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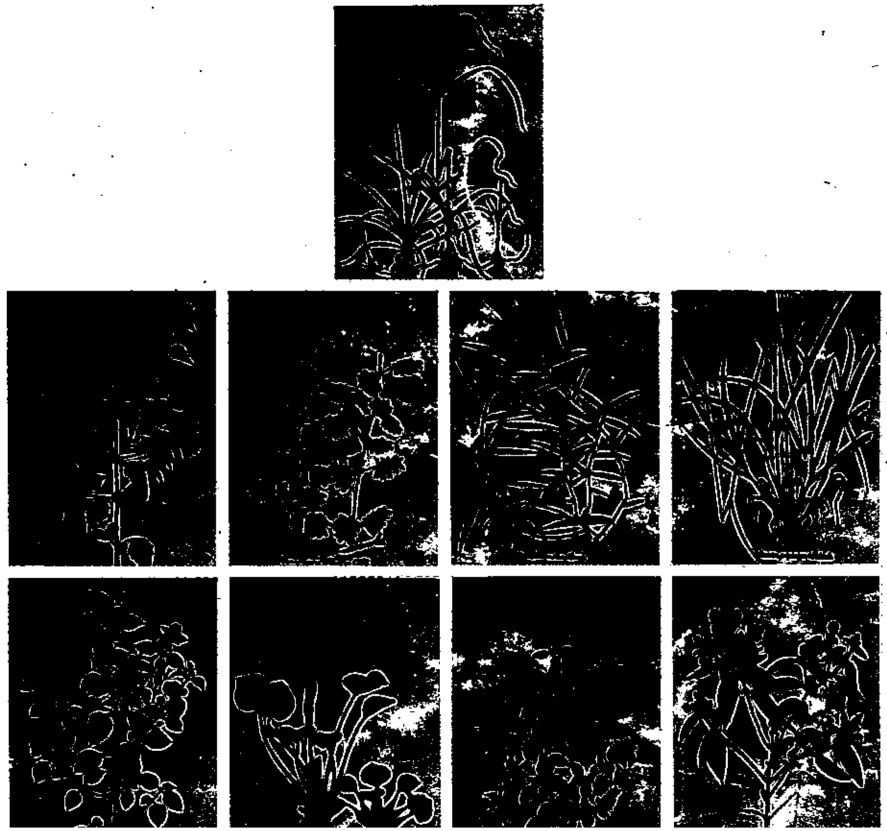
JAKARTA - INDONESIA

PROCEEDINGS OF

THE THIRTEENTH
ASIAN PACIFIC WEED SCIENCE SOCIETY CONFERENCE

JAKARTA, INDONESIA
15 - 18 OCTOBER, 1991

VOLUME I



THEME : VEGETATION MANAGEMENT STRATEGY FOR SUSTAINABLE DEVELOPMENT

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THE THIRTEENTH ASIAN PACIFIC WEED SCIENCE SOCIETY CONFERENCE

Jakarta, Indonesia
October 15 - 18, 1991

Volume I

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PREFACE

The organizing committee was planning to print all the papers presented into the Proceedings of the 13th Asean Pacific Weed Science Society Conference, held on October 15-18, 1991 in Jakarta, Indonesia. So the participants could follow the presentation with full information.

However, due to various reasons, not least of which is time constraint, we were compelled to limit the number of papers included in this Proceedings, Volume I.

The remaining papers will be published in Proceedings, volume II, after the conference and will be mailed to all participants in 6 months time.

We are most grateful to all those devoted much of their efforts and valuable time in ensuring that the Proceedings Volume I was published in time for the Conference with as few error as possible in the limited time available.

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PLENARY LECTURES

WEEDS IN A VEGETATION MANAGEMENT FOR SUSTAINABLE DEVELOPMENT

M. SOERYANI[1]

ABSTRACT

In the cultural development of man, there is a trend of an increasing crisis of intelligibility due to the application of polluting technology and luxurious consumption that produce wastes. The consequences are among others: the increasing trend of cryptic spread of mutant genes among the human pollution, holes in the ozon layer, the greenhouse effects, the acid precipitation, and pollution causing the degradation of natural resources and the quality of life in general. Meanwhile, the homocentric view of man classify vegetation as crops, ruderal plants and weeds. Therefore weed management must be properly integrated into the overall vegetation management for environmentally sound and sustainable development. This approach have to consider technological appropriateness, environmental feasibillity and socio-economic sustainability. Among the technological alternatives are: the development of pesticide alternatives, controlled delivery techniques, biotechnology and integrated vegetation management to optimize crop production through e.g. crop rotation, mixcropping, intercropping, heavy seeding, and sanitation practices.

INTRODUCTION

God created all kinds of beings, including both biotic and abiotic components, each one with its own function, to support life. Human being is one of the almost two million species of living beings, although through acquiring the **noosphere** (**noos** (Gr)= mind), the human mind has practically dominated the **biosphere**. Therefore, in the history of their cultural evolution, human beings have gradually established their role as the mighty agents of changes. Agriculture, which hypothetically started about 10,000 years ago, has been the beginning of man imposing his dominance toward nature. Later on, accelerated by the industrial revolution, technological advacements have replaced most of the natural life support system with an almost completely artificial environment. Most of the present technological developments are based on the negligence of the natural processes and phenomena that works so well, effective, efficient, and inexpensive (see Odum, 1983: 53).

This paper will discuss the human crisis of intelligibility, the anthropocentric perception of man in classifying vegetation: wanted vegetation

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as cultivated plants, and unwanted vegetation as weeds, the principal and practical consequences of sustainable development in weed management, and weed control as an integral part of vegetation management.

CRISIS OF INTELLIGIBILITY

In the present trend of the human evolution, it is obvious that there is a crisis of intelligibility of the human community, that creates difficulties in having a consensus of understanding followed by difficulties in promoting collaborative actions. This ultimately affect the quality of life through the degradation of the quality of the environment. Paul Shaw, an environmental expert of UNFPA, stated that the degradation of the quality of the environment is mainly due to the polluting technology and luxurious consumption that produce a lot of wastes (Anon., 1991: 9- 11). Other causes are inappropriate policy, poverty, humanity's warfaring, and lastly the population growth (Fig. 1).

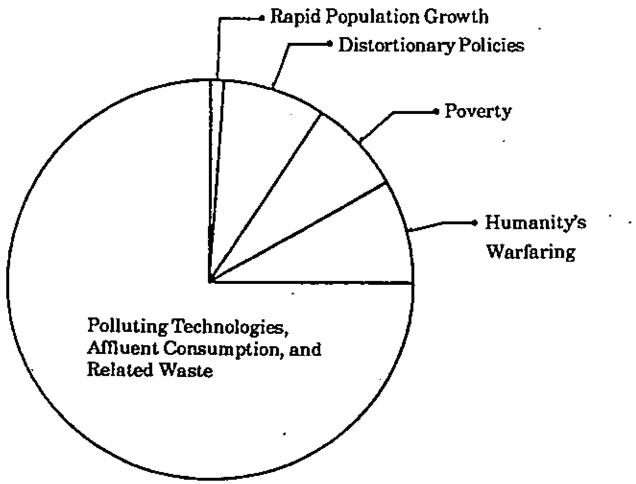

Figure 1. Factors causing the degradation of environmental quality (Anon., 1991: 11)

The crisis of intelligibility that causes an increasing trend in the application of polluting technologies will have a multidimensional consequences. Some of these consequences are among others the following.

1. Crypric Spread of Mutant Genes

Ionizing radiation and many chemicals increase the mutation rate of genes from one form to another. With the increasing use of radiation, and the rapidly expanding number of new chemicals, there is reason for concern that the mutation rate in man may be accelerated. Mutations occurring in somatic cells may lead to cancer or degenerative diseases in exposed individuals, while in germ cells, they may be transmitted to the next generation. The broad classes of mutation are gene mutations and changes in chromosome number or in chromosome structure. This will lead to an accumulation of harmful mutant genes in the population and in turn to increased incidence of hereditary diseases and general decrease in health and wellbeing with severe economic consequences (Lyon, 1983: 75-77). Mutagenic agents include agricultural chemicals such as chlorinated hydrocarbons (endrin, aldrin, dieldrin, DDT, sodiumchlorate, etc.), industrial effluencts and halogenated compound formed during chlorination. In food, pesticide residues, and food additives such as preservatives may be mutagenic. This will have socioeconomic consequences extending indefinitely into the future, due to the accumulation of mutant genes over succeeding generations. There will be an increase of genetic diseases, metal defects, and physically disabling conditions and congenital malformation. This will require extra medical treatments, long-term institutional care and decrease in fitness and productivity in general.

2. Holes of the Ozon Layers

Other human activities that are now threatening the environment is the increasing use of CFCs (chlorofluorocarbons) invented in the 1930's. These chemicals are extremely stable, non-flammable, considered non-toxic and thus harmless to handle. This makes them ideal for many industrial applications, also in pesticide spray, etc. In the stratosphere, unfiltered UV-radiation severs the chemical bonds, releasing chlorine molecules that are highly reactive to ozon molecules. The ozon layers then become thinner or destroyed creating holes. Through these holes, high energy UV light (particularly UV-B [300 nm]) radiation will be transmitted to the earth and causes harmful effects on life on it. To the human beings UV-B may cause sun-burn, cataract, skin aging and skin cancer, suppress the immune defense, etc. UV-B light is also damaging to plant growth (Wilson, 1990: 4-10).

3. Greenhouse Effect

The greenhouse effect is a phenomenon caused by the increase of greenhouse gases (CO_2, NO_2, O_3, methane, etc.) in the atmosphere that due to various activities in the use of energy by industries (including pesticide industries), transportation, fossil fuel generating electricity, and agricultural activities (mainly methane). This affect the albedo, so that the reflection of infrared radiation from earth is reflected back. This causes the increases of the earth temperature. It is predicted that in 50 years the earth temperature will be increased with 3°C (1°C in the equator and 7°C in the two poles). The ice-caps may be melted and there will be an increase of sea levels that most cities in coastal areas will be flooded. It is anticipated that if the sea level will rise to 4 m, one-third of the northern part of Jakarta will be flooded. The rise of sea level up to 8 m will cause almost half of Jakarta covered with sea water. On the contrary some dry areas will become dryer. Consequently, there will be damages to the vegetation that may affect the production of crops, lifestocks and fisheries (Smargorinsky, 1983: 83-85; Houghton & Woodwell, 1989: 18-26).

4. Acid Rain

Acid precipitation is all kinds of matters that fall onto the earth surface, in the form of liquid or vapor, smoke, fog, or extra-fine particles with a pH of less than 5.6. This is closely related to the increase of gases (CO_2, SO_x, NO_x, etc.) in the atmosphere due to various human activities, mainly in the use of energy. The lowering of the pH may have some impacts, e.g. chlorosis, wilting, burning, dieback and dead of the vulnerable vegetations. This was indicated by susceptible trees such as *Lagerstroemia speciosa* (bungur). While some trees are resistant, e.g. *Calophyllum soulattri* (sulastri), *Abrus precatorius* (saga), and *Pithecellobium dulce* (asam landi). Some of the planktons are also susceptible with low pH, which will affect the food chain in fish growth and production.

5. Pollution and Degradation of Natural Resources

As already mentioned earlier, polluting technology and luxurious consumption will produce wastes. These wastes from industries, and other human activities (e.g. the use of agrochemicals fertilizers and pesticides) will pollute our environment and degrade the natural resources. One of the most significant impacts of pesticide industries, was the Bophal incidence of methyl isocyanate contamination that caused damage to the human and natural resources. The whole developing countries are consuming 15% of the accidents of misuse of pesticides were recorded in developing countries, and almost three quarters of the victims died (Soerjani, 1988: 219-234; 1990: 695-715).

WEED AS A VEGETATION

In the historical evolution of man there is a gradually increasing attempt to change and control the environment to use more and more resources and energy to supply human needs and wants. In some sectors of life this have been a dramatic shift, but some may perform a gradual process in agricultural, industrial and social changes.

In agriculture in its broad sense, weed is a plant out of place (King, 1974). This definition is based on the human interests, which further classify wanted

vegetation as crops or cultivated plants, while those that man does not care or has no interest in them as ruderal plants (Numata 1971). See fig. 2.

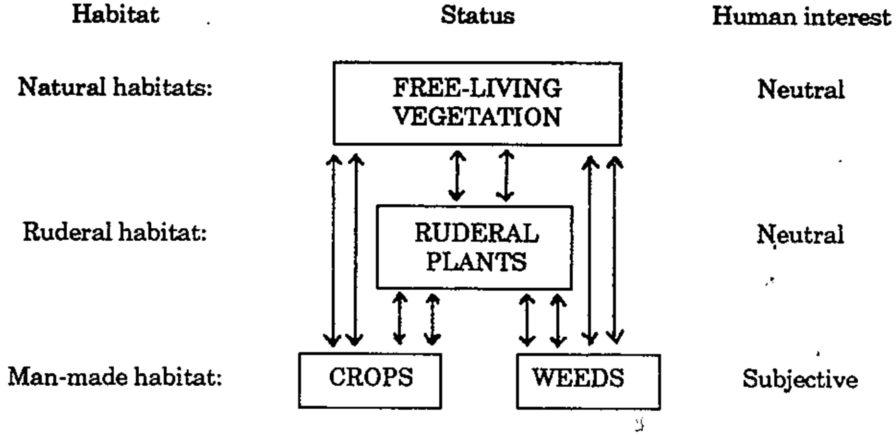

Figure 2. A species of vegetation can have a changed function in various habitat as seen from the human perspective (Soerjani, 1986: 2-3)

In the early state of human life, most species of vegetation are considered as acquiring certain functions to human. Gradually with the technological evolution, the human dominance upon nature is changing the attitude of man. With the high productivity of some of the most desired crops through the application of hitech, less beneficial species of plants may be considered as weeds, under certain location, time and condition. Some of these weeds such as wild rice (*Oryza perennis, O. fatua*, etc.), *Saccharum spontaneum, Ipomoea pes-caprae*, still have potential functions as genetic resource.

VEGETATION MANAGEMENT IN ENVIRONMENTALLY SOUND AND SUSTAINABLE DEVELOPMENT

1. Sustainable Development

Development is the way in which human beings meet their needs and improve the quality of their lives in a sustainable ways. Sustainable development can be defined in many ways. In general, it is defined as meeting the needs of the present equally among members of the community, while providing the opportunity for the future. In this context, the next generations have to formulate their wishes and develop their capability to meet their aspirations and demands. This also indicates the inter-generational scope of sustainable development, and the implications for posterity.

As expressed by Emil Salim (1988) in his foreword for the publication of the Indonesian translation of "Our Common Future", there is a change in the challenge of development from decade to decade since the 1950s, namely the challenges of "balanced development" (1950s), "development for basic needs" (1960s), "development for social equitability" (1970s), "development for the quality of life" (1980s), and now "sustainable development" (1990s). It has to be admitted, that under the present challenge of sustainable development, the other earlier challenges are still valid. Therefore, perhaps the challenge of sustainable development can be seen as the "sum" of all those challenges. What is still lacking is the challenge of "honest and just" development, which has to take place within both local an global environmental context.

As defined in the final draft of the "World Conservation Strategy for the 1990s" (IUCN, UNEP, and WWF, 1990), sustainable development is a "process of social and economic betterment that satisfies the needs and values of all interest groups, while maintaining future options and conserving natural resources and diversity." Further on it is explained in this draft, that there are principles of ecological, social, cultural, and economic sustainability which are applicable in one way or another, to all development activities. Therefore, environmentally sounds and sustainable d- velopment must be implemented through behavior and activities characterized by technological appropriateness, environmental feasibility (including natural resources management) and socioeconomic sustainability (Fig. 3).

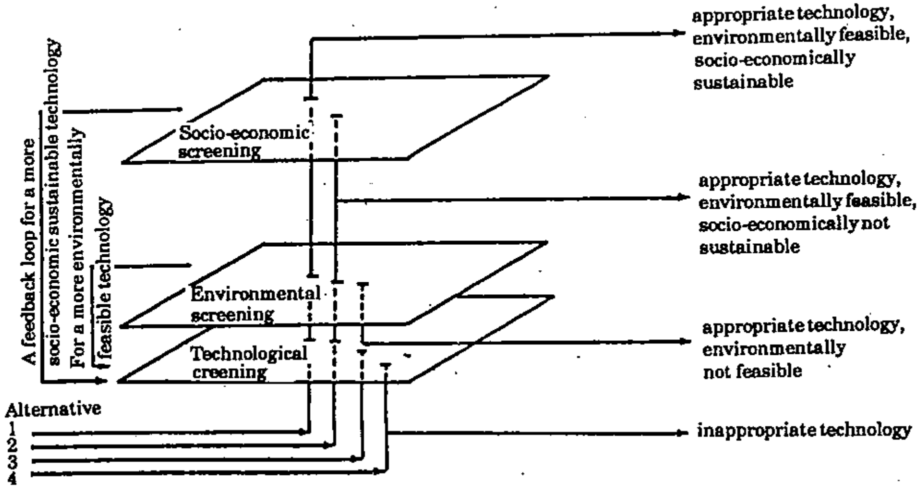

Figure 3. Alternatives of human behavior and activities in environmentally sound and sustainable development to be screened for a technological appropriateness, environmental feasibility and socioeconomic sustainability (modified from Beale, 1980; Soerjani, 1989).

2. Vegetation Management

An environmentally sound vegetation management must therefore based on technological appropriateness, environmental sustainability, and socio-economic feasibility.

2.1. *Technological appropriateness*

Technological innovations in vegetation management must be based on increasing efficiency and effectiveness, through the continuous increase of vegetation productivity while maintaining the sustainability of supporting resources. There is a need of a new trend to work "upstream," and to change the resources exploitation, the processes, the products, the attitude and policies that give rise to pollution.

In vegetation management there are several "wisdom" to refer to. These are among others with the following condiseration.

(a) **Pesticide alternatives.** Paul Müller detected the insecticidal activity of DDT at the Geigy laboratories in Basel, Switzerland, for which he was awarded a Nobel price. He has been considered as contributing pioneer invention contributed to as worldwide search for new types of useful and highly active plant protection chemicals (Voss & Geissbühler in Casida 1990: 3-10). After serving a great deal invention in pest control effort, it has been generally recognized that there is a need for more and noval innovation of chemicals of environmentally acceptibility. It is quite interesting to note that from 1940-1985, the number of pesticide introduced was declining (Fig. 4).

