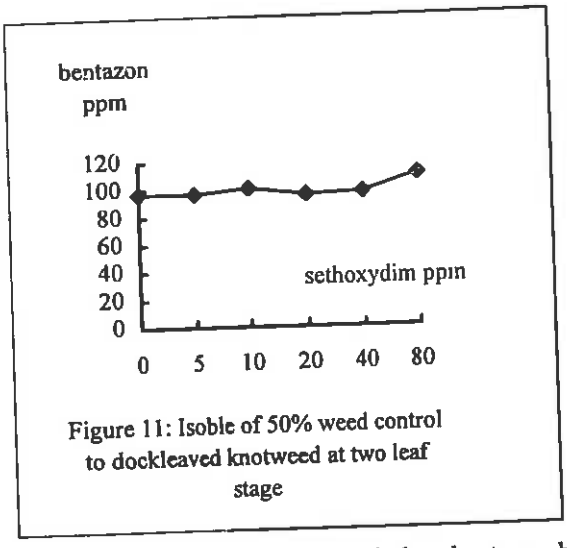


Figure 11: Isoble of 50% weed control to dockleaved knotweed at two leaf stage

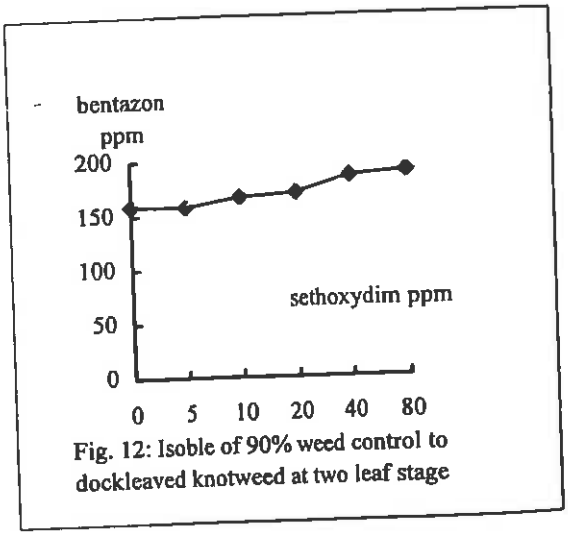


Fig. 12: Isoble of 90% weed control to dockleaved knotweed at two leaf stage

The results above indicated that bentazon had independent activity on redroot amaranth and dockleaved knotweed. When mixture of bentazon and sethoxydim was used to control weeds, sethoxydim had no influence on activity of bentazon against redroot amaranth and dockleaved knotweed. Other researchers also reported that sethoxydim had no influence on effects of bentazon in the mixture against broadleaf weeds such as: *Chenopodium album L., Abutilon theophrasti Medic., Amaranthus powellis(L) Roth, Ipomoea hederacea(L) Jacq.*[Holshouser and Coble, 1990]; *Amaranthus hybridus L.*[Grichar and Boswell, 1987]; *Sesbania exaltata(Raf)Cory, Sida spinosa L., Xunthium strunarium L.*[Retainger et.al., 1981]. Generally speaking, sethoxydim had no influence on effects of bentazon in mixture against broadleaf weeds.

When mixture of sethoxydim and bentazon was used to control weeds, bentazon had antagonistic action on activity of sethoxydim against grasses, but sethoxydim had no influence on effects of bentazon

against broadleaf weeds, this was asymmetric antagonism action between two herbicides. The asymmetric antagonism between herbicides also occurred in other herbicide mixtures. O'Sullivan and Born, O'Sullivan(1983) reported that joint action between diclofop, difenzoquat and 2,4-D, metsulfuron was asymmetric antagonism; Green(1991) reported joint action between quinzalop and Chlorimuron was asymmetric antagonism too.

Acknowledgment:

Special Acknowledgments to Mr. Wang, Huaming in ICAMA who provided the herbicides samples, many helps and guidance in experiments, Mrs. Qi Ming and Mr. Wang Zhongyan in our laboratory who provided a lot of helps during the experiments.

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STUDIES ON JOINT-ACTION OF HERBICIDE COMBINATION OF ATRAZINE WITH ACETOCHLOR

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ABSTRACT

The greenhouse experiments were carried out to evaluate the joint-action of herbicide combination of atrazine with acetochlor. The results showed that the combination was additive for pre-emergence control against barnyard grass (*Echinochloa crus-galli*), but synergized against hundred-day herb (*Zinnia elegans*). The optimum proportion of atrazine with acetochlor was from 2:1 to 1:4. Compared with separate use of atrazine and acetochlor in maize, the combination application can broaden weed control spectrum, lower use rate and decrease injury of atrazine residue to succeeding crops. The evaluation methods used here can also be used for other herbicide combination evaluation.

INTRODUCTION

Atrazine, a triazine herbicide developed in 1957, is a widely used herbicide for control of broadleaf and grassy weeds in corn, sorghum, sugarcane, pineapple and rangeland. It is also used in some areas for selective weed control in canifer reforestation and Christmans tree plantations as well as for nonselective control of vegetation in non-cropping land. Atrazine is one of the biggest herbicides used in corn because of its long persistence, broad-spectrum of weed control and high selectivity to corn plant. But sometimes it is harmful to the succeeding susceptible crops of wheat and soybean under cold and arid or semiarid climate and higher organic matter soils. Acetochlor, a relatively shoot-persistence herbicides, is widely used in corn, soybean, peanut and many other broadleaf crops, as well as many transplanted crops, with very high activity for grass weed control, but with low activity for some broadleaf weeds. Premix and tank mixing of those two herbicides are widely used in corn in China. The joint action of atrazine with acetochlor was evaluated by greenhouse experiments in this paper.

MATERIALS AND METHODS

Test Plants

Grassy weed: Barnyard grass [*Echinochloa crus-galli* (L.) Beauv.]
Broadleaf weed: Hundred-day herb (*Zinnia elegans* Jacq.)

Test Herbicides

Atrazine: 40% SC (Jilin Pesticide Factory)
Acetochlor: 50% EC (Dalian Ruize Pesticide Co. Ltd.)

Experiment Methods

The seeds of barnyard grass and hundred-day herb were sowed in 100 cm^2 clay pots and covered with 1-cm topsoil separately. The pots were thoroughly sucked with water. Pre-emergence treatments of the herbicides and their mixtures were sprayed at the designed rates 12 hours after sowing with a caterpillar crop sprayer (Spray volume: 50 ml/m^2; Caterpillar speed: 30 cm/s; Air pressure: 40 flb/in^2). All treatments were replicated 3 times and cultured in greenhouse. The weed control was investigated by the percent control of weed fresh weight compared with the untreated control 20 days after treatments. Gowing's method (Gowing, D. P. 1960) and the ED_{90} isobole method were used to evaluate the joint action of the combination of atrazine with acetochlor.

RESULTS AND DISCUSSION

The Joint Action of Atrazine with Acetochlor against Grassy Weed-Barnyard Grass

The upper ground part of barnyard grass of each treated pot was cut and weighed 20 days after treatments, the weed control of each treatment was calculated in table 1. The results showed that acetochlor has high activity against barnyard grass, but atrazine has low activity at the treated rates. As the same rate of acetochlor, the barnyard grass control of the combination application of atrazine is nearly the same as the single acetochlor application, which indicated that the atrazine does not antagonise for the weed control of acetochlor.
The hypothetical efficacy of weed control (E_0) of each combination was calculated by Gowing's equation with the observed (practical) efficacy of each single herbicide application (E). The equation is as follow:

$$E_o = X + \frac{Y\,(100-X)}{100}$$

Where X is the observed efficacy of herbicide acetochlor, Y is the observed efficacy of herbicide atrazine. E_o is the hypothetical efficacy of the combination of acetochlor with atrazine at the related rate.

From table 1, the value of the difference of E_o and E is nearly equal to 0, so the joint action of acetochlor with atrazine against barnyard grass is additive.

Table 1. The weed control efficacy of acetochlor and atrazine and their combinations against barnyard grass (%)

Herbicide treatment	Rate (gai/ha)	Percent of weed control (%)		Difference (E—E_o)
		Observed (E)	Hypothesis (E_o)	
Acetochlor	5	24.1		
	10	51.6		
	20	92.9		
	40	97.0		
Atrazine	40	14.1		
	80	16.2		
Acetochlor +Atrazine	5 +40	37.2	34.8	2.4
	10+40	60.1	58.4	1.7
	20+40	93.1	93.9	-0.8
	40+40	98.6	97.4	1.2
	5+80	36.3	36.4	-0.1
	10+80	59.0	59.4	-0.4
	20+80	94.7	94.1	0.6
	40+80	96.1	97.5	-1.4

- The results are the average of three replications.
- The average fresh weight of the untreated control is 5.37 g/pot.

The Joint Action of Atrazine with Acetochlor against Broadleaf Weed--Hundred-day herb

Table 2. The weed control efficacy of acetochlor and atrazine and their combinations against hundred-day herb (%)

		Acetochlor application rates (g ai/ha)						Response curves of acetochlor
		0	187.5	375	750	1500	3000	
Atrazine application rates (gai/ha)	0	—	3.3	14.7	32.8	57.2	84.4	Y_0
	150	26.7	36.7	40.0	66.7	78.0	100	Y_1
	225	44.4	46.4	77.8	88.7	94.4	100	Y_2
	300	53.3	66.7	81.7	90.0	100	100	Y_3
	600	70.4	73.3	86.7	94.4	100	100	Y_4
	900	86.7	94.4	95.3	100	100	100	Y_5
	1800	93.6	100	100	100	100	100	—
Atrazine response curves		y_0	y_1	y_2	y_3	y_4	—	

The results in table 2 showed that the weed control efficacy of acetochlor and atrazine was increased with the application rates. The weed control efficacy of combinations is higher than that of each single herbicide applications, so there is no antagonism action caused by the acetochlor and atrazine mixtures against hundred-day herb.

Linear regression equation of each test group was established from the application rates and percent control. ED_{90} was calculated by the equation. The equation and ED_{90} of each test group are as follows:

Equations and ED_{90} values based on the response of herbicide acetochlor:

Y_0=6.02+0.028X	r_0=0.9745	ED_{90}=3007.6
Y_1=34.9+0.024X	r_1=0.9515	ED_{90}=2309.2
Y_2=58.8+0.017X	r_2=0.7916	ED_{90}=1831.7
Y_3=62.2+0.029X	r_3=0.9155	ED_{90}=969.2
Y_4=73.7+0.020X	r_4=0.9182	ED_{90}=814.7
Y_5=88.8+0.016X	r_5=0.9315	ED_{90}=72.4

Equations and ED_{90} values based on the response of herbicide atrazine:

y_0=38.5+0.036X	r_0=0.8766	ED_{90}=1421.6
y_1=34.1+0.046X	r_1=0.8352	ED_{90}=1221.2
y_2=50.3+0.036X	r_2=0.7147	ED_{90}=1094.6
y_3=57.3+0.059X	r_3=0.7759	ED_{90}=552.0
y_4=57.3+0.149X	r_4=0.8766	ED_{90}=219.9

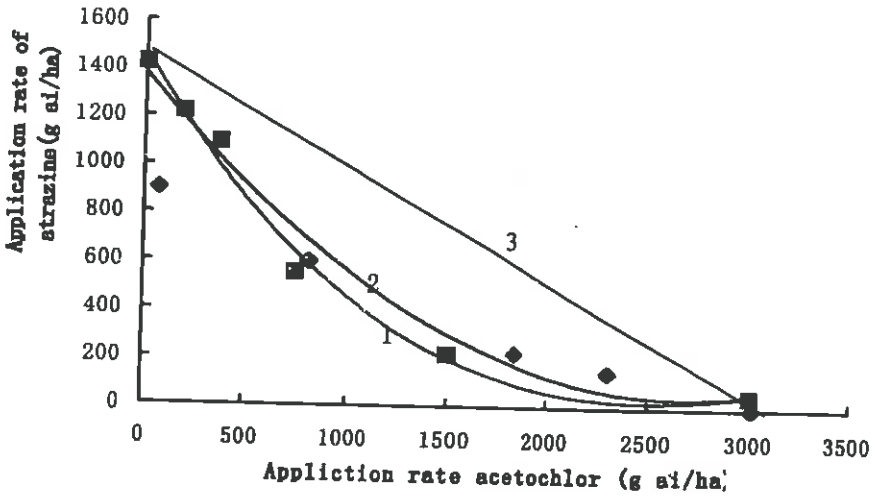


Figure1. ED90 isoboles of the mixture of acetochlor with atrazine

1.The ED_{90} isobole of mixture based on atrazine
2 .The ED_{90} isobole of mixture based on acetochlor
3. The hypothetical additive isobole of mixtures

The isobole of ED_{90} curve was drawn based on the ED_{90} of each test groups (Figure 1). The isoboles of ED_{90} response of acetochlor or atrazine were below the additive isobole, so the joint action of acetochlor with atrazine mixtures was synergized. According to the weed control efficacy and the ED_{90} isobole, the propriety combination of acetochlor and atrazine is about 900~300 g ai/ha atrazine with 450~1200g ai/ha acetochlor. i. e. The range from 900 g ai/ha atrazine mixed with 450 g ai/ha acetochlor (2:1) to 300 g ai/ha atrazine mixed with 1200 g ai/ha acetochlor (1:4) is the propriety proportion of the mixtures. The distance from the ED_{90} isobole of this part to the additive isobole is longer than that of other part, so synergism action in this part is higher than other parts.

Reducing the rate of atrazine and increasing the rate of acetochlor in the mixtures, the residue injury to the succeeding crops could be reduced. In the production and application of the mixture of atrazine with acetochlor, the best proportion of atrazine and acetochlor should be selected according to the economical cost, crop safety, and the field performance of weed control.

CONCLUSIONS

The joint action of the combination application of atrazine with acetochlor was additive for pre-emergence control against barnyard grass, but synergized against hundred-day herb. The propriety proportion of atrazine with acetochlor combination was from 2:1 to 1:4.

This experiment was conducted under the greenhouse condition. The activity of acetochlor in greenhouse was higher than that in the field. The optimum proportion of the combination for the industry and application should be tested further in the field condition.

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THE EFFECTS OF HERBICIDE GLYPHOSATE AND 2,4-D MIXTURES ON WEED DEPRESSION IN SOYBEAN FIELD

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Abstract: Two experiments consisted of Expt. I (Lab. Expt.) and Expt II (a Field Expt., Desa Mojorejo, Malang, at an altitude ca 505 m , Alluvial) have been conducted in the early part of dry season from April 1997 upto November 1997. The Expt. I was to determine whether the expected herbicide mixture doses to control weeds in a selective way. This Expt. I was designed as a FRD with 3 replicates. The treatments were of H_0 = No herbicide applied, 2.4-D applied singly (H_1, H_2, H_3), Glyphosate applied singly (H_4, H_5, H_6), herbicide mixtures of Glyphosate + 2,4-D (H_7, up to H_{15}). Expt. II was to show the effects of time applications of the obtained doses, and was designed as a Split Plot Design with 3 replicates, the Main Plots were of herbicide application times A (= 2 weeks before soil till) and B (= 1 week before soil till), the sub plots were of herbicide mixture doses, i.e. No herbicide applied (C_0) and herbicide mixture of Glyphosate + 2,4-D (C_1 up to C_5). The results of the Expt. II showed that the herbicide mixture doses of 2.62 l Glyphosate/ha + 1.09 l 2,4-D/ha gave the highest soybean dry weight (21.1 q/ha). Such the herbicide mixture controlled well the weed species *Ageratum conyzoides* and *Paspalum conjugatum*.

Key words: Glyphosate, 2,4-D, herbicide mixtures, weed depression

INTRODUCTION

Herbicide mixtures used gave several advantages, as weed control spectrum increased and herbicides dose used decreased (Moenandir, 1993). Herbicide doses may increase the effectivity of weed control. The toxicity of herbicide mixtures of glyphosate and 2,4-D (sistemic) needed time to translocate throughout the plant body. Single herbicide used controlled a certain weed species only. In using such herbicide in soybean field there were not satisfy results in controlling the grasses, broad-leaved and cyperus simultaneously. Therefore, a modification of herbicide used in mixtures may over-come the matter. The herbicide mixture forms have two kind of active ingredients and mode of actions. The glyphosate herbicide active ingredient inhibited amino acid biosinthetic pathway, while the active ingredient of 2,4-D increased the respiration process of weeds. Herbicide doses also indicated the effectivity in weed controlling. The herbicide mixtures of sulfonil urea and imidazolin may prevent the resistant evolution process in weeds (Wrubel and Gressel, 1994). The mode of actions of herbicide mixtures may depress several targeted weed species (Fryer and Evans, 1970). The activities of glyphosate and 2,4-D mixtures was based on the different of mode of actions. (Ashton and Monaco, 1991). Isobol methode (LD_{50} or GR_{50} technique) may be used to show the mechanism of herbicide mixtures (Akobundu, 1975). In general, however, the rational behind the mixtures should be well recognized.

Herbicide doses was one of the consideration in weed control. Optimal herbicide dose used for selective weed control, and the herbicide dose was indicated by the herbicide active ingredient. The low dose of glyphosate and imazaquin herbicide mixtures gave a synergistic respons, while the increment of omazaquin dose gave the antagonistic responses (Hydrick and Shaw, 1994). Glyphosate herbicide aplicated singly ineffectively controlled the broadleaved weeds, while by the additions of 2,4-D herbicide may increase the efficacy, fitotoxicity, compatibility and sinergistic effect of the glyphosate.

Time of applications may avoid the antagonistic effect of the 2,4-D on fixing the amino acid which formed the glyphosate. Hence the use of herbicide mixtures which considered the doses and time of aplication was important to try in this study.

MATERIALS and METHODS

Experiment I

The Expt. I was conducted in Lab. by planting 25 soybean, *Ageratum conyzoides* and *Paspalum conjugatum* (the dominant weed species in soybean field) seeds on petri dishes (ø 9 cm) with two filter papers of Whatman No. 1, respectively. The investigations using GR_{50} technique, to attain the expected selective herbicide dose, and arranged in a FRD with three replicates and 16 treatments, i.e. H_0 = no herbicide, herbicide 2,4-D applied at H_1 = 0.40 ppm (629.08 g a.i/ha), H_2 = 0.60 ppm (943.62 g a.i./ha), H3 = 0.80 ppm (1258.16 g a.i./ha), herbicide glyphosate applied at H_4 = 0.20 ppm (314.54 g a.i./ha), H_5 = 0.30 ppm (471.81 g a.i./ha), H_6 = 0.40 ppm (629.08 g a.i./ha), glyphosate + 2,4-D herbicide mixtures apllied at H_7 = 0.20 ppm + 0.40 ppm, H_8 = 0.20 ppm + 0.60 ppm, H_9 = 20 ppm + 80 ppm, H_{10} = 0.30 ppm + 0.40 ppm, H_{11} = 0.30 ppm + 0.60 ppm, H_{12} = 0.30 ppm + 80 ppm, H_{13} = 0.40 ppm + 0.40 ppm, H_{14} = 40 ppm + 0.60 ppm and H_{15} = 0.40 + 0.80 ppm. (and also according to Colby, 1967).

Experiment II

The Expt. II was situated in the Dessa Mojorejo, East Java, at an altitude ca 505 m in a field of Alluvial soil. It was carried out in the eraly part of the dry season from April upto November 1997. It was arranged in a Split Plot Design with three replicates. The main treatments were of time of applications, i.e. A = 2 weeks before soil till and B = 1 weeks before soil till. The sub treatments were of the Expt. I expected gained doses of herbicide mixtures glyphosate and 2,4-D, i.e. C_0 = No herbicide, glyphosate + 2,4-D herbicide mixtures applied at C_1 = 471.81 g a.i./ha (1.97 l/ha) + 943.62 g a.i. /ha (1.09 l/ha), C_2 = 471.81 g a.i./ha (1.97 l/ha) + 629.08 g a.i./ha (1.45 l/ha), C_3 = 629.08 g a.i./ha (2.62 l/ha) + 629.08 g a.i./ha (0.73 l/ha), C_4 = 629.08 g a.i./ha (2.62 l/ha) + 943.62 g a.i./ha (1.09 l/ha) and C_5 = 629.08 g a.i./ha (2.62 l/ha) + 1258.16 g a.i./ha (1.45 l/ha).

The four soybean seeds (prior were inocculated with Legin) were planted in a three cm depth hole and at 20 cm x 30 cm spacing. The fertilizers were applied to the soil as at the rate of 50 kg Urea/ha, 100 kg SP 36/ha and 100 kg KCl/ha. Thinning of the seedlings at Day - 7 and two emerged seedlings left. Watering and pest and disease controls were done as needed. Herbicide fan spraying of 1.1 m wide using blue nozzle sprayer (ICI product). Weed observations and measurements were made at before the herbicides applied and after the herbicide applied at Days - 14, 28, and 42 in a quadrant of 0.25 m x 0.25 m per plot, containing 4 soybean crops. The soybean seeds and the vegetative development and weed species compositions and its dry weight amount were measures by destructive sampling.

RESULTS and DISCUSSION

The expected doses

The expected doses of glyphosate and 2,4-D herbicides in cocktail were of in the range of the glyphosate: 0.30 - 0.40 ppm and the 2,4-D: 0.40 - 0.80 ppm. The herbicide mixtures used for testing the *P. conjugatum, A. conyzoides* and soybean. The results indicated that at Day - 7 there were additive and sinergistic effects on the shoot and root length and shoot dry weight of *P. conjugatum*, shoot length and dry weight of the *A. conyzoides* sprouts, root length and shoot dry weight of soybean, and can be seen in the following Tables 1, 2, 3 and 4.

Table 1. Inhibition % of shoot and root length, shoot and root dry weight of *P. conjugatum* at Day - 7

Herbicides Glyphosate (ppm)	Shoot length inhibition %			
	2,4-D (ppm)			
	0	0.40	0.60	0.80
0	-	6.15	11.54	13.46
0.20	36.15	38.85-(40.08)	45.38+(43.32)	45.77+(44.74)
0.30	47.31	51.15+(50.55)	53.85+(53.39)	55.00+(54.40)
0.40	47.69	54.23+(50.91)	55.77+(53.73)	57.70+(54.73)
Herbicides Glyphosate (ppm)	Root length inhibition %			
	2,4-D (ppm)			
	0	0.40	0.60	0.80
0	-	12.57	100.00	100.00
0.20	23.56	11.57-(33.17)	15.18-(100)	16.75-(100)
0.30	25.65	11.52-(35.00)	12.57-(100)	100.00=(100)
0.40	34.55	9.95-(42.78)	100.00=(100)	100.00=(100)
Herbicides Glyphosate (ppm)	Shoot dry weight inhibition %			
	2,4-D (ppm)			
	0	0.40	0.60	0.80
0	-	16.67	19.23	22.44
0.20	21.15	21.15-(34.29)	21.79-(36.31)	27.56-(34.74)
0.30	25.64	38.46+(38.04)	42.31+939.94)	43.59+(42.33)
0.40	26.28	42.31+(38.57)	44.23+(40.46)	46.15+(42.83)
Herbicides Glyphosate (ppm)	Root dry weight inhibition %			
	2,4-D (ppm)			
	0	0.40	0.60	0.80
0	-	23.08	100.00	100.00
0.20	26.92	57.69+(43.79)	57.69-(100)	65.38-(100)
0.30	53.85	65.38+(64.50)	65.38-(100)	100.00=(100)
0.40	53.85	69.23+(64.50)	100.00=(100)	100.00=(100)

Notes: figures in brackets denoted expected response value according to Colby (1967)
+ : sinergistic, - : antagonistic; = : additive

Table 2. *A. conyzoides* sprouts length and dry weight inhibition % at Day - 7

Herbicides Glyphosate (ppm)	Sprouts length inhibition %			
	2,4-D (ppm)			
	0	0.40	0.60	0.80
0	-	15.15	21.21	24.24
0.20	12.12	50.00+(49.88)	55.45+(53.14)	58.55+(56.28)
0.30	18.18	51.82+(50.12)	54.55+(53.37)	58.91+(56.49)
0.40	37.64	60.91+(58.27)	61.45+(60.99)	63.63+(63.61)
Herbicides Glyphosate (ppm)	Sprouts dry weight inhibition %			
	2,4-D (ppm)			
	0	0.40	0.60	0.80
0	-	15.15	21.21	24.24
0.20	12.12	33.33+(25.43)	48.48+(30.76)	54.55+(41.98)
0.30	18.18	36.36+(30.58)	48.48+(35.53)	51.52+(41.98)
0.40	36.36	48.48+(46.00)	60.61+(49.86)	72.73+(51.79)

Notes. Figures in brackets indicated the expected response value (Colby, 1967);
+: sinergistic; -: antagonistic

Tabel 3. Soybean shoot and root length inhibition % (Day -7)

Herbicides Glyphosate (ppm)	Shoot length inhibition %			
	2,4-D (ppm)			
	0	0.40	0.60	0.80
0	-	16.80	30.53	32.12
0.20	4.09	8.74-(20.20)	15.10-(33.37)	19.53-(31.90)
0.30	12.37	15.66-(27.09)	16.91-(39.12)	37.00-(40.53)
0.40	32.12	40.30-(43.52)	41.66-(52.84)	52.55-(53.92)
Herbicides Glyphosate (ppm)	Root length inhibition %			
	2,4-D (ppm)			
	0	0.40	0.60	0.80
0	-	27.39	50.88	60.03
0.20	14.67	30.16-(38.04)	50.31-(58.09)	59.27-(65.89)
0.30	16.96	31.30-(39.70)	56.17-(59.21)	65.36-(66.81)
0.40	22.58	61.27+(43.79)	68.65+(61.97)	70.84+(69.06)

Notes: Figures in brackets indicating the expected response value (Colby, 1967);
+: sinergistic;-: antagonistic; = : additive

Tabie 4. Soybean shoot and root dry weight inhibition % (Day - 7)

Herbicides Glyphosate (ppm)	Shoot dry weight inhibition %			
	2,4-D (ppm)			
	0	0.40	0.60	0.80
0	-	8.36	11.67	25.09
0.20	2.43	4.87-(10.50)	5.57-(13.82)	17.77-(26.91)
0.30	4.53	11.42-(12.51)	17.42+(15.67)	24.56-(28.48)
0.40	25.26	25.61-(31.51)	43.73+(33.98)	45.82+(44.01)
Herbicides Glyphosate (ppm)	Root dry weight inhibition %			
	2,4-D (ppm)			
	0	0.40	0.60	0.80
0	-	29.03	55.91	58.06
0.20	19.35	34.41-(42.76)	44.09-(64.44)	61.29-(66.18)
0.30	20.43	22.58-(43.53)	63.92-(64.92)	70.96+(43.53)
0.40	27.96	62.37+(48.87)	69.89+(68.24)	72.04+(69.79)

Notes: Figures in brackets indicating the expected response value (Colby, 1967);
+: sinergistic; -: antagonistic

Table 5. Soybean yield and yield components

Herbicide glyphosate+2,4-D	Pod numbers	Seed numbers	Seed weight per plant, g	Yield qwt/ha
C0:No	18.58 a	34.90 a	3.52 a	11.72 a
C_1:1.97+1.09	21.40 b	42.46 b	4.15 b	13.84 b
C_2:1.97+1.45	26.48 c	56.73 c	5.49 c	18.31 c
C_3:2.62+0.73	26.60 c	56.68 c	5.48 c	18.25 c
C_4:2.62+1.09	33.88 d	68.58 d	6.33 d	21.10 d
C_5:2.62+1.45	35.42 d	67.65 d	6.16 d	20.53 d

Notes. figures followed by the same letter in the same column indicated not significant at p = 0.05:C_0 = No herbicide applied; C_1-C_5 = glyphosate + 2,4-D herbicide mixtures

Soybean yield and yield components

Soybean yield and yield components can be seen in Table 5. The expected doses obtained (from Expt. I) were used in Expt. II.
The treatments C_4 and C_5 did not significantly differ, but significantly differ to the rests ($p = 0.05$), hence the highest soybean yield based on the C_4.

Pods per plant numbers (Table 5) greatly contributed to the highest soybean yield. The highest soybean yield obtained (21.1 qwt/ha) was of the treatment C_4 = glyphosate 629.08 g a.i./ha (2.62 l/ha) + 2,4-D 943.62 g a.i./ha (1.09 l/ha); on the other hand the lowest soybean yield obtained (11.7 qwt/ha) was of the C_0 = no herbicides applied, as was also mentioned by Gardner *et al.* (1985). Apparently the weed infestment without any weed control in the period of the study seriously reduced the soybean yield.

ACKNOWLEDGEMENTS:

The authors are gratefully to the PT Monagro Kimia (Monsanto), Jakarta 10350, for providing the facilities; and also to the other donator.

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USE OF HALOXYFOP-R-METHYL ESTER FOR ANNUAL GRASS WEED CONTROL IN GROUNDNUT(*Arachis hypogea*)

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Abstract: Haloxyfop-R-methyl ester [R-methyl-2-(4-(3-chloro-5-(trifluoro-methyl)-2pyridyloxypropionate] was applied for annual grass weed control in groundnut (var. Tainan 9). The experiments were conducted in 2 locations in Chiang Mai during June-November 1998. The herbicide was treated as postemergence ontop of crop and weeds at 14 -18 days after planting with knapsack sprayer in spray volume of water 375 l/ha. The results showed that haloxyfop-R-methyl ester [R-methyl-2-(4-(3-chloro-5-(trifluoro-methyl)-2pyridyloxy)propionate] at a rate higher than 47.25 g ai/ha provided excellent control of annual grass weeds such as *Digitaria adscendens* H.B.K.Henr., *Echinochloa colona*(L.)Link., *Eleusine indica*(L.)Gaertn. and *Echinochloa crus-galli*(L.)Beauv. Haloxyfop-R-methyl ester at 47.25 g ai/ha gave an effective control of annual grass weeds as fluazifop-butyl [(±)-2-[4-[[5(trifluoromethyl)-2-pyridinyl]oxy] phenoxy]propionic acid] at 150 g ai/ha. It was also found that haloxyfop-R-methyl ester at 33.75 - 67.50 g ai/ha caused no injury to groundnut. The use of haloxyfop-R-methyl ester for annual grass weed control could produce significantly higher yield of groundnut than non weeding plot.

Key words: groundnut, annual grass weed, haloxyfop-R-methyl ester , fluazifop-butyl

Introduction

Weed competition is the most serious problem in groundnut cultivation in Thailand. Different weed control methods are essential for increasing yield (Kosol et al.,1987). One to three times of hand weeding after planting are needed for groundnut production(Atnont et. al., 1988). Labour cost and shortage are the limiting factor that hand weeding can not be used in the field. The use of herbicides for controlling weeds is one of the alternative methods that can solve the yield loss problem in groundnut. Many preemergence and postemergence herbicides were tested in goundnut. Preemergence herbicides that have been used in groundnut were effective but there were many limiting factors such as soil condition and timing of application. The use of postemergence herbicide such as fluazifop-butyl for annual grass weed control was tested in the field (Atnont et.al., 1987). Haloxyfop-R-methyl ester is one of the postemergence selective herbicide that were alredy tested in many broadleaf crops such as soybean (Pornchai, 1995;1997) and Potato(Pornchai,1996). However, there are no report that haloxyfop-R-methyl ester has been tested in groundnut. This research was conduted to determine the effectiveness of haloxyfop-R-methyl ester applied as postemergence herbicide in groundnut.

Materials and Methods

Field studies were conduted at 2 locations in Chiang Mai province during July-November 1998. Groundnut variety Tainan 9 was planted at spacing 20x33 cm. A RCB design with 3 replications was used. Haloxyfop-R-methyl ester at the rates of 33.75-67.50 g ai/ha were treated to compare with fluazifop-butyl at 150.0 g ai/ha , hand weeding and non weeding plot. The herbicidess were sprayed at 14 and 18 days after planting in Location I and II ,respectively. The spray volume of water delivering 350 l/ha with flat fan nozzle. The chemical name of haloxyfop-R-methyl ester is R-methyl-2-(4(3-chloro-5-(triluoromethyl)-2pyridyloxy)propionate with the trade name Gallant-Super and fluazifop-butyl is (±)-2-[4-[[5(trifluoromethyl)-2-pyridinyl)oxy]phenyoxy]propionic acid with the trade name of Onecide-Super. Weed control and

crop injury were evaluated after spraying. Visual estimate was based on 0 to 100% scale. Crop yield was recorded in the sampling area of 4x5 sq.m.

Results and Discussions

The major weeds in both locations were *Echinochloa colona* (L.)Link., *Eleusine indica* (L.)Gaertn., *Digitaria adscendens* H.B.K.Henr., *Echinochloa crus-galli*(L.)Beauv., *Amaranthus spinosus* L., *Amaranthus viridis* L. *Ageratum conyzoides* L., *Cleome viscosa* L. *Porturaca oreracea* Linn. and *Euhorbia geniculata* Ort.

Efficacy of herbicide

Table 1 and 2 indicate efficacy for haloxyfop-R-methyl ester for annnual grass weeds control at 7-35 days after application. The results showed that haloxyfop-R-methyl ester at 33.75 g ai/ha gave incomplete control. Haloxyfop-R-methyl ester at the higher rate 47.25 g ai/ha provided complete control of annual grass weeds from 14 days after application. The use of haloxyfop-R-methyl ester at 47.25 g ai/ha showed as effective control of annual grass weeds as fluazifop-butyl at 150.00 g ai/ha, which is in keeping with reports of Pornchai (1995).

At 30 days after application weeds were collected from each plot. The results are shown in Table 3-6. It was found that the haloxyfop-R-methyl ester at the rate higher than 47.25 g ai/ha could completely control annual grass weeds. Haloxyfop-R-methyl ester could not control of broadleaf weeds in the experiments. This is because haloxyfop-R-methyl ester is a grass weed herbicide (Pornchai,1997).

Crop Phytotoxicity

Crop phytotoxicity was assessed at 7-45 days after application by using visual evaluation. Haloxyfop-R-methyl ester at 33.75-67.50 g ai/ha gave no phytotoxicity to groundnut (Table 7,8).