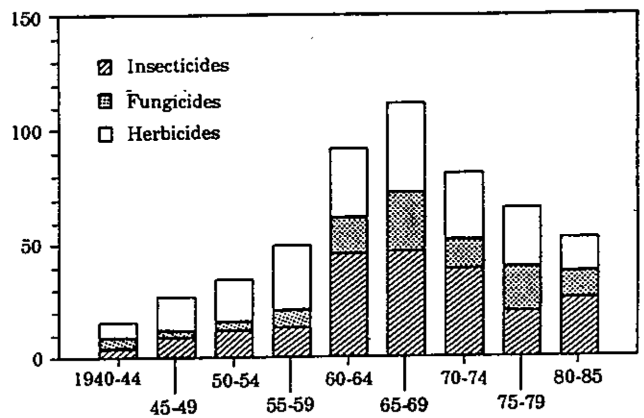

Figure 4. Number of pesticides introduced 1940-1985 (Voss & Geissbühler in Casida, 1990: 8).

At present, a considerable body of information is available on the chemistry of natural products, among others ant secretions (e.g. iridibs, a cyclopentanoid-based group of monoterpenes) as possible substitute for DDT. One compound of this group is iridomyrmecin (appeared in 1952) is active against some DDT- resistant species, while has a lower mammalian toxicity than DDT; 1.5 g/kg compared with 0.2 g/kg, mouse oral LD_{50}, respectively (Toia in Casida 1990: 301-309). *Leucaena leucocephala* de Wit has a great potential as animal feed, but its use is limited owing to the presence of mimosine (ß-(N-(3-hydroxypyridone-4)- alpha-amino propionic acid), which causes alopecia, growth retardation, cataract and infertility in animals. Mimosine and some of its derivates are responsible for the allelopathy of leucaena, therefore they have potential herbicidal activity now still under investigation (Toia in Casida, 1990, loc. cit.).

(b) **Controlled delivery techniques**. Controlled delivery of pesticides implies formulations that protect and release biologically active materials combined with delivery pathways appropriate to the target organism and its environment (Wilkins, 1990: xi-xv). This is particularly to increase the efficiency of delivery of the bioactive materials. It is aimed to have safety to operator and crop as well as expected persistence. There are several efforts in herbicide controlled release formulations, e.g. rubber-based formulation of thiobencarb and butachlor now under investigation for vegetation management of rice-fish culture in Sukamandi, Indonesia (Soerjani, 1991).

(c) **Biotechnology**. Biotechnology through the manipulation of competitive capability of certain crop species is another options in vegetation management. This techniques among others include breeding of herbicide-tolerance crop cultivars (Faulkner in LeBaron & Gressel, 1982: 235-254). Another prospect is the transfer of herbicide-resistant genes from resistant weeds to crops (LeBaron & Gressel 1982: 349-362). it is obvious that potential consequences of this technique is still to be considered, among other a possible combination of the increase of competitive capability with the increase of susceptibility against herbicide(s).

(d) **Integrated vegetation management**. Efforts to integrate various potentials in optimizing crop production as part of vegetation management as a whole is very important. Example are crop rotation, mixcropping inter-cropping, heavy seedings, sanitation practices, etc.

2.2. *Environmental sustainability*

In agricultural practices, environmental sustainability will require environmental impact analysis (EIA or ANDAL[1]) which in Indonesia is based on Government Regulation No. 29 of 1986. The introduction of chemicals, the application of noval technology or the use of bio-agent in biological control* will require an EIA document in which the impacts of these activities will be identified, measured or calculated and evaluated to provide the responsible person with plans for environmental management and plans for environmental monitoring. The principle as how these impacts might be assessed is shown in Fig. 5.

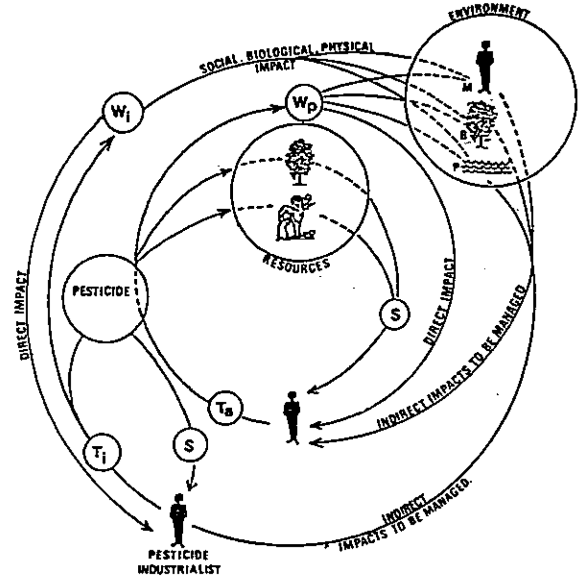

Figure 5. Pesticide industry with industrial technology (Ti) will provide profits ($), but also industrial waste (Wi) which creates direct impacts as well as social, biological, and physical impacts. The use of pesticides by the farmers in agricultural technology (Ta) also provides profit for the farmers, but also creates wastes to affect the farmers directly as well as indirectly to the environment. These indirect impact must be properly managed by the industry and the farmers.

1 Analisis dampak lingkungan

* The author is in the opinion that biological control is wrongly applied may have long-term serious environmental impact more than the use of pesticides.

2.3. *Socioeconomic feasibility*

Ultimately the target of innovation in agricultural technology is the farmers. Hence their condition must consider the farmer's ultimate capability to absorb. This includes social, economic and cultural capability. It is therefore important to be noted, that although scientific knowledge and modern technology are very important and badly needed, there must be efforts by experts to simplify their findings for the farmers and to introduce these step by step, since only innovations simple to understand and easy to be implemented will be effective in persuading farmers in the forceable future (Soerjani *et al.*, 1987: 1-4).

3. Vegetation Management

Weeds are an inescapeable component of vegetation which play a natural role in our man-made ecosystem. Their present and function have to be managed properly, to optimize the benefit of crop production and to maintain the continuous sustainability of our environment to support life. To generate an optimum benefit it is obvious that weed management is a component of vegetation management.

Lastly, it has to be admitted that the natural system will always evolve and shape all components of life, including man. The neutrality and objectivity of our natural system is an unexhoustible source of the moral of human beings (Soerjani in Soerjani *et al.*, 1987: 4).

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CROP-WEED COMPLEXITY IN LOWLAND RICE

KEITH MOODY[1]

ABSTRACT

Knowledge of the life history of weeds and their interactions with soil, climate, associated crop and agronomic techniques is necessary for the development of suitable weed control methods. This need to recognize and understand changes in weed communities as a result of the introduction of new cultural/weed control practices is essential in order to gain insight into the complex effects of crop management practices. More information is needed on the dynamics of weed populations and weed thresholds have to be determined in order to develop appropriate weed control technologies that can be implemented when yield reductions reach unacceptable levels. Weed communities are dynamic and it is important to understand how and why they change. In this paper, examples of the complex interactions between lowland rice (*Oryza sativa* L.) and weeds are discussed and highlighted with emphasis being placed on ecological aspects.

INTRODUCTION

Paddy rice constitutes a managed wetland with a well-defined propose. In most cases, the water is shallow and temporarely created (Pieterse, 1990). Flooding of rice paddies will eliminate many weeds but an adapted weed flora will develop.

All techniques of flooded-field rice cultivation create aquatic conditions during periods of the cultivation cycle and such conditions, which may last for only a few weeks or can involve flooding for many months, during which marsh-like habitats can arise, permit the development of aquatic flora in the rice fields and their associated irrigation and drainage canals and ditches. The aquatic habitat is theoretically continuous although divided into discrete paddies. Nevertheless differences in vegetation in different paddies and within a single paddy sometimes generate distinct micro-habitats (Heckman, 1974).

Most plant species are tolerant of a wide range of soil types and consequently soil factors frequently are not a major limitation to plant distribution. Moisture-related characteristics of the soil such as infiltration rates, permeability and water holding capacity are important factors in determining local distribution of plants. Tiwari and Nema (1967) reported that the primary

[1] Agronomy-Plant Physiology-Agroecology Division, International Rice Research Institute, LosBaños, Laguna, Philippines.

causal factors for weed communities co-existing with the rice crop were the habitat, water status of the field and planting method.

The weeds of rice reflect the diversity of the crop's husbandry and distribution, *Echinochloa crus-galli* (L.) P. Beauv. being the most ubiquitous and internationally important (Turner, 1983) although *Echinochloa colona* (L.) Link is the most commonly reported weed of rice in Southeast Asia (Moody, 1988). Cook (1990) noted that the more weeds ecologically resemble crop plants, the worse they are and suggested that the worst of rice are wild species of rice.

Weeds in rice vary in ease of control in proportion to their ability to survive environmental conditions for rice. To persist in lowland rice fields, weeds must establish and compete succesfully with rice under flooded conditions for approximately 5 months of the year. Subsequent drainage of the fields requires populations to survive under conditions which can vary from severe desiccation to waterlogging depending on rainfall (McIntyre and Barret, 1985).

RICE-WEED ASSOCIATION

Weeds are an inescapable component of vegetation which play a natural role in our man-made cultivation system.

Rice production and weed control are often synonymous; weed control is a central point of coordination for many farm operations. Throughout much of Asia, it is impossible to produce rice economically without a well-planned weed control program. Weeds are still one of the major factors that prevent maximum yields and profits. While agronomic problems change from country to country, the proliferation of weeds remains a constant problem; *E. crus-galli* still remains a serious weed in rice despite concerted efforts over the years using different techniques to control it. For farmers throughout the world, weeds always seem to grow better than crop (Moody, 1980b).

A mixture of desirable and undesirable vegetation has to be altered to get maximum yields. A hectare of soil can support only so much vegetation whether it be crop or weeds. The soil can not distinguish between crop and weeds. Given natural conditions the weeds will take over and the crop is lost. Farmers must use a weed control program that permits the crop to compete most favorably and reach maturity with sufficient yield to make profit.

The interaction between rice and weeds is complex. The way in which a plant species or community interacts with its environment will ultimately determine the role of that species on community within a given habitat. This will depend on the biology of the constituent species and also upon conditions prevailing in the habitat and changes in these conditions (Wade, 1990).

WEED CLASSIFICATION

The plant community in lowland rice field normally consists of a variety of plant types and species. These are usually classified into three groups (grasses, sedges and broadleaved weeds) based on gross morphological features. Moody (1983) suggested another morphological classification and separated weeds into four groups, dicotyledons, monocotyledons, algae and ferns.

A more appropriate classification for lowland rice is one that is usually used to describe aquatic vegetation. This has the advantage in that it encompasses all growth forms. One possible variation follows.

1. Emergent Weeds

These are rooted plants with most of their leaf and stem tissues above the water surface. This life form competes most effectively for light in a vigorous stand of rice (also an emergent) (McIntyre and Barret, 1985). Most of the major weeds of rice fall in this category. Examples are *E. crus-galli, Monochoria vaginalis* (Burm. f.) Presl and *Cyperus difformis* L.

2. Rooted Weeds with Floating Leaves

Examples are *Nymphaea* spp.

3. Submerged Weeds

These are rooted plants that have all (or most) of their vegetative tissue below the surface of the water; the flowers of some species emerge from the water. They usually have thin leaves, sometimes finely dissected, with a thin cuticle to optimize exposure to water which they rely on for their supply and carbon (Wade, 1990). Examples are *Potamogeton* spp. (alternate leaf arrangement), *Najas* spp. (opposite leaf arrangement) and *Myriophyllum* spp. (whorled leaf arrangement).

Pieterse (1990) includes charophytes in this group because they are attached to the soil and as far as control is concerned, are more comparable to submerged vascular plants.

4. Free Floating Weeds

These float on the water surface with stems and leaves above the water and roots suspended in the water. Example are *Salvinia molesta* D.S. Mitchell, *Pistia stratiotes* L. and *Azolla pinnata* R.Br.

5. Algae

Unicellular, filamentous and branched lower plants without differentiated tissues which grow at or below the water surface. Examples are *Spirogyra* and *Hydrodictyon*.

WEED EMERGENCE

During cultivation, the rice field is often subjected to flooding, plowing and turning up of the substrate followed by a period of rice monoculture. This period is usually short because the field is rapidly invaded by weeds (Moody and Drost, 1983).

Most Agricultural soils contain a large reservoir of weed seeds which germinate over time. The number and type of seeds in the reservoir are determinated by a field's cropping history, edaphic characteristics such as moisture-holding capacity and pH, past weed control practices, tillage and land preparation practices, and perhaps of greatest importance - weed seed dormancy. Rate of weed emergence is determined by these factors, as well as by climate, particularly rainfall and temperature, and rate of germination of seedling growth of each species (Zimdahl *et al.*, 1988). Early-germinating plants have a competitive advantage over late-germinating plants.

Zimdahl *et al.* (1988) reported that in a lowland rice soil in the Philippines there was stimulation of germination and emergence immediatelly after soil tillage with 51 to 58% of total emergence occurring within 6 weeks after tillage; tillage caused weed emergence regardless of when it occured. The first large peak of emergence was caused by tillage and subsequent peaks were related to radiant energy.

Saharan (1977) reported that most of the weeds in a flooded rice field began to emerge about 7 days after the last plowing. Among the first to emerge were *Scirpus juncoides* Roxb., *Sagittaria guayanensis* Kunth, *M. vaginalis*, and *Ludwigia adscendens* (L.) Hara. The grasses and other sedge species emerged slightly later. Bakar (1982) found that weed emergence was greatest within the first 2 weeks after final land preparation. However, Zimdahl *et al.* (1988) reported that in a lowland soil an average of only 0.7% of the weeds emerged within 2 weeks of tillage with greater emergence thereafter. Castin and Moody (unpublished) found that an average of 1% of the weeds emerged in the first week after final land preparation; about 27% emerged in each of the following 2 weeks.

Singh and Bhan (1986) reported that the major flushes of weeds occurred during the period from 15 to 45 days after transplanting (DAT); *E. crus-galli* emerged within 15 DAT and its population declined thereafter. *Paspalum distichum* L. invaded the crop about 45 DAT and its population increased until crop harvest. It was during this period that the other weed species completed their life cycles.

COMPETITION

Weeds do not fit into the category of an aerial or a soil pest. They compete with the crop in both environments and, in so doing, their dynamics must be understood in terms of what happens in the soil and above ground. Unlike most pests, weeds are usually problematical as a mixed flora rather than as individual species. Neighboring plants compete for limited resources in the environment and because growing crops and weeds are usually stationary, this is a localized phenomenon.

The genetic control of competitive ability in plants was demonstrated by Sakai (1955). He assumed that competitive ability was controlled directly by genes rather than plant height, tiller number and other quantitative characters. He found no agronomic characters to be correlated with competition effect. On the other hand, Morishima (*unpubl.*, cited in Assémat *et al.*, 1981) and Assémat *et al.* (1981) found high correlations between growth rate in the late tillering stage (increase in plant height x tiller number and percent cover) and competition.

Among rice cultivars, the rate of grain yield increase in response to nitrogen application was negatively correlated with competitive ability (Oka, 1967; Akihama, 1971).

Assémat *et al.* (1981) found that root interaction was more important than shoot interaction in producing neighbor effects; root interaction was cooperative and played a major role in producing the neighbor effect while shoot interaction was antagonistic. It may be inferred that shoot interaction results from mutual shading of the leaves which lowers the efficiency of light energy. On the other hand, the underground space can be diferentially utilized if coexisting plants have different rooting depths. Trenbath (1974) noted that cooperative interaction between plant species resulted from differences in growth rhythm, root depth, and light utilization, and from nutritional complementation.

CULTIVAR SELECTION DUE TO BIOTIC ENVIRONMENTS

Tanner *et al.* (1966) noted that an entirely different morphological type will be selected from a breeding program in which weeds are controlled than in one where weed competition is present.

Morishima and Sano (1983) reported that rice populations responded in their aggressiveness to the neighbor effect of coexisting plants (weeds). An F_7 population from a cross between a Taiwan indica (Ac 130) and a Philippine japonica (Ac 221) was divided into three parts, and one was grown in a weed-free condition while the other two were reared with weeds (*E. crus-galli* and *C. difformis*, respectively). After two successive generations of rearing in bulk, about 20 vigorously growing plants were taken from each plot, and their progeny lines were tested under the three conditions. The response was evaluated by the difference in plant dry weight between weedy and weed-free conditions. Plants from weedy plots had higher tolerance to weeds than those from weeded plots. The results indicate that the populations were selected for their ability to coexist with their neighbors. This may be the initial step of genetic differentiation in niche dimension (Oka, 1988).

WEED THRESHOLDS

Mixture of crops and weeds are of particular interest since weeds cause important reduction in crop yield and are a major agricultural problem worldwide. However, few studies have considered the effect of weeds on the vegetative stage of crops or the canopy structure of crop-weed mixtures. Such studies could form a basis for cultivar selection which would give the crop greater competitive ability against weeds (Storre and Ghersa, 1987).

In developing effective weed management programs for rice, control inputs should be applied only after weeds reach thresholds that cause economic losses to the crop. Basic information on weed thresholds can be used to develop models to determine control options for specific weed situations, when to initiate control inputs, costs of various control inputs and predicting economic returns of different control programs (Smith, 1988). Unfortunately, almost nothing has been done to develop threshold for the major weed species in tropical rice production.

The presence of weeds in crop fields cannot be automatically judged damaging and in need of immediate control (Altieri, 1988). At low density, weeds do not usually affect yields and under some circumstances certain weed even stimulate crop growth. Use of a weed control practice should coincide with the presence of weeds in the crop in sufficient numbers to warrant treatment and at a stage when the weed is most vulnerable.

WEED SHIFTS

For the past 10-15 years in Southeast Asia, there has been a general shift in rice production system from transplanted to direct-seeded, of which wet seeding (pregerminated seed broadcast on puddled soil), has been the main method adopted in Malaysia, Thailand and the Philippines (Moody, 1990a). This shift has resulted in a change in the weed distribution; grassy weeds especially *Echinochloa* species and *Leptochloa chinensis* (L.) Nees have become dominant (Ho and Zuki, 1988; Hare *et al.*, 1989). However, MARDI (1983) attributed the rapid spread of *Echinochloa* species in direct-seeded rice fields to impure crop seeds.