Growth and yield of groundnut

Table 7, 8 indicate that the height of groundnut at 30 days after application of haloxyfop-R-methyl ester and at harvesting peroid were slightly difference from that of the hand weeding plot. The use of haloxyfop-R-methyl ester for annual grass weeds control could significantly increase yield of groundnut when compared to non-weeded plot (Table 7,8). The application of haloxyfop-R-methyl ester at 47.25 g ai/ha could produce yield of groundnut upto 1,606.3 and 1,689.4 kg/ha in experiment I and II, respectively. The use of haloxyfop-R-methyl ester at 47.25 g ai/ha gave similar yield of groundnut to hand-weeded plot.

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Table 1 Efficacy of haloxyfop-R-methyl ester on annual grass weed control in groundnut (Location I).

Herbicide	Rate	Control Rating [1/]								
		7 DAA[2/]			21 DAA[2/]			35 DAA[2/]		
	g ai/ha	ECHCO	ELEIN	DIGAD	ECHCO	ELEIN	DIGAD	ECHCO	ELEIN	DIGAD
Haloxyfop	33.75	6.5	6.0	6.5	8.5	8.0	8.9	8.0	7.8	8.3
Haloxyfop	40.50	7.0	6.5	6.8	8.9	8.3	9.3	8.3	8.0	8.5
Haloxyfop	47.25	8.5	8.3	8.6	10.0	9.8	10.0	9.3	9.0	9.3
Haloxyfop	54.00	9.5	9.3	9.6	10.0	10.0	10.0	9.8	9.3	9.8
Haloxyfop	60.75	9.5	9.3	9.6	10.0	10.0	10.0	10.0	10.0	10.0
Haloxyfop	67.50	9.6	9.5	9.6	10.0	10.0	10.0	10.0	10.0	10.0
Fluazifop	150.00	6.8	9.3	9.7	9.3	9.0	9.3	9.0	9.0	9.0
Hand weeding	-	-	-	-	-	-	-	-	-	-
Non weeding	-	-	-	-	-	-	-	-	-	-

Annual grass weeds: ECHCO = *Echinochloa colona*(L.)Link., ELEIN = *Eleusine indica* Gaertn., DIGAD = *Digitaria adscendens* H.B.K.Henr.

[1/] Control Rating: 0=No control, 10= Completely control. [2/] DAA: Days after application.

Table 2 Efficacy of haloxyfop-R-methyl ester on annual grass weed control in groundnut (Location II).

Herbicide	Rate	Control Rating [1/]				
		7 DAA[2/]		21 DAA[2/]		35 DAA[2/]	
	g ai/ha	ELEIN	DIGAD	ELEIN	DIGAD	ELEIN	DIGAD
Haloxyfop	33.75	7.5	7.7	8.5	8.0	8.0	7.8
Haloxyfop	40.50	8.0	8.3	9.3	9.3	8.3	8.0
Haloxyfop	47.25	9.5	9.6	10.0	10.0	10.0	10.0
Haloxyfop	54.00	9.9	9.9	10.0	10.0	10.0	10.0
Haloxyfop	60.75	9.9	9.9	10.0	10.0	10.0	10.0
Haloxyfop	67.50	9.9	9.9	10.0	10.0	10.0	10.0
Fluazifop	150.00	6.8	9.3	9.8	9.5	9.3	9.3
Hand weeding	-	-	-	-	-	-	-
Non weeding	-	-	-	-	-	-	-

Annual grass weeds: ELEIN = *Eleusine indica*(L.)Gaertn., DIGAD = *Digitaria adscendens* H.B.K.Henr.

[1/] Control Rating: 0=No control, 10= Completely control. [2/] DAA: Days after application.

Table 3. Effect of haloxyfop-R-methyl ester on annual grass weed density and dry weight at 30 days after application (Location I).

Herbicide	Rate	No/ 0.25m^2			g / 0.25 m^2		
	g ai/ha	ECHCO	ELEIN	DIGAD	ECHCO	ELEIN	DIGAD
Haloxyfop	33.75	2.0 b	3.3 b	3.7 b	12.8 ab	7.2 b	15.2 b
Haloxyfop	40.50	1.0 b	3.3 b	3.3 b	7.9 bc	6.5 bc	14.2 b
Haloxyfop	47.25	0.3 b	0.7 b	0.3 b	3.5 bc	2.5cd	1.4 c
Haloxyfop	54.00	0 b	0 b	0 b	0 c	0 d	0 c
Haloxyfop	60.75	0 b	0 b	0 b	0 c	0 d	0 c
Haloxyfop	67.50	0 b	0 b	0 b	0 c	0 d	0 c
Fluazifop	150.00	0.7 b	1.0 b	2.0 b	5.5 bc	2.4 cd	4.8 c
Hand weeding	-	0 b	0 b	0 b	0 c	0 d	0 c
Non weeding	-	17.3 a	16.7 a	17.0 a	23.9 a	35.4 a	37.9 a
	C.V.	97.0%	74.9%	83.2%	83.8%	19.2%	36.7%

Annual grass weeds: ECHCO = *Echinochloa colona*(L.)Link., ELEIN = *Eleusine indica*(L.)Gaertn., DIGAD = *Digitaria adscendens* H.B.K.Henr.

Table 4. Effect of haloxyfop-R-methyl ester on annual grass weed density and dry weight at 30 days after application (Location II).

Herbicide	Rate	No/ 0.25m^2		g / 0.25 m^2	
	g ai/ha	ELEIN	DIGAD	ELEIN	DIGAD
Haloxyfop	33.75	2.0 b	5.7 b	6.7 b	11.8 b
Haloxyfop	40.50	2.0 b	3.0 b	4.9 b	6.4 bc
Haloxyfop	47.25	1.0 b	0.7 c	3.6 b	1.3 c
Haloxyfop	54.00	0.7 b	0 c	2.9 b	0 c
Haloxyfop	60.75	0.3 b	0 c	2.7 b	0 c
Haloxyfop	67.50	0 b	0 c	0 b	0 c
Fluazifop	150.00	1.7 b	1.3 bc	0.1 b	4.3 bc
Hand weeding	-	0 b	0 c	0 b	0 c
Non weeding	-	12.0 a	10.0 a	20.6 a	27.7 a
	C.V.	89.8%	42.2%	78.9%	58.5%

Annual grass weeds: ECHCO = *Echinochloa colona*(L.)Link.,
ELEIN = *Eleusine indica*(L.)Gaertn.,
DIGAD = *Digitaria adscendens* H.B.K.Henr.

Table 5. Effect of haloxyfop-R-methyl ester on annual broadleaf weed density and dry weight at 30 days after application (Location I).

Herbicide	Rate	No/ 0.25m^2			g / 0.25 m^2		
	g ai/ha	AMASP	AMAVI	CLEVI	AMASP	AMAVI	CLEVI
Haloxyfop	33.75	7.0 a	2.3 b	2.3 b	34.8 b	25.4 a	15.6 c
Haloxyfop	40.50	4.0 ab	2.3 b	2.3 b	41.3 b	25.6 a	16.3 c
Haloxyfop	47.25	6.3 a	2.3 b	2.3 b	49.5 ab	26.1 a	29.1 ab
Haloxyfop	54.00	6.7 a	2.7 b	2.3 b	73.5 a	30.2 a	21.9bc
Haloxyfop	60.75	5.0 a	2.3 b	2.3 b	39.0 b	27.5 a	26.5 ab
Haloxyfop	67.50	3.0 ab	2.3 b	1.7 b	34.7 b	25.8 a	33.8 a
Fluazifop	150.00	4.0 ab	2.0 b	2.0 b	42.2 ab	22.5 a	18.4 c
Hand weeding	-	0 b	0 a	0 a	0 c	0 b	0 d
Non weeding	-	5.3 a	2.0 b	1.7 b	25.2 bc	24.0 a	16.2 c
	C.V.	44.4%	34.6%	33.8%	35.3%	29.8%	17.0%

Annual broadleaf weeds: AMASP = *Amaranthus spinosus* L.,
AMAVI = *Amaranthus viridis* L., CLEVI = *Cleome viscosa* L.

Table 6. Effect of haloxyfop-R-methyl ester on annual broadleaf weed density and dry weight at 30 days after application (Location II).

Herbicide	Rate	No/ 0.25m^2			g / 0.25 m^2		
	g ai/ha	AMASP	POROL	EUPGE	AMASP	POROL	EUPGE
Haloxyfop	33.75	3.0 b	3.7 a	2.0 ab	34.9 a	20.6 bc	17.6 ab
Haloxyfop	40.50	3.3 b	3.0 a	2.0 ab	48.9 a	19.3 c	22.2 ab
Haloxyfop	47.25	3.3 b	4.0 a	2.3 ab	37.7 a	31.2 ab	26.4 a
Haloxyfop	54.00	3.7 b	4.0 a	2.3 ab	37.8 a	34.5 a	29.3 a
Haloxyfop	60.75	2.7 b	3.0 a	2.3 ab	28.9 a	30.5 a-c	23.7 ab
Haloxyfop	67.50	2.7 b	4.7 a	2.0 ab	31.1 a	34.4 a	22.0 ab
Fluazifop	150.00	3.3 b	3.0 a	2.0 ab	35.7 a	29.2 a-c	23.9 ab
Hand weeding	-	0 a	0 b	0 b	0 b	0 d	0 b
Non weeding	-	3.3 b	4.3 a	3.7 a	38.5 a	37.1 a	30.6 a
	C.V.	28.3%	31.7%	53.6%	11.2%	18.9%	47.1%

Annual broadleaf weeds: AMASP = *Amaranthus spinosus* L.,
POROL = *Portulaca oleracea* Linn. EUPGE = *Euphorbia geniculata* Ort.

Table 7. Effect of haloxyfop-R-methyl ester on phytotoxicity, high and yield of groundnut (Location I).

Herbicide	Rate	Phyto [1/]	Crop height (cm)		Yield
	g ai/ha		30 DAA [2/]	Harvest	Kg/ha
Haloxyfop	33.75	0	27.5 b	33.8 a	1,444.4 e
Haloxyfop	40.50	0	24.3 b	33.6 a	1,501.9 de
Haloxyfop	47.25	0	25.1 b	35.6 a	1,606.3 bc
Haloxyfop	54.00	0	24.1 b	35.7 a	1,615.0 bc
Haloxyfop	60.75	0	24.7 b	34.4 a	1,639.4 ab
Haloxyfop	67.50	0	23.7 b	35.4 a	1,658.8 ab
Fluazifop	150.00	0	25.4 b	34.5 a	1,540.6 cd
Hand weeding	-	-	31.2 a	35.4 a	1,718.1 a
Non weeding	-	-	25.4 b	31.8 a	561.9 f
C.V.			8.8%	4.7%	12.5%

[1/] Phytotoxicity at 7- 45 days after application : 0= No injury, 10=Killed.
[2/] DAA: Days after application.

Table 8. Effect of haloxyfop-R-methyl ester on phytotoxicity , height and yield of groundnut (Location II).

Herbicide	Rate	Phyto [1/]	Crop height (cm)		Yield
	g ai/ha		30 DAA [2/]	Harvest	kg/ha
Haloxyfop	33.75	0	34.4 b-d	42.3 bc	1,562.5 c
Haloxyfop	40.50	0	34.9 a-d	45.2 ab	1,607.5 bc
Haloxyfop	47.25	0	34.9 a-d	45.4 a	1,639.4 bc
Haloxyfop	54.00	0	36.4 ab	46.8 a	1,653.1 bc
Haloxyfop	60.75	0	36.5 a	45.5 a	1,666.9 b
Haloxyfop	67.50	0	34.7 a-d	44.3 ab	1,687.5 b
Fluazifop	150.00	0	36.6 a	44.5 ab	1,622.5 bc
Hand weeding	-	-	33.9 cd	45.7 a	1,848.1 a
Non weeding	-	-	35.1 a-c	41.1 c	540.6 d
C.V.			13.4%	4.0%	12.6%

[1/] Phytotoxicity at 7- 45 days after application : 0=No injury, 10=Killed.
[2/] DAA: Days after application.

4.3 Newly Developing Herbicides

BAS 625 H - A NEW POST-EMERGENCE HERBICIDE FOR GRASS WEED CONTROL IN RICE

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ABSTRACT: The cyclohexenone type graminicide BAS 625 H (AURA® or TETRIS®) is a new selective herbicide for post-emergence spray applications in rice, discovered and developed by BASF. BAS 625 H is an inhibitor of lipid biosynthesis through interference with ACCase enzyme activity. Trials were carried out in many rice growing countries of the world during 1992-1999. BAS 625 H demonstrated excellent herbicidal activity on important grass weeds including *Echinochloa* species, *Brachiaria platyphylla, Brachiaria plantaginea, Digitaria* species, *Eleusine indica, Ischaemum rugosum*, *Leptochloa* species, *Panicum* species, *Setaria* species, and *Rottboellia exaltata* when applied to dry-seeded, water-seeded and transplanted rice. Optimum rates of BAS 625 H for selective grass weed control range from 50 to 200 g ai/ha depending on application timing and grass weed spectrum as well as the seasonal and climatic conditions of the respective rice growing region. BAS 625 H provides excellent timing flexibility for the control of annual grass weeds at growth stages ranging from full emergence up to the mid-tillering stage which makes it very suitable for many different rice growing systems. BAS 625 H provides optimum herbicidal activity in combination with an additive. Both a pre-mix formulation containing additive as well as a concentrate formulation without additive were developed to meet the requirements of individual regions regarding additives. BAS 625 H can be combined with many other rice herbicides either in tank mixtures or as sequential applications to provide control of annual grasses, broadleaf weeds and sedges. Therefore, the product forms a tool for integrated weed management, as herbicide treatments can be adjusted to the individual grass weed infestation of specific rice fields. Registrations were obtained in 1998/1999 in several South and Central American countries with registrations in many other country's world wide expected.

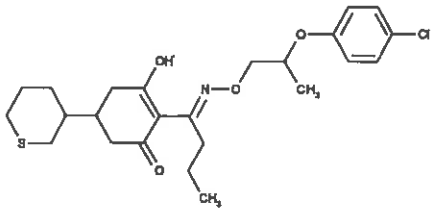
Key words: BAS 625 H, cyclohexenone, ACCase inhibitor, rice herbicide, weed control

Introduction

Grass weed infestations in rice represent a major constraint to rice production and efficient land use. This is related to the grass weeds competitive effects with the crop, negative effects on grain yield, increased labour requirements for weeding and the resulting inefficiencies which occur in the use of water, fertiliser and crop protection products. BAS 625 H is a new post-emergence graminicide for spray application in rice fields which provides a very targeted and problem specific solution for the control of most annual grass weeds. By virtue of its effectiveness at low use rates in combination with its excellent safety to the environment and user, BAS 625 H allows a reduction in the amount of herbicides applied in many rice growing systems while providing superior control of problem grass weeds.

Chemical and physical properties

Structure:



Code number: BAS 625 H

Chemical name:	2-[1-(2-(4-chlorophenoxy)propoxyimino)-butyl] 3-oxo-5-thian-3-ylcyclohex-1-enol (IUPAC)
Trade name:	Aura®, Tetris®
Molecular formula:	$C_{24}H_{32}ClNO_4S$
Molecular weight:	466.04
Appearance:	colourless, highly viscous liquid
Solubility (20 °C):	water: 0.53 mg/100 g
	acetone: > 70 g/100 g
	2-propanol: 33 g/100 g
	ethyl acetate: > 70 g/100 g

Toxicological properties of the active ingredient

Acute oral LD_{50} (rat):	> 5 000 mg/kg, male
	> 3 000 mg/kg, female
Acute dermal LD_{50} (rat):	> 4 000 mg/kg
Inhalation LC_{50} (rat):	> 5.2 mg/litre (4h)
Skin irritation (rabbit):	non-irritating
Eye irritation (rabbit):	non-irritating
Mutagenicity (Ames Test):	non-mutagenic

Eco-toxicological properties of the active ingredient

Aquatic organisms:	
NOEC (trout, 96 h):	12.8 mg/litre
NOEC (carp, 96 h):	19.3 mg/litre
NOEC (water flea, 48 h):	10.9 mg/litre
NOEC (algae, 96 h):	18.1 mg/litre
Avian toxicity:	
Acute oral LD_{50} (mallard duck):	> 2 000 mg/kg
Dietary LC_{50} (mallard duck bobwhite quail):	> 5 000 mg/kg
Beneficial organisms:	
Acute oral and contact LD_{50} (honey bee, 48 h):	> 200 µg/bee
LC_{50} (earthworm, 14 d):	> 1000 mg/kg soil

BAS 625 H shows a favourable eco-toxicological profile with aquatic organisms exhibiting only moderate sensitivity, while birds, bees and earthworms were unaffected by the tested concentrations.

Environmental fate

The hydrolysis rate of BAS 625 H in water is relatively low and is dependent on the pH of the solution. In aerobic and anaerobic water/sediment systems BAS 625 H is degraded completely within a short period of time particularly under the influence of light. The behaviour of BAS 625 H in soil is characterised by fast degradation and a high mineralisation rate. The DT_{50} values in soil under laboratory conditions are very short, ranging from 3 to 13 days. Under practical paddy rice field conditions BAS 625 H is broken down even faster than under laboratory conditions and therefore no risk of accumulation or persistence of residues in soil is expected. Due to the fast dissipation of BAS 625 H neither the parent compound nor its metabolites in soil could be detected in outdoor studies.

Formulation

The standard formulation of BAS 625 H is a 200 g a.i./litre EC formulation for use with an additive such as crop oil concentrate or Dash HC®. For those countries where ready-mix formulations are preferred or required, a 75 g a.i./litre additive containing EC formulation is also available.

Mode of action

BAS 625 H belongs to the group of ACCase inhibitor herbicides which are active through interference with lipid biosynthesis in the meristematic tissues of susceptible grass weeds. After spray application the active ingredient of BAS 625 H is rapidly absorbed by the exposed green plant parts and is rain-fast within one to two hours after application. Once absorbed, BAS 625 H is translocated throughout the treated plant and to the meristematic tissues. Sensitive grass species are controlled due to the disruption of cell membrane biosynthesis, similar to the effects observed with other cyclohexenone herbicides. Soon after treatment with BAS 625 H sensitive grass weeds stop growing. The first signs of injury become visible within three to seven days after application and appear as yellowing or reddening of younger leaves. A typical symptom is that the youngest leaf of treated susceptible grasses can be easily pulled from the leaf sheath, indicating an effect on the meristematic tissues in the stem. Under optimum conditions (warm and humid weather), the grass weeds die off completely within two to three weeks. Selectivity of BAS 625 H in rice is due to a combination of factors including rapid degradation of the parent compound to non-phytotoxic metabolites and reduced transport to the site of action.

Material and Methods

Small plot field trials with plot sizes ranging from 2-20 m² were conducted using randomised block designs with three or more replicates. Treatments were applied in 50-1000 l/ha application volume using knapsack sprayers equipped with either multi-nozzle spray booms or single nozzle spray lances. Trials heavily infested with dicot weeds and sedges were routinely treated with bentazon or other suitable dicot and sedge herbicides at seven days or more before or after application of BAS 625 H to reduce any potential for confounding of the results due to dicot and sedge weed competition. Growth stages of rice and weeds were determined according to the BBCH code system (Stauss, 1990). Herbicidal selectivity and efficacy on weeds was assessed using EPPO guidelines (Anon., 1998).

Results and Discussion

Crop selectivity

BAS 625 H applied post-emergence at recommended rates plus a recommended additive (e.g. oil concentrate or Dash HC) exhibits good to very good crop safety in dry seeded, water seeded and transplanted rice growing systems, provided that applications are made after the rice has reached the 3 leaf stage. Under unfavourable conditions some temporary symptoms (e.g. chlorotic spotting or striping) of the rice leaves can occur after treatment with BAS 625 H, but these symptoms grow out within a short period of time without causing any negative effect on yield. BAS 625 H can be applied to drained as well as to flooded rice paddies provided that the grass weeds are sufficiently exposed to the spray at time of application.

Herbicidal activity

BAS 625 H at application rates of 50 - 200 g a.i./ha in combination with the recommended additive controls the entire spectrum of the most important grass weeds in rice (Table 1 – 4, trial results from North America, South America, Europe, and Asia). Besides its activity on the most important grass weed species in rice, *Echinochloa crus-galli*, BAS 625 H also provides very effective control of *Brachiaria plantaginea, B. platyphylla, Cenchrus echinatus, Digitaria sanguinalis, Echinochloa colona, E. oryzicola, E. crus-pavonis, Eleusine indica, Ischaemum rugosum, Leersia hexandra, Leptochloa chinensis, L. filiformis, L. panicoides, Paspalum* spp., *Rottboellia exaltata and Setaria* spp.. BAS 625 H is also active on *Echinochloa* bio-types which are insufficiently controlled by other active ingredients such as propanil (Table 5). This characteristic makes it particularly suitable for efficient grass weed control strategies using rotation with other herbicides possessing different modes of action. Of practical importance for grass weed management in rice is the great timing flexibility of BAS 625 H which enables effective control of grass weeds from full emergence up to the mid to late tillering stage of the grass weeds. This feature allows targeted post-emergence control of grass weeds dependent on their occurrence (Table 1-4).

Table 1 Herbicidal Efficacy and Crop Safety of BAS 625 H applied at different Growth Stages of Rice in Europe (Field Trials Italy and Spain 1992 - 1998)

Product	Application Rate g a.i./ha	% Crop injury weeks after treatment 1	3	6	% Control *Echinochloa crus-galli* 6
Application timing at GS 13/21 of grass weeds					
BAS 625 H*	100	4 (54)	1 (54)	1 (46)	97 (44)
	150	7 (51)	3 (50)	2 (45)	99 (43)
Application timing at GS 22/25 of grass weeds					
BAS 625 H*	150	4 (96)	1 (94)	0 (82)	97 (79)
	200	7 (79)	1 (79)	1 (65)	98 (61)

plus 0.5 % Dash HC ( ) = number of trials

Table 2 Herbicidal Efficacy and Crop Safety of BAS 625 H applied post-emergence in Rice in South America (Summary of Results 1992 - 1998/99)

Application rate	BAS 625 H*			Fenoxaprop-ethyl**
g a.i./ha	100	150	200	100 - 120
% Crop Injury:				
1 week***	4 (323)	5 (393)	8 (181)	7 (262)
3 weeks***	1 (309)	1 (360)	3 (171)	2 (251)
6 weeks***	0 (303)	0 (350)	1 (169)	1 (244)
% Weed Control 6 weeks ***				
Brachiaria plantaginea	98 (132)	98 (147)	98 (79)	89 (123)
Brachiaria platyphylla	88 (22)	92 (31)	96 (15)	89 (54)
Digitaria sanguinalis	97 (97)	97 (92)	98 (49)	95 (64)
Echinochloa crus-galli	94 (155)	97 (160)	98 (86)	92 (115)
Echinochloa colona	92 (162)	94 (191)	96 (94)	84 (137)
Eleusine indica	92 (32)	92 (30)	95 (17)	82 (25)
Ischaemum rugosum	94 (175)	96 (165)	97 (93)	89 (87)
Paspalum spp.	86 (17)	91 (15)	95 (6)	- -
Rottboellia exaltata	92 (11)	97 (11)	97 (9)	68 (2)

* plus 0.5 % Dash HC Application timing: Rice 3 - 4 leaves up to mid-tillering ( ) = number of trials

** fenoxaprop ethyl (100 - 120 g ai/ha) or fenoxaprop p ethyl (0 to 60 g ai/ha)

*** after herbicide application

Table 3 Herbicidal Efficacy and Crop Safety of BAS 625 H applied at different Growth Stages of Rice in Asia (Field Trials 1992 - 1998/99)

Product	Application Rate g a.i./ha	% Crop Injury			% Control	
					Echinochloa crus-galli	*Leptochloa chinensis*
		weeks after treatment				
		1	3	6	6	6
Application timing at GS 12 - 21 of grass weeds						
BAS 625 H*	75	2 (175)	1 (161)	0 (170)	88 (159)	89 (73)
	100	3 (180)	2 (166)	1 (174)	95 (164)	94 (69)
	125	5 (81)	3 (81)	1 (76)	96 (75)	94 (26)
Application timing at GS 22/25 of grass weeds						
BAS 625 H*	100	2 (88)	1 94)	0 (85)	84 (85)	83 (29)
	125	3 (70)	2 (71)	1 (67)	87 (65)	86 (24)
	150	3 (101)	3 (104)	1 (96)	92 (96)	93 (34)

* applied with 1 % oil concentrate as an additive, or without an additive instead using an additive containing ready formulation

( ) = number of trials

Table 4 Herbicidal Efficacy and Crop Safety of BAS 625 H applied at different Growth Stages of Rice in the United States of America (Field Trials 1992 - 1995, Greenville, Mississippi)

Product	Application Rate	% Crop Injury			% Control		
	g a.i./ha				*Echinochloa crus-galli*	*Leptochloa panicoides*	*Brachiaria platyphylla*
		weeks after treatment					
		1	3	6	6	6	6
Application timing at GS 12 - 21 of grass weeds							
BAS 625 H*	75	2 (34)	1 (30)	1 (31)	95 (62)	96 (27)	93 (47)
	100	4 (59)	2 (54)	2 (51)	96 (84)	96 (27)	95 (57)
Application timing at GS 22/25 of grass weeds							
BAS 625 H*	100	3 (28)	2 (30)	2 (24)	93 (102)	95 (45)	93 (112)
	150	5 (33)	4 (35)	2 (29)	94 (87)	96 (21)	95 (96)

* applied with 1 % oil concentrate as an additive ( ) = number of trials

Table 5 **Activity of propanil and BAS 625 H for control of different bio-types of *Echinochloa* species from Ecuador, Spain, and the USA (Greenhouse trials)**

product	rates g a.i./ha	ECHCG* Spain	ECHCO* USA	ECHSS* Ecuador	ECHSS* Ecuador	ECHSS* Ecuador
propanil	1800	71	98	81	15	68
BAS 625 H**	200	100	95	100	99	100
	100	100	91	100	98	100
	50	100	89	100	98	100
ES/plant height at	application	13/16-18	13/3-5	13/13-18	13/6-9	13/11-15

* evaluation 21 days after treatment
ECHCG = *Echinochloa crus-galli*
ECHSS = *Echinochloa* species unknown
ECHCO = *Echinochloa colonum*
** 1.0 l/ha Dash HC
BAS 625 00 H = 200 g/l, EC
propanil = STAM 34; = 360 g/l propanil, EC

Registration status

BAS 625 H is currently registered in the following countries; Argentina, Uruguay, Colombia, Dominican Republic, Guatemala, Venezuela, Ecuador, Panama, Nicaragua. Registrations are expected in major rice growing countries world wide.

Summary and Conclusions

BAS 625 H is a new broad spectrum rice graminicide belonging to the chemical class of cyclohexenones. Considering its strong activity combined with excellent timing flexibility against important grass species BAS 625 H is expected to contribute significantly to improved grass weed control programmes in rice production world-wide. It will provide the grower with a flexible tool for selective control of grass weeds even when they are at more advanced growth stages. Dependent on grass weed spectrum, rice growing systems and region, the application rates of BAS 625 H will be within the following ranges:

South America	150 - 200 g a.i./ha BAS 625 H (plus 0.5 % Dash HC®)
North America	75 - 150 g a.i./ha BAS 625 H (plus 1 % oil concentrate)
Europe	100 - 150 g a.i./ha BAS 625 H (plus 0.25 - 0.5 % Dash HC®)
Asia	50 - 125 g a.i./ha BAS 625 H (as additive containing formulation)

Acknowledgements

The authors would like to thank all of our colleagues who have contributed to the discovery, research, development and registration of BAS 625 H.

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BAY FOE 5043 (FLUFENACET) - A NEW SELECTIVE HERBICIDE FOR THE USE IN CORN, CEREALS, POTATOES AND OTHER CROPS

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Abstract: BAY FOE 5043 (c.n. flufenacet) is a new oxyacetamide herbicide which is being developed worldwide by Bayer. It is a low application rate compound, compared to current soil applied standards and has a very favourable environmental and toxicological profile. Flufenacet is taken up mainly through the root system and transported via the seedling apoplasts to the meristimatic tissue of the roots and young shoots, where the compound acts through cell division inhibition.
Flufenacet selectively controls a broad range of important grasses in a wide variety of crops, e.g. corn (maize), cereals, cotton, peanuts, potatoes, rice, soybeans, sunflowers and tomatoes. In some instances, small-seeded dicotyledon weeds are also suppressed. In order to achieve a broad spectrum activity, the compound has to be mixed with another broadleaf product. The optimum application timing is preemergence or early postemergence. Due to the good residual activity of the compound, application can also be made in early pre-plant, pre-plant or pre-plant incorporated, e.g. in corn (maize) in the USA.
As new herbicides for corn (maize) a mixture of flufenacet & metribuzin has been introduced in the USA as well as a mixture of flufenacet & metosulam in several Europaen countries.
Flufenacet & diflufenican targets for the control of grasses (*Apera spica-venti*, *Alopecurus myosuroides*) and dicot weeds (e.g. *Galium aparine*) in cereals. Due to its excellent efficacy against barnyardgrass (*Echinochloa crus-galli*), flufenacet fits also as a herbicide for transplanted rice.
Combinations of flufenacet with metribuzin (with different mixing ratios) are available for potatoes. tomatoes and other vegetables. By its mode of action, flufenacet will be also a new tool for the control of triazin-resistant weeds (e.g. *Solanum nigrum*).

Key words: BAY FOE 5043, flufenacet, herbicide, corn, cereals, potatoes, grasses

Introduction

The control of weed grasses and broadleaf weeds is one of the most important measures adopted by the farmers, as a means of minimising crop yield and quality reductions. For several years, acetanilides have been used widely around the world for selective pre- and postemergence control of grasses in a variety of crops.
In the mid 1970's Bayer began to synthesize compounds in this general area of chemistry and success was relatively rapid with the discovery of the oxyacetamide rice herbicide, mefenacet. Oxyacetamides represent a novel class of preemergence herbicides. One of the main goals of the subsequent research was to synthesize and develop an oxyacetamide which would be suitable for use in a number of different arable crops, with clearly lower application rates than the standard acetanilide herbicides and thereby meeting the goal of reduced environmental loading. By 1988, this intensive research effort led to the discovery of BAY FOE 5043 with the common name flufenacet (Deege *et al.* 1995). Flufenacet has already been registered in the USA, France, Germany and some other countries.
Flufenacet is taken up mainly through the root system and transported via the seedling apoplasts to the meristimatic tissue of the roots and young shoots. The mode of action at the molecular level, as with other oxyacetamides, has yet to be identified. Studies with the only commercially available oxyacetamide herbicide, mefenacet, have shown a similarity in mode of action at the cellular and tissue levels to the chloracetanilides (e.g. metolachlor). Although the molecular mode of action of chloracetanilides is also unknown, both classes of compounds inhibit cell division following a delay period. This inhibition results in a complete arrest of cell division in the root and shoot meristematic regions. New growth is halted and elongated tissue may become distorted (Bieseler *et al.* 1997).

Materials and Methods

The biological data presented in this paper are the results from field trials conducted in Europe, USA and Asia between 1993 and 1998. A randomized block experimental design was used with ≥ 3 replications. Plot dimensions ranged from 10 - 20 m². An experimental plot scale compressed air sprayer with a carrier volume of ≥ 100 l/ha was used for all applications. All results are based on the natural weed infestations present in the fields. Efficacy as percent weed control and crop tolerance as percent damage were evaluated visually at various intervals following the treatment.

Results and Discussion

Flufenacet selectively controls a broad range of important grasses in a wide variety of crops, e.g. corn (maize), cereals, cotton, peanuts, potatoes, rice, soybeans, sunflowers and tomatoes. In some instances, small-seeded dicotyledon weeds are also suppressed with flufenacet. The optimum application timing is preemergence or early postemergence.

Corn (maize)

With flufenacet the most important grasses can be controlled with rates of ca. 600 g a.i./ha (table 1). In addition there is a important beneficial side effect against frequently occuring dicotyledon weeds. The optimum application timing in Europe is preemergence. Application in early postemergence is also possible, but the efficacy is not as stable, when compared with preemergence application (Kremer 1997). In order to achieve a broad spectrum activity, flufenacet needs to be mixed with another broadleaf product in corn. A combination of flufenacet & metosulam is available as a 62.5 % water dispersible granule (60 % flufenacet & 2.5 % metosulam) in several Europeen countries. The results show flufenacet & metosulam to be a good low rate alternative to the most commonly used standard. It provides excellent control of the most important grasses *Echinochloa crus-galli* and *Digitaria sanguinalis* with a good efficacy against several dicotyledon weeds. Excellent crop tolerance was observed.

Table 1 Herbicidal activity (% control) and crop tolerance (% damage) of flufenacet and flufenacet & metosulam in corn; application preemergence; trials France, Germany 1993 - 1998

species	n*	flufenacet	n*	flufenacet & metosulam	alachlor & atrazin
rate (g a.i./ha)		600		600 & 25	2016 & 864
Digitaria sanguinalis	8	99	4	100	99
Echinochloa crus-galli	75	94	17	92	94
Setaria verticillata	14	82		-**	-**
Setaria viridis	8	96	9	76	88
Amaranthus retroflexus	31	74	11	91	99
Amaranthus bouchonii			3	99	100
Calystegia sepium			5	52	10
Chenopodium album	115	62	40	81	77
Galium aparine	16	74		-**	-**
Lamium purpureum	8	74		-**	-**
Matricaria chamomilla	16	90		-**	-**
Mercurialis annua	12	52	11	55	96
Polygonum aviculare	17	56	12	80	94
Polygonum convolvulus	33	28		-**	-**
Polygonum lapathifolium	14	50	7	91	96
Polygonum persicaria	22	57		-**	-**
Senecio vulgaris	11	86		-**	-**
Solanum nigrum	55	74	20	82	95
Zea mays	170	0,8	57	1,0	0,0

n* = number of trials -** no results

A co-formulation of flufenacet with metribuzin (54 & 14 WG) has been developed as preemergence herbicide for corn and soybean in the USA (Bloomberg 1997). Due to the good residual activity of the compound, application can also be made also in early pre-plant, pre-plant or pre-plant incorporated. Table 2 shows the very good activity against grasses; control of small-seeded dicotyledon weeds is significantly supported. In order to control also large-seeded dicotyledon weeds like *Ipomoea spp.* or *Xanthium strumarium*, flufenacet & metribuzin has to be mixed with other herbicidal compounds (e.g. atrazin). Plant compatibility of flufenacet & metribuzin was good in all trials in corn as well as in soybeans.

Table 2 Preemergence activity (% control) of flufenacet & metribuzin 54 & 14 WG in corn in comparison to standards against grasses and small-seeded dicotylon weeds; trials USA 1991 – 1997

species	flufenacet & metribuzin	dimethenamide	metolachlor
	650 & 160 g a.i./ha	1480 g a.i./ha	2250 g a.i./ha
Digitaria spp.	99 (30)	99 (4)	97 (11)
Echinochloa spp.	95 (34)	100 (4)	99 (11)
Panicum dichotomiflorum	96 (16)	100 (1)	100 (4)
Pennisetum glaucum	93 (20)	89 (5)	91 (9)
Setaria faberi	92 (116)	89 (50)	94 (37)
Setaria viridis	94 (34)	89 (12)	98 (10)
Abutilon theophrasti	51 (37)	21 (39)	31 (29)
Amaranthus spp.	86 (21)	85 (23)	87 (21)
Ambrosia elatior	68 (16)	42 (16)	19 (9)
Chenopodium album	90 (17)	60 (19)	69 (14)
Polygonum pensylvanicum	69 (7)	28 (4)	58 (5)
Solanum ptycanthum	100 (3)	100 (1)	100 (3)
(no. of trials)			

Field trials in corn under tropical conditions confirmed the good activity of flufenacet against grasses and some dicotyledon species (table 3). Sufficient weed control could be obtained already at lower rates compared to the trials in USA or Europe. Further trials with different mixing partners for broadspectrum weed control are still ongoing in this region.

Table 3 Weed control (%) and phytoxicity (% damage) of flufenacet 60 WP in corn (preemergence appl.) - trials Thailand 1995 to 1997 -

species	flufenacet	flufenacet	flufenacet
	350 g a.i./ha	450 g a.i./ha	700 g a.i./ha
Commelina benghalensis	96 (2)	100 (1)	-*
Digitaria adscendens	93 (2)	95 (2)	98 (2)
Digitaria sanguinalis	-*	95 (1)	100 (1)
Eleusine aegyptica	80 (1)	90 (1)	100 (1)
Echinochloa spp.	85 (4)	89 (2)	100 (1)
Erichloa gracilis	93 (4)	97 (2)	-*
Panicum reptans	89 (4)	92 (4)	96 (2)
Pennisetum polystachyon	92 (2)	95 (2)	-*
Boerhaavia diffusa	100 (2)	100 (1)	-*
Polygonum nodosum	100 (1)	-*	100 (1)
Portulaca oleracea	100 (1)	-*	100 (1)
Sida acuta	95 (2)	100 (1)	-*
Xanthium strumarium	85 (1)	-*	99 (1)
Zea mays	0 (8)	0 (7)	1 (6)
(No. of trials)	-* no results		

Cereals

The application of flufenacet in cereals is primarily targeted for the control of windgrass (*Apera spica-venti*) and blackgrass (*Alopecurus myosuroides*).
Table 4 illustrates the excellent windgrass activity and the good activity against blackgrass in a number of trials in Germany, when applied at 150 g a.i./ha in preemergence or at 180 g a.i./ha in early postemergence. In preemergence, the grass activity tends to be better than in early postemergence. The activity against dicotyledon weeds is insufficient. However, flufenacet enhances the activity of mixing partners, which is particularly important for effective control of *Galium aparine* (Deege *et al.* 1996).
Flufenacet crop tolerance tends to be reduced, but still remains comparatively good with rates above 180 g a.i./ha, which are necessary especially for a high level of blackgrass control.
In order to control the complete spectrum of grasses and broadleaved weeds, a combination of flufenacet & diflufenican, formulated as a 60 % water dispersible granule (40% flufenacet & 20% DFF WG) has been developed and is registered in several European countries.

Table 4 Herbicidal activity (% control) and crop tolerance (% damage) of flufenacet in winter barley and winter wheat; application preemergence and early postemergence; trials Germany 1993 - 1998

species	number of trials	flufenacet 150 g a.i./ha pre	number of trials	flufenacet 180 g a.i./ha early post
Alopecurus myosuroides	29	84	163	86
Apera spica-venti	38	98	57	99
Poa annua	6	97	5	63
Galium aparine	28	48	102	56
Lamium purpureum	6	63	24	60
Matricaria ssp.	19	40	76	46
Myosotis arvensis	2	74	13	86
Stellaria media	21	29	78	12
Veronica hederifolia	10	39	52	27
Viola arvensis	8	20	44	4
Hordeum vulgare	27	0.0	143	1.6
Triticum aestivum	35	0.5	130	1.2

Beside wheat and barley, flufenacet can be applied selectively also in transplanted rice under tropical and subtropical conditions. With its excellent activity against barnyardgrass (*Echinochloa crus-galli*) and other important grasses, flufenacet fits well as a low volume rice herbicide (Palis 1999).

Potatoes

The results shown in table 5 demonstrate that flufenacet is highly suitable as a mixing partner for metribuzin in potatoes. With a rate of 480 g a.i./ha as a preemergence application, flufenacet displays excellent activity against grasses and significantly improves the activity of metribuzin against broadleaved weeds. Very good activity against *Galium aparine*, as well as clearly improved efficacy against *Solanum nigrum*, is demonstrated. Due to its different mode of action, flufenacet is also suitable as a new tool for the control of triazin-resistant weeds in potatoes, one of the major problems in many growing areas in Europe.
This combination is available as a 41.5% water dispersible granule (17.5 % flufenacet & 24 % metribuzin WG) in many European countries.

Table 5 Herbicidal activity.(% control) and crop tolerance (% damage) of flufenacet & metribuzin in potatoes; application preemergence; corresponding trials Germany 1992 - 1998

species	number of trials	metribuzin 350 g a.i./ha	flufenacet & metribuzin 480 & 350 g a.i./ha
Alopecurus myosuroides	4	98	100
Poa annua	2	100	100
Chenopodium album	13	93	96
Galium aparine	7	35	84
Matricaria chamomilla	5	99	100
Mercurialis annua	5	92	96
Polygonum convolvulus	13	65	85
Solanum nigrum	6	43	89
Stellaria media	7	99	97
Viola arvensis	2	100	100
Solanum tuberosum	23	0	0

For the Korean market, a co-formulation of flufenacet & metribuzin 36 & 7 WP has been developed for preemergence weed control in corn, potatoes and soybeans; application rate of this mixture is 1 kg product/ha (360 & 70 g a.i./ha).

Tomatoes

An additional ready mixture of flufenacet & metribuzin (42 & 14 WG) will be available especially in Southern Europe for weed control in tomatoes and also in soybeans (Brinkmann and Dahmen 1997). Table 6 shows the improvement of metribuzin by flufenacet especially against grasses and *Solanum nigrum*, one of the most troublesome weed in tomatoes. Application timing of this product in tomatoes is about 2 weeks before transplanting. Crop selectivity was good in all tested varities; no differential varietal selectivity was observed.

Table 6 Weed control (%) and crop tolerance (% damage) of flufenacet & metribuzin 42 & 14 WG in tomatoes; field trials Italy 1996 - 1998 (preplant application)

weed species	No. of trials	metribuzin 140 – 175 g a.i./ha	flufenacet & metribuzin 336 & 112 g a.i./ha	flufenacet & metribuzin 420 & 140 g a.i./ha
Echinochloa crus-galli	4	54	93	95
Setaria viridis	1	48	100	100
Amaranthus albus	2	56	93	90
Amaranthus retroflexus	10	76	83	88
Chenopodium album	7	76	84	91
Polygonum aviculare	2	77	75	76
Polygonum convolvulus	2	47	47	66
Portulaca oleracea	11	64	77	81
Solanum nigrum	13	10	70	82
L. esculentum	16	0	0	0

Other vegetables

Selectivity of flufenacet in vegetables has been tested in several Asian countries during the last years; some results of these trials are shown in Table 7. Investigations in vegetable crops are still ongoing to find out the optimum application rate/application window and to choose possible mixing partners.

Table 7 Efficacy (% control) and phytotoxicity (% damage, max. value) of flufenacet in vegetables

- Onions, preplant application; trial Thailand 1995 -

species	flufenacet 200 g a.i./ha	flufenacet 300 g a.i./ha	flufenacet 400 g a.i./ha	oxyfluorfen 235 g a.i./ha
Echinochloa colonum	70	96	98	93
Amaranthus spinosus	59	89	91	97
Corchorus olitorius	78	100	100	97
Portulaca oleracea	63	94	98	97
Trianthema portulacastrum	63	81	94	92
Allium cepa	0	0	0	0

- Red pepper, preemergence application; trial Korea 1995 -

species	flufenacet 240 g a.i./ha	flufenacet 360 g a.i./ha	metolachlor 800 g a.i./ha
Cyperus iria	100	100	100
Digitaria sanguinalis	100	100	100
Amaranthus lividus	76	100	100
Chenopodium album	100	100	100
Portulaca oleracea	99	100	100
Capsicum annuum	0	1	2

- Red pepper, preplant application; trial Korea 1996 -

species	flufenacet 300 g a.i./ha	flufenacet + metribuzin 288 + 56 g a.i./ha	flufenacet + metribuzin 360 + 70 g a.i./ha	metolachlor 800 g a.i./ha
Digitaria sanguinalis	90	91	94	90
Panicum dichotomiflorum	95	90	92	100
Chenopodium ficifolium	95	95	95	100
Portulaca oleracea	92	90	92	85
Rorippa islandica	100	100	100	100
Capsicum annuum	1	1	3	1

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BISPYRIBAC - SODIUM, A NEW SELECTIVE RICE HERBICIDE IN DIRECT - SEEDED RICE IN VIETNAM

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Abstract: Bispyribac-sodium (registered trade name: Nominee), which is a new rice herbicide discovered and developed by Kumiai Chemical Industry Co., Ltd., was introduced into Vietnam for testing in 1993. Research work has been conducted continuously in different types of rice culture in this country since then. Results revealed that bispyribac-sodium at 20 to 30 g.a.i./ha with 0.1% (v/v) surfactant - WK applied at early to mid post emergence gave excellent control with broad herbicidal spectrum covering grasses, sedges and broad-leaved weeds. The susceptible weeds observed in experimental fields were *Echinochloa crus-galli, E.colona, Cyperus difformis, C. iria, Fimbristylis miliacea, Ludwigia octovalvis* and *Monochoria vaginalis*. No phytotoxicity was observed in rice plants. Although this herbicide was registered in Vietnam only two years ago, it has been accepted rapidly by farmers because of its excellent herbicidal features, such as broad herbicidal spectrum, wide application window (6-20 days after sowing) and safety to rice.

Key words: Bispyribac-sodium, Nominee, broad spectrum, direct - seeded rice.

Introduction

Rice is the most important crop in Vietnam. The annual sown areas of 1997 are 7.09 millions ha with the production of 27.65 millions tons. Transplanting rice is popular in the North with double cropping system whereas more than 90% of sown areas in the South is direct seeding with double or triple rice cropping system. The areas under direct seeding have been increased from time to time due to shortage of labor for transplanting and other factors. There are four major types of direct seeding namely: traditional wet seeding, dry seeding, zero - tillage seeding and water seeding. Weed infestation is highest under dry seeding. In direct seeded rice, farmers use herbicides to control weeds popularly. In the South, 82.2% of farmers said that they have used herbicides. New herbicides are always subjected to screening to find out the suitable one with good efficacy and safe to the environment for the contribution as component to the integrated weed management in rice. The Cuulong Delta Rice Research Institute (CLRRI) has collaborated with Kumiai Chemical Industry Ltd., to study the compound bispyribac - sodium in direct seeded rice in Vietnam for the past many years since 1993.

Materials and Methods

Bispyribac-sodium is a new rice herbicide discovered and developed by Kumiai Chemical Industry., Ltd. Its trade name is Nominee and the code name during the time of research is KIH 2023. This compound has a chemical name as: sodium 2,6 bis[(4,6 dimethoxypyrimidin - 2 -yl) oxy] benzoate. Experiments on efficacy of this herbicide have been conducted from 1993 until now at CLRRI and farmers' field in the Mekong Delta. Type of rice culture mainly is wet-seeding. Weed densities (plants/m^2) were measured at 35, 42 and 56 days after sowing (DAS) by using a quadrate with the dimension of 0.5m x 0.5m. Dry matter accumulation by each particular weed species (g/m^2) was recorded. Yield components and yield of rice are investigated. The central part of a plot with 5 m^2 size was harvested to get the yield and covered to T/ ha... All agronomical data were analyzed statistically.

Results and Discussion

Experimental results in Summer - Autumn seasons from 1993 to 1995:

The major weeds observed in experimental fields are: *Echinochloa crus-galli, E. colona, Cyperus difformis, C. iria, Fimbritylis miliacea, Ludwigia octovalvis and Monochoria vaginalis* .The data on the effect of bispyibac - sodium (code name KIH - 2023) on weed dry weigh and rice yield are presented in table 1. Dry matter accumulations by weeds are reduced significantly under treated plots as compared to check. The average of weed dry weights in six experiments under bispyribac-sodium @30 g.a.i./ha, bispyribac -sodium@ 45 g.a.i./ha and hand weeding twice are 1.6; 3.1 and 2.7 g/m^2 respectively. Weedy check treatment has the highest weed dry weight with 14.5 g/m^2. The corresponding data on rice yield are 3.61; 4.14; 4.15 and 1.88 T/ha.

Table 1 Dry weight of weeds at 56 DAS and rice yield as affected by KIH 2023 treatment in Winter - Spring and Spring - Summer from 1994 - 1995.

Treatment	S - A 1993(A)	S - A 1993(B)	S - A 1993(C)	S - A 1993(D)	S - A 1993(E)	S - A 1993(F)	Average
I. Weed dry weight (g/m^2)							
KIH 2023 (30 g.a.i./ha)	1.4	1.7	NA	NA	NA	NA	1.6
KIH 2023 (45 g.a.i./ha)	1.4	NA	0.7	1.4	1.8	10.4	3.1
Hand weeding twice	3.2	1.7	0.7	3.2	1.5	3.3	2.7
Weedy check	9.0	11.6	13.6	13.9	16.5	22.2	14.5
LSD (0.05)	2.1	3.3	4.9	4.8	3.0	6.7	
II. Rice yield (T/ha)							
KIH 2023 (30 g.a.i./ha)	3.83	3.40	NA	NA	NA	NA	3.61
KIH 2023 (45 g.a.i./ha)	4.11	NA	4.55	5.36	4.53	2.17	4.14
Hand weeding twice	4.25	2.70	4.68	5.08	4.47	3.73	4.15
Weedy check	2.89	2.13	1.74	2.11	2.11	0.27	1.88
LSD (0.05)	0.38	0.50	0.72	0.97	0.35	0.68	

Remark: (*) Transformed data $\sqrt{x + 0.5}$; NA = Data are not available;

A, B, C, D, E, F = different sites of experimentation; DAS: Days after sowing; S - A: Summer - Autumn.

Experimental results of Winter - Spring seasons from 1993 to 1995.

The results of those experiments have been shown in table 2. The treated plots are superior to weedy check interns of weed dry weight reduction. On the average, weed dry weight in weedy check is 6.5 times higher than that in treated plots. Rice yields under bispyribac - sodium range from 4.42 to 5.07 T/ha as compared to 2.08 T/ha under weedy check. Hand weeding twice treatment has the yield as high as 4.62 T/ha.

Table 2 Dry weight of weeds at 56 DAS and rice yield as affected by KIH 2023 treatments in Winter - Spring and Spring - Summer from 1994 - 1995.

Treatment	Winter -Spring (1993-1994)		Spring -Summer (1994)		Winter -Spring (1994-1995)		Average	
	Dry weight* (g/m^2)	Yield (T/ha)	Dry weight (g/m^2)	Yield (T/ha)	Dry weight (g/m^2)	Yield (T/ha)	Dry weight (g/m^2)	Yield (T/ha)
KIH 2023 (30 g.a.i./ha)	0.7	5.25	4.0	3.60	NA	NA	2.4	4.42
KIH 2023 (45 g.a.i./ha)	0.7	5.36	6.6	3.59	0.7	6.27	2.7	5.07
Hand weeding twice	3.3	5.04	4.5	3.58	0.7	5.23	2.8	4.62
Weedy check	8.9	2.98	11.2	2.63	32.4	0.63	17.5	2.08
LSD (0.05)			5.8	0.85	10.0	1.01		

Remark: (*) Transformed data $\sqrt{x + 0.5}$; NA = Data are not available.

Rates and times of application:

The study on rate and time of bispyribac - sodium application in wet-seeded rice in Vietnam was carried out. Research results are presented in table 3. There are 3 levels of rates including 15, 20 and 25 g.a.i. /ha. Four times of application range from 7, 10, 14 to 21 DAS. All treatments brought down weed dry weights statistically as compared to weedy check except the treatment bispyribac- sodium @15 g.a.i. /ha applied too late at 21 DAS. This may be due to low dose of herbicide (15 g.a.i./ha) which could not control little old seedlings of weeds at 21 DAS. All rice yields are higher than that of check except bispyribac - sodium at low rate (15 g.a.i. /ha) applied too late from 14 to 21 DAS.

Table 3 Effect of bispyribac - sodium at different rates and times of application on weeds in wet seeded rice CLRRI. Autumn - Winter season, 1997.

Treatment	Rate (g.a.i./ha)	Time of application (DAS)(*)	Weed dry weight(**) (g/m^2)	Yield (T/ha)
T1. Bispyribac - sodium	15	7	4.7	3.85
T2. Bispyribac - sodium	15	10	4.9	3.67
T3. Bispyribac - sodium	15	14	6.6	3.52
T4. Bispyribac - sodium	15	21	12.4	3.25
T5. Bispyribac - sodium	20	7	5.0	3.68
T6. Bispyribac - sodium	20	10	5.6	3.78
T7. Bispyribac - sodium	20	14	4.7	3.86
T8. Bispyribac - sodium	20	21	5.4	3.65
T9. Bispyribac - sodium	25	7	4.1	3.69
T10. Bispyribac - sodium	25	10	4.4	3.74
T11. Bispyribac - sodium	25	14	4.9	3.66
T12. Bispyribac - sodium	25	21	5.4	3.64
T13. Hand weeding twice		20 & 30	0.7	3.70
T14. Weedy check			19.1	2.95
LSD (0.05)			2.3	0.65

Remark : (*) DAS = days after sowing

(**) Transformed data $\sqrt{x + 0.5}$

Table 4 Effect of bispyribac - sodium and its combination with other herbicides on weeds in wet seeded rice CLRRI. Summer - Autumn, 1999.

Treatment	Rate (g.a.i./ha)	Time of application (DAS)(*)	Weed dry weight (**) (g/m^2)	Yield (T/ha)
T1. Bispyribac	20	15	9.1	2.40
T2. (Bispyribac + thiobencarb)	1000	7	1.7	2.40
T3. (Bispyribac + thiobencarb)	1000	10	25.2	2.60
T4. Bispyribac + cyhalofop	15+ 37.5	15	2.2	2.27
T5. Bispyribac + cyhalofop	15 + 50	15	5.7	2.83
T6. Bispyribac + cyhalofop	15+ 37.5	20	8.3	2.10
T7. Bispyribac + cyhalofop	15 + 20	20	9.9	2.57
T8. Hand weeding twice		20 & 28	0.2	2.76
T9. Weedy check			48.1	1.60
LSD (0.05)			27.3	0.59

Remark : (*) DAS = days after sowing ; (**) original data of weed dry weight.

The combination of herbicides.

The proprietary mixture of bispyribac-sodium with thiobencarb and the tank mix between bispyribac - sodium and cyhalofop -butyl were evaluated to find out the possibility of controlling more weeds including *Leptochloa chinensis*. Results revealed that all treatments except the proprietary mixture

(bispyribac + thiobencarb) @ 1000 g.a.i./ha applied at 10 DAS, brought down weed dry weight significantly than that in weedy check (table 4). A slight phytotoxicity was observed is both treatments of (bispyribac + thiobencarb) but the rice plants were recovered soon at later stages. All herbicide treatments results in higher rice yield than check statistically except the treatment of bispyribac+cyhalpfop @ 15 + 37.5 g.a.i./ha applied at late stage of 20 DAS.

Acknowledgements:

The author would like to acknowledge to the Kumiai Chemical Industry Ltd., for support in research work and provide travel and accomodation funds to participate in the 17th APWSS Conference held in Bangkok ,Thailand .

BISPYRIBAC SODIUM FOR WEED CONTROL IN PHILIPPINE RICE PRODUCTION SYSTEM-DRY SEEDED, DRY SOWN RICE

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Abstract: Bispyribac sodium was tested for efficacy evaluation against weeds infesting dry seeded rice in Iloilo, Philippines where this type of rice farming is commonly practiced by rice farmers. The product was applied 7 days after true wetness (DATW) at the rates of 20, 25 and 30 grams a.i./ha using a spray volume of 300 L/ha and was compared with standard products namely butachlor and oxadiazon. The experiment was laid out following Randomized Complete Block Design (RCBD) with four replicates and evaluation parameters used including phytotoxicity ratings were based on local regulatory guidelines. Bispyribac sodium applied at all tested rates provided excellent efficacy against jungle rice (*Echinocloa colona,* (L.) Link)) and better than butachlor and oxadiazon . The compound also provided very good control of smallflower umbrellaplant (*Cyperus difformis* L.) and rice flatsedge (*Cyperus iria* L.) though slightly inferior with the registered products as far as smallflower umbrellaplant control is concerned. For the control of primerose willow (*Ludwigia octovalvis* Jacq.) Raven), bispyribac sodium provided excellent control of this weed species when applied at 25-30 g a.i./ha and was better than butachlor but comparable with oxadiazon. Plots treated with bispyribac sodium at 20-25 g a.i/ha had no sign of phytotoxicity on the crop. The highest rate used (30 g a.i./ha) however, caused slight phytotoxicity at 3 days after treatment(DATR) but signs were no longer visible at 7 and 15 DATR evaluation. Among the herbicides treated plots, highest yield was obtained from plots treated with bispyribac sodium at 30 g a.i./ha and even at its lowest rate of 20 g a.i./ha, bispyribac sodium provided better yield than oxadiazon and butachlor treated plots.

Key words: bispyribac sodium, butachlor, oxadiazon, dry seeded rice , phytotoxicity

Introduction

Dry seeded rice culture is becoming a popular practice among rice growers in the Philippines. This type of rice farming started in Iloilo and it is estimated that 50,000 hectares in total is devoted to this type of rice culture (Bayer CPS, 1996) . Presently, farmers in upland areas where water shortage is the main problem , are recognizing the importance of this rice production culture hence hectarage planted to dry seeded rice is expected to grow annually. In the Philippines there are only two herbicides registered on dry seeded rice namely, butachlor and oxadiazon, therefore , there is a need to provide farmers alternatives to control weeds infesting dry seeded rice hence this study was initiated.

Materials and Methods

The trial was conducted on dry seeded rice following randomized complete block design with four replication . Spray volume used in the experiment was 300 l water/ha. The treatments used and respective rates and timings of application are as follows:

Treatments	Rate of application Grams a.i./ha	Timing of application DATW
Untreated	-	-
Bispyribac sodium(Nominee 100 SC, 10% a.i.	20	7
Bispyribac sodium (Nominee 100 SC, 10% a.i.)	25	7
Bispyribac sodium (Nominee 100 SC, 10% a.i..)	30	7
Butachlor (Bolo 600 EC, 60% a.i.)	2000	4
Oxadiazon (Ronstar 250 EC, 25% a.i.)	500	4
Handweeded		20 and 40

Results and Discussion

Bispyribac sodium applied at 7 DATW at the rate of 20 – 30 g a.i./ha provided excellent control of jungle rice and performed better than the reference treatments, butachlor and oxadiazon. For the control of primerose willow , bispyribac sodium at 25 – 30 g a.i./ha provided excellent control and was better than butachlor and comparable to oxadiazon. The compound at all tested rates likewise showed an exceilent control of rice flatsedge however it was slightly inferior with the registered products as far as smallflower umbrellaplant control is concerned (Table 1).

Slight phytotoxicity of bispyribac sodium applied at the highest rate , 30 g a.i./ha was observed at 3 DATR but was no longer visible at 7 and 15 DATR evaluation. No phytotoxicity of bispyribac sodium was observed in all plots treated with 20 and 25 g a.i./ha. Contrary, plots treated with butachlor and oxadiazon exhibited phytotoxicity symptoms up to 7 and 15 DATR evaluations, respectively.

Yield data shows that among the herbicide treated plots , highest yield was obtained from plots treated with bispyribac sodium at the rate of 30 g a.i./ha and even at its lowest rate of 20 g a.i./ha , bispyribac sodium treated plots had better yield than that of butachlor and oxadiazon.

Table 1. Percent weed control of bispyribac sodium and yield data on dry seeded rice (1998 wet season)

Treatment	Rate Grams a.i./ha	Yield Tons/ha	% Efficacy at 45 DATR Evaluation			
			E. colona	*C.difformis*	*C. iria*	*L. octovalvis*
Bispyribac sodium	20	3.8ab	95abc	82.75c	95bc	93.75bc
Bispyribac sodium	25	3.94ab	95abc	87.75b	96.25ab	96.25ab
Bispyribac sodium	30	4.18a	95.75ab	87.5b	96.25ab	96.25ab
Butachlor	2000	3.6abc	86d	97.5a	93.75bc	91.25c
Oxadiazon	500	3.53abc	89.75bcd	96.25a	91.25c	100a
Handweeded		4.28a	100a	100a	100a	100a
Untreated (% Weed infest.)		1.07d	10.75%	12.5%	3.5%	51.25%

Acknowledgement: Bayer Philippines Inc., wish to acknowledge the researchers and their respective staff for their outmost cooperation during the conduct of the trials.

Reference: Bayer CPS, 1996
Moody et. al, 1984

CGA 279'233
A NEW GRASS HERBICIDE IN DIFFERENT RICE PRODUCTION SYSTEMS

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Abstract: CGA 279'233 is a new rice herbicide discovered and being developed world-wide by Novartis Crop Protection. Use rate varies from 100 to 300 g a.i./ha depending on the production system and weed growth stage at application. At such rates CGA 279'233 demonstrated excellent crop selectivity in both transplanted and dry-sown flooded rice at all application timings and in wet-sown rice from the 1.5 leaf stage. The product controls all major annual grass species in rice (*Echinochloa*, *Leptochloa*, *Brachiaria* and *Ischaemum* spp.) from pre-emergence to the three-leaf stage and some annual broadleaf weeds. CGA 279'233 can be applied either broadcast into water or sprayed onto drained fields. Toxicological and eco-toxicological studies indicate excellent safety to users and the environment. The low soil mobility and low water solubility ensure excellent safety to rice. The product is rapidly degraded in soil under flooded conditions, allowing farmers full flexibility in their choice of rotational crops. Work is now ongoing to develop formulations and use recommendations adapted to specific farmers' needs in major rice growing areas world-wide.

Keywords: weed control, herbicides, rice, CGA 279233

Introduction

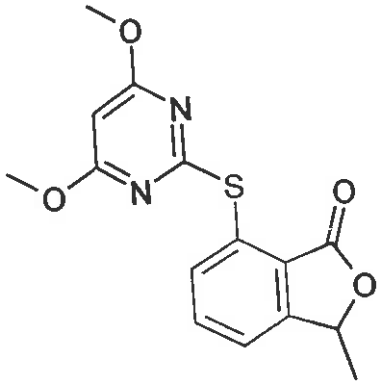
High bio-efficacy, excellent crop selectivity, environmental soundness, applicators safety and cost-effectiveness are key features for the discovery and development of new rice herbicides (Murakami, 1997). New herbicides should also be compatible with the diverse crop management practices, in particular water management. In addition, because of the different rice cultivation systems and weed management practices, new rice herbicides are subject to diverse farmers' expectations. Asian farmers growing transplanted or wet-seeded rice demand herbicides with broad-spectrum activity, excellent crop tolerance and wide application window. A single herbicide application should provide season long control of weeds even in cool areas. In Japan, new products should be easily applied from dikes into flooded fields or sprayed on drained fields (Wakayama et al, 1995; Kamoi and Noritake, 1995). In South East Asia, herbicides should remain effective in case of water shortage at or after application (Moody, 1995). Latin American farmers growing dry-seeded rice demand specialised grass herbicides with wide application window and long lasting grass control, allowing flexible water management and having a broad grass spectrum (Jordan et al, 1998).

The aim of this paper is to describe the basic features of the new rice herbicide, CGA 279'233 and to illustrate how it can provide flexible weed management solutions in the different rice cropping systems. Performance of combinations based on CGA 279'233 developed in Japan and Korea will be presented in a separate paper (Kon et al., 1999).

Chemical and Physical Properties

Chemical name	7-((4,6-Dimethoxy-pyrimidin-2-yl)thio)-3-methyl-phthalide (IUPAC)
Common name	pyriftalid (ISO proposed)

Chemical structure



Empirical formula	$C_{15}H_{14}N_2O_4S$	
Molecular weight	318.35	
Appearance	odourless, white solid	
Melting point	162.16°C	
Vapour pressure	at 20°C:	1.3×10^{-7} Pa (1.3×10^{-9} mbar)
	at 30°C:	7.7×10^{-7} Pa (7.7×10^{-9} mbar)
	at 40°C:	4.1×10^{-6} Pa (4.1×10^{-8} mbar)
Solubility	8.1 mg/L in water 1090 mg/L in n-Octanol 9.6 % in N-Methylpyrolidone	
LogP	2.5	
Formulations	WP 25, WG 75 and GR 0.8 for research purpose	

Toxicology and Eco-toxicology

Based on available studies, CGA 279233 exhibits low toxicity to humans and animals. The reproduction and long term studies are ongoing. So far, there has been no report of adverse findings. The active ingredient properties show also a favourable eco-toxicological profile. Key figures are summarised in Tables 1 and 2.

Table 1. Summary of acute toxicity of CGA 279233 (technical material)

Test	Species	Result
Acute oral	Rat	$LD_{50} > 5000$ mg/kg
Acute dermal	Rabbit	$LD_{50} > 2000$ mg/kg
Acute inhalation	Rat	$LD_{50} > 5.54$ g/m^3
Dermal sensitisation	Guinea pig	No classification required
Skin/eye irritation	Rabbit	No classification required

Table 2. Summary of ecotoxicity of CGA 279233 on fish and wildlife (technical material)

Test	Species	Result
Acute toxicity	Mallard duck	$LD_{50} > 2000$ mg/kg
Acute toxicity	Common carp	$LC_{50} = 100$ mg/L
Acute toxicity	Earthworm	$LC_{50} = 982$ mg/kg dry soil
Acute toxicity	Honey bee	$LD_{50} > 138.5$ µg/bee
Reproduction	Daphnia	LOEC = 1.2 mg/L

Biological Efficacy

Mode of action and herbicidal symptoms

Biochemical studies show that CGA 279'233 acts on weeds through inhibition of the enzyme acetolactate synthase (ALS). The herbicide is mainly taken up through the roots and the base of the shoot of weeds following application under flooded field conditions. The growth of susceptible weeds is rapidly inhibited resulting in death of the treated plants within one to three weeks after application. Some weeds may continue to germinate after application but will not develop further than the two-leaf stage and will then be overgrown by the crop. As is the case for other ALS-inhibitor herbicides, crop competition is important in order to achieve complete weed control.

Soil degradation

The degradation half-lives in different soils were estimated using both bio-tests with *Echinochloa* on Swiss soils incubated at 20°C and 20% soil humidity ('upland bio-test') and also by making HPLC analyses of the parent AI in flooded soils incubated at 30°C ('paddy /HPLC'). CGA 279'233 was found to degrade faster in soils under flooded, anaerobic conditions (Table 3).

Table 3. Degradation half-lives in lab studies found using biotest and HPLC methods in different soils

	Incubation		Half-life (days)	
Soil	Temp (°C)	Method	CGA 279233	Pretilachlor
Swiss soil	20	'Upland bio-test'	38.0	20.0
Swiss soil	30	Paddy / HPLC	7.8	11.4
SEA / Japan soils	30	Paddy / HPLC	5.9	10.0

Soil adsorption

Adsorption Kd values of the parent compound of CGA 279'233 on soils was estimated using HPLC to determine the equilibrium concentration of parent active ingredient in the supernatant aqueous phase after overnight shaking of 1 ppm solutions of herbicide in 10mM $CaCl_2$ with slurries of different soils. The Kd values varied significantly between soils and were positively correlated with soil organic matter content. Mean values were slightly higher than for pretilachlor, which was measured using the same methods (Table 4). From the Kd and KOc values found, we can classify CGA 279'233 as well adsorbed and, thus, only moderately mobile in different soils.

Table 4. Adsorption of CGA 279233 and pretilachlor on different soils.

			CGA 279 233		PRETILACHLOR	
Country	no soils	OM (%)	K_d	KO_c	K_d	KO_c
Japan	7	2.8 - 3.9	36.3	1936	29.5	1498
Indonesia	2	3.4 - 3.9	24	1080	19.5	883
Korea	2	2.3 - 2.9	6.7	438	11.5	757
Switzerland	2	2.9 - 3.5	12.5	676	8.1	440
MEAN	13	2.3 - 3.9	24.3	1380	21.9	1126

High soil adsorption and low water solubility ensure good crop tolerance and reliable performance of CGA 279233. Even on soils prone to high water leakage, it has low risk of damage to non-target crops. Owing to the longer dissipation half-life under non-flooded conditions, CGA 279'233 provides adequate residual control of grasses until flooding in dry-sown flooded rice. Rapid degradation under flooded conditions then allows farmers full flexibility in their choice of rotational crops.

Crop selectivity and weed control in different rice cropping systems

In Japan, CGA 279'233 was tested at Novartis Research Station, Ono (Hyogo prefecture) on mechanically transplanted japonica rice. In order to obtain different climatic conditions at application and to investigate residual activity, transplanting dates were varied between mid April and early June. In addition, six small plot trials were carried-out in farmer fields in 1996. The product was broadcast into water as granules (10 kg/ha). Transplanted japonica rice showed excellent tolerance to 240 g ai/ha, which gave excellent control of *Echinochloa oryzicola* from pre emergence to 3 leaf stage (Table 5). The residual activity of CGA 279'233 was sufficient when rice was transplanted early. Following pre-emergence application of CGA 279'233, however, a few *Echinochloa* plants emerged and remained at the 1-2 leaf stage for several weeks until they were overgrown by rice. The addition of 120-180 g a.i./ha pretilachlor can avoid the emergence of *Echinochloa* following pre-e.nergence herbicide application (Murakami and Kim, 1999; Murakami and Ebner, 1983).