Widespread adoption of molinate in Muda area, Malaysia for the control on *Echinochloa* species has resulted in species displacement in favor of *L. chinensis* and *Ischaemum rugosum* Salisb. (Ho *et al.*, 1990).

I. rugosum, which is spread as a seed contaminant, has become more important as a rice weed in the Philippines (Estorninos and Moody, 1982; Pablico and Moody, 1985), India (Nandpuri *et al.*, 1985; Hedge and Pandey, 1990) and Thailand (Teerawatsakul, 1981). In Malaysia, *I. rugosum* is such a serious problem in the Sungai Manik area that some farmers have gone back to the labor intensive transplanting method of rice cultivation (Ooi, 1988).

A program of weed control does not usually simply remove one species from within a community but will alter the relationships between the constituent species by disturbing the environment, altering competitive interactions, or creating stress so disrupting the natural pattern of development change occuring in the community. The excessive and usually undesirable growth of plants are a symptom of change and not its cause (Cook, 1990).

At the International Rice Research Institute, delay in flooding transplanted rice to reduce damage due to the golden apple snail [*Pomacea canaliculata* (Lamarck)], an important rice pest has resulted in a shift in the weed species; *L. chinesis* and *Fimbristylis miliacea* (L.) Vahl have become more important components of the weed flora. *L. chinensis* is characterized by abundant seed production as well as a short life cycle; heavy infestations cause severe damage to rice (Noda, 1979). It is increasing in importance as a weed of direct-seeded rice in the Philippines, Malaysia and Vietnam (Moody, 1990a).

The weed control method used will affect the weed species growing in association with rice. The use of herbicides moves the agroecosystem toward low species diversity which is contrary to the high species diversity of the natural ecosystem. Mahn and Helmecke (1979) stated that reliance on a single herbicide could result in quantitative changes in the structure of the weed population in as few as 5 years. As weed population stresses are shifted by herbicides, weeds formerly of secondary importance may emerge as primary weed problems.

In the Philippines, perennial weeds such as *Scirpus maritimus* L. and *P. distichum* have become troublesome when herbicides have been used to control susceptible annual weeds such as *E. crus-galli* and *M. vaginalis* (Vega *et al.*, 1971; Mercado, 1979; Moody and Drost, 1983; Janiya and Moody, 1989). In Indonesia, *E. crus-galli* is increasing in transplanted rice with the continued use of 2,4-D and metsulfuron-methyl for broadleaved weed control.

Janiya and Moody (1989) reported that *Echinochloa glabrescens* Munro ex Hook.f. was dominant in unweeded and herbicide (butachlor and thiobencarb-2,4-D)-treated plots while *M. vaginalis* was dominant in hand-weeded plots. The dominance of *E. glabrescens* in the unweeded plots was due to massive seed production. Reasons suggested for the increase in the dominance of *E. glabrescens* and the decrease in the efficiency of weed control due to herbicides were (a) a build-up in weed density such that there was insufficient herbicide taken up by each plant to cause kill, (b) faster herbicide degradation due to an increase in soil microflora in later crops, and (c) less likely, the development of herbicide resistance.

CONCLUSSIONS

Rice fields in general support a diverse fauna and flora. This occurs in spite of the drastic intervention required to prepare the fields for planting (Fernando, 1980). In the future, changes will take place in the weed flora as there are changes in cultural techniques and weeding methods. This must be taken into consideration in developing new rice cultural methodologies.

Studies of existing weed communities are important for their management and control. A knowledge of community patterns and the effect of edaphic, climate and biotic factors on growth and reproduction, help to gain insight into the mechanism of specialization and distribution of the species. Such studies reveal the interactions between species and their environment and thus offer an opportunity to locate vulnerable points at which the weeds can be successfully attacked for control.

A dynamic weed research program is needed to develop innovative and effective weed management strategies to combat changes that will occur in weed flora composition as a result of the introduction of new cropping practices (Moody, 1990b). Weed management is perhaps the most important element needed to improve crop stability in the humid tropics (Harwood, 1979).

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RESEARCH, INFORMATION, EDUCATION AND EXTENSION

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Research, information services, education and extension in weed science are all processes - they do not achieve any weed control by themselves, but allow people to achieve weed control better, faster, and more easily. The four processes form a natural and overlapping continuum, and all four are essential to us as weed workers if we are to better manage the problems assosiated with weeds and their control.

Processes are methods of achieving ends, and like any other processes the four that we are concerned with here need clearly defined aims, established starting points, effective methods, and most importantly, clearly stated goals.

Let us consider what each of these four processes is about.

Research is the process of discovering new knowledge or information about weeds and their control. The new information may be either of a fundamental nature (basic research) or of an immediately useful nature (applied research), but in either case research produces the basic commodity on which all work with weeds and their control must be based. Weed research has been going on for a long time in most countries, so that we already have a large amount of appropriate data available to us on weeds and their control in some agricultures, but not yet enough in others.

Information service is the process of accumulating knowledge about weeds and their control in its raw, reviewed and interpreted forms, and making it available to others. Information services give people access to what is already known about weeds and their control. Information services specifically about weeds are a relatively new phenomenon throughout the world, and especially in the Asian-Pacific region.

Education is the process of training people to be weed scientists. Its aims are to provide us with well-trained people who can foresee, avoid, manage, and solve problems associated with weeds and their control. The training of weed scientists is also relatively new throughout the world, and I doubt whether any Asian-Pacific country is yet training enough weed scientists.

Extension is the process of passing on information about weeds and their control - especially information of a technological and practical nature. It does not necessarily involve education, although it would be difficult to separate the two processes since effective extension must involve some education of the end user of the extension process. Extension workers are the most important of the four groups of weed scientists to be discussed here today, since until a new

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technology is used by farmers it may as well not have been invented by researchers, recorded by information services, or talked about by educators. Yet how many extension workers are here today?

It is my pleasure to open today's discussion on what research, what information services, what education and what extension are appropriate to weed workers in the Asian-Pacific region. Who should do each of these things for us? Who they should benefit? The ultimate beneficiary must usually be the farmer or other grower, and through them each nation's food supply, economy, and therefore political independence. The subject is complicated by the different levels of technology of different countries in the region, and by our different cultures.

RESEARCH

Weed research generally aims at answering two types of questions - one about the identification and biology of weeds of the region, and the other about their control.

Questions about weed identification are usually easy to answer. Weeds are great travellers, and most of our more serious species are exotics that are already widely recognised as weeds both locally and overseas. We have, however, an increasing number of more locally important species of weeds which have arisen either locally important species of weeds which have arisen either through persistance or through invasion. Persistent local weeds are those that already occupy an area of land which we want to develop for agricultural or other purposes, and which can tolerate the clearance and cultivation which we normally carry out. Invading species have come into the Asian- Pacific region from elsewhere in the world, arriving either as desirable plants (e.g. ornamentals, crops or pastures) or as hitch- hikers along with some other commodity moved around by us restless people. Many of the papers at this Conference list the weeds of the areas under study, and several discuss the identify and biology of weeds which are both new to the region and new to agricultural science. In this way we develop an ever clearer picture of the weeds of our locality, country and region and can begin to produce lists of and books about our specific weed problems.

Questions are usually only asked about weed biology when a particular weed becomes difficult to control. Research into the biology of weeds is particularly important, however, to their long term management. It is now some years since the Western Australia Department of Agriculture started intensive research into the biology of the major weeds of cropping in the state in the belief that their long term effective management is more likely through better understanding of their biologies than through the repeated use of herbicides.

Unfortunately this enlightend attitude has yet to reach far beyond the boundaries of that perticular state.

The main question in weed science research is always how to control the weeds in a locally acceptable way. We all know of the five methods available to us for weed control - hygeine, crop competition, and physical, biological and chemical control and that wherever possible these should be integrated into specific systems for managing local weeds in the local context. It is the specific application of these methods that usually requires the most research and extension.

Hyge ine and crop competition have long been fundamental to effective weed control, and are generally ignored at the farmer's peril.

Hyge ine is less important in shifting agriculture than in permanent agriculture since many of the 'weeds' of these systems are useful to the farmer for other purposes and the areas are usually rotated back to bush fallow as soil fertility declines, and at least one paper at this Conference documents the survival of the seeds of annual weeds under rainforest fallow. Another aspect of weed hygeine is the management of environmental factors such as soil moisture, fertility and shade to make the area less suitable for specific weeds. Unforntunately this is often impossible given other constrains, including the crops that have to be grown.

Many of the traditional varieties of crops throughout our region are reasonably competitive with weeds but relatively low-yielding because they invest a large amount of energy into the production of leaves and stems. The amount of energy going into root competition and the production of allelopathic chemicals in these varieties is largely unkown, but is probably considerable. Many modern crop varieties, on the other hand, invest more of their energy into grain production and less into the production of leaves, stems, and probably roots and allelochemicals as well, making them less competitive with weeds and more dependent on other methods of weed control. Since biological control is rarely possible in cropping systems this means a greater dependence on physical or chemical methods, both of which may be out of the reach of poorer farmers. Alternatives to crop competition exist in intercropping, alley cropping, cover cropping and mulching, all of which are traditional methods of both weed control and increasing crop production in intensive farming systems through the Asian-Pacific region. Their effects are obtained through competition, smothering and allelopathy, and our region needs more research into these methods of weed control than it has yet received. Much of this research can be carried out by at the local level without inputs of herbicides and equipment. Intercropping and sequential cropping have not been possible in the high technology monocultural systems favoured by Australian farmers to date, but the advent of gantry farming may make both techniques more possible.

Biological control has many advantages where it can be applied, but its use has so far been limited to weeds of extensive areas such as pastures. Despite its emotional appeal it is an expensive and uncertain area of research, and one which is perhaps still best carried out by specialised laboratories in the more technically developed countries. Many of the more important weeds are, as mentioned before, great travellers, so that the results of biological control in one country can sometimes be readily transferred to the same weed in another part of the region.

Research into physical weed control has lagged behind research into chemical weed control throughout the world, largely due to its major drawbacks of high energy requirement, short term effectiveness, damage to crop plants, and (in the case of power farming) soil degradation.

The use of hand labour for weed control is traditional throughout the region, but is now only possible where labour is both available and economic. The general trend seems to be that labour is becoming scarcer and more expensive in most agricultures, although hand weeding almost always persists in some limited form. How can research help the hand weeder? How far can local farming implements and local farming practices be modified to improve the efficiency on hand weeding with hoes or other implements? This appears to be a generally neglected area of weed control research, but it is one which I think will be taken up at next February's First International Weed Control Congress in Melbourne.

Hand labour has been displaced by animal power in many types of agriculture. It happened in Europe during the industrial revolution at a time when labour was becoming scarcer and more expensive and there are more mouths to feed. It is interesting to note that the first essays on weeds and weed science coincided with the introduction of animal power for sowing and weed control. Such a change has of course also occured in many of the agricultures of our Asian-Pacific region, but as with hand weeding the research establishment had largely ignored animal powered weeding and its potential improvement through improved implements and animal management. This is probably a good thing.

Power farming only became possible about seventy years ago with the development of agricultural tractors and their associated implements. A great deal of research has been and continues to be done into improving mechanical weed control, and it is still the most important method of weed control in the world. Apart from its great expense in fossil fuel and relatively short effectiveness, mechanical weed control can be very damaging to soil structure and has led to serious soil erosion and degradation. Recognition of this problem is leading to the development of reduced and no-till cropping systems and more recently to research into gantry farming in an effort to maintain mechanical weed control without its adverse effects.

Effective herbicides have complemented and even replaced mechanical weed control in higher technological monocultures, but their adoption in lower technology agriculture and particularly in multiple cropping systems is posing many problems. Research and innovative thinking are necessary to determine their value before a herbicide is introduced into any particular cropping system. Herbicides undoubtedly have an important role in many agricultural systems, but not necessarily in all. Most of the basic research into herbicide discovery, development and application will continue to occur outside our region, but it is interesting to note the paper in this Conference on anilofos, which the authors claim to be an Indian discovery and development. Extensive research into herbicides and their application will continue to be important to us in our Asian-Pacific region, and we will inevitably see them making a greater impact on weed control in most of our cropping and other land management systems.

INFORMATION SERVICES

Information services provide the necessary link between weed scientists engaged in research, education and extension. Information services have always existed, firstly by direct contact between people and then by the printed page. Very recently we have seen the rise of the even faster, more flexible, cheaper and more efficient methods of electronic communication.

Weed science has been well served during its short history by its printed information services, with numerous journals, proceedings and books from overseas and now from more local and regional sources. Of special regional value are the journals of the various weed science societies, the proceedings of the Asian-Pacific Weed Science Society and of the many national weeds conferences, and recent books such as Weeds of Rice in Indonesia. I look forward to an ever greater production of books, texts, journals and proceedings covering weed science and weed control in the Asian-Pacific region. Weed Abstracts has been very valuable to us in the region, since it has allowed us to access information on weeds and their control from throughout the rest of the world.

The most exiting local development in information services occured four years ago with the creation of SEAMEO BIOTROP's South East Asian Weed Information Center (SEAWIC). I congratulate them of developing so well during their first three years and only securing continuing finance - finance which we, as the Asian-Pacific weed science community - must pick up ourselves in the near future. SEAWIC is a potentially powerful and valuable service to all Southeast Asia and neighbouring countries, including Australia, and we probably do not use its services enough. The other exciting development is the introduction of cheap and rapid electronic information transfer between centres and countries through systems such as fax and CD-ROM, although these will never replace the printed word for ease of access.

EDUCATION

Education in weed science should provide the community both with general agriculturalists who are aware of weeds and weed control and with specialist weed science researchers, educators and extension workers. Weed science should be a part of all agriculture courses at all level, since some understanding of weeds and their control is essential whether students are at school, college, or university.

Specialised training in weed science started in the USA in the 1950s and 1960s, and has been relatively slow to spread. This is suprising since in most types of agriculture weeds cause more damage than insects, diseases and mammals put together; I blame it on the entrenched position of pathologists and entomologists in western universities. The essential nature of weed science seems to be better recognised in many of the countries of the Asian-Pacific region than it is in Australia, a position which Australian weed scientists are having trouble correcting.

I believe that all undergraduate courses in agriculture and related subjects should contain enough weed science to alert undergraduates to the importance of weeds, to enable them to recognise the major weeds of their area and understand their biologies, and to make them aware of the methods available for weed control. Far too many people in Australia and other western countries believe that the first approach to weed control is to use a herbicide, and this mentality has to be strenuously opposed.

Postgraduate education in weed science should be concentrated into about ten Universities in our region in order to achieve the critical mass necessary for effective education. It is important to distinguish between postgraduate research degrees and postgraduate coursework degrees, since their roles are different and both are needed. Weed science is an applied science, and I believe that most practictioners require a broader understanding of the subject than a purely research degree can offer. I see little merit in training a weed scientist in the finer points of research methodology whilst he or she can neither identify nor discuss the biology of even the common weeds of their locality. Similarly, I believe that students should work on appropriate weeds during their research training - tropical weeds for tropical students, and temperate weeds for students from the cooler countries. I make a plea to all supervisors of overseas postgraduate students to ensure that such students take appropriate undergraduate courses as well if they have not already covered weed science at university, and to make sure that they work on appropriate weeds. I believe that part of most postgraduate weed science courses should where possible be undertaken in the home country, doing research on local weeds on local contexts.

EXTENSION

Extension is one of the most important processes in weed science since it serves to inform the end user - usually the farmer - about appropriate methods of weed control. Since decision makers such as politicans, administrators and the general public also need to be informed of the importance of weed control, we all need to be involved in extension all of the time.

The main targets for weed science extension are undoubtedly the people who need and who practice it most - the farmers of our region. Both farmers and ourselves know that weeds impose one of the greatest constraints on farm production through loss of productivity and increased costs, both of which lead to significant loss of profit or even, on some cases, total loss of crop. As weed scientists we have often been unsuccessful - in Australia at least - in our extension programs to the general public. Many people laugh when I tell them that I am a study weeds! Most Australian at least assume that weeds are either an insignificant.

Successful extension requires that the receiver has confidence in the giver of the information, and this can cause problems when the extension agent does not have the right background, sex or culture to enable him or her to talk comportably with the farmer.

One of the most important aspects of extension in weed science is the ability to adapt technology to local conditions and cultures. New technology is unlikely to be adopted unless the extension worker ensures that there is full understanding and where necessary local redevelopment of the technology. Thus two of the extension worker's most important functions are to ensure that local farmers both understand it and can adapt it to their local needs and conditions. The environmental, cultural and economic conditions of many of the farmers of our region are far removed from those of farmers in the more technological agricultures in which new technologies are so often developed. It is, therefore, particularly important that as much research and development takes place locally rather than overseas, and the continuation and further development of research stations throughout the region is vitally important in this regard. The training and retention of good extension workers is also critically important.

As weed scientists we have often also been unsuccessful in our extension programs to the public. Many people still laugh when they ask me what I do and I tell them that I study weeds! Most people assume that weeds are either insignificant or are easily controlled, two statements that most weed scientists know to be untrue. It is strange that the only news about weeds to make headlines in the Australian papers is when a new weed invades a National Park such as Kakadu, whereas a new weed problem in agriculture or pasture scarcely rates a mention.

APPROPRIATE RESEARCH, INFORMATION SERVICES, EDUCATION AND EXTENSION

Before discussing these four processes, it is important for us to remember the wide range of agricultural technologies found across the Asian-pacific region and their extreme diversity.

Agriculture and horticulture in our region vary from highly industrialised to peasant systems, from agricultures with large areas of monocropping to small areas of shifting mixed crops, from very productive systems which require high energy inputs to less productive systems of very low energy input, from systems relying on human and animal power to those which are totally reliant on mechanical and chemical energy, from systems which rely on complex external support systems including information, advice, credit and marketing to systems which rely largely on their own resources, and from systems which are herbicide dependent to those in which herbicides are scarcely or never used. The more'Western', industrialised, or high-technology ends of these models are often seen as the ones that should be aimed at since they seem to be successful in many industrailised countries. They have indeed allowed relatively small number of farmers to support large urban populations, who are then free to do other things. This apparent success has, however, only been achieved at the expense of significant social, cultural and environmental degradation and loss may not be sustainable, so that each country and culture has to decide for itself how far and how fast it is going to travel along the road towards high technology and farming and dependency on power and herbicides for weed control.