Table 5. Average performance of CGA 279233 broadcasted into water as GR 0.8 at 240 g a.i./ha in Japanese transplanted rice, 1993-1997.

Application timing	% phytotoxicity 7- 15 DAA	% phytotoxicity 30-45 DAA	*Echinochloa oryzicola* % control 40-55 DAA
Pre emergence	5 (18)	2 (18)	94 (17)
1.5-2.5 leaves *Echinochloa*	4 (17)	1 (17)	95 (16)
3.0-3.5 leaves *Echinochloa*	5 (13)	1 (13)	97 (12)

Mean across trials; DAA= days after application; ( )= number of trials

In Indonesia, CGA 279'233 was tested at Novartis Research Station, Cikampek (West Java) on tropical wet-sown rice. After drainage of the field, the product was sprayed from 6 to 12 days after seeding as WP 25 or WG 75 together with a silicon or a non-ionic surfactant (0.2 % vol./vol.). Water was re-introduced two days after application. After some slight initial phytotoxicity (yellowing, stunting), rice recovered rapidly. *Echinochloa* was well controlled at 100-125 g a.i./ha when CGA 279233 was applied from 6 to 9 days after application (Table 6). In addition, CGA 279'233 at such application rate controlled *Marsilea crenata, Sphenochlea zeylanica* and *Ludwigia octovalvis* (data not presented).

Table 6. Average performance of CGA 279'233 sprayed at 250 L/ha as WP 25 or WG 75 on drained field in tropical wet-sown rice, Cikampek Indonesia 1993-1998.

Application timing	**Rate (g a.i./ha)**	**Phytotoxicity (%)**		**Control of *Echinochloa crus-galli* (%)**
		10-15 DAA	30-40 DAA	40-50 DAA
1- 2 leaves Echinochloa (6 DAS)	100	14 (15)	4 (15)	92 (15)
2-3 leaves Echinochloa (9 DAS)	125	10 (6)	4 (6)	93 (6)
3-4 leaves Echinochloa (12 DAS)	150	15 (6)	5 (5)	86 (6)

Means across trials; DAA= days after application; ( )= number of trials; DAS= days after seeding

In Colombia, CGA 279'233 was tested in the two major rice growing regions, Tolima and Llanos on dry-sown flooded rice. CGA 279'233 sprayed at 200-300 g a.i./ha from pre emergence to 1-2 leaf stage of rice together with a silicone, non-ionic surfactant (0.2% vol./vol.) or a crop oil concentrate (0.5-1 % vol./vol.) was safe to rice. It controlled key grass species season long with a single application (Table 7).

Weed Spectrum

At the recommended application rates and timings, CGA 279'233 controls all major annual grass species present in different rice cropping systems world-wide (Table 8). It also controls some annual broadleaves species. In addition, it caused transient inhibition of annual sedges (*Cyperus difformis, Cyperus iria* and *Scirpus mucronatus*).

Table 7. Performance of CGA 279'233 sprayed at 200 L/ha as WP 25 or WG 75 at 200-300 g a.i./ha in Colombian dry-sown flooded rice, 1996-1998.

Application timing	Phytotoxicity (%)		Weed control at 40-50 DAA (%)		
	8-10 DAA	30-40 DAA	*Echinochloa colonum*	*Ischaemum rugosum*	*Digitaria* sp.
At emergence of rice	1 (9)	0 (9)	93 (7)	92 (2)	98 (3)
At 1-2 leaves rice	2 (9)	0 (9)	94 (6)	93 (3)	98 (2)

Means across trials; DAA= days after application; ( )= number of trials

Table 8 Weed species controlled by CGA 279233

Annual grasses	Annual broadleaves
Echinochloa crus-galli	*Ludwigia octovalvis*
Echinochloa colonum	*Marsilea* sp.
*Echinochloa glabrescens**	*Sphenoclea zeylanica*
Echinochloa oryzicola	
*Brachiaria platyphilla**	
Digitaria horizontalis	
Digitaria sanguinalis	
Ischaemum sp.	
*Leptochloa chinensis**	

*Data obtained from trials in farmers' fields in Philippines, Thailand and Brazil.

Compatibility with other rice herbicides

CGA 279'233 demonstrated excellent compatibility with sulfonylureas, such as bensulfuron-methyl, cinosulfuron, imazosulfuron and pyrazosulfuron. The combination with pretilachlor has shown improved initial control of *Echinochloa* in Japan and also contributes to the residual control of annual broadleaves and sedges. Investigations on compatibility with further rice herbicides are ongoing.

Conclusions

Laboratory, greenhouse and field experiments demonstrated that CGA 279'233 can fulfil expectations for a modern grass herbicide in transplanted, wet-sown and dry-sown flooded rice world-wide.

The most attractive features of CGA 279233 can be summarised as follows:

- Excellent crop tolerance due to low soil mobility
- Pre to early-post emergence application window
- Broad grass spectrum and control of some annual broad-leaved weeds
- Broadcast application into water or spray on drained field
- Residual activity on drained soil allowing flexible water introduction
- Rotational freedom due to quick degradation under flooded conditions
- Very safe toxicological and eco-toxicological profile.

Work is now ongoing to develop formulations (such as "one-shots" in Japan and Korea; Kon et al., 1999). In parallel to required registration trials, specific trials are carried-out to define use recommendations adapted to specific agronomic and weed management practices (Ellis, 1992; Moody, 1995; Zoschke, 1994) in major rice producing countries world-wide in order to optimise chemical input. CGA 279'233 should become a safe, flexible and cost efficient tool for rice farmers to manage weeds and secure rice production.

Acknowledgements

The authors would like to thank all Novartis associates and external co-operators world-wide in the discovery and development of CGA 279'233. We thank them for the high quality and engagement in their work in laboratory, greenhouse and field.

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CGA 279'233
A NEW TIMING-FLEXIBLE GRASS COMPONENT OF ONE-SHOT HERBICIDES IN TRANSPLANTED RICE IN JAPAN AND KOREA

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Abstract: CGA 279'233 was evaluated in a series of field trials in 1997-1999 as a grass herbicide in transplanted rice in Japan and Korea. In Japan, CGA 279'233 at 180 g a.i./ha, in mixture with pretilachlor and sulfonylureas, applied from pre-emergence to the 3 leaf stage provided season-long control of *Echinochloa oryzicola* (Vasing) as well as other key broadleaf weeds and sedges. All formulations showed excellent selectivity to rice. Both conventional granular and easy-to-apply formulations (SC or WG) of the combinations are being developed. In Korea, CGA 279'233 at 180 g a.i./ha in mixture with a sulfonyurea and applied 10 to 20 days after transplanting (DAT) effectively controlled *Echinochloa crus-galli* better than the best local standard applied at 15-20 DAT. In conclusion, CGA 279'233 is an excellent grass herbicide with good timing flexibility and crop tolerance as a component of one-shot herbicides in transplanted rice both in Japan and Korea.

Keywords: weed control, one-shot herbicides, rice, CGA 279'233.

Introduction

Weed control in rice in Japan and Korea demands herbicides of the highest performance. The characteristics of a high performance grass herbicide are excellent crop safety, high efficacy on *Echinochloa* species especially large seedlings, season-long weed control and the formulation flexibility necessary for incorporation into easy-to-apply products. In recent years, there has been rapid development of labour-saving one-shot herbicides in Japan (Konnai, 1993; Takeshita, 1994; Koura et al., 1994; Wakayama, 1995; Murakami, 1997) and Korea (Ryu et al., 1993). The rate of conventional granular one-shot herbicides (GR) has decreased from 30 to 10 kg/ha. This trend is also towards new and easy-to-apply solid (WG) and flowable (SC) one-shot herbicides at doses of 1 to 5 kg or l/ha. CGA 279'233, discovered and being developed globally by Novartis Crop Protection, is an innovative grass herbicide selective in all rice cropping systems (Allard et al., 1999).

This paper details the biological performance of the different formulations of CGA 279'233 as one-shot herbicides in field trials in Japan and Korea.

Materials and Methods

Field trials in Japan

Between 1997-1999, the GR and WG formulations of CGA 279'233 and mixtures were tested in a series of field trials in six locations in machine-transplanted rice (Table 1). Field trials consisted of small-plots of 4-12 m^2 with 2 replications in a RCBD. The test herbicides were applied at 1.0 to 3.5 leaf stages of *Echinochloa oryzicola* (ECHOR). Other target weeds were *Scirpus juncoides* (SCPJO), *Monochoria vaginalis* (MOOVP) and annual dicots of mainly *Lindernia pyxidaria* (LIDPY) and *Elantine triandra* (ELTTP). The application methods included broadcast (GR), dripping with pipette after water-dilution to 5 L/ha (WG/OF) and dripping without dilution (SC) into plots flooded with 4 to 6 cm depth of water.

Table 1. Formulations of CGA 279'233 (content and standard rate of active ingredient)

Product (JP code no.)	Form.	Product rate (kg/ha)	Active ingredient (g a.i./kg) & [g a.i./ha]				
			CGA 279'233	Sulfonylurea			Pretilachlor
				Pyrazosulf-uron-ethyl	Bensulf-uron-methyl	Azimsulf-uron	
NOJ-101 (1kg)	GR	10	18 [180]	3.0 [30]	-	-	18 [180]
NOJ-102	WG	1	180 [180]	21 [21]	-	-	180 [180]
NOJ-103[N] (1kg)	GR	10	18 [180]	-	3.0 [30]	0.6 [6]	18 [180]
NOJ-104[S] (1kg)	GR	10	18 [180]	-	5.1 [51]	-	18 [180]

[N] For northern Japan; [S] for southern Japan.

Crop tolerance and weed control were evaluated based on the biomass of rice and each weed species, respectively, by comparing with those in weed-free plots. There were 2 to 3 evaluations up to the maximum tillering stage of the crop. Agronomic practices such as the variety used, seedling preparation, fertilisation and control of insect pests and diseases followed the local recommendations at each location.

Field trials in Korea

CGA 279'233 was tested as both GR and WG formulations (Table 2) between 1997-1998 in Korea in five locations in machine-transplanted rice. Field trials consisted of 10-20 m^2 with three replicates in a RCBD. The target weeds were *Echinochloa crus-galli* (ECHCG), *Scirpus juncoides* (SCPJO), *Monochoria vaginalis* (MOOVA), *Aneilema keisak* (ANEKE) and *Ludwigia prostrata* (LUDPR). At application times of 15 and 20 DAT, *Echinochloa* plants had 2.0-3.5 and 3.0-4.0 leaves, respectively. GR was spread by hand into water. WG was diluted in water and dripped into the plots with a pipette. Weed control was evaluated on the basis of visual biomass reduction around 50 DAA and crop tolerance was also visual biomass reduction around 15-20 DAA.

Table 2. Formulations of CGA 279'233 (content and standard rate of active ingredient).

Product	Form.	Product rate (kg/ha)	Active ingredient (g a.i./kg) & [g a.i./ha]	
			CGA 279'233	Cinosulfuron
CGA 279'233/cinosulfuron (279/cino)	GR	30	6.0 [180]	0.8 [24]
CGA 279'233/cinosulfuron (279/cino)	WG	0.5	360 [180]	48 [24]
Molinate/cinosulfuron (molinate/cino)	GR	30	50 [1500]	0.8 [24]

Results and Discussion

Crop Tolerance and Weed Spectrum in Japan

In Japan, rice tolerated all treatments of all granule formulations (NOJ-101, NOJ-103 and NOJ-104) and WG formulation (NOJ-102) of CGA 279'233 in all timings of applications very well. (Table 3). Tolerance was similar to the standards. The early symptoms of phytotoxicity were slight yellowing and stunting. However, the rice recovered quickly within two weeks.

Table 3. Tolerance of rice to granular and WG formulations of CGA 279'233 in Japan.

Product	Form	Rate (kg/ha)	Application Timing[D]	Phytotoxicity (%) & [no. trials]	
				6-19 DAA	25-48 DAA
NOJ-101	GR	10	Pre-emergence	6 [4]	5 [4]
			1.0-2.5	7 [7]	5 [7]
			3.1-3.3	9 [4]	0 [4]
NOJ-103 or NOJ-104	GR	10	Pre-emergence	9 [22]	4 [18]
			1.0-2.9	3 [10]	3 [10]
			3.1-3.5	10 [19]	3 [20]
PROSPER A[A] or PROSPER[B]	GR	10	Pre-emergence	6 [12]	4 [11]
			1.0-2.9	5 [11]	3 [11]
			3.0-3.5	7 [11]	1 [12]
NOJ-102	WG	1	Pre-emergence	6 [19]	1 [19]
			1.0-2.5	6 [27]	4 [27]
			3.1-3.5	7 [26]	0 [26]
DIEHARD[C]	WG	0.6	Pre-emergence	7 [9]	5 [9]
			1.0-2.9	6 [9]	6 [9]
			3.0-3.5	5 [12]	0 [12]

[A] Pyriminobac-methyl/mefenecet/bensulfuron at 30/450/30 g a.i./ha.
[B] Pyriminobac-methyl/mefenecet/bensulfuron at 30/225/51 g a.i./ha.
[C] Cafenstrole/pyrazosulfuron at 300/21 g a.i./ha.
[D] Leaf stage of *Echinochloa oryzicola*.

The GR formulations of CGA 279'233 controlled over 97% of *Echinochloa oryzicola*, *Scirpus juncoides*, *Monochoria vaginalis* and several annual dicots in all timings (Table 4). The results are similar to the GR formulations of pyriminobac-methyl. However, the WG formulation of CGA 279'233 showed superior control of *Echinochloa oryzicola* larger than 2.9 leaves compared with the WG cafenstrole mixture (Table 4). Control of *Echinochloa oryzicola* was more robust with less site-to-site and year-to-year variation when compared with the standards (Figure 1). The excellent performance of the CGA 279'233 mixtures indicates the good compatibility

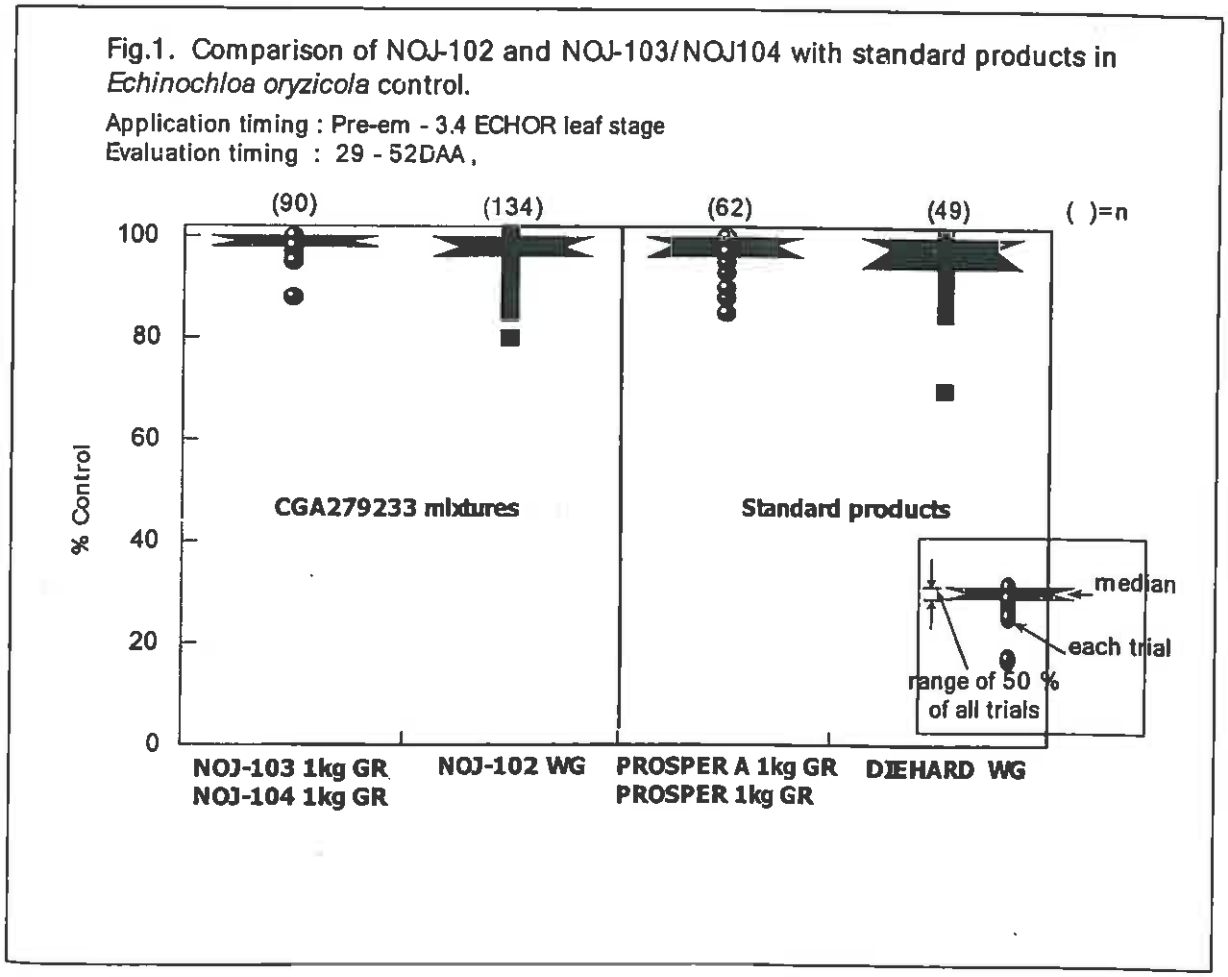
of pretilachlor that provides pre-emergence and residual activity and added activity for large *Echinochloa* plants. The sulfonylureas improved the spectrum on *Scirpus juncoides*, *Monochoria vaginalis* and other dicots.

Table 4. Performance of granular and WG formulations of CGA 279'233 against in Japan.

Product	Form	Rate (kg/ha)	Application Timing[D]	Weed control (%) & [no. trials]			
				ECHOR[D]	SCPJO[E]	MOOVP[F]	Others[G]
NOJ-101	GR	10	Pre-emergence	98 [4]	99 [3]	100 [2]	99 [3]
			1.0-2.5	98 [6]	99 [7]	99 [6]	99 [5]
			3.1-3.3	100 [3]	98 [3]	98 [3]	98 [3]
NOJ-103 or NOJ-104	GR	10	Pre-emergence	99 [18]	98 [15]	99 [16]	99 [18]
			1.0-2.9	99 [13]	99 [5]	99 [5]	99 [5]
			3.1-3.5	99 [16]	98 [15]	99 [22]	99 [23]
PROSPER A[A] or PROSPER[B]	GR	10	Pre-emergence	97 [11]	98 [8]	99 [7]	95 [9]
			1.0-2.9	98 [10]	99 [9]	99 [8]	97 [7]
			3.0-3.5	98 [9]	97 [8]	99 [10]	98 [11]
NOJ-102	WG	1	Pre-emergence	96 [18]	98 [12]	96 [13]	98 [17]
			1.0-2.5	98 [22]	96 [27]	98 [26]	99 [21]
			3.1-3.5	97 [20]	95 [13]	97 [14]	97 [20]
DIEHARD[C]	WG	0.6	Pre-emergence	98 [8]	99 [6]	99 [5]	98 [7]
			1.0-2.9	96 [8]	98 [9]	99 [8]	100 [9]
			3.0-3.5	89 [8]	94 [6]	98 [7]	96 [8]

[A] Pyriminobac-methyl/mefenecet/bensulfuron-methyl at 30/450/30 g a.i./ha.
[B] Pyriminobac-methyl/mefenecet/bensulfuron-methyl at 30/225/51 g a.i./ha.
[C] Cafenstrole/pyrazosulfuron-ethyl at 300/21 g a.i./ha.
[D] *Echinochloa oryzicola* at 29-52 days after application (DAA); [E] *Scirpus juncoides* at 32-59 DAA; [F] *Monochoria vaginalis* at 29-50 DAA; [G] annual dicots at 26-52 DAA.

Fig.1. Comparison of NOJ-102 and NOJ-103/NOJ104 with standard products in *Echinochloa oryzicola* control.



Crop Tolerance and Weed Spectrum in Korea

In Korea also, rice tolerated all treatments of all granular and WG formulations of CGA 279'233 at both application timings of 15 and 20 DAT very well (Table 5 and 6). Tolerance was similar to the standard, molinate/cinosulfuron. The early symptom of phytotoxicity was slight stunting. As in Japan, rice recovered quickly within two weeks.

Table 5. Tolerance of rice to a granular formulation of CGA 279'233 in 1997 in Korea.

Active ingredients	Rate (g a.i./ha)	Application timing	Phytotoxicity (%)			
			Jeonbuk University	Chungnam University	Kyungbuk University	Jeonnam University
279/cino GR	180/24	15 DAT	10	7	0	2
		20 DAT	10	10	0	1
Molinate/cino GR	1500/24	15 DAT	0	20	0	1
		20 DAT	0	7	0	1

Table 6. Tolerance of rice to granular and WG formulations of CGA 279'233 in 1998 in Korea.

Active ingredients	Rate (g a.i./ha)	Application timing	Phytotoxicity (%)			
			Chinchon	Chungnam University	Wonkwang University	Jeonnam University
279/cino GR	180/24	15 DAT	5	0	2	0
		20 DAT	6	0	2	0
279/cino WG	180/24	15 DAT	4	1	3	5
		20 DAT	5	3	2	3
Molinate/cino GR	1500/24	15 DAT	3	7	1	0
		20 DAT	3	0	1	0

The GR formulation of CGA 279'233 gave over 92% control of *Echinochloa crus-galli*, *Scirpus juncoides*, *Monochoria vaginalis*, *Aneilema keisak* and *Ludwigia prostrata* in all timings (Table 7). *Echinochloa* and *Ludwigia* control was superior to that given by molinate/cinosulfuron. The WG formulation performed similarly to molinate/cinosulfuron, but was superior to this standard against *Ludwigia*.

Table 7. Performance of granular and WG formulations of CGA 279'233 between 1997-1998 in Korea.

Active ingredients	Rate (g a.i./ha)	Application timing[A]	Weed control (%) & [no. trials]				
			ECHCG	SCPJO	MOOVP	ANEKE	LUDPR
279/cino GR	180/24	15 DAT	96 [9]	97 [7]	98 [7]	95 [6]	100 [3]
		20 DAT	92 [9]	93 [7]	96 [7]	97 [6]	98 [3]
279/cino WG	180/24	15 DAT	90 [5]	99 [5]	99 [4]	92 [3]	100 [2]
		20 DAT	87 [5]	98 [5]	95 [4]	90 [3]	98 [2]
Molinate/cino GR	1500/24	15 DAT	95 [9]	98 [7]	100 [7]	97 [6]	81 [3]
		20 DAT	85 [9]	97 [7]	100 [7]	98 [6]	50 [3]

[A] 15 DAT = 2.0-3.5 leaf of ECHCG; 20 DAT = 3.0-4.0 leaf of ECHCG.

Conclusions

The field results show that the GR formulations of CGA 279'233 mixtures demonstrated very consistent and reliable performance at least equal to best standards of pyriminobac-methyl/mefenecet/bensulfuron-methyl in Japan and molinate/cinosulfuron in Korea. The WG formulation in Japan is an innovative and superior solution over the current standard of cafenstrole/pyrazosulfuron-ethyl with its wider application window. CGA 279'233 showed excellent crop tolerance due to low soil mobility and good compatibility with sulfonylureas and pretilachlor. All formulations demonstrated timing flexibility against *Echinochloa oryzicola*, *Echinochloa crus-galli* and the common annual broadleaves and sedges. In Japan, where *Scirpus juncoides*, *Lindernia pyxidaria* (LIDPY) and *Elantine triandra* (ELTTP) have developed resistance to sulfonylureas, the pretilachlor component added an extra dimension in controlling and managing these resistant weeds (Itoh et al., 1997; Aoki et al., 1998; Hirata et al. 1999; Sugiura et al., 1999).

CGA 279'233 demonstrates excellent formulation flexibility as both solids and liquids. Whilst this paper reports on the solid formulations, several liquid formulations for easy-to-apply application are also being developed in Japan. In Korea, CGA 279'233 will be a new alternative to old products with environmental concerns.

Acknowledgement

The authors would like to thank all Novartis associates and external co-operators who conducted the field trials and commented on the early manuscript.

This paper is a tribute to Dr. Shiaki Murakami, whose untimely passing on 20 August 1999 is deeply felt by all those who knew and worked with him. He contributed significantly to the development of CGA 279'233 in Japan and was the original senior author of this paper.

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CLOMAZONE + PROPANIL FOR WEED CONTROL IN RICE (*ORYZA SATIVA*)

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Abstract: Various combinations of clomazone at 150-210 g + propanil at 340-500 g ai/ha were evaluated for the control of weeds in rice (*Oryza sativa*) in the Philippines and Thailand. Treatments were sprayed at 7-10 days after seeding or planting and the weeds were at two to four-leaf stage. All combinations provided outstanding control of grasses, and good to excellent control of broadleaf weeds and sedges even at 45 days after application. Minor, transient whitening of rice leaves was observe in direct-seeded rice but disappeared within 14 days. No whitening was observed in transplanted rice. Grain yield was significantly higher than the untreated/unweeded control.

Key words: herbicide mixture, clomazone, propanil, post-emergent herbicide, rice

Introduction

Weeds when left uncontrolled, reduce potential yield in the range of 45-95% depending on the cultural system, cropping season, plant spacing, amount of fertilizer applied, ecological and climatic conditions, and type and density of weed of infestation (Moody 1991, Ampong-Nyarko and De Datta 1991 as cited by Naylor 1996).

Mixing herbicides and applying them simultaneously widens the spectrum of weed control and, saves time and application costs (Kwesi Ampong-Nyarko and S.K. DeDatta, 1991). Using herbicides with a new mechanism of action prevents the evolution of herbicide-resistant weeds and weed populations shifts associated with the use of a single herbicide (K. Moody, 1996). Thus, the efficacy of clomazone, a new chemistry, mixed with propanil were conducted in various lowland rice cultures.

Clomazone, a proprietary product of FMC Corporation, is a selective pre-emergent soil applied herbicide, for the control of weeds in various crops like rice, soybeans, sugarcane, tobacco, oilseed rape, potatoes, pumpkins, and succulent peas. When applied pre-emergence, clomazone is effective for the control of grassy weeds and some broadleaves. Clomazone is absorbed by the plant through the roots and shoots and is translocated in the xylem and then diffuses within the leaf (FMC, 1993). It inhibits the biosynthesis of both chlorophyll and carotenoids in susceptible species through inhibition of an enzyme in the isoprenoid pathway. Susceptible species emerging from the treated soil are devoid of pigmentation and quickly die.

Propanil is a chloroacetamide herbicide which has been used in Asia since 1970 (Naylor, 1996). It is a contact herbicide that is applied post-emergence. It is effective against several grassy and broadleaf weeds. Rice is extremely tolerant of propanil because rice plants have high levels of aryl acylamidase, a hydrolyzing enzyme, which detoxifies propanil. (Kwesi Ampong-Nyarko and S.K. De Datta, 1991).

This paper presents the initial findings on the herbicide combination, clomazone and propanil, collated from several studies conducted in the Philippines and in Thailand.

Materials and Methods.

Philippines: A premix of clomazone (C) + propanil (P) formulated as emulsifiable concentrate was tested at the rates of 150+348; 180+405; and 210+473 g ai/ha on direct-seeded rice in Laguna and on transplanted rice in Nueva Ecija. On direct-seeded rice paddies, treatments were applied at 6 days after sowing (DAS) and on transplanted, at 7 days after planting (DAP). In another trial in Iloilo, tank-mixtures of clomazone + propanil was applied on direct-seeded rice paddies at the rates of 160+400; 180+400; and 200+400 g ai/ha at 8 DAS. A knapsack sprayer with flat fan nozzles, delivering a calibrated volume of 250-300 liters of

spray solution per ha, was used in all of the three experiments. Plot size per treatment was 20 m^2. Treatments were replicated 4 times and were arranged according to complete block design.

The following data were collected: (a) crop injury ratings at 3, 7, and 15 days after spraying (DASP) using the Fertilizer and Pesticide Authority's standard phytotoxicity rating scale for herbicides; (b) percent weed control rating as presented in Table 1, at 15, 30, and 45 DASP by weed species; (c) weed density and fresh weight (biomass) using a 50x50 cm^2 quadrant at 45 DASP; and (d) computed grain yield per 12 m^2. Grain yield was converted to ton/ha (14% moisture content).

The data were subjected to analysis of variance (ANOVA) except for the qualitative rating on crop injury and percent weed control. Differences on the effectiveness among treatments were determined using the Duncan's Multiple Range Test (DMRT) at 5% level of significance.

Thailand: Clomazone (C) + propanil (P) premix was also tested in Nakhon Pathom and Suphanburi, in direct-seeded rice, at 180 g + 420 g, 210 g + 470 g, and 240 g + 540 g ai/ha. Treatments were applied at 8 DAS using a knapsack sprayer with fan type nozzles, and calibrated to deliver 500 liters of spray solution per ha. Ratings for crop injury were taken at 7, 15, and 30 DASP; and for weed control, in a scale of 0 to 10 (10 = complete control) , at 30 and 60 DASP.

Table 1. Percent weed control rating used to assess herbicide activity in Philippine trials.

Rating, %	Main Category	Detailed Description
0	No Effect	No weed control
10	Slight Effect	Very poor weed control
12		Poor weed control
30		Poor to deficient weed control
40	Moderate Effect	Deficient weed control
50		Deficient to moderate weed control
60		Moderate weed control
70	Severe Effect	Weed control satisfactory
80		Satisfactory to good weed control
90		Very good to excellent weed control
100	Complete Effect	Complete weed destruction.

Results and Discussion

Philippines

For brevity, only the results on percent weed control at 45 DASP are presented in this paper.

Laguna Trial (Direct-Seeded): This trial was conducted at the University of the Philippines Los Baños, Laguna, Philippines in September to December, 1998. The predominant weed species found in the experimental area were *Ludwigia octovalvis* (29%), *Sphenoclea zeylanica* (17%), *Monochoria vaginalis* (12%), *Cyperus iria* (12%), and *Echinochloa colona* (7%) (Table 2). These weeds were at 2-4 leaf stage at the time of application. Irrigation was applied after herbicide application following farmer's field practice.

Clomazone + propanil mixture effectively controlled the above mentioned weeds (Fig. 1). The lowest rate of application, 150C+338P g ai/ha, was equally as effective as the highest rate of 210C+473P g ai/ha.

Whitening of the rice leaves was observed three days after spraying but disappeared within 14 days thereafter (Fig. 2). In no case did the minor bleaching result in stunting, necrosis, or plant stand loss. Likewise, whitening, which was attributed to clomazone, did not adversely affect the grain yield. As shown in Figure 3, the yields from the treated plots were not significantly different from the hand-weeded but were significantly higher than the untreated-plots.

The above findings indicated, that clomazone + propanil applied at 6 DAS resulted to a broad spectrum weed control providing significant high rice grain yield comparable to hand-weeded plots.

Iloilo Trial (Direct-Seeded): Trial was conducted in Dumangas, Iloilo through the Regional Crop Protection Center, Department of Agriculture, Iloilo City, Philippines, in November, 1998 to February, 1999. The predominant weed species in this trial were grasses, *Leptochloa chinensis* (25%), *Ischaemum rugosum* (21%), *E. crusgalli* (11%); sedge, *C. iria* (26%); broadleaves, *L. octovalvis* and *S. zeylanica* combined (10%) (Table 2). All rates of clomazone + propanil mixture gave 91-95% control of grasses, 89-94% of broadleaf weeds and 87-93% of sedges (Fig. 4). Whitening of rice seedlings was observed, but as in the Laguna trial, plants completely recovered within 14 days and had no adverse effects on yield. As shown in Figure 3, yields from clomazone + propanil-treated plots were as high as the hand-weeded and were almost twice as much as the untreated.

Central Luzon Trial (Transplanted): This trial was conducted at the Maligaya Agricultural Research Consultancy Experiment Station, Munoz, Nueva Ecija, Philippines in June to September, 1998. Table 2 show that, based on the untreated plots, the weed species present and their number per m^2 were: *E. glabrescens/L. chinensis* (122), *M. vaginalis/S. zeylanica* (84) and *C. difformis/C. iria* (67). Clomazone + propanil combinations provided 94-98% control of both grasses and sedges, and 78-86% of broadleaf weeds (Fig. 5). Unlike in direct-seeded rice, clomazone did not have whitening effects on transplanted seedlings. Yields from clomazone + propanil-treated plots were as high as the hand-weeded and were significantly higher than the untreated (Fig 6).

Thailand

Echinochloa crusgalli, L. chinensis, and C. iria were predominant in both the Suphanburi and Nakhon Pathom trials. Some *S. zeylanica* and *Fimbristylis miliacea* were also observe but only in Suphanburi and in Nakhon Pathom, respectively. Again, for brevity, only the 60-day weed control ratings are presented.

The mixture of clomazone + propanil, at all rates, effectively controlled the above weed species (Fig 7). In a scale of 0-10, the average control ratings at the Suphanburi and Nakhorm Pathom trials against *L. chinensis* were 9.6 and 9.9, *E. crusgalli*, 9.7 and 7.0, and *C. iria*, 9.6 and 9.4, respectively. Control of *F. miliacea* was rated at 9.8 and of *S. zeylanica* at 8.5. No whitening of rice seedlings was observed. Yield from clomazone + propanil-treated plots were as high as the hand-weeded and were significantly higher than the untreated (Fig. 8).

Table 2. Weed species composition in the experimental areas of Laguna, Iloilo, and Central Luzon, Philippines at the conduct of the trials.