Failure to realise the wide gulfts which separate the technically more advanced and more energy dependent farmers of some countries from the more self-sufficient but less well supported farmers of other countries can easily lead to misunderstanding, waste and frustation in all aspects of research, information services, education and extension.

Both the high technology and low technology agricultural systems are built on cultural bases which are not easily or quickly changed. All agricultural systems have their faults, and probably none is truly sustainable in the long term. Agricultural systems in low technology countries may not be able to feed their increasing populations, whilst the heavy dependence on agricultural inputs of farmers in the more technically advanced countries is putting enormous pressures on the soil, water and other resources which are needed to sustain it.

We must constantly remind ourselves of the end users during today's discussions on weed science research, information services, education and extension in the Asian-Pacific region. We find that we must deliver research, information services, education and extension at appropriate levels - levels which may not of our choosing, but which are appropriate to the needs of our many different agricultures. The term 'appropriate technology' has come to mean low-level technology, but this is wrong. Each level of agricultural sophistication have its appropriate level of technology, and all levels of research, information service, education and extension can be either appropriate or inappropriate.

As a final message I would remind us all that weed science does not stand alone, but that it is only one aspect of agricultural technology. It cannot advance very far in front of others aspects such as plant breeding and the availability of credit, but neither can they advance very far unless weed scientists are providing appropriate and affordable levels of weed control. Agricultural advancement must go forward as an integrated package on all fronts simultaneously, and we as weed scientists must keep in constant touch not only with each other but with other agriculturalists providing research, information, education and extension services in all other disciplines.

CONCEPT, CHARACTERISTICS, CROP-WEED COMPETITION, SUCCESSION AND EVOLUTION IN FARMLAND, GRASSLAND AND WOODLAND-ECOLOGICAL STUDIES OF WEEDS

M. NUMATA[1]

INTRODUCTION

The concept of weeds vs. crops originated with the extablishment of agriculture. There was description of farmland weeds in "Enquery into Plants" by Theophratus of the old Greek Age before the Christian era. In "Natural History" by Plinius in the Roman Age, there are descriptions about the season of cultivation, the period of cropping, weeding and fallowing, rotation of cropping, and examples of farmland weeds.

Weed science is a relatively new science. In Japan, "Weed Science" by J. Hanzawa (1909) was the earliest book on the subject. He wrote the book as a textbook on applied botany when he was 30 years old. The contents are the definition of weeds, the dispersion of weeds, the injury of weeds, the usefulness of weeds, the eradication of weeds, the identification of weeds, and parasites on weeds. There is no idea in it about weed communities in a farmland ecosystem.

After World War II, herbicides such as 2-4D were used, and the realtionship between crops and weeds changed. The author recalls early books on weeds, for example, Hamel et Dansereau (1949), Ellenberg (1950), Harper (1960), and Salisbury (1961). The author and prof. W. Holzner edited "Biology and Ecology of Weeds", Dr. W. Junk, the Hague (1982).

WHAT IS A WEED?

The weed is an obstacle to the crop (not only farmland herbaceous crops, but also tree crops, fodder crops, and fish crop, etc.). It is a pest or nuisance in a broad sense. However, what is a weed is a relative concept depending on who is dealing with it. When the author studied a barley field in Central Bhutan, (Numata, 1987), a weed *Persicaria nepalensis* grew thick competing with barley. The authors asked a farmer "why don't you eradicate them?". He answered that, true it really is a weed, and the yield of barley will decrease, however it is also a good fodder in the winter. Therefore, the farmer permitted it to grow thick.

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The weed is usually thought of as a non-invitee or not a welcome plant. It is "a wild herb growing in an undesirable site" (concise O.E.D.) and "a valueless plant growing wild" (Random House), however, the difference between a wild plant, a ruderal plant and a weed should be recognized. K. Yamashita, a member of an expedition studying the origin of wheat wrote of *Aegilops* spp. as the ancestor of wheat, a weed species of the field, a wayside plant (=ruderal plant) and a component of a grassland (=wild plant), that is the same *Aegilops* is a weed as well as a ruderal and wild plant (Yamashita, 1956). When I studied a semi-arid grassland in Armenia, I was surprised to find wild orchard grass, red clover and tulips (Numata, 1976).

CHARACTERISTICS OF WEEDS

According to experiments on the competition between a crop (upland rice) and weeds (Numata and Niiyama, 1953, Niiyama and Numata, 1962, 1969), if too many weeds germinate, they result in self-thinning. However, if there is some space, there are supplementary germinations, that is, they have intraspecific and interspecific density regulation ability. Sometimes the after-ripening period is rather long, and they produce hard seeds as wild plants. The growth form has plasticity so *Digitaria adscendens* is basically a tussock form, but when the planting distance of upland rice becomes wider, the growth form becomes t-p type which is intermediate between tussock and procumbent with adventitious roots on the nodes of the fallen erect stem. It is a growth-form strategy covering a wide space.

The study of crop-weed competition involves using the Latin Square Method with (I) the complete weeding plots for the total period (II), non-weeded plots (control) (III), complete weeding plots one month after seeding (IV), complete weeding plots 5 weeks after seeding and (V) the complete weeding plots 6 weeks after seeding. The coefficient of homogeneity and the summed dominance ratio showed the critical point of weed injury between 5 and 6 weeks after seeding. Non-weeding after the critical point damages the yield of upland rice. The critical point shows the allowable limit for weeds.

The following random block method was conducted with the following seeding times: early (A), usual (B) and late (C), and weedings: complete (I), weeding after the critical point (IV), weeding after 8 weeks (V). Then, the growth of weeds C>B>A, and yield of upland rice A>B>C, II>I in A, that is the amount of weeds before the critical point is dependent ("cooperative") on the yield of upland rice.

The third experiment on the planting distance of upland rice: 5cm (P), 10cm (Q), 15cm (R) and the weeding time I, IV, V shows that the coverage of weeds was R>Q>P and crop yield was P>Q>R. Therefore, there is an optimum density of a crop relative to the weed growth with a yield of : II>I in Q and R.

This shows the existence of an allowable limit on the amount of weeds and on the weeding time. This allowable limit is equal to the most homogeneous (CH being smallest) or random, namely coefficient of homogeneity (CH) or randomness in the distribution of weeds and shows the optimum period for weeding.

To know the influence of cultivation time, an every-month-starting-denudation experiment was conducted in Japan from Hokkaido to Kyushu. In Chiba, the autumn type was *Ambrosia artemisiifolia* community, and the spring type was the *Setaria glauca-Digitaria adscendens* community. When the denudation is early, *Poa annua, Stellaria media*, etc. have 2 seasons per year, however, *Digitaria violascens* is different and does not flower and bear fruits when denudation is delayed.

The process of the establishment of weed communities was traced by DS (degress of succession) and RS (rate of succession). From the standpoint of pollination type, the pioneer species after denudation are of self-pollination type and apogamous types at first, and then shift to the wind pollination type.

The characteristics of weeds are common to pioneer species and aliens (Salisbury, 1961). Thellung (1912) classified them into neophyte (naturalized plants in a natural environment), apophyte (naturalized plants in an artificial environment) and ephemerophyte (temporarily naturalized plants). Sukopp (1960) classified them into membership naturalization where exotic plants become the members of indigeneous plant communities, and replacement naturalization where exotic plants make a new plant community as a dominant. It is in understood from the standpoint of a plant community receiving exotic species that there is ecesis resistance (difficult to receive them) and ecological homeostasis (easy to receive them) (Nagy, 1964). Pioneer and weedy species gradually decrease along with the progression of the succession of the buried-seed population. Brechley (1920) proposed weed control by fallowing.

The evolution of weedings is discussed on *Avena* as crop and weed (Yamaguchi, 1976), on *Oryza sativa* as cultivated and wild rice, and weedy wild rice in a paddy field (Oka, 1976). The characteristics of weeds are self-incompatibility, polyploidy, therophyte, the polymorphism of seeds (*Chenopodium album* has 4 kinds of seeds with different surface colors and characters on one plant. These have different ecological characteristics and germination times (Harper, 1965) and the excretion of allelopathic substances. Pioneer species are often composite plants which are aggressive in the top of evolution and sometimes control the activity of Azotobacter and fertility of soil (Rice, 1974).

As a result, the weed is defined as a nuisance for man (Harper, 1965) on one hand and as a colonizer in the habitat disturbed by man (Baker, 1965) on the other. The latter is so to say, a weedy colonizer in the weedy habitat (Mulligan, 1965).

GRASSLAND WEEDS AND WOODLAND WEEDS

The author studied the structure and dynamics of man-made grassland in Chiba (Numata and Yoda, 1957). A man-made grassland is made up of a mixture of Gramineae and Leguminosae. However, the phosphorus absorption coefficient of soil is higher because of the volcanic ash soil there, and legumes like Ladino clover soon disappear because of the shortage of phosphorus. The distribution of fodder is first random based on the dispersal of fodder seeds, but gradually it becomes contagenous after the disappearance of some plants. In this naked space, thin-yellow patches of *Cerastium glomeratum* (an alien) were often seen in the winter. An indigenous species, *C. holosteoides* var. *hallaisanense* is not tolerable to competition with fodder species. It is distributed only on the field path outside the sown grassland. In the same space, *Erigeron annuus* and *E. canadensis* grow well in the summer. This is the seasonal aspect og grassland weeds.

The author studied semi-natural pastures from northern to southern Japan, Nepal, Bhutan, Pakistan, Brazil and Papua New Guinea, etc. In Japan, *Sasa calamagrostis*-type, *Miscanthus sinensis* type and *Pleioblastus*-type, etc. are found in mowed grassland, and *Poa pratensis* type, *Zoysia japonica* type, etc., are found in grazing grasslands. For those grasslands, he calculated DS, RS, IGC (Index of Grassland Condition), etc. and classified the species (No. of species) and the dominance (summed dominance ratio, SDR) percentage of G (graminoid), L (legumes), Th (annuals), etc. He also observed the grazing rate or palatability. The judgment of the grassland condition and trend is done using those indices (Numata, 1965, 1966, 1991).

Thorny shrubs and poisonous plants are found among the weeds of grasslands. There are *Rosa multiflora* (a thorny shrub) in semi-natural grassland in southwest Japan and *Cotoneaster microphyllus* (Rosaceae) in semi-natural pastures of *Cynodon dactylon-Imperata cylindrica* type in the lowlands of Nepal Himalaya. This is a kind of vicarious plant (Numata, 1965).

The author and his collaborators made an experiment changing the number of cuttings from once a year to twice a year, three times a year and no cutting (control and progressive succession) with the Latin Square method (Numata, 1976). Then, there was a decrease with frequent cutting with weeds such as *Miscanthus sinensis, Lespedeza bicolor*, and an increase with frequent cutting and weeds such as *Pteridium aquilinum, Arundinella hirta, Calamagrostis hakonensis, Zoysia japonica* and *Hydrocotyle ramiflora*. Among them, the ratio of the crop-like plants to the weed-like plants changed.

There are similar relationships in woodlands and in grasslands. *Larix kempfeli, Cryptomeria japonica*, and *Chamaecyparis obtusa* as crop trees and other weed trees are easily distinguished. In the study of a young plantation of *Chamaecyparis obtusa* (Sakura and Numata, 1976), *Bidens frondosa*, and

Erechtites hieracifolia, etc. were found in a one-year stand, *Erigeron candensis*, etc. in a two-year stand, *Miscanthus sinensis*, etc. in three to five-year stands five-year stands, and *Mallotus japonicus, Broussonetia kazinoki*, etc. as a pioneer sun tree with long life of seeds. In a young stand of *Cryptomeria japonica* (Sakura and Numata, 1980), the tendency is basically similar, but in the weeding plot and the non-weeding plot, three species (*Mallotus japonicus, Ampelopsis brevipedunculata, Weigela coraeensis*, etc.) were dominant from the beginning.

In a bomboo forest (*Phyllostachys bambusoides, Ph. nigra* var. *henonis*, and *Ph. eludis*), if the canopy is open and light, *Miscanthus sinensis* and *Pleioblastus chino* grow well, and the bamboo forest becomes degraded to the direction of a deciduous broad-leaved secondary forest with *Pinus densiflora, Quercus serrata, Q. acutissima*, etc. Even if the canopy is relatively closed, the bamboo forest shifts sometimes in the direction of an evergreen broad-leaved forest with *Camellia japonica, Torreya nucifera, Aucuba japonica, Nandina domestica*, etc. particularly of the slope is not steep. If the slope is steep, the bamboo forest can be a topographical climax. Regarding bamboos as a crop, co-existing *Oplismenus undulatifolius, Houttuynia cordata, Cypripedium japonicum, Reineckea carnea, Disporum sessile* ect. are companions of the crop with the habitat segregation. On the other hand, trees and shrubs competing with the bamboo for progressive and retrogressive succession are actually weedy enemies of the bamboo forest (Numata, 1955).

EPILOGUE

The author is interested in the weed problem as a bridge of applied ecology between general ecology and technological fields. The concept of weed is opposite to that of crop, and is closely related to the pioneer species and naturalized plants. The weed is not an invitee which is injurious or a colonizer of the denuded land. Farmland weeds in a strict sense can become members or dominants of a weed community in a farmland. There is another group of ruderal plants which grows on paths between farmlands and cannot enter the farmland. Weeds are usually an enemy of crops, however sometimes they are friends within the allowable limit of the amount of weeds and the weeding time. Weeds is grasslands and woodlands are also studied as plants in contrast to fodder plants and crop trees. The relationships between them are quantified using DS, RS, IGC, etc.

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WEED MANAGEMENT

GERMINATION AND GROWTH OF WEEDS FROM SEEDS TREATED WITH PARAQUAT

ISMAIL SAHID AND OTHMAN HASSAN[1]

ABSTRACT

Studies on the effects of paraquat on germination and growth of four weed species, namely *Borreria latifolia* (Aubl.) K. Sch., *Echinochloa colona* (L.) Link, *Eleusine indica* (L.) Gaertn. and *Euphorbia prunifolia* were carried out in the laboratory and greenhouse. Paraquat at 25 ppm applied to petri dishes containing these weed seeds reduced germination more than 60% as compared to the control. Paraquat applied directly to these weed seeds on the soil surface caused a marked reduction on germination, radicle length and fresh weight of grass species (*Ec. colona* and *El. indica*) as compared to broadleaf (*B. latifolia* and *Eu. prunifolia*). The emergence of *El. colona* and *Ec. indica* seedlings were inhibited by paraquat at 12.5 ppm. It was observed that *El. indica* and *Ec. colona* emergence were not much affected when paraquat was mixed thoroughly in soil.

INTRODUCTION

Four species of weeds, namely *Borreria latifolia, Eleusine indica, Euphorbia prunifolia*, and *Echinochloa colona* have fast become important as weed in crop and non-crop situation in Malaysia. *B. latifolia*, though occasionally found in young rubber and oil palm plantations, occurs mostly in field crop situations. It is also considered a prolific seeder. *Eu. prunifolia*, in recent years has emerged to be a prominent weed pest for groundnut and other grain legumes (Piang and Jam, 1979). *El. indica* is also a common annual grass weed in plantation as well as in pasture (Hawton, 1980). This species can produce an average of 15,200 seeds/plant (Chin, 1979). *Ec. colona* is a serious weed especially in a direct-seeded rice as well as in transplanted rice field (Noda, 1977).

Paraquat is widely used to control weeds during land preparation in direct seeded rice field and in other crops. The effect of herbicidal treatment on subsequent growth of grass seedlings or on seed reserves in the soil form an important aspect in weed control measures. In numerous studies, paraquat when applied directly to seeds on the soil surface decreased germination or seedling growth of several grass species (Appleby and Brenchley, 1968; Klingman and Murray, 1976; Egley and Williams, 1978; Salazar and Appleby, 1982). However, not many studies were conducted on the effect of paraquat on

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germination and growth of tropical weeds. Most of the researches were mainly on control aspects at postemergence stage.

The objective of this study is to evaluate the influence of paraquat on germination and seedling growth of the four weed species when applied either directly to seeds or soil.

MATERIALS AND METHODS

Weed Seeds

Seeds of two broadleaf weeds namely, *B. latifolia* and *Eu. prunifolia* and two grass species, namely *Ec. colona*, and *El. indica* were used in this experiment. The seeds of *B. latifolia* and *El. indica* were collected from a rubber estate in Sungai Buluh, Selangor while those of *Eu. prunifolia* and *Ec. colona* seeds were collected from Tanjung Karang, Selangor. After air-drying, the harvested seeds were stored under laboratory conditions in air- tight glass bottles.

Herbicide

Paraquat (1,1′-dimethyl-4,4′ bipyridylium) was obtained from I.C.I. under the trade name Gramoxone which contained 200 g a.i./litre.

Laboratory Experiment

Fifty seeds of each of the four weed species were placed on 9 cm filter paper in a series of petri dishes that contained 8.0 ml of the herbicide solution or distilled water. The concentration of paraquat used were 0, 25, 50 and 250 ppm. The petri dishes were placed in a dark germination chamber at a constant temperature of 28° C. After 2 days and continuing through 10 days, germination counts were made daily. Seeds were considered germinated when the radicle protruded through the seedcoat. Radicle length and fresh weight of the seedlings were recorded after 10 days. The experimental design was a randomized complete block with five replications. The experiment was conducted twice and the means were averaged. Each species was analyzed separately with all data subjected to an analysis of variance with mean separation by Duncan's multiple range test.

Greenhouse Experiment

Three experiments were conducted in the greenhouse to determine the effect of paraquat on seed germination and seedling growth of four weed species. Herbicide and weed species were the same as in the laboratory experiment. For the last two experiments, paraquat was sprayed by using a laboratory sprayer that delivered a volume of 200 l/ha to give a mean final

concentration of either 0, 25, 50 or 250 ppm active ingredient (calculated on an oven-dry basis). Soil used in the experiment was sandy clay with an organic matter content of 1.1% and a pH of 6.2. The temperature in the greenhouse ranged from 27 to 33° C.

The experimental design was a completely randomized block with five replications. All the analyzed data presented are averages from two sets of experiments. Each species within each experiment was analyzed separately. All the data were subjected to an analysis of variance with mean separation obtained by Duncan's multiple range test.

The three experiments (methods of application) were as follows:

Herbicide applied directly to seeds. Forty seeds of each species were placed in separate petri dish lids, sprayed with paraquat solution at different concentration (0, 25, 50 and 250 mg/l) and oven-dried at 20°C for 3 hours. The seeds were then placed firmly on an untreated, moist soil surface in individual plastic trays (30 cm length, by 30 cm width and 10 cm depth). The tray of soil were thereafter lightly watered to maintain adequate soil moisture for seed germination. Emerged seedlings per tray were counted at every 2 days until 21 days after treatment.

Herbicide applied to seed and soil. Seeds for each of four species, namely *B. latifolia, Eu. prunifolia, Ec. colona* and *El. indica* were placed on the surface of moist soil in trays of similar dimensions as the above, and sprayed with 0, 25, 50 or 250 ppm of paraquat. The trays of soil were watered daily to maintain adequate soil moisture. All trays were placed in the greenhouse for 3 weeks. After this growth period, percent emergence per tray and shoot heights of five randomly sampled plants per tray were recorded. Aboveground parts of the plants were harvested and weighed.

Paraquat applied directly to soil. Treated soil at appropriate concentrations of paraquat (0, 25, 50 or 250 ppm) were shaken gently in the rotating drum. The treated soil were placed in plastic trays. Twenty seeds of each of the four species were sown at a depth of 0.5 cm. The soil in the trays were watered lightly to maintain adequate moisture for seed germination and seedling growth. Seedlings emergence were counted at 21 days after planting. Shoot length and fresh weight were also recorded as before.

RESULTS

Laboratory Experiment

After 10 days, seeds treated with 250 ppm paraquat decreased germination of all four species as compared to untreated seeds (Table 1). Seeds treated with 25 ppm paraquat showed a greater reduction in germination which was more than 60% of the control of all four species.

Table 1. Effect of paraquat on germination, radicle length and fresh weight (% of control) of four weed species 10 days after exposure to paraquat in petri dishes*

Concentration (ppm)	*B. latifolia*	*Eu. prunifolia*	*Ec. colona*	*El. indica*
		Germination		
0	100a	100a	100a	100a
25	32c	28b	40b	30b
50	45bc	22b	20c	20bc
250	11d	8c	8c	4c
		Radicle length		
0	100a	100a	100a	100a
25	37b	20b	6b	6b
50	25b	12bc	4b	3b
250	10c	8c	2b	2b
		Fresh weight		
0	100a	100a	100a	100a
25	71b	70b	33b	27b
50	71b	50b	3c	23c
250	42c	40c	3c	13d

* Means within columns followed by the same letter do not differ significantly at the 5% level according to Duncan's multiple range test.

Paraquat concentration of 25 ppm, caused a significant reduction in radicle length and fresh weight of all four weeds. However, greater reduction on radicle elongation and fresh weight of two grass species were also observed due to paraquat treatment. The reduction on radicle length of *Ec. colona* and *El. indica* was much greater than those of *B. latifolia* and *Eu. prunifolia*.

Greenhouse Experiment

Paraquat applied directly to seeds: There was a reduction on the percentage emergence of four weed species with increase in herbicide concentrations (Figure 1). It was observed that the rate of emergence of *Ec. colona* and *El. indica* was lower on exposure to 250 ppm paraquat as compared to *B. latifolia* exposed to 50 ppm paraquat.

Herbicide applied to seed and soil: When paraquat was applied to exposed seeds on the soil surface, the emergence percentage of the grass weeds was much more affected than those of broadleaf weeds (Table 2). Treatment with 5 ppm paraquat reduced the emergence of grass species. Paraquat inhibited the germination of both grass species at 12.5 ppm. However, paraquat at the highest concentration of 250 ppm showed a significant reduction on the emergence of the two broadleaf weeds.

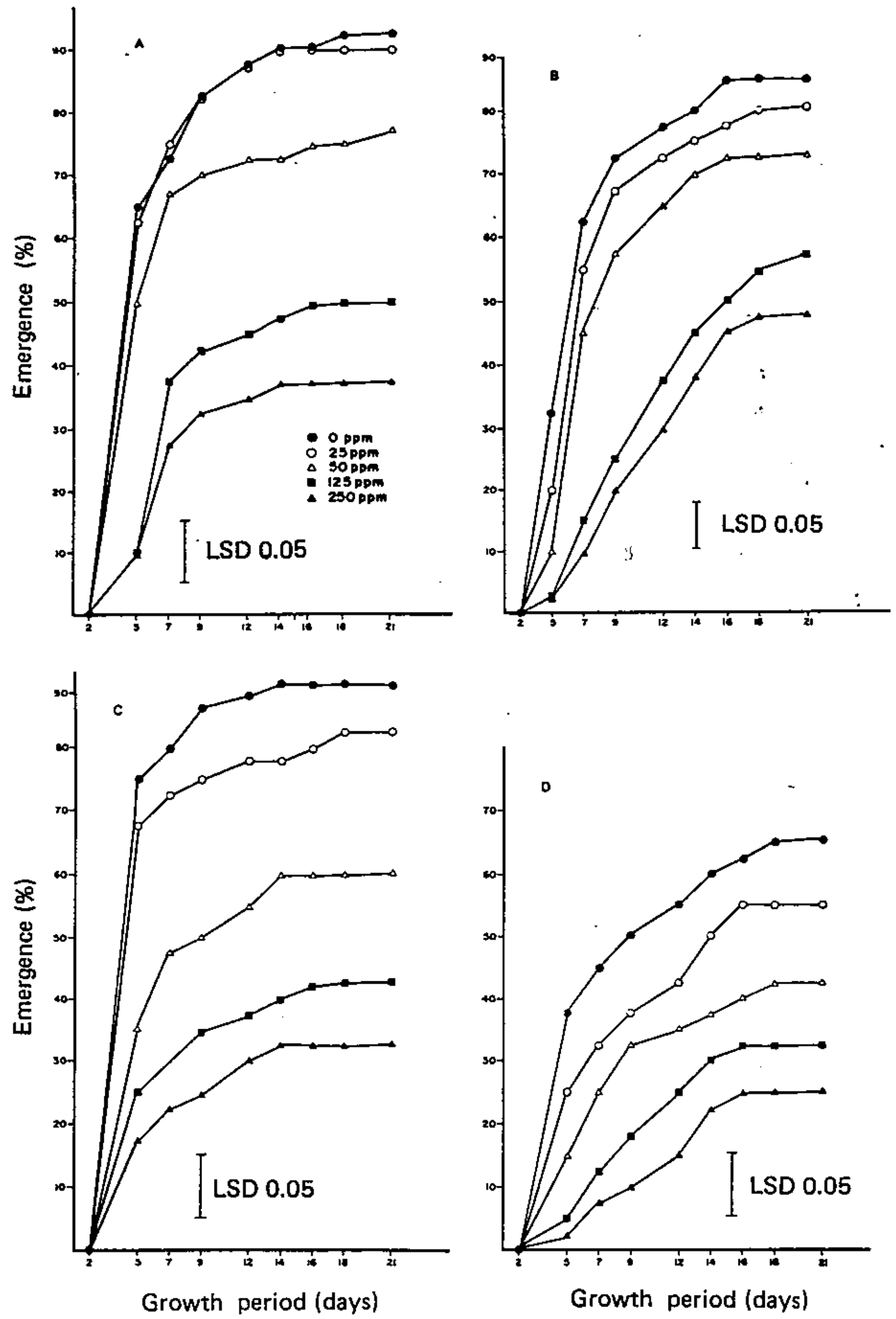

Figure 1. Effect of paraquat on the emergence percentage of A) *Eu prunifolia*, B) *B. latifolia*, C) *El. indica* and D) *Ec. colona*

Table 2. Effects of paraquat applied to seeds on soil surface on the emergence, shoot length and dry weight of four weed species*

Concentration (ppm)	*B. latifolia*	*Eu. prunifolia*	*Ec. colona*	*El. indica*
		Emergence (%)		
0	88a	88a	78a	64a
5	71a	81a	2b	1b
12.5	62ab	75ab	0b	0b
25	59b	60b	0b	0b
		Shoot length (mm)		
0	63a	338a	31a	210a
5	37b	188b	1b	6b
12.5	29b	76cd	0b	0b
25	28b	44d	0b	0b
		Fresh weight (mg/plant)		
0	951a	4315a	257a	1145a
5	587b	1464b	2b	12b
12.5	487c	290c	0b	0c
25	444c	95d	0b	0c

* Means within columns followed by the same letter do not differ significantly at the 5% level according to Duncan's multiple range test.

Paraquat was not effective in reducing fresh weight of *B. latifolia* as compared to the grass species. The reduction in dry weight was attributed to the decrease in germination where shoot length inhibit shoot emergence (eventhough radicle emergence had occurred). In some instances there was no shoot emergence at all.

Paraquat applied directly to soil. The effect on the percentage of seedlings emergence when paraquat was mixed thoroughly in soil was not effective in reducing germination and growth as compared to direct application to the seeds sown on soil surface (Table 3). All species showed significant decrease in emergence when exposed to 50 ppm of paraquat as compared to control.

Two grass weeds (*Ec. colona* and *El. indica*) showed significant decrease in emergence on exposure to the highest paraquat concentration (250 ppm) as compared to the control. Increasing paraquat concentrations of 25, 50 and 250 ppm did not affect the emergence of broadleaf weeds significantly. Seedling growth of *Ec. colona* and *El. indica* were reduced when exposed to the highest concentration (250 ppm). The reduction of fresh weight of *El. indica* and *Ec. colona* was 99 and 91% of the control, respectively. Similarly, fresh weight of *B. latifolia* and *Eu. prunifolia* was reduced by 51 and 75% of the control, respectively.

Table 3. Effect of paraquat which was mixed thoroughly in soil on emerence, shoot length and fresh weight of four weed species, 3 weeks after treatment*

Concentration (ppm)	*B. latifolia*	*Eu. prunifolia*	*Ec. colona*	*El. indica*
		Emergence (%)		
0	80a	88a	73a	78a
25	60b	75b	53b	75a
50	57b	70b	48b	53b
250	52bc	63b	35c	7c
		Shoot length (mm)		
0	65a	26a	216a	190a
25	48b	23a	192b	72b
50	39bc	19b	111c	17c
250	26c	10bc	31d	2d
		Fresh weight (mg/plant)		
0	214a	257a	1175a	1704a
25	175b	168b	1048a	270b
50	157c	144c	956a	62c
250	104d	64d	98c	8d

* Means within columns followed by the same letter do not differ significantly at the 5% level according to Duncan's multiple range test.

DISCUSSION

Paraquat has been used widely as post-emergence and pre-emergence herbicides in controlling various weed species. For post-emergence application, paraquat is normally sprayed directly onto leaf surface of plant. However, it can also enter plant tissues through other surfaces, such as those of the roots or seed coat (Damanakis *et al.*, 1970). Therefore, the reduction on germination and growth of weeds in petri dishes proved that paraquat could be absorbed by the germinating seeds. Turley and Adamson (1963) reported that paraquat can be absorbed from the soil surface by new seedlings as they emerge.

Paraquat applied directly to seeds laid on the soil surface, inhibit the emergence of the two grass weeds but not the broadleaf species. There was also a good correlation between effects on germination and effects on seedling growth. Paraquat inhibition to germination of the two grasses and the failure to inhibit the germination of the broadleaf weeds, is in agreement with the previous report, that paraquat inhibit grass (turfgrass) seed germination but not broadleaf (clovers) seed germination (Appleby and Brenchly, 1968). Perhaps, seeds of grass species in general are more susceptible to paraquat than seeds of broadleaf species. The results of this study suggest that grass seeds in the early stages of germination also absorb toxic levels of paraquat from their surrounding plant parts due to direct contact of the seeds to the herbicide.

When paraquat was mixed thoroughly with soil, germination of two grass species were not severely affected as compared to those laying on soil surface. The contact between paraquat ions and the soil particle increased, when paraquat was mixed with the soil, and consequently reduced the availablity to the seedlings. It has been reported earlier that paraquat ions are strongly adsorbed by the soil particles through cationic exchange capacity (Calderbank, 1968). Seedlings have low affinity to absorb paraquat as compared to high adsorption by soil particles. The inactivation of paraquat by adsorption on soil particles has been shown by many workers (Coats *et al.*, 1966; Knight and Tomlinson, 1967; Calderbank and Tomlinson, 1968). It seems that, in the field, weed seeds beneath soil clods or covered lightly with soil by cultural practices will be protected from paraquat. However, paraquat may inhibit emergence of some grasses, particularly if the herbicide comes in contact with seeds laying on soil surfaces.

The cause of paraquat phytotoxicity in germinating seeds is not understood. Typically, paraquat is very active in photosynthetic tissues though much slower activity can also occur through respiration in darkness (Mees, 1960). Since the rate of respiration in germinating seeds prior to radicle emergence is very rapid (Toole *et al.*, 1956), the role of respiration in determining the phytotoxicity of paraquat to germinating seeds cannot be discounted.

Results of this study suggest that grass species can be controlled to some extent with paraquat applied prior to germination. Field research is needed to verify these findings.

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PHYTOTOXICITY OF FENOXAPROP-ETHYL TO FIVE LOWLAND RICE VARIETIES

PIRMAN BANGUN[1]

ABSTRACT

The phytotoxicity of fenoxaprop-ethyl to five lowland rice varieties was tested at Singamerta Experiment Farm, West-Java in the dry season of 1989. Cisadane, IR 36, Krueng Aceh, IR 46, and IR 64 varieties were tested with fenoxaprop-ethyl at 60, 90 and 120 g a.i./ha, fenoxaprop-ethyl at 60 g a.i./ha + 2,4-D at 140 g a.i./ha, followed by one hand-weeding, with two hand-weedings as control.

No rate of fenoxaprop-ethyl caused any visual symptom of toxicity in the rice plants, but 120 g a.i./ha suppressed height, and reduced tiller number during early growth and grain yield.

INTRODUCTION

The acceptance of a herbicide for weed control in a crop depends on the appearance of toxicity as well as the efficacy towards the target weeds. Since each variety may give a different response to the herbicide, research on the toxicity of herbicides is urgently needed.

The objective of this trial was to study the toxicity of fenoxaprop-ethyl herbicide to five varieties of lowland rice which are generally planted by Indonesian farmers (CRIFIC, 1986 ; PUSLITBANGTAN, 1988). The main targets of this herbicide are grasses such as *Echinochloa crusgalli* (L.) Beauv. and *E. colona* (L.) Link (Hoechst, no year). The population and spread of these weeds are increasing rapidly in Indonesian lowland rice (Bangun, 1986), and the efficacy of this herbicide toward these grasses has not been locally recorded.

MATERIALS AND METHODS

The research was conducted at Singamerta, Serang in the dry season from August 10 to November 19, 1989.

The trial used a split plot design with three replications. The main plot treatments were the five rice varieties (Cisadane, IR 36, Krueng Aceh, IR 46 and IR 64), whereas the subplot treatments consisted of three rates of fenoxaprop-ethyl herbicide (60, 90, and 120 gr a.i./ha), and one rate of a mixture of

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fenoxaprop-ethyl (60 g a.i./ha) and 2,4-D (140 g a.i./ha) followed by one hand-weeding, and two hand-weedings.

Seedlings at the age of 21 day, were planted at 25 x 25 cm spacings in 3 m x 5 m plots. Each plot was fertilized with 30 kg N and 45 kg P_2O_5/ha at planting time followed by 30 kg N/ha three weeks after transplanting and another 30 kg N/ha at the primordia flower stage.

The herbicide fenoxaprop-ethyl (Furore) was sprayed at 17 days after transplanting (dat), as was the mixture of that herbicide with 2,4-D. Especially for single dosage of fenoxaprop-ethyl the application was followed by a hand weeding at 28 dat. Treatments were applied with a Knapsack Sprayer with a blue Polijet nozzele, at 1.5 kg/cm^2. Hand weeding was done at 21 and 42 dat, by pulling and drowning the weed into the mud.

The parameters observed were phytotoxicity of rice, rice height and tiller number and rice grain yield. Phytotoxicity was observed visually at 28 and 49 dat based on growth, form and colour of leaf using a score of 0 - 4 as follows: no toxicity (0), slightly toxic (1), moderately toxic (2), heavily toxic (3), very heavily toxic which some rice plants dead (4); with 0 - 5 %, 5 - 20 %, 20 - 50 %, 50 - 75 %, and >75 % the form, growth, colour of leaf, height and tiller number of the rice respectively.

The growth of rice was observed as plant height and the number of tillers at 28 and 42 dat and at harvest, with a plant measured from the soil surface up to the plant tip. The number of tillers was based on the total number of tillers except at harvest where only the productive tiller number was used.

The yield/ha of rice was estimated from harvested plots from which the border row was discarded. After threshing, drying and separating empty grains, the grain weight was taken and adjusted to 14 % moisture content.

The data of plant height, tiller number and grain yield were statistically analyzed and the differences among treatment means tested by using Tukey honestly significant difference at the 5 % level.

RESULTS AND DISCUSSION

Phytotoxicity of Rice

The toxicity of fenoxaprop-ethyl to rice is given in Table 1. At 28 dat toxicity was identified by the yellowish colour of the leaves and only appeared in Cisadane at 120 g a.i./ha and IR 64 at all rates. Toxicity was still apparent at 49 dat, however it was still insignificant (below score 1). At that age the symptoms had appeared in all varieties tested except Krueng Aceh, whereas the toxicity symptom in IR 64 was decreassing. Therefore it is clear that fenoxaprop-ethyl at the rate of 60, 90 and 120 gr a.i./ha or their mixture with 2,4-D were safe for all varieties. The toxicity symptom in Krueng Aceh was

not apparent due to the low number of tillers because of the low sprouting capability of seeds during the seedling stage.

Table 1. The toxicity of fenoxaprop-ethyl to five rice varieties, 28 and 49 days after transplanting at Singamerta, 1989.