	Laguna	Iloilo	Central Luzon
	Weed Density, %*		
Grasses			
Echinochloa colona			
Echinochloa crusgalli			
Ischaemum rogusum			
Leptochloa chinensis			
Leptochloa glabrescens			
Broadleaf Weeds			
Ludwigia octovalvis			
Monochoria vaginalis			
Spenochlea zeylanica			
Sedges			
Cyperus difformis			
Cyperus iria			
Fimbristylis littoralis			
Total Number/m^2	**130**	**230**	**273**

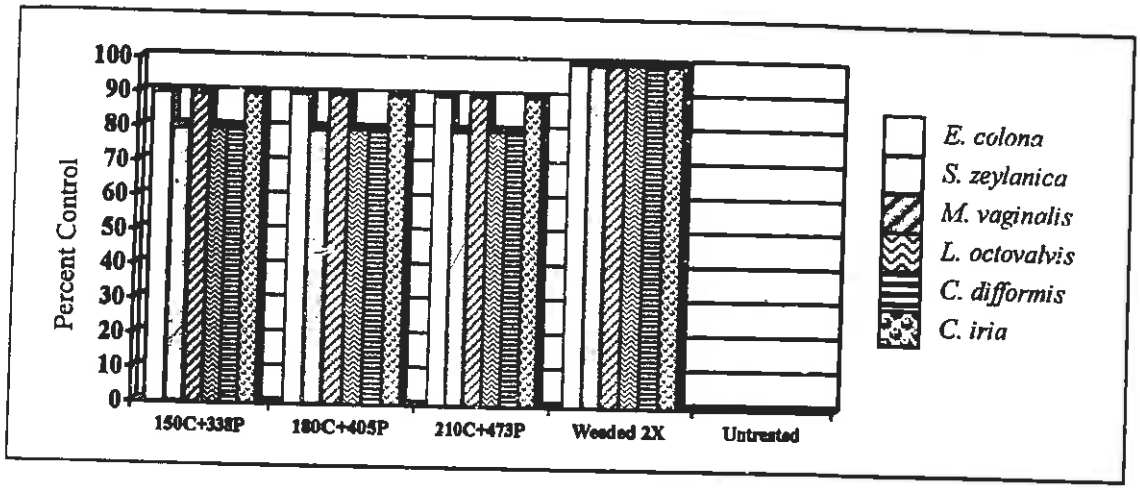


Fig. 1. Percent control rating of different weed species as affected clomazone (C) + propanil (P) in direct- seeded rice applied at 6 DAS. Laguna. Philippines. 1998. Assessed at 45 DASP.

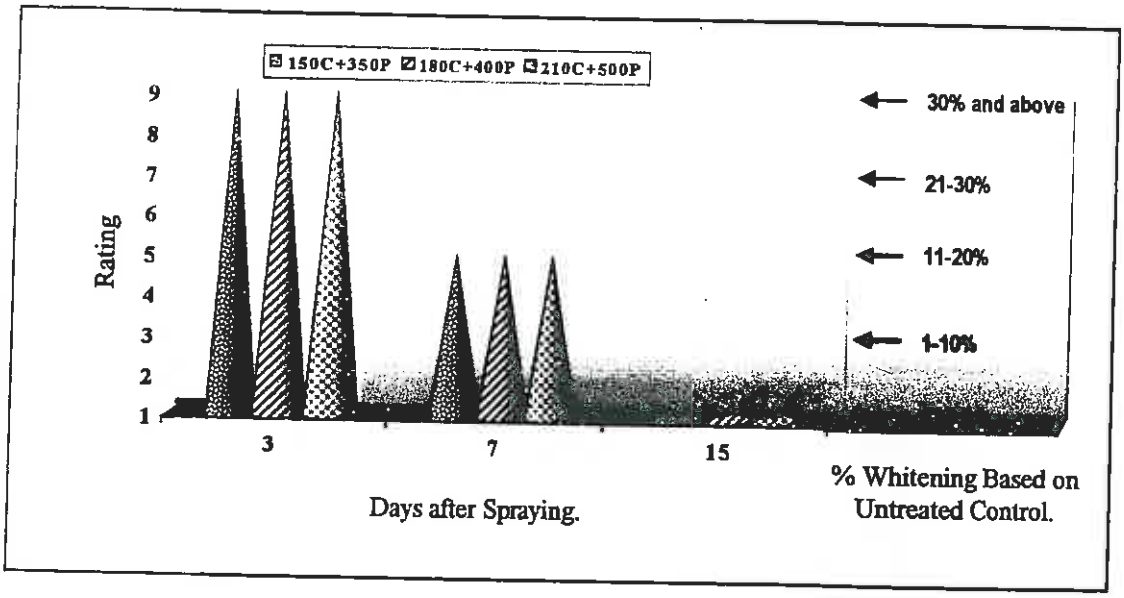


Fig. 2. Degree of bleaching of direct-seeded rice treated with clomazone (C) + propanil (P) applied at 6 DAS. Laguna. Philippines. 1998.

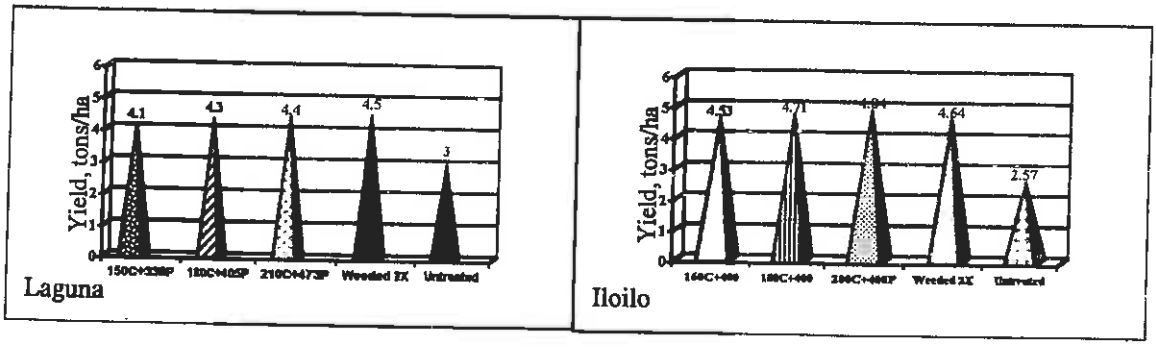


Fig. 3. Rice grain yield as affected by clomazone (C) + propanil (P) in direct-seeded rice. Laguna and Iloilo, Philippines. 1998.

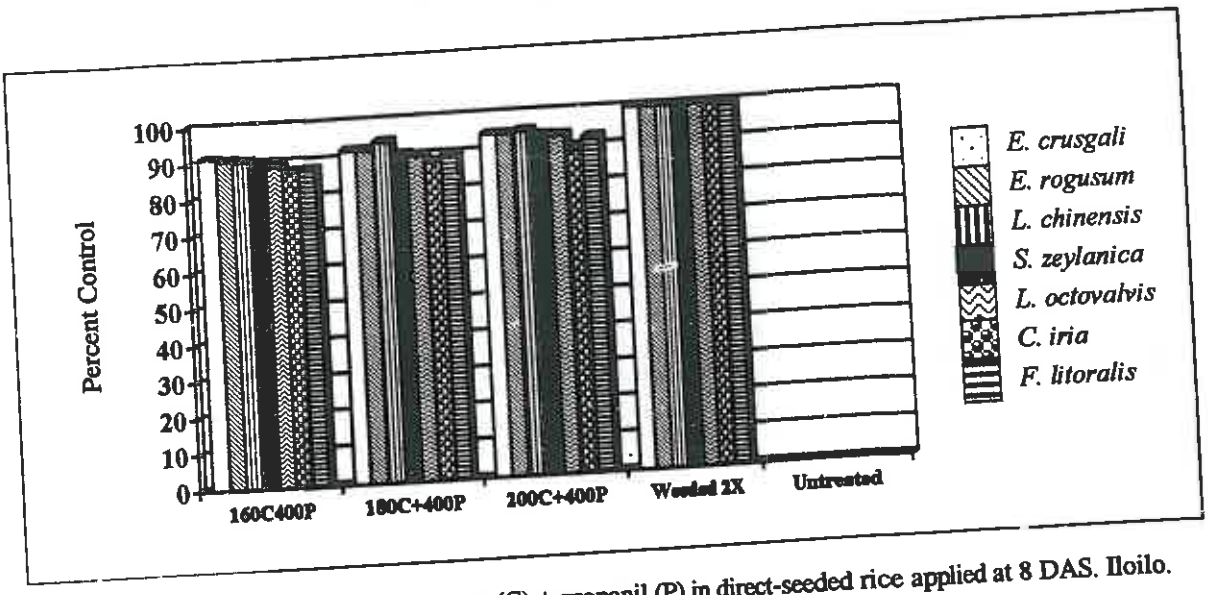


Fig. 4. Percent weed control of clomazone (C) + propanil (P) in direct-seeded rice applied at 8 DAS. Iloilo. Philippines. 1998. Assessed at 45 DAT.

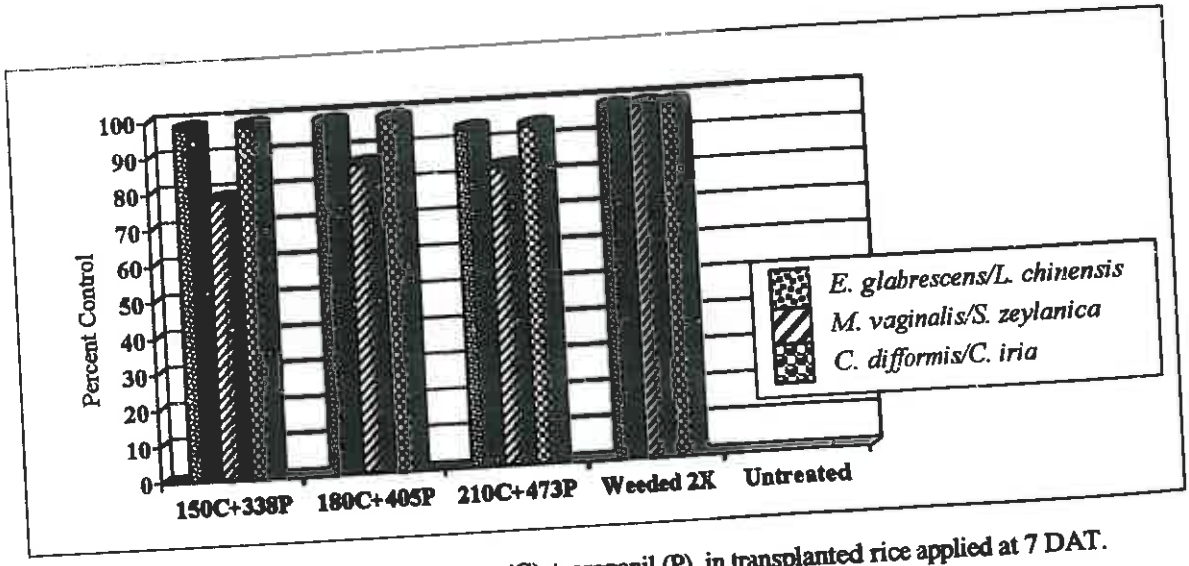


Fig. 5. Percent weed control of clomazone (C) + propanil (P) in transplanted rice applied at 7 DAT. Central Luzon. Philippines. 1998. Assessed at 45 DAT.

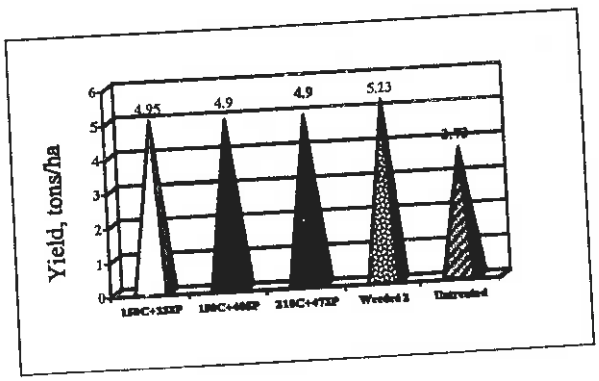


Fig. 6. Rice grain yield as affected by clomazone (C) + propanil (P) in transplanted rice. Central Luzon, Philippines. 1998.

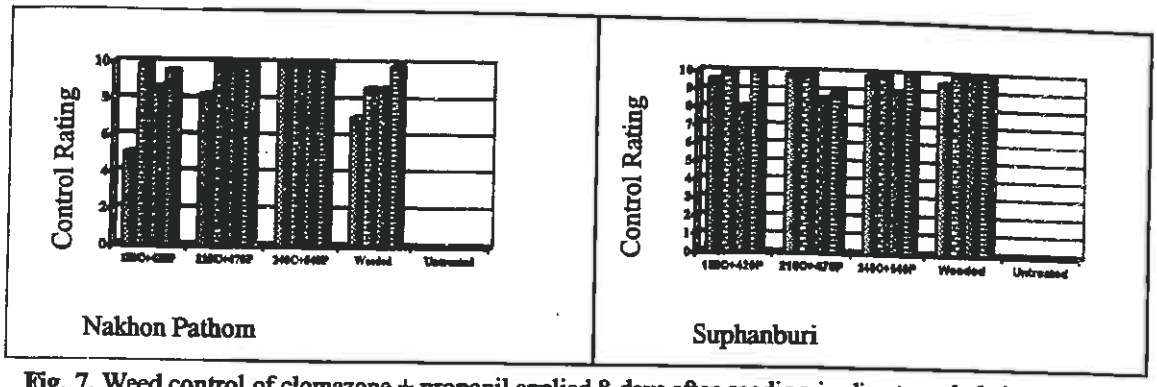


Fig. 7. Weed control of clomazone + propanil applied 8 days after seeding in direct-seeded rice. Nakhon Pathom and Suphanburi, Thailand. 1999. Assessed at 60 days after spraying.

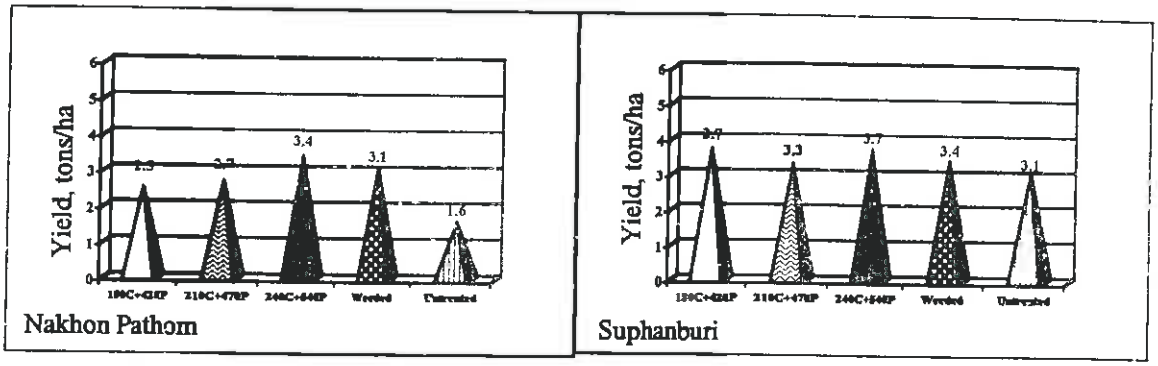


Fig.8. Rice grain yield as affected by clomazone (C) + propanil (P) in direct-seeded rice. Nakhon Pathom and Suphanburi, Thailand. 1998.

Acknowledgements:

FMC International S.A. acknowledges and appreciates the efforts of the following scientists for conducting the field trials on clomazone + propanil mixtures, the results of which are presented in this paper. These are Dr. Gil L. Magsino, Weed Scientist, National Crop Protection Center, University of the Philippines Los Baños, College, Laguna, Philippines; Mr. Virgilio F. Cuaresma and Allan Sulleza, Senior Agriculturist and Research Assistant of the Regional Crop Protection Center, Department of Agriculture, Iloilo City; and Mr. Hilario Cabanilla, Manager, Maligaya Agricultural Research Consultancy, Nueva Ecija, Philippines; Dr. Sombat Chinawong, Weed Scientist, Kasetsart University and Mr. Ferdinand Gargantiel of Pitsulin Company, Bangkok Thailand.

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EFFECTS OF PRIMISULFURON ON QUACKGRASS (*Elytrigia repens*) POPULATIONS IN CORN (*Zea mays*)

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Abstract: Quackgrass (*Elytrigia repens* (L.) Nevski.) is one of the ten worst weeds in the world and it is one of the major perennial weeds infesting many croplands in temperate regions. The persistent and vigorous rhizome system of quackgrass makes control extremely difficult. Field experiments were conducted during 1989-1991 to determine the effects of single or sequential postemergence applications of primisulfuron, 2-[[[[[4,6-bis(difluoromethoxy)-2-pyrimidinyl]amino]carbonyl]amino]sulfonyl]benzoic acid, on quackgrass population in field corn. Primisulfuron at 20 or 40 g a.i./ ha controlled quackgrass effectively. The addition of a cultivation 30 days later following the application of primisulfuron at 20 g/ha, either at early stage or late stage of quackgrass growth, did not improve quackgrass control over primisulfuron treatment without a cultivation. A single early postemergence application of primisulfuron at 40 g/ha was as effective as a split application of 20 g ha^{-1} applied at the one- to three-leaf growth stage of quackgrass, followed by one second application of 20 g/ha at the four- to six-leaf growth stage. Primisulfuron applied in 1990 was as effective in reducing quackgrass populations as sequential applications applied in 1990 and 1991 when evaluated 53 and 61 weeks after treatment (WAT). Quackgrass population was reduced over 90% across all application sequences 61 WAT.

Key words: perennial weed, postemergence, residual control, sulfonylurea

Introduction

Quackgrass is one of the ten worst weeds in the world and it is one of the major perennial weeds infesting many croplands in the United States (Holm et al., 1977). Quackgrass infests crops grown in temperate regions (Holm et al., 1977) and causes yield losses (Ivany, 1978; Young et al., 1984). The persistent and vigorous rhizome system of quackgrass makes control extremely difficult (Bhowmik et al., 1992; Ivany, 1978; Stoltenberg and Wyse, 1986).

There are several herbicides that have the ability to control quackgrass in dicotyledonous crops (Bhowmik and Bhanson, 1990; Stoltenberg and Wyse, 1986). However, selective postemergence quackgrass control in corn was unavailable until recently with the discovery of sulfonylurea herbicides (Beyer et al., 1988). Weed control with sulfonylurea herbicides has shown to be dependent on application rate and the growth stage of weeds at application time (Beyer et al., 1988; Bhowmik, 1995; Bhowmik et el., 1992; Bhowmik and O'Toole, 1992; Foy and Witt, 1990; Mitra and Bhowmik 1999; Ngouajio and Haygood, 1993). In most cases, an optimum control of weeds is obtained with application to young weeds.

Primisulfuron is a sulfonylurea herbicide that can be used postemergence to selectively control quackgrass in corn (Bhowmik, 1995; Bhowmik and O'Toole, 1991; Gillespie and Vitolo, 1993; Gillespie et al., 1988). The recommended rate of primisulfuron for quackgrass control is 40 g/ha, but acceptable quackgrass control has been reported with primisulfuron applied rates as low as 20 g/ha, under favorable growing conditions (Bhowmik, 1995; Gillespie and Vitolo, 1993; Gillespie et al., 1988).

This study was conducted to: a) compare the effectiveness of single and sequential applications of primisulfuron and b) evaluate how timing of primisulfuron applications will affect quackgrass populations in subsequent cropping seasons.

Materials and Methods

General. Experiments were conducted at the University of Massachusetts Experiment Station, South Deerfield, on a Hadley fine sandy loam (Typic Udifluvents) containing 3.2% organic matter with a pH of 6.5. The area was heavily infested with quackgrass. The initial culm density was over 325 culms/m^2. Conventional tillage consisted of moldboard plowing followed by two diskings in the spring.

Plots were 3 by 6 m and 'Agway 584S' corn was planted in 75 cm rows at a density of 62,800 plants/ha. A blanket treatment of premix combination of metolachlor [2-chloro-N-(2-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide] and atrazine [6-chloro-N-ethyl-N-(1-methylethyl)-1,3,5-triazine-2,4-diamine] at 2.7 kg/ha was applied preemergence for annual weed control. Treatments were applied with a CO_2 backpack sprayer at a pressure of 152 kPa in 189 l/ha, using 8002 flat fan nozzles. All treatments were applied with a non-ionic surfactant[1], X-77, at 0.25% (v/v) of total spray solution.

Quackgrass control was visually estimated at various times on a scale of 0% to 100%, where 0% = no control and 100% = complete control. Quackgrass culm density and dry weights were also determined at various times. Corn was harvested from the center row of each plot. Grain yield was adjusted to 15% moisture.

Quackgrass control in 1991 following application made in 1990, was determined by assessing the regrowth of quackgrass culms in each plot. The quadrats (20 by 20 cm) were placed randomly within each plot within a corn row at the initiation of the study, and remained there until the 1991 tillage operation, when the procedure was repeated. Quackgrass culms/400 cm^2 were counted 8, 50, 52 WAT in 1990 and 9, 53 and 61 WAT in 1991 and then converted to quackgrass culm density/m^2.

Data were subjected to analysis of variance and means were separated by Duncan's multiple range test at $p = 0.05$, using the appropriate error term (SAS Inst., 1985).

Rate study

Primisulfuron (Beacon 75WDG, 75% a.i.) was evaluated at 0, 10, 15, 20, 25, and 30 g/ha applied at the four- to six-leaf stage of quackgrass which corresponded to approximately 4 weeks after corn planting on May 6, 1989. Treatments were replicated three times in a randomized block design. Quackgrass control was rated 8 weeks after treatment (WAT). Regrowth of quackgrass was monitored in 1990 (52 WAT) to evaluate the residual effects of primisulfuron on quackgrass populations.

Effects of cultivation

A field study was conducted in 1989 to determine the effects of cultivation following postemergence application of primisulfuron in controlling quackgrass. Corn was planted on May 7, 1989. Primisulfuron at 20 or 40 g/ha was applied on June 12, 1989 at the four-leaf stage of quackgrass with and without a cultivation. Experimental procedures were similar to the previous experiment and this study was conducted in an adjacent field. All growth parameters used for evaluations were similar to the previous study. Treatments were replicated three times in a randomized block design. Quackgrass control was rated 4 WAT and quackgrass culm density was estimated 8 WAT. Corn was harvested October 20, 1989. Regrowth of quackgrass plants was monitored in 1990 (50 WAT) to evaluate the residual effects of primisulfuron on quackgrass populations.

Study on sequential application

This experiment was conducted to compare the effects of single application and sequential applications of rimsulfuron. Corn was planted on May 3, 1990 and May 8, 1991. Postemergence treatments were applied on June 12 and June 28, 1990, when the quackgrass was at the three- to four-leaf and six- to seven-leaf stages, respectively. The single application was applied at the early stage, while the split

[1]Ortho X-77 spreader containing alkylarylpolyoxyethylene glycols, free fatty acid, and isopropanol, Valent, RR1, Box 173, Dallas Center, IA 50063.

applications were made at the early stage and followed by a sequential application at the late stage of quackgrass. Primisulfuron was also applied at 20 and 40 g/ha sequentially in 1990 and 1991 to the same plot. The treatments were applied at the one- to four-leaf stage of quackgrass on June 5, 1991. The experimental design was a randomized block with three replications. Quackgrass control was rated 2, 5, and 9 WAT. Corn injury was determined 2 WAT. Corn was harvested October 21, 1991. The residual quackgrass control was monitored 9, 53 and 61 WAT.

Results and Discussion

Rate study

Primisulfuron at 15, 20, 25 or 30 g/ha controlled quackgrass 78 to 88% 4 WAT and the control increased over 97% 8 WAT (Table 1). Similar results were reported by Bhowmik (1995) and Ngouajio and Haygood (1993) where the quackgrass control increased to at least 90% or better 6 WAT with primisulfuron at 15 g/ha or greater.

Table 1 Effect of primisulfuron rates on quackgrass control, culm density and corn yields in 1989 in South Deerfield, MA.

Treatment	Rate	Quackgrass, WAT[1]			Corn yield	
		Control		Culm density	Silage	Grain
		4	8	52		
	g/ha	%		no./m^2	Kg/ha	
Untreated check	-	0 d[2]	0 d	1367 a	25178 b	3722 b
Cultivated check	-	99 a	98 ab	50 b	62899 a	11456 a
Primisulfuron	10	78 c	95 c	133 b	60794 a	11561 a
Primisulfuron	15	82 bc	98 ab	50 b	60726 a	11490 a
Primisulfuron	20	87 b	97 b	117 b	68365 a	12324 a
Primisulfuron	25	87 b	99 b	34 b	58934 a	11551 a
Primisulfuron	30	88 b	99 a	17 b	50893 a	9649 a

[1]WAT = weeks after initial postemergence treatment applied at the three- to four-leaf stage of quackgrass.
[2]Means followed by the same letter within a column are not significantly different at the 5% level according to Duncun's multiple range test.

The quackgrass culm density decreased with all rates of primisulfuron (Table 1). Primisulfuron at 30 g/ha significantly reduced quackgrass culms to 17 culms/m^2 compared to 1367 clums/m^2 in the untreated plot. Similar decline in quackgrass population following primisulfuron treatment was reported earlier (Bhowmik, 1995). All primisulfuron treatments significantly increased silage and grain yields of corn and the yields were comparable to the yields from the cultivated check (11456 kg/ha).

Effects of cultivation

Primisulfuron at 20 or 40 g/ha controlled quackgrass over 95% 4 WAT (Table 2). These treatments also reduced quackgrass populations effectively 8 WAT. The highest rate (40 g/ha) of primisulfuron significantly reduced quackgrass populations 50 WAT. The addition of a cultivation 30 days later following the application of primisulfuron at 20 or 40 g/ha, at the four leaf stage of quackgrass growth, did not improve quackgrass control over primisulfuron treatment without a cultivation. Similar results were reported earlier in

a study where cultivation did not improve quackgrass control with nicosulfuron (2-[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]-N,N-dimethyl-3-pyridinecarboxyamide) (Bhowmik, 1995).

All of the primisulfuron treatments resulted in significant increase in silage and grain yields of corn. A single treatment of primisulfuron at 20 g/ha applied at the four-leaf stage of quackgrass increased silage and grain yields of corn by 21531 and 4270 kg/ha, respectively, over the untreated check. Similar corn yield increases were obtained with a primisulfuron treatment (20 or 40 g/ha) followed by one cultivation.

Table 2 Effects of cultivation on the activity of primisulfuron in quackgrass control, culm density and corn yields in 1989 and 1990 following postemergence applications in 1989 in South Deerfield, MA.

Treatment	Rate	Quackgrass, WAT[1]			Corn yield	
		Control	Culm density		Silage	Grain
		4	8	50		
	g/ha	%	no./m^2		kg/ha	
Untreated check	-	0 b[2]	625 a	938 a	28708 b	5455 b
Primisulfuron + X-77	20	97 a	25 b	212 cde	50239 a	9725 a
Primisulfuron + X-77 Cultivation	20 +	95 a	25 b	262 cde	48669 a	9280 a
Primisulfuron + X-77	40	98 a	25 b	12 e	41492 a	8276 a
Primisulfuron + X-77 Cultivation	40 +	97 a	5 b	36 e	44407 a	9011 a

[1]WAT = weeks after initial postemergence treatment applied at the three- to four-leaf stage of quackgrass.
[2]Means followed by the same letter within a column are not significantly different at the 5% level according to Duncun's multiple range test.

Study on sequential application

A single early postemergence application of primisulfuron at 40 g/ha was as effective in quackgrass control as a split application of 20 g/ha applied at the three to four-leaf stage of quackgrass, followed by a sequential application of 20 g/ha at the six to seven-leaf stage (Table 3). These treatments completely eliminated quackgrass culms 61 WAT. No differences in quackgrass culm density between the single application and sequential applications of primisulfuron were observed. All of the primisulfuron treatments significantly increased silage and grain yields compared to the yields obtained in the untreated plot. However, there were no differences in either silage or grain yields of corn among the various primisulfuron treatments.

The sequential application of primisulfuron at 20 or 40 g/ha applied in 1990 followed by an repeat application of the same rate in 1991 resulted in excellent control of quackgrass. Primisulfuron applied in 1990 was as effective in reducing quackgrass populations as sequential applications applied in 1990 and 1991 when evaluated 53 and 61 WAT.

In general, primisulfuron was effective in controlling quackgrass. These studies indicate that excellent control of quackgrass can be obtained with primisulfuron, and the residual control is evident in the following growing season. In summary, one spring application of primisulfuron at 20 or 40 g/ha for two consecutive years resulted in complete control of quackgrass under conventional tillage corn.

Table 3 Effects of timing of sequential applications of primisulfuron on quackgrass control, culm density and corn yields in 1990-1991 following postemergence applications in 1990 in South Deerfield, MA.

Treatment	Timing	Rate	Quackgrass, WAT[1]				Corn yield (1991)	
			Control	Culm density				
			5	9	53	61	Silage	Grain
		g/ha	%	no./m^2			kg/ha	
Untreated check		-	0 c[2]	634 a	134 a	466 a	28484 b	5204 b
Cultivated check		-	98 a	-	-	-	53290 a	10402 a
Primisulfuron	1990	40	99 a	3 b	60 b	0 b	64539 a	11725 a
Primisulfuron + Primisulfuron	1990 + 1990	20 + 20	99 a	3 b	3 b	0 b	54724 a	9907 a
Primisulfuron + Primisulfuron	1990 + 1991	20 + 20	100 a	3 b	3 b	0 b	52706 a	9593 a
Primisulfuron + Primisulfuron	1990 + 1991	40 + 40	99 a	18 b	10 b	0 b	57864 a	10534 a

[1]WAT= weeks after initial postemergence treatment, applied on June 12, 1990.
[2]Means followed by the same letter within a column are not significantly different at the 5% level according to Duncun's multiple range test.

Acknowledgements:

The author thanks Randy Prostak for his technical help in field studies. Massachusetts Agric. Exp. Sta. J. Art. No. 3257.

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FLAZASULFURON(SL-160)FOR WEED CONTROL IN BERMUDAGRASS IN GOLF TURF

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Abstract: Field studies were conducted from 1998 to 1999 in Golf turfgrass in Jiangsu province, to evaluate flazasulfuron (SL-160) for turfgrass tolerance and post control of annual grasses, annual and perennial sedges and broad-leaved weeds. When flazasulfuron was applied at 0.05kg ai ha^{-1}, the injury to burmudagrass (cv. Tifway) was slight, with a maximum of 7.5% injury. While the injury to bermudagrass (cv. Tifway) was up to of 22.8% (10 DAT), 17.5% (30 DAT) and 9.35% (60 DAT) with flazasulfuron at 0.075 kg ai ha^{-1}. The height of turfgrass and roots weight had not been influenced by the chemical. Averaged over all field trials 60 DAT, annual grasses (*Digitaria suguinalis, Echinochloa cruss-galli, Setaria viridis*) control with flazasulfuron at 0.025, 0.0375, 0.05 and 0.075 kg ai ha^{-1} was 46.1%、80.6%、95.7% and 100% in 1998, 58.9%、85.6%、96.0% and 100% in 1999 respectively; sedges (*Cyperus rotundus,Cyperus iria, Fimbristylis miliacea, Kyllinga brevifolia*) control with flazasulfuron at 0.025, 0.0375, 0.05 and 0.075 kg ai ha^{-1} was 67.6%、85.5%、96.0% and 100% in 1998, 68.3%、84.1%、95.7% and 100% in 1999 respectively, broad-leaved weeds (*Capsella bussa-pastoris, Acalypha australis, Rorippa indica,Rorippa palustris, Malachium aguaficam, Hydrocotyle sibthorpioides, Oxalis corniculata, Erogeron bonariensis*) control with flazasulfuron at 0.025, 0.0375, 0.05 and 0.075 kg ai ha^{-1} was 85.5%、88.4%、98.0% and 98.5% in 1998, 67.6%、84.3%、94.8% and 98.8% in 1999 respectively.

Key words: flazasulfuron, weed control, golf turf

Introduction

Golf course is rapidly developing in China recently. More than 80 Golf courses had been set up by the end of 1998. At least, more than 15 Golf courses are in building. Weed control is a key component in any successful turfgrass management program, several herbicide can be used to control weeds as preemergence or postemergence treatment(1,2).Most of the postemergence herbicide can only control one or two of grasses, sedges and brodleaved weeds in turfgrass in Golf.

Flazasulfuron is a new herbicide that can be applied to some warm-season turfgrass for control of sedges, brodleaved weeds and annual grasses. In China, no information is available on the weed control with flazasulfuron and the tolerance of Bermudagrass to flazasulfuron, studies were conducted to determine the weed control spectrum, proper rate and the affect on Bermudagrass with flazasulfuron.

Material and Methods

Experiment with different rates of flazasulfuron in Golf turf: Two field trials were conducted during 1998 and 1999 in Silport Golf Club and Grand Shanghai Golf Club, kunshan, Jiangsu province, where

were located on a sandy over loam. Experiments were initiated in Silport Golf Club on 19 May, 1998 and in Grand Shanghai Golf Club on 5 May, 1999. The test areas were in the rough areas, where were naturally infested (approximate 75% ground cover) with *Digitaria sanguinales, Echinochloa cusgalli,Kyllinga brevifolia, Hydrocotyle sibthorpioides, Erigeron canadensis, Kummerwia striata, Plantago asiatica and Alternantnera philoxeroides at* 2-5 leave stage in Tifway bermudagrass maintained at 6-cm height and irrigated as needed to prevent wilting.

Weed control spectrum with different rates of flazasulfuron in turf: Testing 32 species weeds (table 2) with flazasulfuron at 0.025, 0.0375, 0.05 and 0.075 kg ai ha^{-1} In Jiangning county, Jiangsu province. Treatment (Table 1 and 2) were applied with a SWOS-08 hand pump sprayer set to deliver 100L/ha. The turfgrass injury ratings were based on 0 to 100 where 0=no injury, 1-15=minor leaf discoloration, 16-30=moderate discoloration with some necrosis, >30= moderate to severe leaf discoloration and necrosis, and 100=complete kill. Injury ratings were made 10 DAT[1],30DAT and 60 DAT. Dry turf roots were weighted after root drying sampled 60 DAT. Weed control ratings were based on 0 to 100 where 0=no control, ≥80%=acceptable control, and 100= complete control. Weed control ratings were made 10 DAT, 30 DAT and 60 DAT. Weed number and fresh weight were counted and weighted in Golf turf in Kunshan and 30 DAT in Jiangning county.

The experimental design was a randomized complete block with four replications. Plot size was 1.5 by 3 m. The data were subjected to analysis of variance.