Treatments	Dosage	28 dat						49 dat					
	g a.i./ ha	Cisa-dane	IR 36	Krueng Aceh	IR 46	IR 64	Mean	Cisa-dane	IR 36	Krueng Aceh	IR 46	IR 64	Mean
		....					*	....					
Fenoxaprop	60	0	0	0	0	0.1	0	0.2	0	0	0	0	0.1
Fenoxaprop	90	0	0	0	0	0.3	0.1	0	0.2	0	0	0.2	0.1
Fenoxaprop	120	0.3	0	0	0	0.2	0.1	0.3	0	0	0.5	0	0.2
Fen.+2,4-D	90+140	0	0	0	0	0	0	0.3	0	0	0.2	0	0.1
Hand weeding	-	0	0	0	0	0	0	0	0	0	0	0	0
Mean		0.1	0	0	0	0.1		0.2	0	0	0.1	0	

* scoring = 0 - 4; with 0 = no visual symptoms and 4 = heavy toxicity
dat = days after transplanting

Plant height

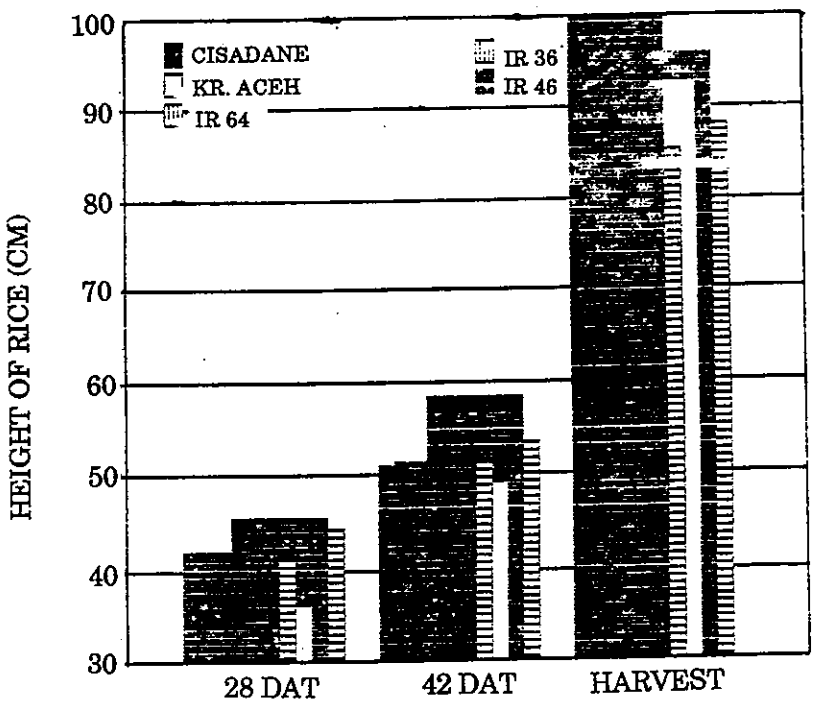
The influence of the treatments on plant height of rice is shown in Table 2. The herbicides influenced the height of rice significantly at 28 dat and harvest, primarily at the higher rates, although there was no plant height difference between treatments at 42 dat. At harvest the hand-weeded rice was significantly taller than the highest rate of fenoxaprop-ethyl, suggesting that fenoxaprop-ethyl at 120 a.i. g/ha hampered the rice growth.

Table 2. The influence of fenoxaprop-ethyl on the height of rice at Singamerta Exp. Station, 1989.

Treatments	Dosage g a.i./ha	Rice height (cm) 28 dat	42 dat	harvest
		....	cm	....
Fenoxaprop-ethyl	60	43.5 x*	53.4 x*	91.5 xy*
Fenoxaprop-ethyl	90	42.1 x	52.8 x	92.2 xy
Fenoxaprop-ethyl	120	38.9 x	50.8 x	89.7 x
Fen.ethyl + 2,4-D	90 + 140	43.0 x	53.6 x	93.9 xy
Hand weeding 2 x	-	41.7 x	53.5 x	94.3 y

* Figures in the same column followed by the same letter are not significantly different at 0.05 level, according to Tukey honestly significant test.

The height differences among the five varieties tested was caused by genetic differences between varieties (Figure 1).



DAT = Days after transplanting

Figure 1. The influence of fenoxaprop-ethyl herbicide on the height of five rice varieties at 28 and 42 dat and at harvest time.

Number of Tillers

The number of tillers during vegetative growth and at harvest is shown in Table 3.

The influence of fenoxaprop herbicide on the tiller number at the immature stages was significant. Tiller numbers in plots sprayed with 120 g a.i./ha were significantly lower than in those sprayed with 60 and 90 g a.i./ha. There was a tendency for the formation of tillers to be stimulated at lower rates of fenoxaprop-ethyl at 28 and 42 dat.

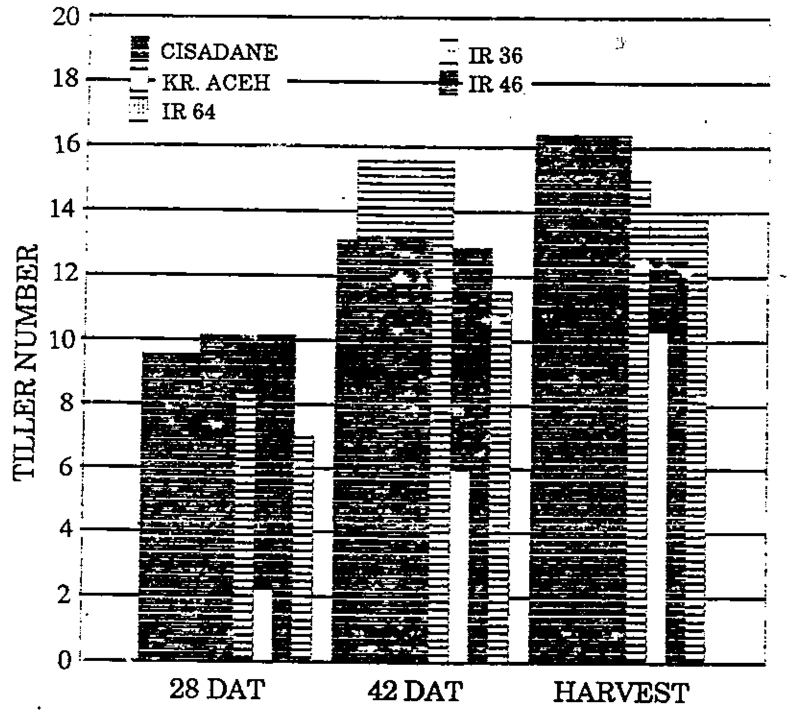
At harvest time there were no significant differences of productive tillers among treatments.

The number of tillers which was significantly different among the five varieties was caused by the difference in genetic characters (Figure 2).

Table 3. The influence of fenoxaprop-ethyl on the tiller number of rice at Singamerta Exp. Station, 1989

Treatments	Dosage g a.i./ha	Tiller number 28 dat	42 dat	harvest
Fenoxaprop-ethyl	60	8.3 y*	13.0 y*	13.3 x*
Fenoxaprop-ethyl	90	8.0 y	12.3 xy	14.1 x
Fenoxaprop-ethyl	120	5.8 x	10.6 xy	13.5 x
Fen.ethyl + 2,4-D	90 + 140	7.6 xy	10.3 x	12.9 x
Hand weeding 2 x	-	7.4 xy	12.6 xy	14.1 x

* Figures in the same column followed by the same letter are not significantly different at 0.05 level, according to Tukey honestly significant test.



Dat = Days after transplanting

Figure 2. The influence of fenoxaprop-ethyl herbicide on tiller numbers of five rice varieties at 28 and 42 days after transplanting and at harvest time.

Rice Grain Yield

The grain yield of rice is shown in Table 4. The highest yield was obtained from Cisadane variety (2862 kg/ha), followed by IR 36 (2708 kg/ha), and the lowest from Krueng Aceh was due to fewer tillers. In general, the low yield was due to serious attack of stem borer.

Table 4. The influence of fenoxaprop-ethyl on the grain yield of five rice varieties at Singamerta, 1989

Treatments	Dosage g a.i./ha	Cisadane	IR 36	Krueng A.	IR 46	IR 64	Mean
		t/ha					
Fenoxaprop-ethyl	60	3.2	2.7	1.2	2.2	2.2	2.3 xy*
Fenoxaprop-ethyl	90	2.8	2.8	1.7	1.8	1.9	2.2 xy
Fenoxaprop-ethyl	120	2.4	2.4	1.3	1.7	1.2	2.0 x
Fen.ethyl + 2,4-D	90 + 140	2.8	3.0	0.6	2.1	2.2	2.2 xy
Hand weeding 2 x	-	3.1	2.7	1.7	3.0	2.9	2.7 y
Mean		2.9 c	2.7 bc	1.3 a	2.3 bc	2.1 b	

* Figures in the same column (x,y) or row (a,b,c) followed by the same letter are not significantly different at 0.05 level, according to Tukey honestly significant test.

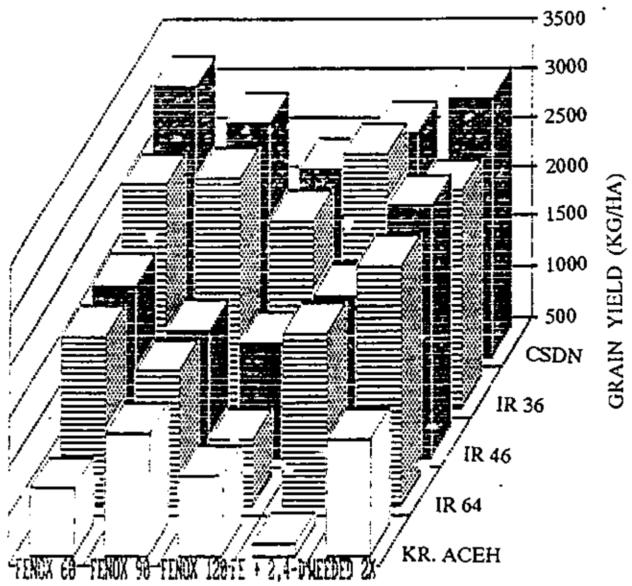


Figure 3. The influence of fenoxaprop-ethyl herbicide on grain yield of five rice varieties.

The influence of fenoxaprop-ethyl on grain yield was not significant compared to two hand-weedings except in the plots sprayed at 120 g a.i./ha. This again indicated that herbicide fenoxaprop-ethyl at high dosage significantly reduced the yield of rice (Figure 3).

CONCLUSION

Fenoxaprop-ethyl herbicide applied at 17 dat at rates of 60, 90 and 120 g a.i./ha and 90 g a.i./ha + 2,4-D at 140 g a.i./ha did not cause toxicity in the rice plants. The use of fenoxaprop- ethyl herbicide at 120 g a.i./ha reduced the growth and grain yield of rice, but not at the rates of 60 and 90 g a.i./ha.

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PROSPECTS FOR BIOHERBICIDE DEVELOPMENT IN SOUTHEAST ASIA

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ABSTRACT

Biological weed control research in Southeast Asia is limited and research efforts have been directed almost exclusively to the use of insects for control of aquatic weed species. Plant pathogens also offer excellent opportunities to be utilized in biological weed control programs. Field observations and results of preliminary experiments indicate the prospects for discovering and subsequently developing specific bioherbicides for major weeds of rice and other crops in Southeast Asia are excellent.

INTRODUCTION

For one half of the world's population rice (*Oryza sativa* L.) is the major stable food crop. Major rice-producing countries are in Asia, Latin America, and Africa, with over 90% of the world's rice production in Asia. There have been dramatic increases in rice production from 1960 into the 1980's. These increases were due to the introduction and use of modern rice varieties and production technologies. Most of this increase in rice production was realized in South and Southeast Asia. However, during the past five years increases in average yields and in rice crop area have ceased (IRRI 1989).

Over 70% of the world's rice is produced in irrigated ricelands, the most favorable rice growing environment. Less favorable, but increasingly important rice growing environments, are the rainfed areas, the uplands, and the deepwater rice areas. In Asia irrigated rice areas are limited and there has been a decline in growth in irrigated areas devoted to rice production (IRRI 1989). Therefore, increases in rice production will not be realized by simply increasing crop areas, but rather by increasing irrigated rice yields and by improvements in the less favorable rice environments of the rainfed, the uplands, and the deepwater rice systems (IRRI 1989).

Tremendous gains in irrigated rice yields have been made through semi-dwarf, photoperiod insensitive, and fertilizer responsive varieties and much of the yield potential has been achieved (IRRI 1989). Improved management strategies through technology change, rather than plant breeding *per se*, are likely to provide the future gains in rice productivity.

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As population growth continues, scientists, farmers, politicians alike are challenged to meet this ever-increasing need for rice by developing and implementing technology to increase rice production and to decrease costs of production. This research and development must be in the context of long-term sustainability of rice production, environmental and economic sustainability, and the well-being of society. Increased productivity is central to improving nutrition, alleviating hunger, and increasing farm income in most rice-producing countries.

This paper will briefly review the weed problems in rice-based cropping systems, examine the prospects of biological weed control, and describe a research program focused on assessing the potential of naturally occurring plant pathogens on selected weed species.

WEEDS AND THEIR CONTROL

Weeds are a major problem in all Southeast Asia rice production systems including transplanted lowland rice, broadcast seeded flooded rice, rainfed rice, deep water rice, and upland rice, commonly causing yield losses of 40% or more (De Datta and Barker 1977; Noda 1977; Chandler 1979; Gupta and O'Toole 1986; Vongsaroj *et al.* 1988; De Datta *et al.* 1989). Available weed control strategies include water management, other aspects of habitat management, hand weeding, mechanical control, and chemical herbicides each with its advantages and limitations. Managing water for weed control in rice can provide good control of some (but not all) weeds in irrigated lowland rice although it is applicable only where irrigation systems are available (Williams *et al.* 1990). Hand weeding is expensive (if labor must be hired) and time consuming. Mechanical weeders can reduce labor costs, but yields are also often reduced when mechanical weeders are used. Herbicide use in rice is dependent upon reliability of the product, sensitivity of rice seedlings, availability, and economics. In much of the rice production area in Southeast Asia, especially in upland and rainfed rice where individual farms are small, few farmers use herbicides. In the larger scale production areas and in areas where labor costs are high herbicides are more widely used. However, concerns over widespread use of chemical herbicides include applicator safety, environmental contamination, and population shifts towards more noxious problematic weeds. Prospects for biological control using insect or plant pathogens to control weeds in rice without harming the crop or the environment have received almost no study (Gupta and O'Toole 1986).

Biological weed control efforts in Southeast Asia, with the exception of two aquatic weeds, water hyacinth (*Eichhornia crassipes* (Mart.) Solms.) and kariba weed (*Salvinia molesta* D.S. Mitchell), are not extensive. Most of the work has involved the use of insects as biocontrol agents with only a cursory examination of plant pathogens as potential biocontrol agents of tropical weeds (Napompeth 1982; Torres 1986; Evans 1987; Nayek and Banerjee 1987; Moody *et al.*, in preparation).

De Datta *et al.* (1989) concluded their paper with the following statement: "Weed scientists and agronomists are challenged to develop and continue to improve weed control technologies that are economically and ecologically sustainable." This project is the commencement of a collaborative research effort within Southeast Asia to discover and develop appropriate biocontrol strategies for major weed problems in rice. These strategies must be both economically and ecologically sustainable.

BIOLOGICAL WEED CONTROL

Biological control of weeds is the deliberate use of natural enemies to suppress the growth or reduce the population of a weed species. Two primary strategies, the classical or the inoculative strategy and the inundative or the bioherbicide strategy have evolved for biological weed control. Numerous published articles describe the fundamentals, methodology, and progress of biological weed control (Wapshere 1982; Schrder 1983; Watson 1989; Hasan and Ayres 1990; Watson 1991; Charudattan 1991).

Bioherbicides are a relatively new weed control strategy and involve the application of spore suspensions of a weed pathogen in a manner analogous to a chemical herbicide application. The use of bioherbicides is based on the fundamental epidemiological principles of plant pathology. Plant disease is the result of the interaction amongst the host plant, the pathogen, and the environment. Serious, devastating disease epidemics of crop plants do occur, but they are the exception rather than the rule since many factors can limit disease development. Pathogen factors such as low inoculum levels, weakly virulent pathogens, and poor spore dispersal mechanisms; environmental factors such as unfavorable moisture and/or temperature conditions; and plant factors such as low susceptibility of the host, host defense response, and widely dispersed host populations often limit disease. The bioherbicide approach is an attempt to bypass many of these restraints on disease development by periodically dispersing an abundant supply of virulent inoculum uniformly onto a susceptible weed population. The application is timed to take advantage of favorable environmental conditions and/or the most susceptible stage of plant growth. Similarly the bioherbicide often is formulated to avoid unfavorable environmental conditions and to facilitate application. As a consequence, the development of an effective bioherbicide requires a comprehensive understanding of the pathogen(s) involved, the biology and population dynamics of the target weed(s), the optimum requirements for disease initiation and development, and the complex interactions within the host-pathogen system.

To date, two biological herbicides have been registered for use in the United States. DEVINE, a liquid formulation of *Phytophtora palmivora* (Butl.) Butl. was registered in 1981 for control of strangler vine (*Morrenia odorata* (H.&A.) Lindl.) in Florida citrus groves. COLLEGO, a dry powder formulation of *Colletotrichum gloeosporioides* (Penz.) Sacc. f. sp. *aeschynomene* was registered in 1982 for the control of northern jointvetch (*Aeschynomene virginica* (L.) B.S.P.) in rice and soybeans in Arkansas, Louisiana, and Mississippi. Another bioherbicide product (LUBOA 2) is being used in China for the control of dodder (*Cuscuta* spp.) in soybean. No other bioherbicides are as yet registered for use, but active research programs in various laboratories within North America, Europe, and elsewhere are making rapid progress towards the development of additional bioherbicide products for specific weed problems (Watson 1989; Charudattan 1991).

The development of a biological herbicide involves three major phases or stages: 1) discovery, 2) development, and 3) deployment. The discovery phase involves collection of diseased plant material, isolation of causal organisms, demonstration of Koch's postulates, identification of the pathogen(s), culture of the pathogen(s) on artificial media, and maintenance of the pathogen cultures in short-term and long-term storage. The development phase includes: 1) determination of optimum conditions for spore production, 2) determination of optimum conditions for disease development and host damage, 3) examination of the infection process, 4) determination of the mode of action of weed pathogens and/or toxins, 5) determination of host range, and 6) quantification of weed control efficacy. The third phase, deployment, involves the close collaboration amongst the researchers, the farmers, and the industrial sector for the production, possible commercialization, and use of bioherbicides. Field evaluation, formulation, fermentation (spore production), regulatory aspects, marketing, and implementation are essential aspects of this phase.