Result and Discussion

Weed control in Golf turf. Flazasulfuron was applied at 0.025kg ha^{-1} before 4-leaved of grasses controlled 46.1-64.2% of grasses, 67.6-77% of sedges and 85.5-96.2% of broadleaved weeds. When Flazasulfuron was applied at 0.05kg ha^{-1} before 4-leaved of grasses controlled at least 95.7% of three kind weeds. When the rate is at 0.075 kg ha^{-1},weed control were almost 100% in 1998. The result of weed control by different rate of Flazasulfuron in 1999 is as good as in 1998 (See table 1).

Table 1 Weed control with Flazasulfuron in golfturf (60 days after treatment) 1998-1999 Jiangsu

Herbicide	Rate	1998						1999					
		Grasses		Sedges		broadleaved weeds		Grasses		Sedges		broadleaved weeds	
	kg ha^{-1}	No.	W.	No.	W.	No.	W.	No.	W.	No.	W.	No.	W.
Flazasulfuron	0.025	46.1	64.2	67.6	77.0	85.5	96.2	58.9	66.7	68.3	78.2	67.6	89.6
	0.0375	80.6	88.6	85.5	84.5	88.4	96.5	85.6	87.4	84.1	86.7	84.3	87.8
	0.050	95.7	98.8	96.0	97.0	98.0	99.1	95.8	97.0	95.7	98.2	94.8	92.2
	0.075	100	100	100	100	98.5	99.7	99.7	99.3	100	100	98.8	99.2
bentazon +MCPA	1.250	46.7	48.2	100	100	94.8	92.4	2.6	33.8	100	100	78.4	83.6
untreated		(46.4)	(73.9)	(207.1)	(53)	(61.4)	(243.3)	(158.4)	(27.5)	(89)	(34.7)	(75)	(177.6)

Note: the number in the brackets are weed number(plant) or weight(g) per m^2.

1.DAT=days after treatment

Weed control spectrum. The control of 32 species weeds was influenced by the rate of flazasulfuron. Flazasulfuron was applied at 0.05 kg ha^{-1} controlled most of them ≥80% during two yeas tests in bermudagrass. But flazasulfuron failed to control perennial grasses. When flazasulfuron was applied at <0.05 kg ha^{-1}, failed to control *Polygonnm aviclara, Kummerwia striata, Plantago asiatica, Lobelia chinensis, Calystegia hederacea, Artemisia argyi.*It also failed to control *Medicago* spp. and *Alternanthera philoxeroides,* when flazasulfuron was applied at <0.075 kg ha^{-1}(Table 2).

Table 2 Weed control by different rate of flazasulfuron 1998-1999 Jiangsu

Weeds	Kg a.i ha^{-1}			
	0.025	0.0375	0.050	0.075
Grasses				
Digitaria sanguinales	+	++	+++	+++
Echinochloa cusgalli	+	++	+++	+++
Setaria viridis	+	++	+++	+++
Sporobolus indicus	+	++	+++	+++
Lolinm temnlentun	++	+++	+++	+++
Paspalum distichum	0	0	+	+
Sedges				
Kyllinga brevifolia	++	+++	+++	+++
Cyperns iria	++	+++	+++	+++
fimbristylis miliacea	++	+++	+++	+++
Cyperus rotundus	0	+	++	++
Broadleaved weeds				
Rorippa globosa	++	+++	+++	+++
Acalypha anstralis	+	++	++	+++
Capsella bursa-Pastoris	++	+++	+++	+++
Malachium aguaticum	++	+++	+++	+++
Rorippa palustris	+	++	+++	+++
Oxalis corniculata	0	++	+++	+++
Hydrocotyle sibthorpioides	0	++	+++	+++
Erigeron canadensis	0	+	++	+++
Sonchus brachyotus	0	+	++	+++
Cerastium arvense	0	+	++	+++
Polygonum spp.	0	+	++	+++
Erigeron linifolius	0	+	++	+++
Potentilla chinensis	0	0	+	++
Eclipta protrata	0	0	+	++
Polygonnm aviclara	0	0	0	+
Kummerwia striata	0	0	0	+
Plantago asiatica	0	0	0	+
Lobelia chinensis	0	0	0	+
Calystegia hederacea	0	0	0	+
Artemisia argyi	0	0	0	0
Medicago hispida	0	0	0	0
Alternantnera philoxeroides	0	0	0	0

Note: +++: 90-100%; ++: 80-90%; +: 65-80%; 0: <65%

The lasting of weed control. According to the observation in different time after treatment, when flazasulfuron applied at 0.075 kg ha^{-1} and 0.05 kg ha^{-1}, the weed control kept more than 62 days and 30

days respectively.

The injury to turfgrass. When flazasulfuron was applied at 0.05kg ha^{-1}, did not reduced the density and the color of turfgrass. When flazasulfuron was applied at 0.075kg ha^{-1}, minor leaf discoloration can be seen at 10 DAT. It disappeared at 30 DAT and 60 DAT (Table 3). There were not injury to the plant growing and root growing of turfgrass (Table 3).

Table 3 The affect on turfgrass (cv. Tifway) by flazasulfuron 1998 Jiangsu

Herbicide	Rate Kg ai ha^{-1}	Injury rating			Height of turf (cm)	Weight of root (mg cm^{-3})
		10DAT	30DAT	60DAT		
flazasulfuron	0.025	0	0	0	25.25	54.67
	0.0375	5.0	2.0	0	24.75	53.95
	0.050	7.5	4.0	4.0	24.0	54.91
	0.075	22.75	17.5	9.25	23.5	51.25
bentazon +MCPA	1.275	6.75	2.0	0	24.0	54.11
hand weeding		2.25	0	0	24.25	49.02
untreated		0	0	0	25.0	51.23

Note: Treated at 7 cm height of turf. The result of turf height in table were observed at 62 DAT.

Acknowledgement: The author wish to appreciate Professor Du Jingrong , who gave a lot of help to the studies.

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IMAZAMOX: A NEW HERBICIDE FOR SOYBEAN

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Abstract: Field trials were conducted in Harbin in 1992 – 1998 to assess the efficacy and crop safety of imazamox. Results indicated that imazamox gave good control of a broad spectrum of grasses and broadleaved weeds from pre-em. to post-em. applications of 50 – 70 g ai/ha, but best control was effected by early post-em. applications. It is possible that soybean (*Glycine max*) is injured slightly after post-em application of 50 – 70 g ai/ha. No residual injury observed in wheat (*Triticum aestivum*) and corn (*Zea mayse*), no marked residual injury in rape (*Brassica campestris*), chinese cabbage (*Brassica prkinensis*), sugar beet (*Beta vulgaris*) as succession crop planted 12 months after application of 40 – 80 g ai/ha.

Key words: imazamox, weed efficacy, soybean safety, residual injury

Introduction

Imazamox (Jindou 4SL,4% a.i.) is an imidazone herbicide being developed by American Cyanamid Company. Early postemergence applications of the herbicide control a broad spectrum of grasses and broadleaf weeds. The herbicide is selective in many leguminous crops including soybean.

Field trials to assess the efficacy, crop safety and residual injury of imazamox were conducted in Harbin in 1992 – 1998.

Methods and Materials

Imazamox, imazamox / imazethapyr (Jinpursuit 5SL,5% a.i.) and imazethapyr (Pursuit 5SL,5% a.i.) provided by American Cyanamid Company were applied in the experiments.

The field trials were conducted in black soil with 2.52 – 2.88% of organic material,pH6.70 — 6.75.

The weed specials are banyard grass (*Echinochloa cruss-galli*), green foxtail (*Setaria viridis*), smart weed (*Polygonum bungeanum*), lambsquarters (*Chenopodium album*), climbing bindweed (*Polygonum convolvulus*), cocklebur (*Xanthium strumarium*), black nightshade (*Solanum nigrum*), velvetleaf (*Abutilon theophrasti*) and pigweed (*Amaranthus retroflexus*) ect..

The experimental design of plot test involved four replications of randomized block with size of 20 m^2.

A kapsack sprayer having 4 kg/cm^2 of work stress was used. 300 L/ha of liquid were sprayed.

Pairing test of efficacy of pre-em. and post-em. application

In 1992, preemerge treatments were performed April 27th and post emerge treatment May 20th at that time soybean were spreading two true leaves.

Determination action of ammonium sulfate as synergist

During 1995-1997, all trails was post-em treatment and added ammounium sulfate in the spray solution or not. The herbicides were sprayed when soybean spread two true leaves. At that time grasses were at stage of 2 – 3 leaves and height of broad leaf weeds was less than 3 – 7 cm.

Effect of combination of imazamox and imazethapyr

Tank mixture was applied 1995 - 1996. Imazamox/imazethapyr mixture was applied 1997. The herbicides were sprayed when soybean spread two true leaves.

Influence of imazamox residual in soil on succession crops

Imazamox was applied at 0, 40, 60, 80, 100g ai/ha in soybean 1996 and 1997 respectively. The experiment involved three replications of randomized blocks with size $42m^2$. The plots were kept weedfree.

The plots were plowed, harrowed and ridged after harvest 1996 and 1997. Wheat, corn, rape, sugar beet and chinese cabbage were sowed 1997 and 1998 respectively. At that time imazamox residual in soil for 12 months.

Results and Discussion

Efficacy of imazamox on controlling weeds

The results showed that activety of imazamox was observed to grasses and broad leaf weeds in the experimental plots. The weeds growth were inhibited severely, leaves were chlorotic and blight. Active of imazamox is much more high when early post-em than pre-em.application. The sensitivety of varied weeds to imazamox is defferent. Pig weed and nightshade are the most sensitive, they were controled completely when doze of imazamox was 20 — 30g ai/ha. Banyard grass, foxtail, lambsquarters, smart weed, cocklebur were more sensitive, weed control was more than 90% when imazamox doze was 40 — 50g ai/ha, this is alike to imazethapyr on 75g ai/ha. Generally, imazamox activety is higher than imazethapyr.

Ammonium sulfate as synergest

The activety of imazamox added ammonium sulfate was higher than that added no ammonium sulfate (Woznica et al., 1997). The effect of imazamox added ammonium sulfate at 40g ai/ha was equivalent to of imazamox at 50g ai/ha (see fig.2).

Imazamox mixed with imazethapyr

The results showed that effect of imazamox mixed imazethapyr (25+25g ai/ha) were near of imazamox at 50g ai/ha or imazethapyr at 75g ai/ha (see fig.3). The effect of combine formulation of imazamox/imazethapyr at 50g ai/ha was equivalent to of mixture of imazamox and imazethapyr at 25+25g ai/ha.

Safety for soybean

Contact spot were observed after applying imazamox or imazamox/imazethapyr. Some new leaves were wriked in a week, a few of foliage back and petiol became brown, even growing point was withered in those plots where high doze imazamox or imazamox/imazethapyr was applied. Some plants were shorter than check plants in two weeks, however new leaves were normal, growth recovered in three weeks (Nelson and Renner, 1998).

The result of yield showed that there was a positive correlation between soybean yield and weed activety at 40 — 100g ai/ha. Accidently, soybean yield less marginally than in manual weed plots (see fig.4).

Influence of imazamox residual in soil on succession crops

Wheat emergence and growth was normal in every plot, no injury symptom was observed after 12 months treatments. Shoot fresh weight were tested May 12th. The seed weight per square meters were recorded on harvesting. There was no significant difference among the treatments.

Corn emerged normally in the plots and no marked injury symptom was observed at each growth stage. The shoot fresh weight were tested June 1st, there was no significant difference between

treatments and untreatments except those plots where imazamox was applied at 120g ai/ha. Plant height, ear weight and kernel weight were measured on harvesting, no significant difference were observed whatever application was carried out or not (Cobucci et al., 1998).

Rape emerged normally in the plots. Ggowth of the seedling were inhibited in those plots where imazamox was applied at 80, 120g ai/ha 12 months before. Plant height and fresh weight in these plots much less than in control plots. Although no significant difference was observed in the others Less density and seed yield obtained in the plots of 80, 120g ai/ha 12 months.There was no significant difference in the others.

Sugar beet began emerge normally in the plots. Shoot fresh weight was measured June 10th. imazamox residual in 12 months at 80, 120g ai/ha decreased seedling weight. However, it was approximate in the others. Root tuber yield was measured in the plots, similar result was obtained.

Chinese cabbage emerged normally in every plot. Shoot fresh weight and yield less marginally in those plots where imazamox was applied at 120g ai/ha 12 months before than in the check plots. There was no significant difference in the others.

Conclusion

Imazamox is an effective, broad-cpectrum and less-residual herbicide, this was been proved by the experiment results 1992 — 1998.

imazamox added ammonium sulfste (20% v/v) controled Echinochloa cruss-galli, Setaria viridis, Chenospodium album, Polygonum bungeanum, Amaranthus retroflexus, Xanthium strumarium effectively at 50 — 70g ai/ha: The activety was higher than imazethapyr.

The activety of imazamox/imazethapyr at 25+25g ai/ha was equivalent to of imazethapyr at 75g ai/ha.

The optimum application time for imazamox and imazamox/imazethapyr is early postemergence when soybean has two true leaves, grasses have 1 — 4 leaves and broadleaf weed height less than 5 cm.

Within recommended doze, it is possible that soybean is injured slightly after applying imazamox or imazamox/imazethapyr, however normal growth recovers in 2-3 weeks, so there is no significant loss yield of soybean.

Within recommended doze, 12 months after applying imazamox, no residual injury observed in wheat and corn as succession crop, no marked residual injury observed in rape, chinese cabbage, sugar beet. In practice, application can be not uniforme, so it is possible that crops growth is inhibited to some extent because of excessive local concentration (more than 80g ai/ha).

Table 1 Inflence of imazamox treatment after 12 months on shoot fresh weight of crop
Harbin,1996 — 1998

treatment (g ai/ha)	shoot fresh weight (g / plant)				
	wheat	corn	rape	sugar-beet	chinese cabbage
imazamox 40	0.80	3.7	3.2	4.0	11.5
60	0.77	4.1	3.7	4.1	9.7
80	0.78	4.0	2.6	3.5	9.3
120	0.77	3.3	1.6	3.3	7.9
untreatment	0.74	4.0	3.5	3.9	8.8

Table 2 Inflence of imazamox treatment after 12 months on yield of crops

Harbin, 1996 — 1998

treatment (g ai/ha)	yield (kg / ha)				
	wheat	corn	rape	sugar-beet	chinese cabbage
imazamox 40	927	9800	1230	22600	5040
60	967	9400	1340	21600	4960
80	980	9200	1088	20800	4880
120	950	9400	788	21300	4640
untreatment	943	9200	1175	23800	4880

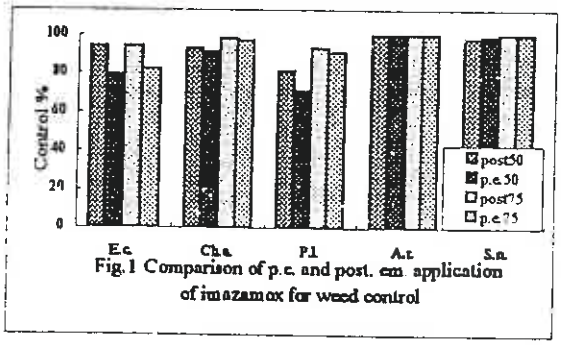


Fig.1 Comparison of p.e. and post. em. application of imazamox for weed control

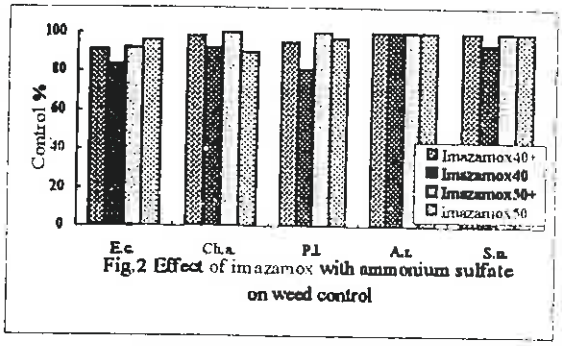


Fig.2 Effect of imazamox with ammonium sulfate on weed control

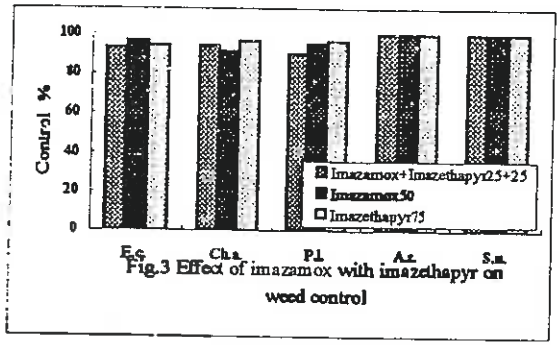


Fig.3 Effect of imazamox with imazethapyr on weed control

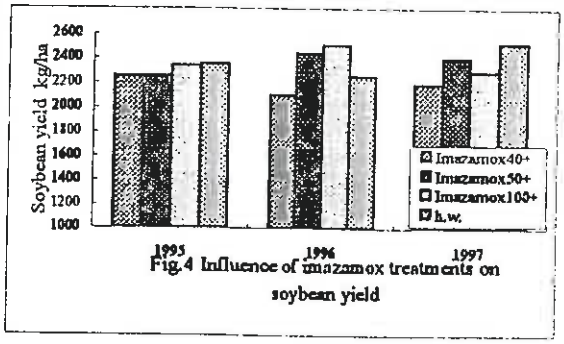


Fig.4 Influence of imazamox treatments on soybean yield

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IMAZAPIC: A NEW BROAD SPECTRUM HERBICIDE FOR WEED CONTROL IN SUGARCANE IN THAILAND

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Abstract: Imazapic is a broad-spectrum imidazolinone herbicide discovered by American Cyanamid Company. The compound has been developed and registered for use on sugarcane in Thailand. Field trials with imazapic (trademark, CADRE®) and its tank-mix with pendimethalin (trademark, STOMP®), were carried out in new cane plantings during 1997-1998. Imazapic alone at range of 75-150 g ai/ha and the tank mixture of imazapic + pendimethalin at 75 + 750 g ai/ha, applied pre-emergence to the cane, demonstrated good to excellent weed control, with excellent residual activity against a wide range of grasses, broad-leaved weeds (BLWs) and nutsedge. Residual control was of sufficient duration to require only a single herbicide application up to the time of crop canopy cover, compared to current commercial standards with shorter residual, requiring sequential program applications. Key weeds controlled by imazapic and its tank-mix with pendimethalin included: *Brachiaria reptans, Dactyloctonium aegyptium, Eleusine verticillata, Leptochloa chinensis, Rottboellia exaltata, Trianthema portulacastrum, Tribulus terrestis* and *Cyperus rotundus*. Good crop tolerance to pre-emergence applications of imazapic have been demonstrated at rates up to 200 g ai/ha. Similarly the mixture of imazapic with pendimethalin
has also shown good crop selectivity.

Key words: imazapic, pendimethalin, sugarcane, grasses, broad-leaved weeds, nutsedge.

INTRODUCTION

Sugarcane is one of the economically important crops grown in Thailand. Weeds are the main problem in cane fields, significantly impacting early crop establishment, yield and sugar quality. Certain weeds, including itchgrass (*Rottboellia exaltata*) and nutsedge (*Cyperus rotundus*) are difficult to control with conventional herbicides registered for use in sugarcane. The main herbicides currently in use are atrazine, ametryn and diuron at high use rates and in sequential applications (Suwanketnikom, 1998).

Imazapic, (RS)-2-(4,5-dihydro-4-isopropyl-4-methyl-5-oxoimidazol-2-yl)-5-methylnicotinic acid (IUPAC), is a new broad-spectrum imidazolinone herbicide developed by American Cyanamid (Cyanamid Technical Bullentin, 1999). Like other imidazolinone compounds, imazapic controls weeds by inhibiting the enzyme acetohydroxyacid synthase (AHAS), which is involved in amino acid synthesis. Imazapic has been tested and registered in sugarcane, peanuts and turf in several countries around the world. In Thailand, field trials on new plant cane were conducted during 1997-1998.

This paper describes the field performance of imazapic applied pre-emergence to the crop as a stand-alone product and in tank-mixes with pendimethalin.

MATERIALS AND METHODS

Two field trials were conducted in new cane plantings in Kanchana Buri (Trial I) and Suphan Buri (Trial II) provinces between 1997 and 1998. Cane varieties K 88-92 and U-Thong 2 were planted in the trials at Kanchana Buri and Suphan Buri, respectively. Imazapic 24% aqueous suspension (AS) and pendimethalin 33% emulsifiable concentrate (EC) were tested alongside atrazine as a commercial standard, hand weeding and untreated check. All trials were arranged in randomized complete block designs with 3 replications. Plot sizes were 6.5 x 8.0 m. with plant spacings of 0.5 x 1.3 m. Furrow irrigation was used for watering. Rates of imazapic ranged from 50 - 200 g ai/ha for stand-alone treatments and 50-100 + 750-1000 g ai/ha for tank mixtures of imazapic + pendimethalin. Herbicides were applied pre-emergence to the weeds and cane at 2 days after planting using a knap-sack sprayer fitted with a fan-type nozzle. Spray volume was 500 l/ha. Soil type was sandy loam at the Kanchana Buri trial site and silty clay loam at Suphan Buri. The bio-efficacy of weed control was determined by visual assessments, using Bryan's method (Bryan, 1997). Crop selectivity and yield were also assessed.

RESULTS AND DISCUSSIONS

Herbicidal Activity and Spectrum

Trial I

The key weed species present at the site were: grasses - *Brachiaria reptans, Leptochloa chinensis, Rottoellia exaltata* and BLWs - *Tribulus* sp. and *Trianthema portulacastrum,* roughly in the ratios 25%, 25%, 25%, 12.5% and 12.5% respectively. The summary weed control data are presented in Table 1. At the first month after application, all the herbicide treated plots showed generally good control of total weeds. However, by 60 days after application (DAA), treatment differences were obvious with plots treated with imazapic at 150 g ai/ha showing excellent control of the key grasses (> 94%), compared to 40 - 60% control for the atrazine treatment. The tank mixture of imazapic + pendimethalin at 75 + 750 g ai/ha demonstrated good to excellent control of all grass weeds (70 - 94%) up to 90 DAA.

Trial II

The key weed species present were: grasses - *Eleusine verticillata* and *Dactyloctenium aegyptiune,* broadleaved weeds - *Trianthema portulacastrum* and nutsedge - *Cyperus rotundus,* roughly in the ratios 27%, 12%, 5% and 56% respectively. The data are presented in Table 2. Imazapic at the rate of 100 g ai/ha provided 86-100% control of *E. verticillata* and *D. aegyptium* up to 90 DAA, but only moderate control of *T. portulacastrum* (44% at 60 DAA). To control *C. rotundus*, 100 - 150 g ai/ha of imazapic was required (74 - 90% at 90 DAA). In the treatment of imazapic + pendimethalin at 75 + 750 g ai/ha, >90% control of all grass weeds and nutsedge were recorded, and more than 60% control of the key BLW, *Trianthema,* up to 90 DAA. Residual weed control performance for all treatments of imazapic and imazapic + pendimethalin were outstanding, compared to atrazine.

Table 1. Effect of imazapic and imazapic+pendimethalin on weed control in sugarcane, Thailand, 1997-1998 (Trial I)

Treatment[1]	Rate G ai/ha	% Weed Control[2] at 30, 60, 90 DAA[3]														
		BRARE			ROTEX			LEPCH			TRIPO			TRITE		
		30	60	90	30	60	90	30	60	90	30	60	90	30	60	90
Imazapic	50	93	54	75	50	0	-	65	32	34	92	-	-	100	-	-
Imazapic	75	95	86	91	61	62	-	97	45	30	77	-	-	100	-	-
Imazapic	100	100	83	93	95	56	-	93	65	50	67	-	-	100	-	-
Imazapic	150	100	100	99	93	94	-	100	83	89	100	-	-	100	-	-
Imazapic	200	100	100	96	99	100	-	97	71	55	100	-	-	100	-	-
Imazapic+ pendimethalin	50+750	100	83	87	92	25	-	100	88	87	98	-	-	100	-	-
Imazapic+ pendimethalin	75+750	100	97	94	94	70	-	100	96	92	100	-	-	100	-	-
Imazapic+ pendimethalin	100+1000	100	99	94	99	75	-	100	96	93	100	-	-	100	-	-
Atrazine	2500	70	60	5	87	38	-	83	81	52	100	-	-	100	-	-
Pendimethalin	2000	100	92	77	100	100	-	98	100	88	100	-	-	100	-	-
Hand weeding	-	25	0	89	33	100	-	23	86	100	100	-	-	0	-	-
Untreated[4]	-	(20)	(35)	(54)	(30)	(45)	-	(13)	(29)	(26)	(13)	-	-	(3)	-	-

1. Application timing = 2 days after planting. 2. Assessment by visual rating, 0-100 scale (0 = no control; 100 = complete control) 3. DAA = days after application.
4. % Ground cover of weed species.

BRARE = *Brachiaria reptans*, ROTEX = *Rottboellia exaltata*, LEPCH = *Leptochloa chinensis*, TRIPO = *Trianthema portulacastrum*, TRITE = *Tribulus terrestris*

Table 2. Effect of imazapic and imazapic+pendimethalin on weed control in sugarcane, Thailand, 1997-1998 (Trial II).

Treatment[1]	Rate g ai/ha	% Weed Control[2] at 30, 60, 90 DAA[3]											
		ELEVE			DACAE			TRIPO			CYPRO[4]		
		30	60	90	30	60	90	30	60	90	30	60	90
Imazapic	50	68	49	67	-	100	100	29	33	-	64	70	73
Imazapic	75	88	50	45	-	62	100	49	33	-	89	66	49
Imazapic	100	95	79	86	-	100	100	54	44	-	84	39	74
Imazapic	150	96	98	95	-	100	95	57	57	-	70	84	90
Imazapic	200	99	96	100	-	100	100	82	67	-	89	92	95
Imazapic+ pendimethalin	50+750	97	100	100	-	100	100	64	100	-	37	27	38
Imazapic+ pendimethalin	75+750	97	98	99	-	100	91	83	67	-	84	84	91
Imazapic+ pendimethalin	100+1000	99	100	100	-	100	100	79	100	-	85	86	86
Atrazine	2500	55	32	45	-	100	100	83	100	-	0.5	47	30
Pendimethalin	2000	100	100	100	-	100	100	80	100	-	(28)	(37)	(47)
Hand weeding	-	33	100	100	-	88	100	0	100	-	0	1	33
Untreated[5]	-	(48)	(53)	(48)	-	(20)	(30)	(15)	(10)	-	(17)	(10)	(6)

1. Application timing was 2 days after planting. 2. Assessment by visual rating, 0-100 scale (0 = no control; 100 = completely control) 3. DAA = days after application.
4. Weed control of CYPRO was compared to pendimethalin treatment.
5. % Ground cover of weedspecies.

ELEVE = *Eleusine verticillata*, DACAE = *Dactyloctenium aegyptium*,
TRIPO = *Trianthema portulacastrum*, CYPRO = *Cyperus rotundus*.

R. exaltata and *C. rotundus* are the most troublesome weeds in cane fields. Current commercial herbicides do not provide sufficiently long duration control of these two weed species, requiring the cane growers to carry-out sequential program applications during the growing season. Pendimethalin is a herbicide for the control of *R. exaltata* in Thailand (Suwunnamek, 1995), so it is good partner for imazapic.

Crop Tolerance and Effect on Yield

Two different cane varieties were grown in the trials. Both varieties showed good crop tolerance to imazapic at rates up to 200 g ai/ha (Table 3). Crop tolerance to imazapic treatments was refleted in the cane yields (Table 4). All treatments of imazapic and imazapic + pendimethalin provided cane yields significantly higher than the atrazine treatment, hand weeding or untreated check.

Table 3. Phytotoxicity of imazapic and imazapic + pendimethalin on plant cane applied as pre-emergence, Thailand, 1997-1998.

Treatment	Rate g ai/ha	Phytotoxicity[1] at 15, 30, 60, 90 DAA							
		15 DAA[2]		30 DAA		60 DAA		90 DAA	
		Trial I	Trial II	Trial I	Trial II	Trial I	Trial II	Trial I	Trial Ii
Imazapic	50	0	0	0	0	0	0	0	0
Imazapic	75	0	0	0	10	0	0	0	0
Imazapic	100	0	0	0	10	0	0	0	0
Imazapic	150	0	0	0	20	0	10	0	10
Imazapic	200	0	0	0	20	0	20	0	0
Imazapic+ pendimethalin	50+750	0	0	0	0	0	0	0	0
Imazapic+ pendimethalin	75+750	0	0	0	10	0	0	0	0
Imazapic+ pendimethalin	100+1000	0	0	0	0	0	0	0	0
Atrazine	2500	0	0	0	0	0	0	0	0
Pendimethalin	2000	0	0	0	0	0	0	0	0
Hand weeding	-	0	0	0	0	0	0	0	0
Untreated	-	0	0	0	0	0	0	0	0

1. Assessment by visual rating, 0-100 scale (0 = no crop injury; 100 = completely killed)
2. DAA = days after application

CONCLUSIONS

Imazapic alone and the tank-mixture of imazapic with pendimethalin provided excellent broad-spectrum weed control of key grasses, BLWs and sedges (including *Rottboellia exaltata* and *Cyperus rotundus*), with good crop selectivity in sugarcane fields in Thailand. Effective rates required were 75 - 150 g ai/ha for imazapic alone or 75 + 750 g ai/ha for the mixture of imazapic +

pendimethalin, applied pre-emergent to the weeds and plant cane. One herbicide application can provide excellent control of weeds up to the time of crop canopy cover, compared to sequential program applications required by the current commercial standards.

Table 4. Effect of imazapic and tank mixture of imazapic + pendimethalin on sugarcane yield, Thailand, 1997 ~ 1998.

Treatment	Rate g ai/ha	Cane Yield (% increase from Untreated Check)	
		Trial I (Var. K-88-92)	Trial II (Var. U-thong 2)
Imazapic	50	0	886.1
Imazapic	75	33.2	926.9
Imazapic	100	60.6	890.0
Imazapic	150	93.0	966.9
Imazapic	200	52.0	946.1
Imazapic+ pendimethalin	50+750	93.7	827.6
Imazapic+ pendimethalin	75+750	81.2	726.9
Imazapic+ pendimethalin	100+1000	42.0	846.9
Atrazine	2500	0	846.9
Pendimethalin	2000	200.0	846.9
Hand weeding	-	(77.4 mt/ha)	(65.6 mt/ha)
Untreated check	-	(44.9 mt/ha)	(8.1 mt/ha)

ACKNOWLEDGEMENTS

We are grateful to Dr. Kleopan Suwanarak of the Department of Agriculture and Prof Rangsit Suwanketnikom of Kasetsart University , who gave valuable advice during the course of the field trials. The close co-operation of the Field Crops Research Center, Suphan Buri, especially Mr. Artasit Boontum, is greatly appreciated. We would like to acknowledge the great effort of Mr. Wichit Chomsuk, formerly with Cyanamid's technical staff, in conducting much of the trial work.

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IMAZAPYR/GLYPHOSATE : AN EFFECTIVE NEW HERBICIDE FOR GENERAL WEED CONTROL (GWC) IN OIL PALM AND RUBBER PLANTATIONS

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Abstract: A series of field experiments were conducted under mature oil palm and rubber plantings for general weed control using TACKLE® AS, a co-formulation of 75 g imazapyr and 180 g glyphosate per liter. In mature oil palm plantations (>50 % shade), TACKLE® at 1.0 L/ha applied either by conventional knapsack sprayer (CKS) or controlled droplet application (CDA), gave very good control against most of the major weed species including grasses, broadleaf-weeds and sedges for up to 3 months after application. TACKLE® performed particularly well in the low lying or high table areas where the treatments gave consistently very good control over problematic weeds like, *Paspalum conjugatum*, *Axonopus compressus* and *Cyperus spp*. In these areas, TACKLE® was superior to glyphosate + metsulfuron methyl and paraquat based tank-mixture treatments. Generally, applications of TACKLE® by CDA showed better efficacy than CKS. Under rubber plantings (>50 % shade), TACKLE® at 1.0 L/ha performed just as well as the plantation standards of glyphosate mixtures, but better than the paraquat mixture in controlling mixed weed species for a period of at least 3 months. In an experiment under simulated rainfall conditions, TACKLE® was found to have excellent rainfastness properties. Results revealed that TACKLE® at the recommended rate of 1.0 L/ha, was not adversely affected by the simulated rain wash-off even at one hour after treatment.

Key words: TACKLE®, imazapyr, glyphosate, general weed control, rainfastness

Introduction

TACKLE® is a new co-formulation, imazapyr based herbicide developed by American Cyanamid Company for broad spectrum weed control in mature oil palm and rubber plantations. This product is a pre-mixture of 75 g imazapyr and 180 g glyphosate per litre. TACKLE® herbicide is registered and sold in Malaysia. Registration of TACKLE® is pending in Thailand, Indonesia and Vietnam. In oil palm and rubber plantations, chemical weed control forms a significant component of the total cost of upkeep. In general, weed control in plantations is mainly confined to spraying the palm circles and harvesting paths in oil palm plantings, strip spraying in rubber plantings and selective spot spraying of some noxious and woody weeds.

This paper summarises results obtained from a series of field trials on general weed control in mature oil palm and rubber plantations in Malaysia. The sites were selected to reflect typical plantation conditions in terms of the composition and density of weeds and soil type.

Materials and Methods

Trials were laid out both in mature oil palm and rubber plantings under varying shade conditions (30-60%) on both well drained as well as low lying area/water logged soil. The trials were laid out using a randomised complete block design with three replications. Plot sizes ranged from 72 m^2 – 2000 m^2 and the inherent variations in weed infestation were also taken into consideration when deciding on the plot size. Conventional knapsack sprayers (CKS), fitted with 5/64 fan-jet nozzles and controlled droplet applicators

Assessments on the performance of various treatments were based on visual assessment of the percentage of weed control (0-100%) at defined periodic intervals.

An experiment to evaluate the rainfastness of TACKLE® was carried out by using simulated rainfall technique on uniform stands of *Paspalum conjugatum* weed species grown in pots. Three pots were used for each treatment replicated three times. TACKLE® at 1.0 L/ha and glyphosate at 1.0 L/ha were evaluated. Treatments were applied using a conventional knapsack sprayer fitted with a flat fan nozzle, calibrated to deliver a spray volume of 300 l/ha. Treatments were sprayed at 1 hour, 2 hour, 4 hour and 6 hour before the application of simulated rain. Rainfall simulation was done by using a sumi-shower system which was pre-calibrated to deliver an average of 8mm of simulated rain over a period of 60 minutes. Assessments on weed control were then scored visually at regular intervals for up to 4 weeks after application (WAA).

Results and Discussions

Experiment 1

This trial was laid down in an area which was mainly infested with a mixture of weeds consisting of *Ottochloa nodosa, Axonopus compressus, Ageratum conyzoides, Asystasia gangetica* and *Borreria latifolia*. The results obtained are illustrated in Table 1.

Table 1 Field performance of TACKLE for general weed control in mature oil palm plantings.

Treatments	Rate (L,kg/ha)	Rate (gai/ha)	Weed[1] Control (%)				
			1	4	8	12	16WAA
TACKLE® (Imazapyr + glyphosate)	1.0	75 + 180	35	90	90	85	65
Glyphosate + Metsulfuron-methyl	1.0 + 0.05	360 + 15	45	90	95	83	67
Glufosinate ammonium	3.0	450	80	93	78	48[2]	95
Untreated Check	-	-	0	0	0	0	0

[1] Major weeds species : *Ottochloa nodosa, Axonopus compressus, Ageratum conyzoides, Asystasia gengetica, Borreria latifolia.*

[2] Plot re-sprayed

Single application of TACKLE® at 1.0 L/ha demonstrated excellent control on the mixed weeds species, lasted for about 4 months. Broadleaf weeds (BLWs), i.e. *Asystasia gangetica* and *Borreria latifolia* began to recolonise from seeds by about 60-90 days after treatment which was the main reason for the reduction in weed control after 90 days. The level of control obtained was comparable to the plantation standard, glyphosate + metsulfuron methyl mixture but TACKLE® was superior to glufosinate ammonium, where a re-spray was required three months after application. The re-spray was carried out in according with plantation practice when the weed control fell below 50%.

Experiment 2 & 3

Two trials were carried out in low lying/water logged soil in a field infested largely with *Cyperus spp., Cynadon spp., Eleusine indica, Axonopus compressus, Paspalum conjugatum, Ottochloa nodosa, Asystasia gangetica* and *Ageratum conyzoides.* In experiment 2, treatments were compared using CKS application whilst in experiment 3, the treatments were compared using CDA equipment where paraquat + metsulfuron methyl was excluded for obvious reasons. Results obtained are illustrated in Table 2 and Table 3.

Table 2 Field performance of TACKLE for general weed control in matured oil palm using conventional knapsack sprayer under low lying/water logged soil. (Experiment 2)

Treatments WAA	Rate (L,kg/ha)	Rate (gai/ha)	Weed[1] Control (%) 2	4	8	12
TACKLE® (Imazapyr + glyphosate)	1.0	75 + 180	37	77	78	33
TACKLE® (Imazapyr + glyphosate)	1.25	93.75 + 225	40	83	83	50
TACKLE® (imazapyr + glyphosate)	1.5	112.5 + 270	48	89	88	52
Glyphosate + Metsulfuron-methyl	1.0 + 0.05	360 + 15	42	65	60	23
Paraquat + Metsulfuron-methyl	1.5 + 0.05	375 + 15	89	27	10	0
Untreated Check		-	0	0	0	0

[1] Major weeds species : *Cyperus spp., Cynadon spp., Eleusine indica, Axonopus compressus, Paspalum conjugatum, Ottochloa nodosa, Asystasia gangetica, & Ageratuim conyzoides.*

Based on the results in Table 2, TACKLE® at 75 + 180, 93.75 + 225 and 112.5 + 270 gai/ha showed good control against the major weed species found in the oil palm plantations and residual control lasted for at least 60 days. Under this type of soil conditions, TACKLE® provided better weed control than the glyphosate + metsulfuron methyl mixture and was clearly superior to paraquat + metsulfuron methyl mixture when applied with CKS.

In Experiment 3, under similar soil conditions as in Experiment 2, controlled droplet applicator (CDA) was compared to conventional knapsack sprayer (CKS). The general performance of TACKLE in terms of weed control as well as the control duration was even better. TACKLE® was tested at rates of 75 – 112.5 g imazapyr + 180 – 270 g glyphosate/ha demonstrated higher level of weed control and showed a longer duration of control for up to 90 days. At these rates, TACKLE® was as good or even better than the glyphosate + metsulfuron methyl mixture. Generally ultra low volume application by CDA of TACKLE® produced better and more consistent weed control as compared to the high volume application by CKS.

Table 3 Field performance of TACKLE® for general weed control in mature oil palm using controlled droplet application (CDA) under low lying/water logged soil. (Experiment 3)

Treatments	Rate (L,kg/ha)	Rate (gai/ha)	Weed[1] Control (%)			
			2	4	8	12 WAA
TACKLE® (Imazapyr + glyphosate)	1.0	75 + 180	35	87	85	64
TACKLE® (Imazapyr + glyphosate)	1.25	93.75 + 225	40	90	90	73
TACKLE® (imazapyr + glyphosate)	1.5	112.5 + 270	43	92	90	73
Glyphosate + Metsulfuron-methyl	1.0 + 0.05	360 + 15	42	87	82	63
Untreated Check	-	-	0	0	0	0

[1] Major weeds species : *Cyperus spp., Cynadon spp., Eleusine indica, Axonopus compressus, Paspalum conjugatum, Ottochloa nodosa, Asystasia gangetica, & Ageratuim conyzoides.*

Experiment 4

This trial was conducted in a mature rubber plantation. The experimental site selected was inland, where the dominant weeds were *Axonopus compressus, Crytococoum accrescens, Asystasia gangetica* and *Adiatum spp.* Results obtained are shown in Table 4.

Based on the results obtained under inland conditions, a single application of TACKLE® at 1.0 L/ha gave good control against the mixed weed population and was comparable to glyphosate + metsulfuron methyl but was superior to paraquat + metsulfuron methyl in terms of both efficacy, as well as duration of weed control.

Table 4 Field performance of TACKLE® for general weed control under mature rubber on inland soil.

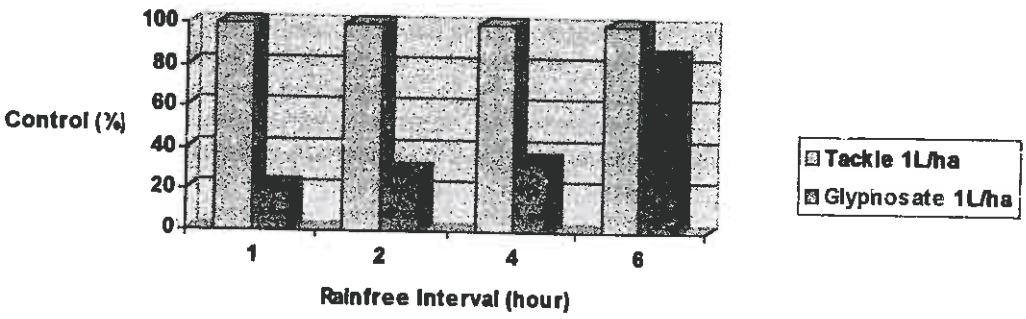
Treatments	Rate (L,kg/ha)	Rate (gai/ha)	Weed[1] Control (%)			
			4	8	12	16 WAA
TACKLE® (Imazapyr + glyphosate)	1.0	75 + 180	85	93	87	81
Glyphosate + Metsulfuron-methyl	1.0 + 0.05	360 + 15	91	93	88	80
Paraquat + Metsulfuron-methyl	1.5 + 0.05	375 + 15	82	79	59	48
Untreated Check	-	-	0	0	0	0

[1] Major weeds species : *Axonopus compressus, Crytococoum accrescens, Asystasia gangetica, Adiatum spp.*

Experiment 5

Results of a trial evaluating rainfastness of TACKLE® are illustrated in Table 5. TACKLE® was found to have excellent rainfastness property from 1 hour after treatment on *Paspalum conjugatum*. The results at 1 hour rain free interval showed complete control against *Paspalum conjugatum* and there were no differences compared to the level of control achieved for the 6 hour rain free treatment. However, the effectiveness of glyphosate was adversely affected by the rainfall. At 1, 2 and 4 hour rain free interval, glyphosate efficacy was reduced by 60 – 75 % at 28 days after treatment. Glyphosate only gave good weed control (85%) i.e. *Paspalum conjugatum* at 6 hour rain free period. TACKLE® provided 100% control at all rain free intervals.

Table 5 Comparison of rainfastness activities[1] of TACKLE® and glyphosate.



[1]Rain was simulated at 8 mm in 1 hour
Indicated weed : *Paspalum conjugatum*

Conclusions

From the results obtained from the wide range of trials reported in this paper, TACKLE® has demonstrated excellent control of the major weed species found in mature oil palm and rubber plantations. Results also indicate that ULV application of TACKLE® using CDA produced better bioefficacy and more consistent performance as compared to the high volume application by CKS. TACKLE® also demonstrated outstanding rainfastness properties which is a key benefit under the high rainfall tropical climate conditions which exist in most areas under plantation.

Acknowledgement

The authors would like to thank Mr. S.S.Maniam, the Field Manager of Jenderata Estate and Mr. Chung Gait Fee of Sime Darby Plantation for their assistance in carrying out these trials.

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POST-EMERGENCE GRASS WEED CONTROL WITH BAS 625 H IN ASIAN RICE CULTURES (RESULTS FROM THAILAND, KOREA, MALAYSIA, VIETNAM AND TAIWAN 1994-98)

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Abstract: The cyclohexanone herbicide BAS 625 H provided excellent post-emergence control of important grass weeds in rice (*Oryza sativa* L.) including *Echinochloa crus-galli* (L.) Beauv., *Echinochloa colonum* (L.) Link, *Leptochloa chinensis* (L.) Nees and *Ischaemum rugosum* Salisb.. BAS 625 H demonstrated excellent timing flexibility, controlling emerged grass weeds up to mid-late tillering stage. Selectivity was good in all major rice varieties tested once the rice had reached the three leaf or greater stage of growth. The recommended application rate for BAS 625 H ranges from 50 to 125 g ai/ha, depending on the spectrum and growth stage of grass weeds to be controlled as well as the stage of rice development. An additive containing formulation of BAS 625 H has been developed to meet the application requirements of Asian growers. For complementary control of broadleaf weeds and sedges, BAS 625 H can be applied in sequence or in tank mixture with other herbicides.

Key words: rice, BAS 625 H, graminicide, ACCase inhibitor, post-emergence, timing flexibility

Introduction

BAS 625 H (tradename: TETRIS®) is a new post-emergence graminicide (cyclohexanone chemical class / ACCase inhibitor) for spray application in rice, developed by BASF (Finley *et al.*, 1999). In Asia field trials were carried out in Korea, Thailand, Vietnam, Malaysia, and Taiwan in dry-seeded, wet-seeded and transplanted rice. Results from 1994-98 are summarised in this paper.

Material and Methods

Field trials were designed as randomised block with three or four replicates. Plot size ranged from 2-10 m^2. Treatments were applied using knapsack sprayers equipped with either a spray boom with 4-6 flat fan nozzles or a single nozzle spray lance. Water volumes ranged from 300 to 1000 litres/ha. Rice cultivation and fertilisation followed standard recommendations. The infestation with grass weeds was partly increased by broadcasting seeds at 5-10 kg/ha in case of low natural population's. Grass coverage at time of evaluation across trials ranged from 25-80 % for *Echinochloa crus-galli*, 5-10 % for *Echinochloa colonum*, 5-50 % for *Leptochloa chinensis* and 2-3 % for *Ischaemum rugosum*. Trials strongly infested with broad leaf weeds and sedges were oversprayed with bentazon or 2,4 D at 7 days or later after use of graminicides to exclude interactions. Growth stages of rice and weeds were determined according the BBCH code system (Stauss, 1990). Herbicide selectivity and efficacy on weeds were assessed according EPPO guidelines (Anon., 1998). Larger numbers of trials were summarised by using BOX and WHISKER plot analysis (Cleveland, 1985). The following herbicides were used: BAS 625 H (Tetris, ready formulation containing 75 g a.i./l + methyloleat, EC; Aura, 200 g a.i./l, EC), propanil (Porpa, 360 g a.i./l, EC), thiobencarb + propanil (Saturnil, 400+200 g a.i./l, EC), molinate + propanil (Arrosolo, 33.1+33.1 %, EC), fenoxaprop-p-ethyl (Whip Super, 80.5 g a.i./l, EC), quinclorac (Facet, 50 %, WP), bentazon (Basagran, 480 g a.i./l, SL), cyhalofop-butyl (Clincher, 50 %, WP), pyribenzoxim (Pyanchor, 1%, EC).

Results

Frist trials with BAS 625 H were conducted in Southern Taiwan in wet-seeded rice, applied at the 3-5 leaf and during tillering stage of *E. crus-galli* (Figure 1). BAS 625 H was tank mixed with crop oil concentrate (COC) for better leaf uptake by the grass weed. Treatments at GS 13/14 of rice (= GS 13/15 of barnyard grass) showed good selectivity at 75 and 100 g a.i./ha BAS 625 H and very good control of *E. crus-galli*. The higher rate of 125 g a.i./ha caused slightly more initial crop injury (8 %) in the form of discoloration of rice leaves, but the crop recovered quickly. Treatments of BAS 625 H at the tillering stage of grasses (GS 21/22) were more selective, but still very effective. At a rate of 125 g a.i./ha 95 % grass control was achieved under severe infestation conditions.

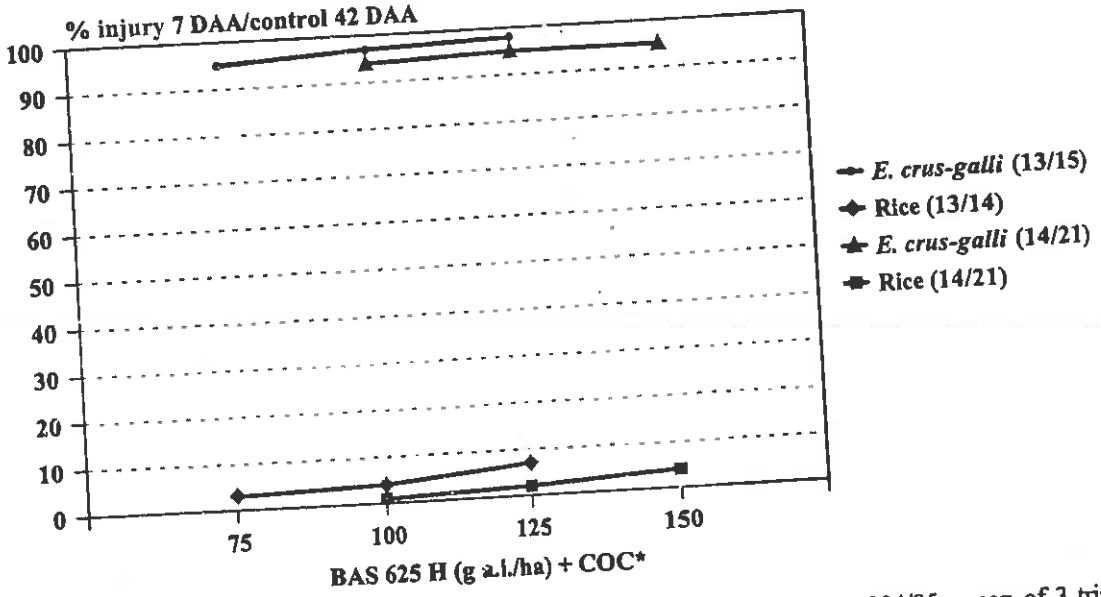


Fig. 1 Grass control with BAS 625 H in wet-seeded rice (Pingtung, Taiwan 1994/95; mean of 3 trials; water volume 300 l/ha); ( ) = growth stage at application; DAA = days after application; * COC = 2 l/ha crop oil concentrate

In Thailand BAS 625 H was tested at different application timings at 10, 15 and 25 days after seeding of pre-germinated rice. The trial fields were infested with *E. crus-galli*, *E. colonum* and *L. chinensis*. The results are summarised according to application timings in comparison with reference products (Figure 2). BAS 625 H, applied at 10 days after seeding of rice, provided very good control of grasses at 50-75 g a.i./ha. Later treatments at 15 and 25 days after seeding achieved very good grass control at 125 g a.i./ha, superior or equal to reference products. BAS 625 H induced initially slight rice injury in the form of leaf discoloration at effective rates, which completely grew out within a short period. Reference products were more injurious to rice.

In Malaysia (Figure 3), BAS 625 H was applied at 10-11 and at 21-25 days after seeding of rice. Selectivity was better when applied to a well-established crop in comparison with treatments during very early stages of rice development. Early use of BAS 625 H provided excellent control of *L. chinensis* and *I. rugosum* at 75 g a.i./ha, whereas the control of *E. crus-galli* due to significant re-emergence in one trial was somewhat lower. In comparison, later applications at 125 g a.i./ha provided very good crop safety and control of all grass species, superior to reference products.

Field experiments in wet-seeded rice were carried out in Vietnam during the growing period 1997/98. BAS 625 H was applied at 12 days after sowing, corresponding to GS 13/14 of grasses and crop. No rice injury was observed (Table 1). At a rate of 75 g a.i./ha BAS 625 H provided very good control of *E. crus-galli* and *L. chinensis*, superior to reference products. This was also reflected by the highest rice yield recorded in the BAS 625 H treatments, which was statistically significant (Duncan p=0.05).

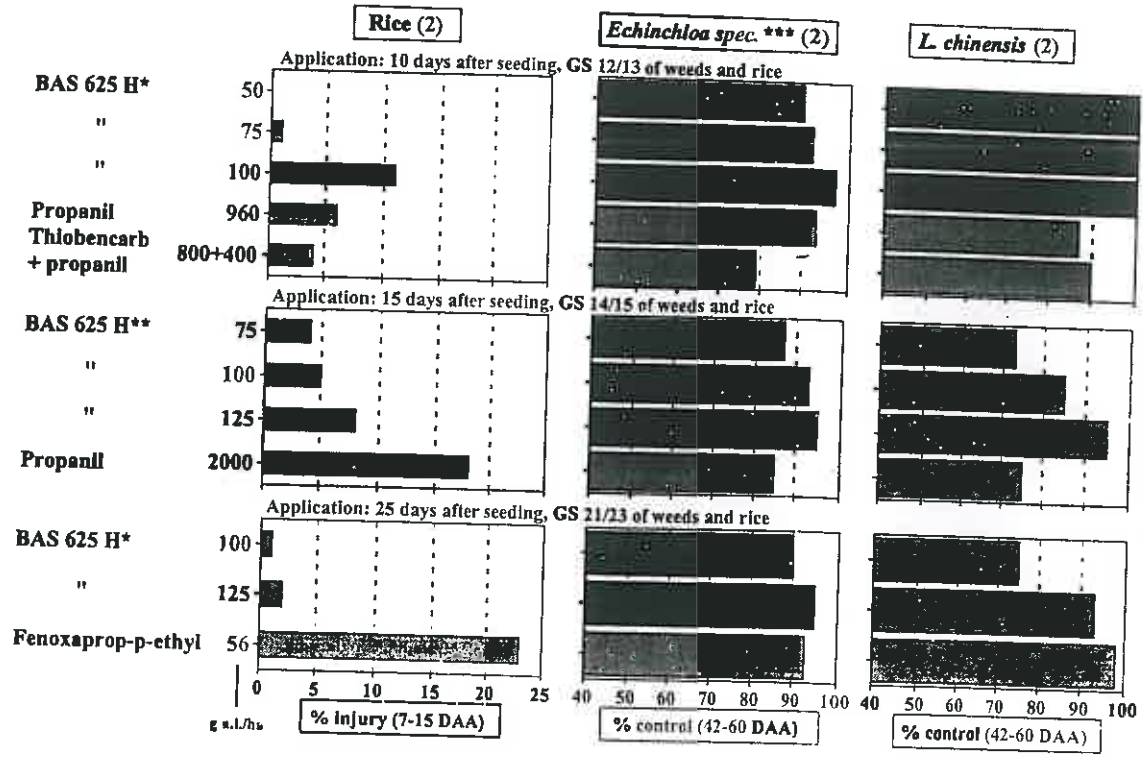


Fig. 2 Post-emergence activity of BAS 625 H in wet-seeded rice (Suphunburi, Nonthanburi, Thailand 1995-98; summary of 6 trials); ( ) = no. trials; DAA = days after application; water volume: 300-500 l/ha; * + COC; ** + methyloleat; *** mixed population of *E. crus-galli* and *E. colonum*

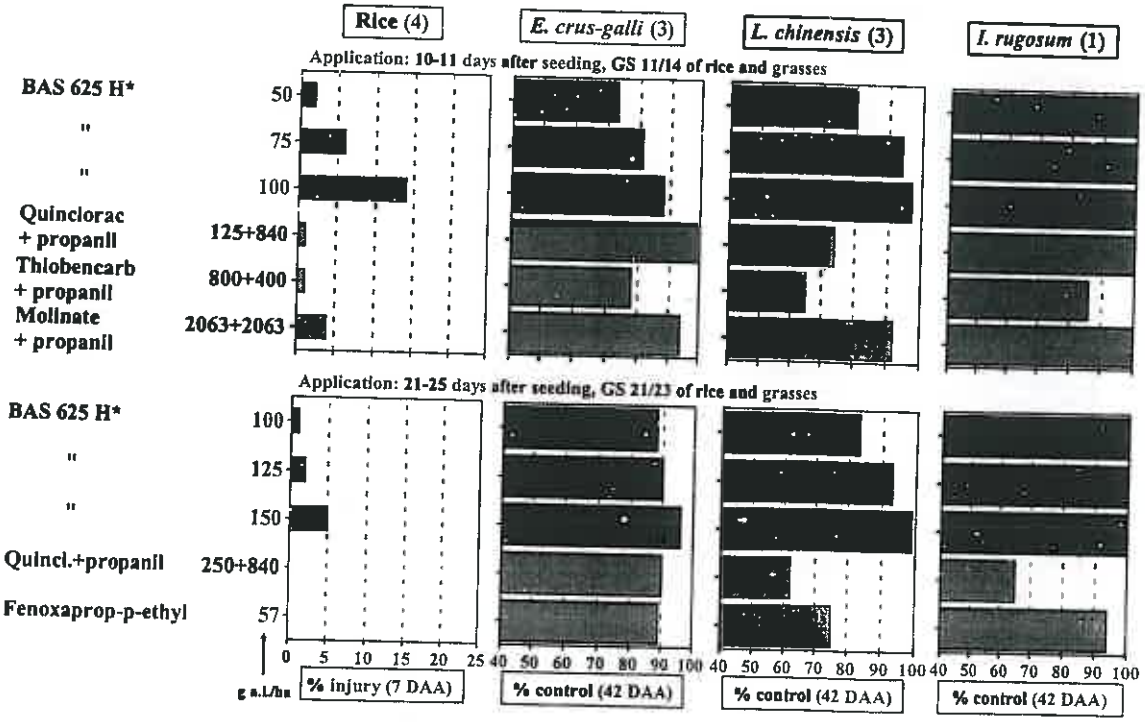


Fig. 3 Post-emergence activity of BAS 625 H in wet-seeded rice (Simpang Epat, Alor Pulai, Malaysia 1995-98; summary of 8 trials), ( ) = no. of trials; DAA = days after application; water volume: 300 l/ha; * + 2 l/ha crop oil concentrate

Table 1 Post-emergence activity of BAS 625 H in wet-seeded rice (Phuoc Thanh, Vietnam 1999-98); ( ) = % weed coverage in untreated; DAA = days after application; *ready formulation with methyloleat; ** Duncan test (p = 0.05)

Treatment	a.i./ha (g)	% rice injury		% weed control (42 DAA)		Yield (t/ha)
		7 DAA	21 DAA	*E. crus-galli*	*L. chinensis*	
Untreated	-	-	-	(28)	(26)	3.48 e**
BAS 625 H*	37.5	0	0	87	84	6.14 c
BAS 625 H*	52.5	0	0	90	86	6.20 b
BAS 625 H*	75	0	0	93	88	6.37 a
Cyhalofop-butyl	60	0	0	91	81	6.20 b
Fenoxaprop-p-ethyl	30	0	0	89	76	6.06 d

BAS 625 H was extensively tested in Korea during 1995-98 as straight product and in combination with other herbicides for complementary weed control (Table 2). Although treatments at 15 to 25 days after rice seeding caused some slight initial discoloration of rice leaves, this had no negative influence on further crop development as rice recovered within a short period thereafter. BAS 625 H effectively controlled *E. crus-galli*, *L. chinensis* and *Panicum dichotomiflorum* at rates of 100 g a.i./ha and above, irrespective the partly advanced growth stage of grasses (tillering). Combinations of BAS 625 H with bentazon for the control of broadleaf weeds and sedges also provided superior control of *E. crus-galli*.

Table 2 Post-emergence grass control with BAS 625 H in seeded rice (Naju, Kwangju, Paju in Korea 1995-98); DAA = days after appl.; DAS = days after seeding; GS of grasses = 13/24; * + 2 l/ha crop oil concentrate; ** ready formulation with methyloleat; ( ) = no. of trials;

Treatment	a.i./ha (g)	DAS	% rice injury		% weed control		
			7 DAA	21 DAA	*E. crus-galli*	*L. chinensis*	*P. dichot.*
Year 1995/96	Crop: dry and wet-seeded rice				Site: Kwangju, Naju		
BAS 625 H*	75	15-25	3 (8)	0 (8)	90 (8)	63 (2)	42 (2)
BAS 625 H*	100	15-25	5 (8)	0 (8)	93 (8)	86 (2)	86 (2)
BAS 625 H*	150	15-25	9 (8)	1 (8)	95 (8)	94 (2)	96 (2)
Quinclorac	300	15-25	0 (4)	0 (4)	97 (4)	0 (2)	0 (2)
Year 1996	Crop: dry-and wet-seeded rice				Site: Kwangju, Naju		
BAS 625 H*	125	15-20	14 (2)	3 (2)	93 (2)	-	-
BAS 625 H + bentazon*	125 1500	15-20	13 (2)	2 (2)	95 (2)	-	-
Cyhalofop-b. + bentazon	300 1900	15-20	4 (2)	0 (2)	76 (2)	-	-
Pyribenzoxim	30	15-20	5 (4)	0 (4)	87 (4)	-	-
Pyribenzoxim + bentazon	30 1500	15-20	15 (2)	3 (2)	72 (2)	-	-
Year 1998	Crop: dry-seeded rice				Site: Paju		
BAS 625 H**	75	25	3 (1)	0 (1)	91 (1)	97 (1)	-
BAS 625 H**	100	25	9 (1)	3 (1)	100 (1)	98 (1)	-
BAS 625 H** + bentazon	105 1600	25	7 (1)	2 (1)	94 (1)	98 (1)	-
Cyhalofop-b. + bentazon	300 1900	25	2 (1)	0 (1)	70 (1)	97 (1)	-
Pyribenzoxim	30	25	8 (1)	5 (1)	81 (1)	90 (1)	-

Initially, BAS 625 H trials in Asia were carried out in tank mixture with crop oil concentrate. Subsequent field experiments in Taiwan focused on the development of an optimised ready formulation with a built-in additive. The resulting ready formulation TETRIS® contains 75 g a.i./l BAS 625 H in combination with the additive methyloleat was tested at 75 and 100 g a.i./ha in a trial series compared to the tankmix of BAS 625 H (200 g a.i./l, EC) + crop oil concentrate (Figure 4).

The summary of 11 resp. 14 trials, respectively, was carried out as BOX and WHISKER plot analysis. The ready formulation of BAS 625 H at 75 g a.i./l performed at both test rates comparable to the reference tank mixture of BAS 625 H (200 g/l, EC) + crop oil concentrate regarding selectivity in seeded and transplanted rice as well as for the control of *E. crus-galli* and *L. chinensis*.

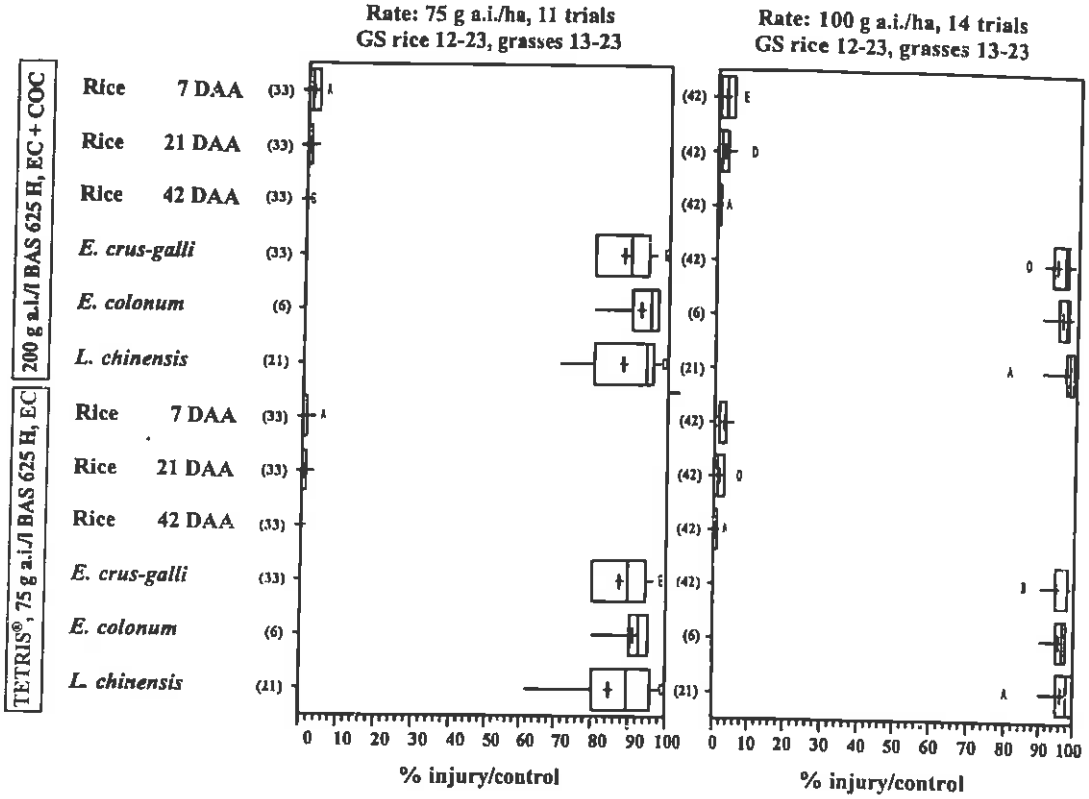


Fig. 4 Performance of the ready formulation of BAS 625 H 75 g/l methyloleat, EC (TETRIS®) in comparison with the tank mixture (Pingtung, Taiwan 1997-98); spray volume = 300 l/ha; DAA = days after application; ( ) = no. of observations

After application of BAS 625 H at very early growth stages (GS 11/13), newly emerging weeds, particularly of *E. crus-galli*, were observed occasionally due to limited residual activity. In order to prevent this happening 50 g a.i./ha of BAS 625 H were tested in combination with 125g a.i./ha quinclorac in seeded and transplanted rice in Southern Taiwan (Table 3). Quinclorac is well known to have good residual activity on *Echinochloa* species. Treatments were applied at GS 11-14 of rice and grasses in trials with severe infestation of *E. crus-galli* and a inadequate infestation of *L. chinensis*. None of the treatments caused relevant crop injury. BAS 625 H alone, at 50 g a.i./ha, provided moderate control of *E. crus-galli*, but provided good activity against *L. chinensis*. Quinclorac at 125 g a.i./ha showed good suppression of *E. crus-galli*, but did not control *L. chinensis*. The combination of 50 g a.i./ha BAS 625 H plus 125 g a.i./ha quinclorac improved the control of both grass weeds at excellent crop safety.

Table 3 Selectivity and herbicidal activity of BAS 625 H and quinclorac alone and in combination after early application (GS 11/14) in seeded and transplanted rice (Pingtung, Taiwan 1997-98); DAA = days after application; * ready formulation with methyloleat; ( ) = % ground cover

Treatment	a.i./ha (g)	% injury injury		% weed control (42 DAA)	
		7 DAA	21 DAA	*E. crus-galli*	*L. chinensis*
Untreated	-	(17)	(32)	(76)	(11)
BAS 625 H*	50	1	0	73	82
Quinclorac	125	0	0	82	2
BAS 625 H* + quinclorac	50 + 125	1	0	90	92
No. of trials	-	9	9	9	6

Based on the trial results the following suitable application rates of BAS 625 H at different stages of grass weed and rice development were derived (Table 4). The number of days after sowing of rice may differ in individual countries due to specific local growing conditions of rice.

Table 4 Suitable application rates of BAS 625 H to control grasses in Asian rice cultures

Timing	Growth stage (rice and grasses)	Application rates
7-13 days after sowing	GS 12/13	40-50 g a.i./ha BAS 625 H + 100-150 g a.i./ha quinclorac
14 – 20 days after sowing	GS 13/21	75-100 g a.i./ha BAS 625 H
21 – 28 days after sowing	GS 21/24	100- 125 (- 150)* g a.i./ha BAS 625 H

* 150 g a.i./ha in case of heavy infestation and advanced stages of grass weeds

Discussion

The new cyclohexanone herbicide BAS 625 H proved to be an effective graminicide for selective post-emergence weed control in Asian rice cultures. The product showed excellent timing flexibility for the control of *Echinochloa crus-galli, Echinochloa colonum, Leptochloa chinensis* and *Ischaemum rugosum*, when applied from three leaves of rice up to mid-late tillering stage of the grass weeds. The application rates of BAS 625 H for effective grass control varied from 50 to 125 (150) g a.i./ha depending on growth stage of grasses as well as on specific growing conditions in individual countries. Crop safety of BAS 625 H was rated good in wet- and dry-seeded rice once the crop had established three leaves. The temporary discoloration of rice leaves after application, which occurred in some of the trials, grew out quickly and had no negative effects on further crop development. The test results demonstrate that BAS 625 H provides a reliable stand-alone solution for post-emergence grass weed control in different rice growing systems. In order to meet the requirements of Asian growers an additive containing ready-formulation (TETRIS, 75 g a.i./l, EC) was developed for spray volumes of 200-1000 litres per hectare. BAS 625 H in combination with quinclorac proved to be advantageous for early post-emergence herbicide applications at 2-3 leaf stage of grasses and rice due to improved residual activity on barnyard grass and the extension of quinclorac's activity spectrum towards *Leptochloa chinensis*. This combination also provides an effective tool for anti-resistance management. For the control of broadleaf weeds and sedges BAS 625 H can be tankmixed with combination partners like bentazon, as shown in Korean field experiments. Due to its unique features BAS 625 H represents an excellent tool for the integrated weed control systems, allowing the adjustment of the herbicide use to the actual grass weed infestations in specific fields. This is in line with the concept of sustainable weed management systems (Moody, 1995). First registrations of BAS 625 H in Asia are expected in 1999/2000.