Biological herbicides, are most often host specific and usually will control only one weed species. As a result, bioherbicides are narrow spectrum and normally will be used in combination with other weed control methods including hand weeding, mechanical, or low rates of chemical herbicides to obtain broad spectrum control of common weed species complexes associated with crop production systems.

COLLABORATIVE BIOHERBICIDE RESEARCH PROGRAM IN SOUTHEAST ASIA

The goal of this project was to establish a collaborative research and development program between McGill University and appropriate organizations and institutes in Southeast Asia to facilitate the discovery and implementation of biological weed control strategies against major problem weed species in rice-based cropping systems. The initial collaboration has been with scientists at the International Rice Research Institute (IRRI) and scientists at the University of the Philippines at Los Baños (UPLB).

From August 10 to October 25, 1990, I was a Visiting Scientist at IRRI supported by CIDA. The project, "Establishment of a Collaborative Biological Weed Control Program in Southeast Asia," involved surveying weeds of rice for disease, collection of diseased weeds, isolation of the causal organism(s), and initiation of tests to evaluate selected pathogens as candidate bioherbicides for major weeds in rice-based cropping systems. After discussions with Dr. K. Moody (IRRI) and weed scientists at UPLB, the following major weeds of rice-based systems in Southeast Asia were selected as primary targets for the bioherbicide approach: jungle rice, (*Echinochloa colona* (L.) Link), barnyard grass (*E. crusgalli* (L.) P. Beauv.), monochoria (*Monochoria vaginalis* (Burm. f.) Kunth), smallflower umbrella sedge (*Cyperus difformis* L.), rice flatsedge (*C. iria* L.), purple nutsedge (*C. rotundus* L.), gooseweed (*Sphenoclea zeylanica* Gaertn.), globe fingerush (*Fimbristylis miliacea* (L.) Vahl), and giant sensitive plant (*Mimosa invisa* Mart.). Irrigated, rainfed lowland, upland, and deepwater rice systems were examined in the Philippines, Thailand, Malaysia, and Indonesia. Pathogens were collected only in the Philippines and over 120 collections of pathogenic organisms from 34 different weed species were made.

A total of 189 cultures isolated in 1990 are presently stored at IRRI. Fungal organisms isolated from jungle rice, goosegrass (*Eleusine indica* (L.) Gaertn.), smallflower umbrella sedge, rice flatsedge, purple nutsedge, long-fruited primrose willow (*Ludwigia octovalvis* (Jacq.) Raven), globe fingerush, and monochoria were inoculated onto their respective host plants under greenhouse conditions. Many of these isolates were pathogenic on their hosts and are presently being evaluated at IRRI as biocontrol agents for these noxious, troublesome weeds.

RESEARCH PROTOCOLS

The following is a brief outline of the experimental procedures followed during a bioherbicide research program.

1) **Collection of organisms (discovery):** Diseased weed material is collected from rice fields and the causal organisms isolated in pure culture using standard plant pathology techniques. Koch's postulates are evaluated on host plants grown under controlled environment conditions in the greenhouse, or on healthy weeds in the field and the pathogens identified. Permanent cultures of the collected organisms are maintained.
2) **Culture conditions:** Sufficiently large quantities of viable spores (infective propagules) are required to conduct studies on disease development

and host range of the pathogens and to provide an efficient method of spore production for subsequent field applications. These studies are also the initial phase of the scale-up procedures directed towards large scale industrial "fermentation" or smaller scale "cottage" industry production. Results of the laboratory shaker culture experiments formulate the basis of subsequent studies in 2L, 14L, and larger "fermentation" systems.

Various liquid culture media (Czapek Dox, Richard's, Malt Extract, Potato Dextrose and V-8) are prepared and seeded with the pathogens to determine the optimum liquid culture for maximum spore production.

If cultures fail to sporulate or do not sporulate profusely, media will be altered (reduced carbohydrate content, altered composition, or incorporation of host plant extract) or culture conditions (light/dark sequence, near ultraviolet light) will be altered to induce sporulation. Some pathogens may not sporulate in submerged liquid culture and appropriate solid media culture systems will be determined.

3) **Disease development:** The biology of each pathogen-host combination must be carefully examined to determine the optimum conditions (and environmental limits) for spore germination, penetration, infection, and disease development. Studies are conducted in controlled environment growth chambers and/or in a greenhouse. A spore suspension of the pathogen is prepared from the liquid culture media in distilled water and sprayed onto test plant seedlings. The fungus is applied at a rate of 10^9 spores/m^2 and placed into a dew chamber at 27 C in the dark for 24 hours. After the dew period, the inoculated plants are removed from the dew chamber and placed into a controlled environment chamber (27 C day 12 hr and 22 C night 12 hr). Plants are in the 2-3 leaf stage with 3-4 plants per pot with 4 replications. Appropriate non-inoculated control plants are part of each experiment. Disease incidence and severity are recorded 7 days and 14 days after inoculation. In subsequent experiments the following parameters are studied: dew period temperature (20, 24, 28, 30, 32, 34 C), dew period duration (continuous - 6, 12, 18, 24, 30, 36 hours, interrupted - multiples of 3, 6, and 9 hours) spore concentration (10^4 to 10^9 spores/m^2), environmental conditions during disease development (temperature ranges of 15-25, 20-30, 25-35) and plant growth stage (seedling, 2-3 leaf, 4-5 leaf, and 6 leaf).

4) **Host range:** Utilizing the optimum conditions for disease development determined above, the laboratory host range of the pathogen is determined. Most bioherbicides must, of necessity, have a restricted host range; therefore host range determination is an important phase of the bioherbicide research program. Plants closely related to the known host are the most intensively tested group while plant species of more distant relationship are less intensely tested. At least 4 plants of each test species are inoculated with the bioherbicide pathogen. Approximately 50-75 different plant species are tested and each test has appropriate control (known host plants) treatments. Results of host range tests conducted under artificial growth chamber conditions must be viewed with some caution as most studies extend the actual host range of the pathogen. Therefore, host range studies are also conducted under field conditions. These studies are set up similar to a disease garden with 1-2 m lengths of each test species planted in rows and artificially inoculated with the bioherbicide spray suspension. Three to four replications plus suitable control treatments (host plant) are included in each of two growing seasons. Two applications of the spore suspension are made, once at the seedling stage and once just prior to flowering of the test species. Disease incidence and disease severity are recorded 1 wk, 2 wks, and 4 wks after application. If disease symptoms occur on the test species, attempts to re-isolate the pathogens are conducted. Tests to detect symptomless infection are also conducted.

5) **Host damage:** Within controlled environment chambers and in the greenhouse, using optimum conditions determined previously, the effect of the microbe on the host plant is determined. Parameters such as weed biomass productivity, reproduction, and propagule survival are evaluated. Based on the results of the growth chamber and greenhouse experiments, the efficacy of the bioherbicide is determined under field conditions. Four rates of the pathogen (0, 10^7, 10^8 and 10^9 spores/m^2) are applied at three different growth stages of the weed. Disease incidence, disease severity and weed control rating are recorded 2 and 4 wks after application. Plots are harvested at the end of the growing season with weed density and weed biomass being recorded. Other experiments are conducted in the field to evaluate the efficacy of the bioherbicides to control the target weed in the cropping system and to integrate the bioherbicide strategy with other weed control tactics used in rice-cropping systems.

6) **Production scale-up:** Larger-scale propagation of these microorganisms in fermentors is required for two purposes: 1) to supply a sufficient quantity of viable spores for field assessment of their effectiveness, and 2) to establish the critical culture parameters for scale-up production. Nutrient requirements (C- and N-sources, minerals, growth factors) as well as physical conditions of culture (temperature, pH, agitation, aeration) for maximum yields of the active form of the microorganism are established. Efforts are made to replace commercial laboratory media for cultures with less expensive C- and N-sources, e.g., molasses, grain mash, fish meal, soybean meal, whey, etc. Techniques will also be developed to produce sufficient quantities

of fungal spores for on farm use in the Philippines and other Southeast Asian countries. These systems would utilize inexpensive, readily available materials and allow farmers to grow their own biocontrol agent.

POTENTIAL IMPACT OF THE PROJECT

A fundamental need of the rice farmers is to have safe, low-cost, effective means to control weeds in their crops. The potential benefits of this project include:

a) Viable alternatives to hand labor (reduced cost, more time for other pursuits),
b) Viable alternatives to chemical herbicides (less cost, reduced hazards to applicator and the environment),
c) On-farm production of bioherbicide product is feasible,
d) Opportunity for small "cottage" industry to develop,
e) Opportunity for larger scale industry to produce, market, and supply bioherbicide products for larger markets throughout Southeast Asia, and
f) Excellent opportunities for graduate student training.

With the necessity to develop long-term sustainable rice production, there is clearly a need to discover new knowledge and develop the technology that will increase rice production and decrease the costs of production within the context of environmental sustainability and human well-being. To do this, recent advances in science and future advances must be incorporated into rice production systems. Pests continue to be a major limiting factor in rice production and new technologies are being advanced for the control of insect pests and crop diseases. Development of efficacious biocontrol strategies is a key component to sustainable development in Southeast Asia, but to date biocontrol of weeds is in its infancy. Prospects for biological control of important rice weeds is excellent and, through subsequent collaborative research and development programs, viable and sustainable biocontrol strategies of weeds will contribute to the reduction of chemical pesticide inputs, to the reduction of the accumulation of toxic residues in the soils, to dependable pest management practices, and to reduce dependency on imported inputs.

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CROP WEED COMPLEXITY

INTEGRATED WEED MANAGEMENT OF DIRECT SEEDED WET RICE FIELDS IN SOUTH EAST ASIA AND PASIFIC REGIONS, WITH SPECIAL REFERENCE TO MALAYSIA

KAZUYUKI ITOH[1]

ABSTRACT

Rice has been planted for more than four thousand years throughout the Asia-Pasific region. Traditionally, it is cultivated by transplanting method in a lowland area and hillside. In the irrigated areas of Thailand, Philippines, Sri Lanka, Malaysia and Fiji Island, rapid changes from transplanting to direct seeded method have been motivated by the introduction of effective herbicides, development of short-culm and early maturing rice cultivars and high labour cost of transplanting.

Changes in the rice planting method has caused a shift of weed population and flora. Tremendous increase in the population of grassy weeds especially *Echinochloa crus-galli* complex, *E. colona*, *E. stagnina*, *Leptochloa chinensis* and *Ischaemum rugosum* has been noticed.

Effective weed control through integrated weed management (IWM) for wet seeded rice are discussed.

INTRODUCTION

Direct seeding of rice is the predominant crop establishment technique in the granary areas in Malaysia. This method of crop establishment could be conveniently classified into wet seeded and dry seeded rice cultures.

In the Muda area of Malaysia, dry seeded rice culture is carried out mainly in the off cropping season (February/March), in a non puddled soil condition. In certain areas, volunteer seeding method is also practised with minimum tillage. Volunteer seedling is a non-seedling method. Seedling establishment is depending on the shattered or discharge seeds from the combine harvester in the previous season crop. The number and weight of all dispersed seeds by combine harvester were 735 seeds/m^2 and 19.5 g/m^2 respectively (Hiraoka *et al.*, 1990). The average yield loss due to the utilization of combine harvesters was recorded as 3 - 5 % (Abdullah, 1987). As a result every field receives as much as 100 - 200 kg seeds/ha. The quantity of shattered grain is equivalent to 2 - 3 times of the recommended seed rate (60 kg/ha) used for dry seeded culture.

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Wet seeded culture under puddled field is a better method compared to the dry seeded culture for weed control, because puddling is an essential technique for weed control. Most of the buried young seedlings and stems of the perennial weeds do not establish after good puddling. In addition, puddling enables uniformity in seedling establishment. Under circumstances of unlimited water supply for crop requirement, wet seeded rice culture is superior to dry seeded crop establishment in terms of weed management and crop performance.

PRACTICES OF WET SEEDED TECHNOLOGY

In recent years, labour shortage and rising labour cost have motivated many farmers in the Philippines, Thailand and Malaysia to switch from transplanted to direct seeded rice. Under wet seeded condition, the land is rotovated twice and subsequently levelled with wooden plank or banana stem. Fig. 1 shows dramatic changes in the method from transplanting to direct seeding, in the Muda area of Malaysia. The changes were closely related to the development of new cultivars and widespread adoption of combine har-

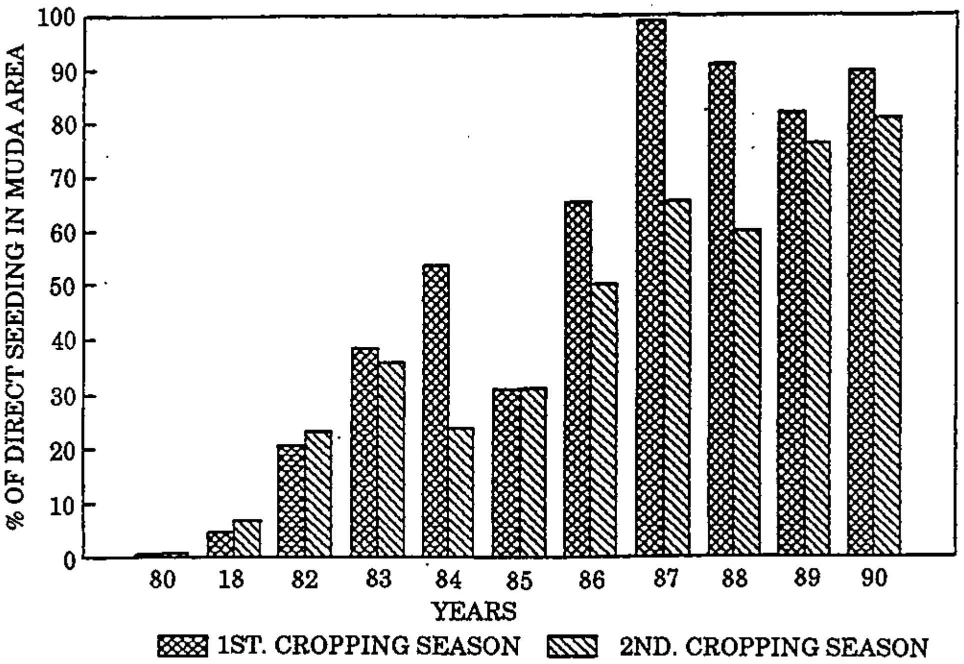

Figure 1. Quick changes due to direct seeding method in the Muda area, Malaysia. Source : Division of Agriculture, MADA

vesters. The most popular rice variety, MR 84 which is relatively short, high yielding and resistant to blast and Tungro, was released in 1986. This cultivar dominated the major irrigated areas in Malaysia due to its high adaptability to direct seeded condition and its tolerance to mainly the pressure of high plant density (Chen, 1987). At present, approximately 62% of Muda area is planted with MR 84.

Under wet seeded rice culture, the fields are irrigated 5 to 10 days after seeding (DAS). Post-emergence herbicides are sprayed after the crop has established and the water level is sufficient. In Malaysia, surface drainage after puddling the field was carried out by pulling a "gunny sacks" filled with soil, to form small drains, while in Fiji Island, farmers usually construct field ditches by using metal drum drawn by cattle.

Field ditches could also be costructed from tractor wheel rut. Advanced method of field ditch construction using an auger trencher has been successfully tested in the Muda area (Kanetani, 1991).

Field studies indicated that the tractor wheel-rut ditch was more effective than the manually constructed ditch with reference to field drainage after puddling. The water logged area after a week were 9.7 % in no-drainage field, 7.3 % in a field applying the gunny sack drainage and 3.5 % in fields with tractor wheel ruts (Fujii *et al.*, 1991). Concerning the surface water drainage effect, the percentage of undrained area was 10.5 % , 8.3 % and 3.3 % respectively (Fig. 2). It is observed that there is a close inverse correlation between seedling establishment of the crop and the duration of water logging.

Selection of cultivars and plant densities are also important factors for weed control. Comparative studies were carried out by Tay *et al.* (1990), Azmi and Othman (1987), De Datta and Nantasomsaran (1990), etc. under wet seeded puddled field condition. The ideotype for direct seeding is envisioned to possess low tiller number with compact panicles of intermediate length. This ideotype should have strong culm, bearing erect leaves and possesses a deep rooting system (Tay *et al.*, 1990).

Field levelling, puddling and drainage are the most important factors to achieve optimal crop establishment. Seasonal rice yields in the Muda Scheme (96,000 ha) of Malaysia is shown in Table 1. The contrast in the average yield between transplanting method and direct seeded method is not distinct. However, many farmers are of the opinion that wet seeded rice culture could produce higher yield resulting from more spikelet number per unit area.