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SULFENTRAZONE FOR PRE-PLANT WEED CONTROL IN PINEAPPLE (*Ananas comosus L.*)

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FMC International S.A., Manila, Philippines

Abstract: Sulfentrazone alone and in combination with other herbicides were evaluated for weed control in pineapple in the Philippines and Thailand. Sulfentrazone alone or in combination was applied at 0.125-1.00 kg Ai/ha. Diuron, ametryn or bromacil at 1.8-3.6 kg Ai/ha were used in tank-mix combinations. Treatments were applied 1-15 days before planting (DBP). Weed control was good to excellent with sulfentrazone alone at 0.5-1.0 kg Ai/ha for at least 6 months after treatment (MAT). Tank mixing enhanced weed control. Plant crop yields were higher than in the untreated. No photoxicity was observed with sulfentrazone and there were no detectable residues in the flesh and shell of pineapple fruits treated with 0.5 kg and 1.0 kg Ai/ha.

Key words: sulfentrazone, pineapple, herbicide

Introduction

The continuous use of the same herbicides has been associated with the evolution of herbicide-resistant weeds and weed population shifts (Moody, 1996). Thus, the need to identify herbicides with different mode of action and/or effective herbicide combinations is an ongoing strategy by a number of pineapple weed scientists (Personal communication).

One of the newly identified products, which has potential use in pineapple plantations, is sulfentrazone. Sulfentrazone is an aryl triazolinone herbicide discovered and developed by FMC Corporation, U.S.A. It controls weeds by inhibiting the protophyrinogen oxidase in the chlorophyll biosynthetic pathway resulting in the buildup of toxic intermediates and the disruption of cell membranes (FMC, 1993). It is absorbed primarily by the roots of the plant following soil applications. It is now registered in various countries for use on soybeans, sugarcane, and tobacco for the control of a wide spectrum of grass and broadleaf weeds and sedges.

Hence, several field trials were conducted to determine the efficacy of sulfentrazone for pre-plant weed control in pineapple fields in the Philippines and Thailand. Results of these trials are presented in this paper.

Materials and Methods

Bukidnon Trials (Philippines. Four trials were conducted in Bukidnon from January 1997 to July 1999. These were designated as F-7697B, F-8897, F-71D and F-84A. Sulfentrazone, formulated as a suspension concentrate containing 480 g Ai/L (Authority® 480SC), was tested at rates of 0.125, 0.250, 0.5, and 1.0 kg Ai/ha applied alone and at 0.5 kg in combination with either diuron, bromacil or ametryn at 1.8-3.6 kg Ai/ha. Herbicide treatments were applied between 1-8 days before planting (DBP) using a CO_2-driven backpack sprayer equipped with a flat fan nozzle and calibrated to deliver 927 liters of spray solution per ha. Weeds had already emerged at the time of application in these trials; thus, a non-ionic surfactant was added to the spray mixture at 0.1% by volume. Weeds were counted by species one day before herbicide application and every month thereafter for 6 months.

Plot size per treatment was 36 m^2; each replicated four times, and arranged according to Randomized Complete Block Design (RCBD). Weed count data were transformed to $Y' = \log (Y + 0.5)$ prior to statistical analysis.

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Samples of pineapple fruits at harvest from Trial 7697B were sent to Hawaii Agriculture Research Center (HARC), Hawaii, U.S.A and analyzed for sulfentrazone residues.

Davao Trials (Philippines). A trial was also conducted in Subasta, Davao City, from September 1996 to March 1998. Sulfentrazone at 0.25, 0.50, and 0.750 kg Ai/ha was applied 15 DBP using a knapsack sprayer with a fan type nozzle calibrated to deliver 1,900 liters/ha. Each treatment was replicated four times, arranged according to RCBD. Data gathered were weed counts, weed weights, and weed control ratings at 0.5, 2, 3, and 4 months after treatment (MAT). Phytoxicity ratings were recorded at 0.5, 1, and 2 MAT. The European Weed Research Council (EWRC) system was used in the evaluation of herbicidal efficacy and phytotoxicity symptoms.

Chonburi and Hua-Hin Trials (Thailand). Trials were conducted in Chonburi and Hua-Hin from July 1997 to January 1999. Sulfentrazone was applied at 0.5, 0.75 and 1.0 kg Ai/ha immediately after soil preparation using a knapsack sprayer calibrated to deliver 500 liters/ha. Pineapple suckers were planted 7 DBP. Plot size was 24 m^2; each treatment replicated three times, arranged according to RCBD. Weed control rating, weed count and fresh weights by weed species were taken at 0.5, 1, 2, 3, and 4 MAT. Phytotoxic effects, plant height and crop fruit yields were recorded at harvest.

Results and Discussion

Bukidnon Trials (Philippines): The weed species composition in the four trials is shown in Table 1. Total weed counts in trial F-7697B show that sulfentrazone-treated plots had significantly less weeds than the untreated (Fig. 1a &1b). Sulfentrazone at 0.5 kg and 1.0 kg were more effective than the 0.125-kg and 0.250 kg Ai/ha. The rate of 0.5 kg was equally as effective as the 1.0 kg Ai/ha.

Weeds in this experiment were removed at 4.5 MAT because the weed density in the untreated control had reached intolerable levels. Hand-weeding following herbicide treatment to control escapes is a practice in the plantation. Weed regrowths, 45 days after hand-weeding, were significantly lower in the sulfentrazone-treated plots than in the untreated. (Fig. 1b). Sulfentrazone was effective against sedges. Rates as low as 0.25 kg Ai/ha almost completely suppressed sedge germination even at the 6-month observation period. No phytotoxic symptoms were observed in any of sulfentrazone treatments. Plant crop yields in sulfentrazone-treated plots were significantly higher than in the untreated (Fig 2). No residues of sulfentrazone were detected in the flesh and shell of pineapple fruits treated with 0.5 kg and 1.0 kg Ai/ha.

Weed counts from trial F-8897A show that tank-mixing sulfentrazone at 0.5 kg Ai/ha with either diuron or bromacil at 1.8 kg Ai/ha significantly improved weed control over sulfentrazone alone (Fig 3). Plots were hand-weeded at 3.3 MAT due to the heavy weed population in the untreated. The escapes in the treated plots were severely stunted in growth and are indicated in their fresh weights, which were significantly lighter than in the untreated (Fig. 4).

Results with trials F-84A (Fig. 5) and F-71D (Fig. 6) show that doubling the rate of diuron from 1.8 kg to 3.6 kg Ai/ha in combination with sulfentrazone at 0.5 kg Ai/ha slightly improved total weed control up to 3 MAT. All treatments, thereafter, gave similar degree of weed control. The tank-mix of sulfentrazone + ametryn was as effective as sulfentrazone + diuron when applied at the same rates. Sulfentrazone alone or in combination had significantly less number of weeds than in the untreated.

Davao Trial (Philippines): *Cypress rotundas* was the most predominant weed species in the trial site followed, in descending order, by *Cleome rutidosperma, E. indica, D. ciliaris, E. colona* and *M. invisa.* Based on the European Weed Research Council Rating System and weed counts, sulfentrazone at 0.50 and 0.75 kg Ai/ha gave good to satisfactory weed control through the 4-month observation period (Fig. 7). Sulfentrazone at 0.250 kg Ai/ha gave satisfactory control but only up to 3 MAT. The rate of 0.75 kg was numerically but not statistically better than the 0.50 kg Ai/ha. No phytotoxic effect was observed with sulfentrazone treatments.

Chonburi and Hua-Hin Trials (Thailand): The most predominant weed species in Hua-Hin trial was *Digitaria sanguinalis* (75 plants/m^2) while that in Chonburi was *Ipomoea obscura.*(59 plants/m^2). Other weed species, in high numbers, in either location were: *Brachiaria distachya, Rhynchelytrum repens, Leptochloa chinensis, Euphorbia heterophylla,* and *Ageratum conyzoides* (Table 2). Overall, sulfentrazone, at all rates, effectively controlled the above-listed grass and broadleaf weeds through the 4 MAT observation period. In a scale of 0 to 10, where 10=complete control, sulfentrazone at 1.0, 0.75, and 0.50 kg Ai/ha were rated as 9.0, 8.5, and 8.0 in Chonburi, and as 8.5, 8.0, and 7.5 in Hua-Hin,, respectively (Fig. 8).

No phytotoxic effects with sulfentrazone treatments were observed. Plants in sulfentrazone-treated plots, in both trial locations, were not only significantly taller than in the untreated, but also yielded significantly larger and heavier fruits (Fig. 9).

Table 1. Weed species composition in the experimental areas recorded at 3 months after planting. Bukidnon, Philippines.

TRIAL LOCATION	F-7697B	F-8897	F-71D	F-84A
Weed Population, Total Number/m^2	278	317	132	72
	Weed Density, %			
Grasses				
Paspalom conjugatum	2 %	7 %	1 %	2 %
Roettbolia exaltata		7 %		
Digitaria sanguinalis	4 %	3 %	11 %	3 %
Eleusine indica	2 %	1 %	1 %	3 %
Cynodon dactylon		1 %		
Echinochloa colona	4 %	1 %		
Broadleaf Weeds				
Ipomea triloba	56 %	2 %	1 %	16 %
Borreria laevis	13 %	48 %	30 %	20 %
Ageratum conyzoides	1 %	5 %		
Mimosa invisa		22 %	18 %	10 %
Sida acuta	3 %	2 %	8 %	3 %
Chromolaena odorata			18 %	7 %
Crassocephalum crepidioides	1 %	2 %		16 %
Sedges				
Cyperus rotundus/C. iria	14 %		3 %	3 %

Table 2. Weed species composition in the experimental areas. Chonburi and Hua-Hin, Thailand.

TRIAL LOCATION	CHONBURI	HUA-HIN
Weed Population, Total Number/36 m^2	165	180
	Weed Density, %	
Grasses		
Brachiaria distachya	5.9 %	25.7 %
Digitaria sanguinalis	21.2 %	41.9 %
Echinochloa colona	1.1 %	
Leptochloa chinensis		5.5 %
Rhynchelytrum repens		2.2 %
Broadleaf Weeds		
Ageratum conyzoides	14.7 %	3.2 %
Borreria alata	3.5 %	0.3 %
Euphorbia heterophyela	15.7 %	16.4 %
Ipomea abseura	37.9 %	
Melochia corchoriforia		0.7 %

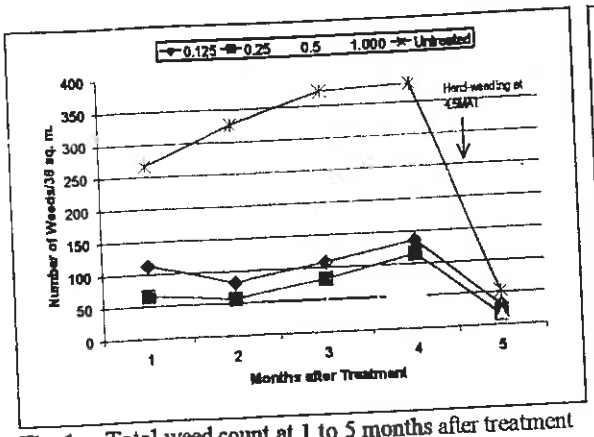


Fig. 1a. Total weed count at 1 to 5 months after treatment of sulfentrazone applied pre-plant on a pineapple field. F-7697B. Bukidnon, Philippines.

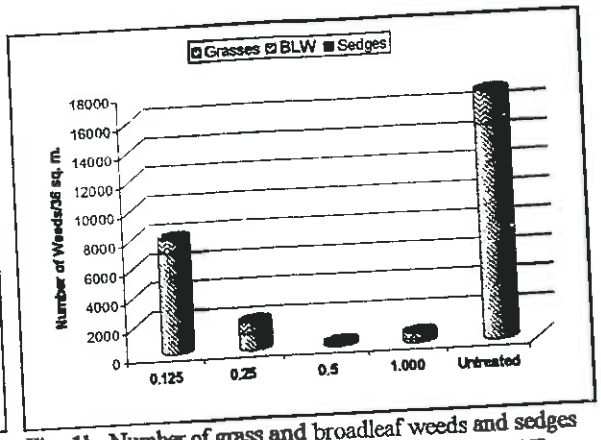


Fig. 1b. Number of grass and broadleaf weeds and sedges at 6 MAT, where plots were hand-weeded at 4.5 MAT. F-7697B. Bukidnon, Philippines.

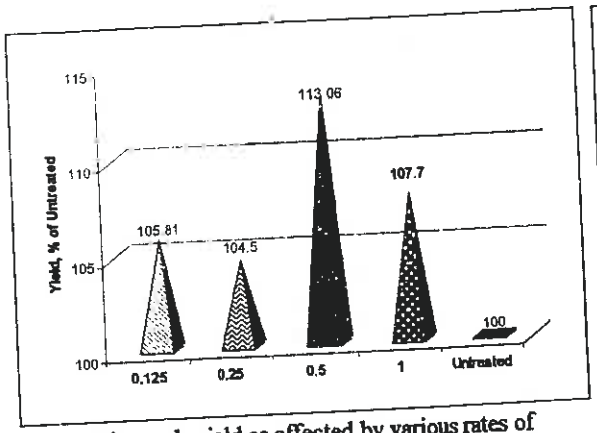


Fig. 2. Pineapple yield as affected by various rates of sulfentrazone. F-7697B. Bukidnon, Philippines.

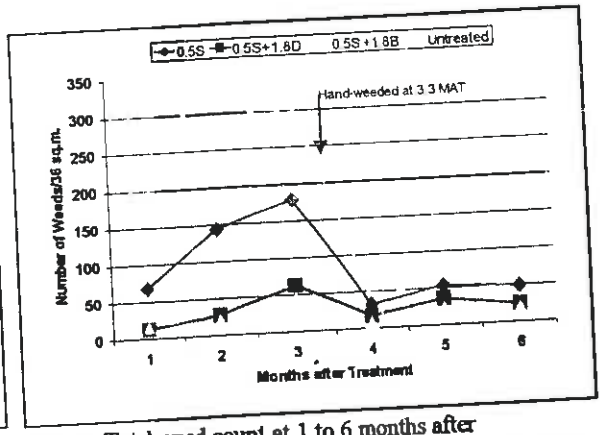


Fig. 3. Total weed count at 1 to 6 months after sulfentrazone (S) treatment applied tank-mixed with either diuron (D) or bromacil (B) on a pineapple field. F-8897A. Bukidnon, Philippines.

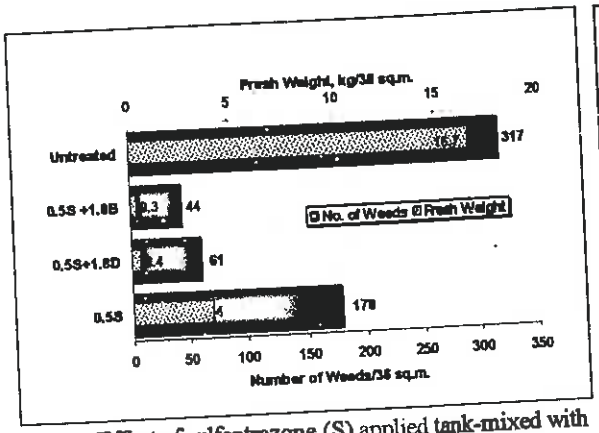


Fig. 4. Effect of sulfentrazone (S) applied tank-mixed with either diuron (D) or bromacil (B) on the number and fresh weight of weeds on a pineapple field 3 MAT. F-8897A. Bukidnon, Philippines.

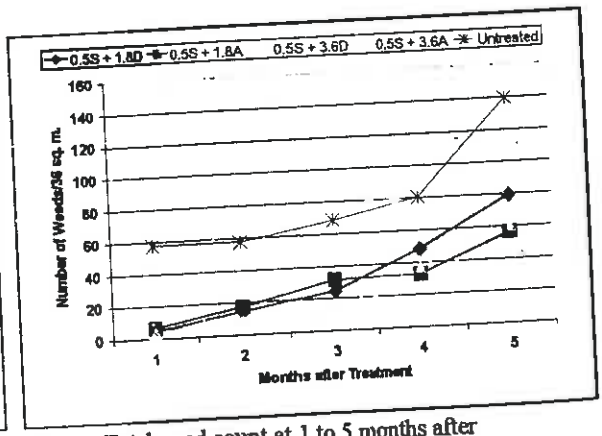


Fig. 5. Total weed count at 1 to 5 months after sulfentrazone (S) treatment applied tank-mixed with either diuron (D) or ametryn (A) at 1.8 and 3.6 kg Ai/ha on a pineapple field. F-84A. Bukidnon, Philippines

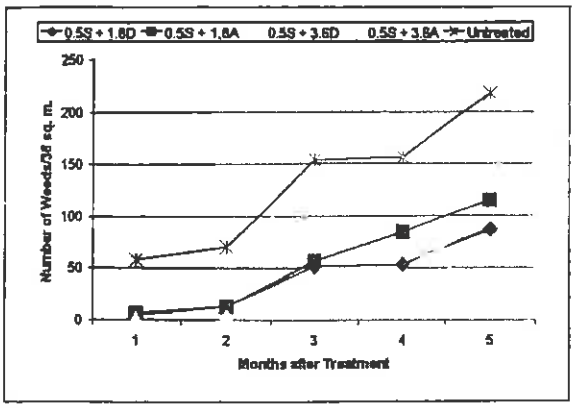


Fig. 6. Total weed count at 1 to 5 months after sulfentrazone (S) treatment applied tank-mixed with either diuron (D) or ametryn (A) at 1.8 and 3.6 kg Ai/ha on a pineapple field. F-71D. Bukidnon, Philippines.

European Weed Research Council Weed Control Rating System (EWRC).

Rating Scale	Weed Response Description
1	Completely Destroyed
2	Very Good Control
3	Good Control
4	Satisfactory
5	Just Satisfactory
6	Unsatisfactory
7	Poor
8	Very Poor
9	As Untreated

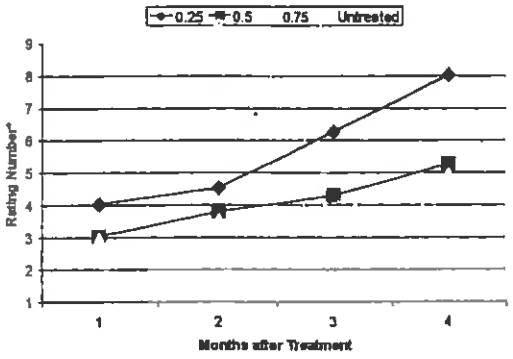


Fig. 7. Weed control at 1 to 4 months after sulfentrazone (S) treatment applied pre-plant on a pineapple field. Davao, Philippines.

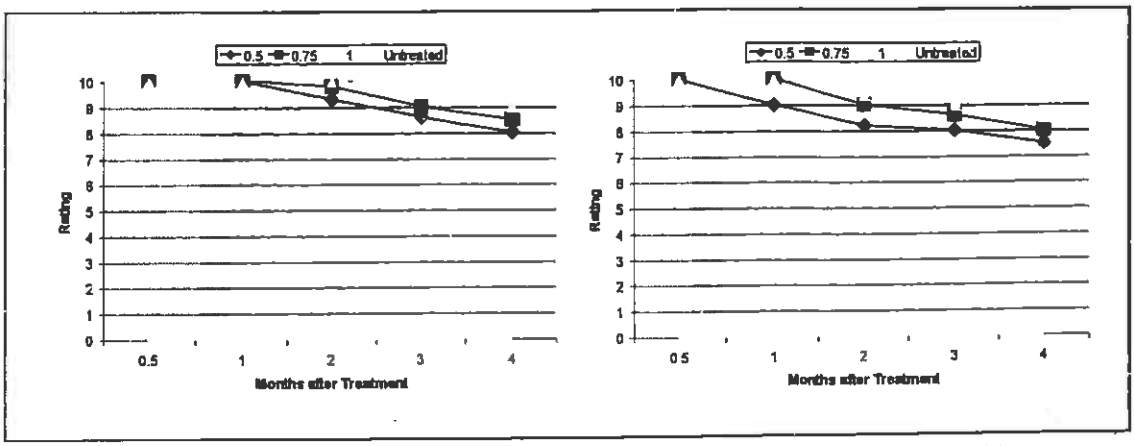


Fig. 8. Total weed control rating for sulfentrazone in Chonburi, and Hua-Hin pineapple fields. Thailand. *Rating: 0 = no control; 10 = complete control.*

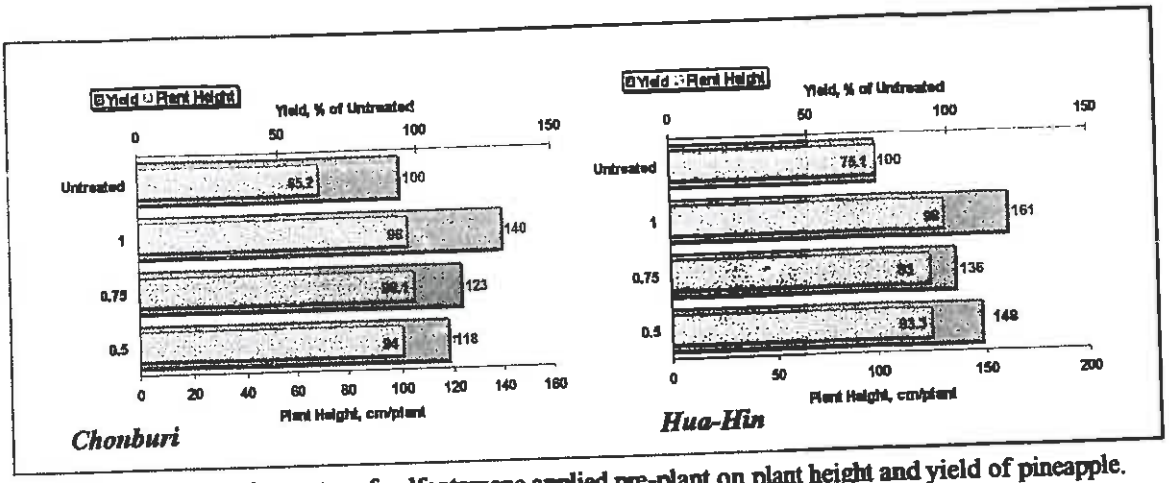


Fig. 9 Effect of various rates of sulfentrazone applied pre-plant on plant height and yield of pineapple. Chonburi, and Hua-Hin, Thailand.

Acknowledgements:

FMC International S.A. acknowledges and appreciates the assistance provided by the following researchers for the conduct of the field trials in the Philippines: Drs. L. Lucas, C. Sison, R. Baltazar and E. Seña and in Thailand: Dr. K. Suwanarak, Department of Agriculture and Mr. F. Gargantiel of Pitsulin Company.

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THE PERFORMANCE OF SOME NEW SELECTIVE HERBICIDES FOR WEED CONTROL IN WHEAT UNDER DIFFERENT SEED RATES IN EGYPT

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Abstract: Two field experiments were conducted in naturally infested fields by weeds in Monufia Univ. during 1997 and 1998 seasons to show the effect of some herbicides at one rate under seed rates on controlling broad-leaved weeds and wheat productivity. Each experiment had a combination of three seeds rates i.e. 95, 143 and 190 kg/ha. where the herbicides used were Metosulam, Tribenuron, Metribuzin, Bromoxynil and Isoproturon each at the recommended rate. The soil was clay and seed var. was Sakha 69. The main finding indicated that all of these herbicides gave more reduction in dry weight of broad-leaved weeds than hand pulling of weeds. The best treatment in controlling weeds was Metsulam followed by both Bromoxynil and Tribenuron. The high seed rate gave good result in control weeds than both low and meduim seed rates. In the same time using of herbicides and seed rate 143 kg/ha gave high yield with different significantly, while using Isoprotum and hand pulling gave the lowest seed yield. Naturally the unweeded control was the worst treatment and gave more reduction in seed grain yield as a result of high competion between broad-leaved weeds and wheat plants.

Key words: herbicides, broad-leaved weeds, control, seed rates, weight

Introduction

Wheat is the most widely grown cereals. Its importance in the world due to its uses mainly as bread and as a starting material for numerous food production in Egypt. The increasing of wheat production to narrow the gap between production and consumption is a nationd gool. Therefore , intensive efforts are bring paid to increase the local production vertically and horizonatally. Weed control in such crop become a problem especially under heavy weed infestation. This need to fined out suitable treatments for controlling weeds in wheat [Nassar (1998) and Tahoon (1994) reported that using herbicides gave controlling of broad leaved weeds in wheat where (Nayak *et al*,, 1983) and Salem et al (1994) founded that using different seeding rates gave significance in yield and its components in wheat . Also, (Ahmad *et al.*, 1991) and (Bajpal *et a.,l* 1989) found that using some urea herbicides gave more reduction in broad leaved weeds in wheat]. The main of the present study to show the effect of some herbicides at low rate under different seeding rates on broad leaved weeds which associated wheat and also its effect on wheat productivity.

Material and methods

Two fields experiments were conducted during two successive seasons 1996/97 and 1997/1998 at Monufia Univ Agric. Fac. Egypt. to investigate the effect of seeding rates and some herbicides as well as hand pulling of weeds on controlling broad - leaved weeds assocciated wheat , using the local variety Sakha 69, the soil type was heavy clay soil . The cultural practies were used , the plot size was 21 m^2. The preceding crop was cotton as a summer crop and clover as a winter cutting crop. Sowing drill machine was used. The treatments in this research were as follows.

A. Main plots (seeding rates) (1) 95 (2) 143 and (3) 190 kg/ha.
B. Sub plots (herbicides) were:

1- Metosulam (Sinal 10% SC) [N-(2.6-dichloro-3 methyl phenyl)5.7 dimethoxy (1,2,4) triazolo 1.5 – a pyridine-2-sulfonamide] applied at 3-4 leaf stage post-em. at the rate of 95.2 cm^3 /ha.
2- Tribenuron (Granstar) 75% DF. Sulfmetheton-methy-methyl-2-N(4-Methoxy-6- methyl-1,3,5-traizin-z-yl- methyl amino carbo-yl-amino) sulfonyl benzoate at the rate of 19.0 gm/ha post – em.
3- Metribuzin (Sencor) 70% w.p 4-Amino-6-1.1 dimethyl ethyl 1-3-methyl thion1,2,4 triazin –5- (4H) one at the rate of 130 gm/ha post-em at 3-5 leaf stage.
4- Bromoxynil (Brominal) [3,5-dibromo-4-hydroxy benzo nitrile] 24% EC at 4-5 leaf stage at the rate of 2.38 L./ha post-em.

5- Isoproturon (Arelon)[3-(4-iso propyl phenyl) 1.1-dimethyl urea 50% FL. Applied at 3-5 leaf at the rate of 2-98L/ha.
6- Hand pulling twice. Once at 30 days from sowing and the other at 60 days from sowing .
7- Unweeded Control: without herbicides or hand pulling for weeds.

All herbicides were sprayed by knapsack sprayer CP3 equipped with nozzle boom. The water volume used was 475 L/ha.The experiments were laid in a split plot design with 4 replications. The seeding rates were arranged in main plots and weed control treatments in subplots at random. Each subplot was 3x7m the weed survey were taken from one m^2 from each subplot after 70 days from sowing and then the dry weight of each weed was taken . At harvest the yield of wheat and its component were recorded. The data were statistically analyzed and the D.M.R. was used to compare mean values at 5% level of significance.

Results and Discussion

I- Effect on broad-leaved weeds :-

Weed survey showed that predominated weeds in wheat experimental field were (*Rumex dentatus*) (sorrel), (*Brassica tournefortii*) (white mustard), (*Beta vulgaris*) (swiss chard) and (*Medicago polymorpha*) (bur clover) beside other weeds as lamsquarter, sow thistle, purse and chicory were rarely. The data recorded in table (1) show that high seeding rate was the best in controlling weeds because of the competition between wheat and weeds, where the low rate gave more chance for weed germination and its growing and then consider the worst in controlling weeds. On the other hand both of metosulam and tribenuron gave high reduction in the dry weight of broad – leaved weeds with significant as compared by hand pulling or Arelon. But both of metribuzin and Arelon gave moderate effect on controlling weeds. All herbicides used as well as hand pulling were good treatments and gave significant differences as compared by unweeded control. These data agreement with Nassar (1998) and Tahoon (1994).

II-Effect on straw, grain yield and its components:

If we look to tables (3) and (4) which illustrated the effect of both seeding rates and herbicides in compination. We shall see that the low rate of seeding rates gave high grain yield because of the increasing of number of branches and no.of spikes per plant as a result of control weeds, where the high rates gave in all cases decreasing in grain yield as a resulting of decreasing both no.branches and no.of spikes per plant . About the straw yield there were significance differences among treatments and unweeded control because of some weeds were still in fields until the harvest of wheat and it gave straw yield. Especially the grassy and some broad – leaved weeds. This results were in agreement with (Nayak *et al.*, 1983) and (salem *et al.*, 1994).

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Table 1 Effect of seed rates on the dry weight of weeds g/m^2 after 70 day from sowing.

Season	1996/97			1997/98		
Seed rates kg/ha main weeds	95	143	190	°95	143	190
Brassica tournefotii	23.14 a	15.20 b	8.45 c	21.25 a	14.22 ab	9.11 b
Beta vulgaris	31.20 a	25.15 a	14.40 b	33.00 a	26.65 b	12.41 c
Medicago polymorpha	19.75 a	12.35 ab	6.12 b	21.35 a	11.50 b	7.00 ab
Rumex dentatus	27.10 a	18.20 b	11.65 b	22.13 a	16.75 ab	10.10 b
Other weeds	16.70 a	9.30 a	6.50 b	13.17 a	8.41 ab	5.50 a

Means followed by the same alphabetical letters were not significant at 5% level in each column.

Table 2 Effect of herbicides on dry weight of broad-leaved weeds in (g/m^2)after 70 days from sowing.

Seasons	1996/97							1997/98					
Treatments / Weeds	*Hand pulling twice*	*Metsulam*	*Tribenuron*	*Metribuzin*	*Bromoxynil*	*Isoproturon*		*Hand pulling twice*	*Metsulam*	*Tribenuron*	*Metribuzin*	*Bromoxynil*	*Isoproturon*
Brassica tournefotii	37.11 a	15.50 b	4.10 c	5.35 c	6.18 c	6.00 c	11.30 b	47.11 a	20.20 b	4.00 c	6.11 c	8.30 c	6.00 c	12.37 d
Beta volgaris	42.00 a	17.20 b	3.20 c	4.40 c	7.11 c	5.10 c	12.22 b	40.15 a	18.00 b	3.00 c	4.10 c	8.00 cd	5.00 c	13.30 d
Medicago polymorpha	20.10 a	8.20 b	2.70 c	3.81 c	4.75 c	4.00 c	6.17 c	22.00 a	8.11 b	2.00 c	3.15 c	4.10 c	4.00 c	8.17 b
Rumex dentatus	32.60 a	15.70 b	5.50 c	6.20 c	7.35 c	5.00 c	9.32 c	30.00 a	14.40 b	4.10 c	6.70 c	8.00 d	6.00 cd	10.12 d
Other weeds	44.00 a	20.10 b	11.22 c	10.30 c	13.45 c	9.40 c	12.50 c	50.00 a	24.30 b	12.50 c	13.30 c	16.60 c	11.15 c	18.44 bc

Means followed by the same alphabetic letters were not significant at 5% level in each column.

Table 3 Effect of seed rates on grain yield and its components.

Seasons	1996/97			1997/98		
Seed rates kg/ha	95	143	190	95	143	190
No. spikes/plants	5.50 a	3.2 b	1.30 c	5.00 a	3.77 ab	1.00 b
Weight of spikes seeds (g).	3.8 a	2.65 a	1.20 b	4.10 a	2.88 b	1.33 b
Weight 1000 seeds in (g).	47.11 a	37.21 b	30.10 c	45.55 a	34.12 b	31.11 b
Straw yield Ton/ha	11.41 c	12.10 bc	13.00 a	11.58 b	12.33 b	14.40 a
Grain yield Ton/ha	7.20 a	6.18 a	4.22 b	7.00 a	5.85 ab	3.18 b

Means followed the same alphabetic letters were not significant at 5 % level in each column.

Table 4 Effect of herbicides on grain yield and its components.

Season	1996/97							1997/98					
Treatments / Yield	*Hand pulling twice*	*Metsulam*	*Tribenuron*	*Metribuzin*	*Bromoxynil*	*Isoproturon*		*Hand pulling twice*	*Metsulam*	*Tribenuron*	*Metribuzin*	*Bromoxynil*	*Isoproturon*
No. spikes/plant wheat of seeds	1.55 b	3.10 a	5.20 a	4.75 a	4.11 a	4.80 a	4.00 a	1.60 c	2.71 b	5.35 a	5.00 a	4.70 a	4.85 a	3.72 ab
Weight of seeds Per spike in gm.	1.11 b	2.70 a	3.95 a	3.30 a	3.00 a	3.10 a	2.75 a	1.00 c	2.11 b	4.70 a	4.10 a	4.00 a	3.60 a	2.45 b
Weight of 1000 seeds	30.00 b	37.10 ab	48.12 a	47.00 a	45.10 a	41.40 a	36.60 ab	31.30 c	38.00 ab	44.50 a	44.12 a	40.11 a	42.00 a	37.30 b
Straw yield ton/ha	12.12 a	11.00 b	10.60 b	11.40 b	10.55 b	9.95 b	11.42 ab	11.32 a	10.10 a	11.14 a	12.35 a	12.00 a	12.70 a	11.33 a
Grain yield ton/ha	3.10 c	5.30 ab	7.75 a	7.00 a	6.15 a	7.12 a	5.15 b	2.70 b	5.45 a	7.00 a	6.16 a	6.10 a	6.00 a	5.20 a

Means followed by the same alphabetic letters were not significant at 5% level in each column.