According to the survey conducted by MADA on the first cropping season in 1988, each family possessed 1.6 ha of land and their total income from rice cultivation per family was M$ 3,109.83. Total expenditure for one rice cropping season in that year was M$ 1,697.28. The average expenditure on herbicides was only M$ 44.48 (US$ 16.06) or 2.6 % of total product cost in 1988. Although average cost of weed control per ha was M$ 22.61 in the transplanting period

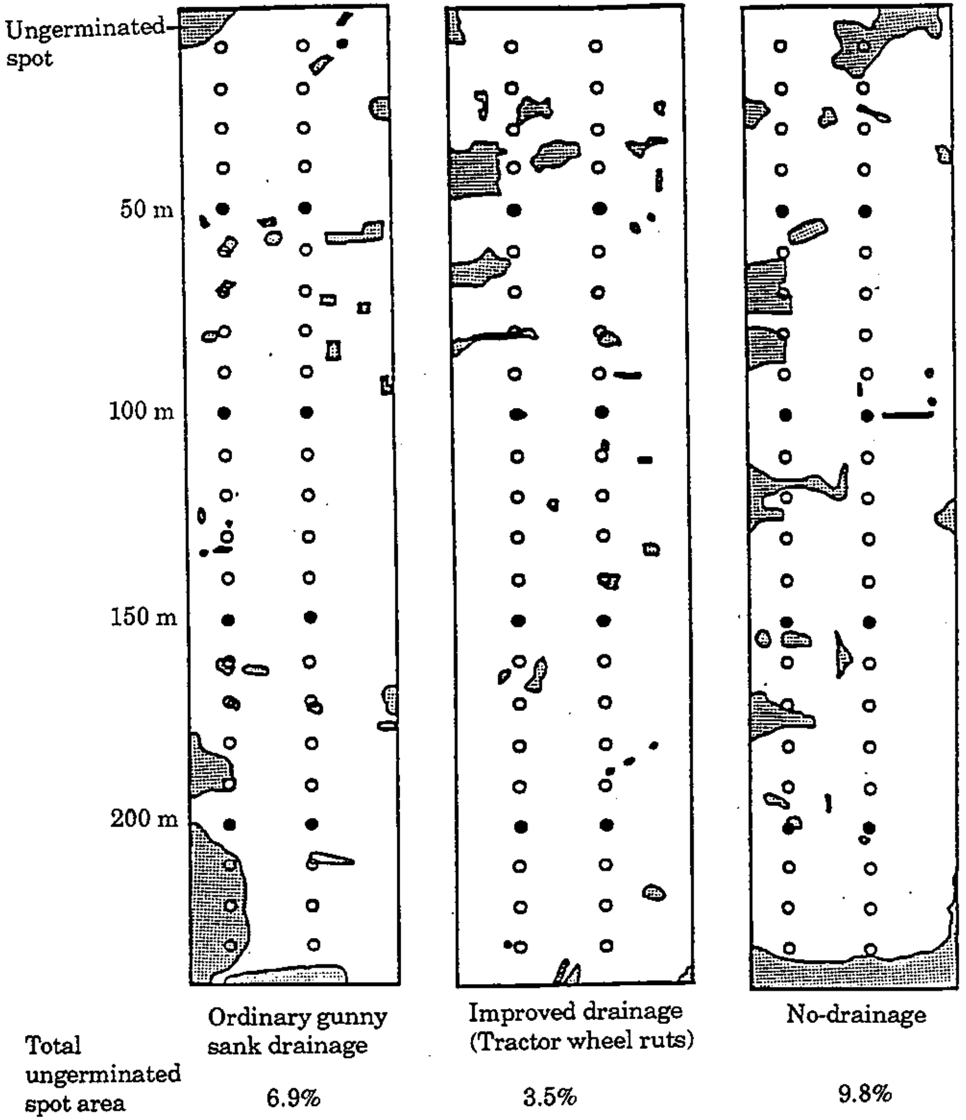

Figure 2. Comparison on establishment of seedlings in surface water drainage field through the wheel ruts of a tractor (Quoted from Kanetani, 1991)

Table 1. Seasonal change of rice yields in the Muda fields, Malaysia (ton/ha)

Year	1st.*	2nd.*	
1970	3.77	3.68	Started the double cropping
1971	3.94	3.89	
1972	3.99	3.85	
1973	4.02	3.90	
1974	4.14	4.05	
1975	4.18	3.68	
1976	4.71	3.85	
1977	4.02	3.68	
1978	-	3.60	Stopped the cultivationof 1st.cropping season
1979	4.39	4.08	
1980	3.98	4.01	Started the direct seeding method
1981	3.76	4.10	
1982	2.94	3.72	Infected rice tungro disease
1983	2.69	2.71	
1984	2.95	4.20	
1985	3.57	4.00	
1986	3.51	4.20	Introduced MR 84 variety
1987	2.29	4.03	Stopped irrigation water in 1st.cropping season
1988	2.86	3.83	Damaged grassy weeds
1989	3.29	4.32	

* cropping season. 1st. cropping season : main cropping season. (March - August), 2nd. cropping season : off cropping season (October - January).
Source : Division of Agriculture, MADA.

(1976 - 1981), Muda farmers spent an average of M$ 24.71/ha for weed control in this year. In 1988 there was heavy damages caused by grassy weeds and consequently the farmers had to spend more money purchasing herbicides to arrest this menace. Each farmer obtains a small total income in the Muda area. Even though a farmer knows an effective herbicide, but if the yield is the same comparing before and after use then preference would be given for the utilization of the cheaper herbicide (Table 2).

Nevertheless if there is an effective herbicide and good management of rice cultivation, a better net income could be envisage, because there should be an increase in the yield up to 1-3 ton/ha. In Malaysia, North Sumatra and the Central Plain of Thailand where real wages were on the rise in the early 1980 (Fig. 3). During this time, direct-seeding is likely to expand more rapidly compared with Central Java (De Datta and Flinn, 1986). At present, in Indonesia, especially Central Java, where real wages are rising, direct-seeding may become more popular in the future.

Table 2. Commercially available herbicides with cost per hectar in the Muda area, Malaysia

Kind of herbicide	Recommended rate (kg a.i./ha)	Herbicide M$/ha	costs US$/ha
Molinate (Odram)	3.0	121.70	43.94
Molinate/Propanil (Arrosolo)	4.0	142.50	51.44
Oxadiazon (Ronstar-2D)	0.5	90.00	32.49
Pretilachlor (Sofit)	0.5	90.00	32.49
Benthiocarb (Saturn 5 G)	3.0	98.00	35.38
Propanil (Stam F-34)	3.0	90.00	32.49
2,4-D IBE (Rumputox)	0.8	18.00	6.50
2,4-D Sodium salt (K2,4-D Sodium)	0.8	8.30	3.00
Bensulfuron methyl (Londax)	0.1	57.40	20.72
Metsulfuron methyl (Ally 20 DF)	0.01	8.50	3.07
Bensulfuron/Metsulfuron (Sindax)	0.05	30.00*	10.83
Phenoxaprop ethyl (Whip's)	0.06	106.00*	38.27
Quinclorac (Facet)	0.25	155.00*	55.96
Paraquat (Gramoxone)	0.25	31.00	11.19

* New herbicides, the price observed in the first cropping season, 1991, the other data observed in the first cropping season, 1990.
US$ 1.00 = M$ 2.77

MAJOR WEEDS AND SHIFT TO POTENTIAL WEEDS

Major Weeds Under Wet Seeded Rice

The weed spectrum in the Muda area of Malaysia is shown in Table 3. *Echinochloa crus-galli* complex (*E. crus-galli*, *E. crus-galli* var., *formosensis* = *E. glabrescens*, *E. oryzicola*, etc.), *Leptochloa chinensis*, *Fimbristylis miliacea*, *Marsilea crenata* and *Monochoria vaginalis* are the five most important weeds in the Muda area (Ho, 1991). *Ludwigia hyssopifolia*, *Sagittaria guyanensis* and *Sphenoclea zeylanica* are also common weeds in the Muda area. *Echinochloa* species in the northern Peninsular Malaysia is shown in Table 4.

Most of these weed species in rice fields are also found at the edges of the canals and drains (Table 5). *Hymenachne pseudo-interupta*, Wild rice (*Oryza rufipogon*) and *Scirpus grossus* are also important weeds in the fields.

Eleocharis spp. are found near the coast or tidal zone. Most of the annual weeds (*Echinochloa crus-galli*, *Cyperus difformis*, *Monochoria vaginalis*) are not found in the canals. These weeds are dispersed by agricultural machineries, cattles and irrigation water.

Major weeds of wet seeded fields in the Fiji Island are *E. crus-galli*, *Scirpus juncoides* and *Monochoria hastata*. Also, *E. crus-galli* is dominant now (Table 6). The flora is quite similar to the Malaysian species.

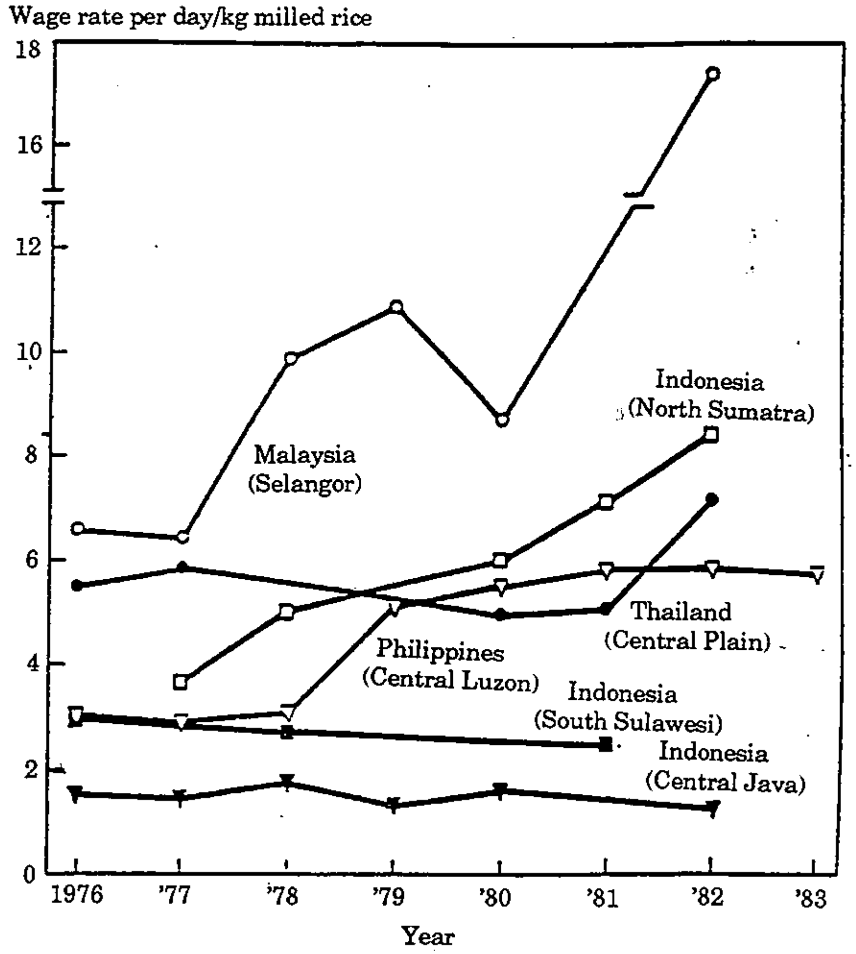

Figure 3. Long term trends in real agricultural wages in Indonesia, Malaysia, the Philippines and Thailand.
Real wage derived at wage rate per day divided by the price per kg of milled rice.
(Quoted from De Datta and Flinn, 1986)

Table 3. Weeds in Muda paddy fields, Kedah, Malaysia (1990/91)

Constantly discovered weeds	Commonly found weeds	Rarely found weeds
Bacopa rotundifolia	*Brachiara mutica*	*Aeschynomene indica*
Cyperus difformis	*Echinochloa oryzicola*	*Azola pinnata*
Cyperus iria	*Echinochloa stagnina*	*Blyxa malayana*
*Echinochloa colona**	*Cyperus babakan**	*Ceratopteris pteridoides*
Echinochloa crus-galli	*Cyperus pilosus*	*Crotalaria quinqifolia*
Fimbrystylis miliaceae	*Cyperus procerus*	*Cyperus compactus*
Leersia hexandra	*Cyperus pulcherrimus*	*Cyperus imbricatus*
Leptochloa chinensis	*Hymenachne pseudo-interupta*	*Eleocharis dulchis*
Limnocharis flava	*Lemna minor*	*Eleocharis orchodaris*
Ludwigia hyssopifolia	*Ischaemum rugosum*	*Enhydra fluctuans*
Marsilea crenata	*Oryza rufipogon*	*Fuirena umbellata*
Monochoria vaginalis	*Melochia corchorifolia**	*Hydrocera trifolia*
Najas graminae	*Paspalum distichum*	*Hydrilla verticillata*
*Scirpus grossus**	*Scirpus juncoides*	*Ipomoea aquatica*
Sagittaria guyanensis	*Scirpus lateriflorus*	*Isachne globosa*
Sphenoclea zeylanica	*Utricularia flexuosa*	*Monochoria hastata*
		Nymphoides indica
		Ottelia alismoides
		Panicum repens
		Pistia stratiotes
		Polygonum barbatum
		Rotala indica
		Salvinia molesta

* Serious under dry seeded field.

Shift to Potential Weeds

Major rice weeds in the KADA field of Kelantan, Malaysia is shown in Table 7. *E. crus-galli* was not found in the first season of 1990. However, with the introduction of direct seeding recently, the species appeared under wet seeded KADA fields in 1991.

It is anticipated that continuous efforts to control annual grasses may trigger weed shift in favour of the perennial grasses such as *Ischaemum rugosum*, *Echinochloa stagnina*, *Oryza rufipogon*, *Paspalum distichum*. *Ischaemum rugosum* was found in both upland and lowland condition. *E. stagnina* could be found along the band of fields in the Muda area. Nevertheless *O. rufipogon* is currently a minor weed in direct seeded rice Malaysia. Its

Table 4. *Echinochloa (x=9) species in Northern Peninsular Malaysia*

Common name	Species name	Synonyms	Names used in error or inappropriate names
Tainubie (J)	*E. oryzicola* Vasing. (4x, 2n=36)	*Panicum oryzicola* Vasing. *E. crus-galli* (L.) Beauv. var. *oryzicola* (Vasing.) Ohwi *E. phyllopogon* (Stapf.) Koss. ssp. *oryzicola* (Vasing.) Koss. var *genuina* Koss.	*E. crus-galli* (L.) Beauv. var. *hispidula* (Retz.) Honda
Hime-tainubie (J)	*E. crus-galli* (L.) Beauv. var. *formosensis* Ohwi (6x, 2n=54)	*E. glabrescens* Munro ex Hook.f. *E. crus-galli* (L.) Beauv. var. *kasaharae* Ohwi *E. micans* Koss. *E. oryzoides* (Ard.) Fritsch	
Inubie (J) Barnyard grass (E) Sambau misan (M)	*E. crus-galli* (L.) Beauv. var. *crus-galli* (6x, 2n=54)	*Panicum crus-galli* L. *E. crus-galli* (L.) Beauv. ssp. *genuina* (Hack) Honda var. *echinata* (Trin.) Honda	*E. caudata* Roshev. *E. crus-galli* (L.) Beauv. var. caudata (Roshev.) Kitagawa
Kohimebie (J) Jungle rice (E) Sambau padi burung (M)	*E. colona* (L.) Link (6x, 2n=54)	*E. colonum* (L.) Link *Oplismenus colonum* (L.) H.B.K. *Panicum colonum* (L).	*E. crus-galli*(L.)Beauv. spp. colonum Honda
Sambau merah (M)	*E. stagnina* (Retz.) Beauv. (6x, 2n=54) *E. picta* (Koen.) Michael (14x, 2n=126)	*Panicum stagninum* Retz. *E. stagnina* (Retz.) Beauv.	*P. crus-galli* (non Beauv.) Hooker f.

J: Japanese name, E: English name, M: Malay name

Table 5. Dominant weeds in canals of Northern Peninsular Malaysia

Species	Life style	Propagation	place		
			KADA	MADA	KRIAN
1. *Eichhornia crassipes*	Flo	V.	+++	+++	+++
2. *Hymenachne pseudointerrupta*	S-A	V.Se	++	+++	+++
3. *Hydrilla verticillata*	Sub	V.Se	+++	++	+++
4. *Oryza rufipogon*	S-A	V.(Se)	+++	++	+
5. *Scirpus grossus*	S-A	V.(Se)	+++	+	++
6. *Ludwigia adscendens*	Eme	V.se	+	+++	++
7. *Polygonum barbatum*	S-A	V.se	+++	+	+
8. *Ipomoea aquatica*	Eme	V.	+	+++	++
9. *Eleocharis dulcis*	S-A	V.se	+++	+	+
10. *Nymphaea nouchali*	Eme	V.	-	++	++
11. *Pistia stratiotes*	Flo	V.(Se)	+	++	+
12. *Limnocharis flava*	S-A	Se	+	++	+
13. *Eleocharis ochrostachys*	S-A	V.Se	+	++	+
14. *Leersia hexandra*	S-A	V.Se	+	+	++
15. *Utricularia aurea*	Sub.	V.se	+	+	++
16. *Cyperus distans*	S-A	V.se	++	+	+
17. *Monochoria hastata*	S-A	Se	+	+	++
18. *Ottelia alismoides*	Sub.	Se	+	+	++
19. *Lemna perpusilla*	Flo.	V.Se	-	++	++
20. *Azolla pinnata*	Flo.	V.Sp	-	+	++
21. *Salvinia molesta*	Flo.	V.Sp	-	+	++
22. *Ceratopteris thalictroides*	Sub.	Sp	+	+	+
23. *Marsilea crenata*	S-A	V.Sp	+	+	+
24. *Alocasia macrorrhiza*	S-A	V.	+	+	+
25. *Ceratophyllum demersum*	Sub.	V.Se	-	-	++
26. *Nymphoides indica*	Eme.	V.	++	-	-
27. *Najas graminea*	Sub.	V.Se	-	-	++
28. *Nelumbo nucifera*	Eme.	V.Se	-	-	++
29. *Alternanthera sessilis*	S-A	V.Se	-	+	-
30. *Salvinia cucullata*	Flo.	V.Sp	+	-	-
31. *Echinochloa stagnina*	S-A	V.	-	+	-

Flo.: Floating; Sub. : Submerged; Eme. : Emergence; S-A : Semi- aquatic
V : Vegetative propagation; Se : Seed propagation; () : A few case observed ;
Sp : Spore propagation
+++ : Very common; ++ : Common; + : Frequent; - : not observed

potential menace is high, because wild species can easily be established by seeds under wet seeded fields and under volunteer seedling. Out-crossing of O. rufipogon with cultivated rice may result in annual weed types which are likely to be more noxious (Itoh *et al.*, 1990b). A weed shift tendency and typical weeds from transplanting to wet seeding method is shown in Table 8. Noxious weeds which includes herbicide resistant/tolerant weeds and perennial weeds will still remain in the near future.

Table 6. Major weeds of irrigation rice fields in Fiji.

Scientific Name	a or p	Common Name	Degrees of infestation
Echinochloa crus-galli (G)	(a)	Barnyard grass	***
EchinOchloa stagnina (G)	(p)	Perrenial barnyard	**
Cyperus difformis (C)	(a)	Small flower umbrella plant	*
Eleocharis ochrostachys (C)	(p)	Kuta (F)	* (salty soil)
Scirpus juncoides(C)	(p)	Bunchy sedge	***
Monochoria hastata (M)	(a)	Pikerel weed	***
Ludwigia hyssopifolia (D)	(p)	Nai Qisa (F)	*

Note :
G : Gramineae
C : Cyperaceae
M : Monocotyledons
D : Dicotyledons
(a) : annual weed
(p) : perennial weed
(F) : Fijian name
*** : heavy
** : moderate
* : slight

Table 7. Major rice weeds in KADA, Kelantan, under transplanted rice

Species	Frequency (%) in 1987 *	Relative frequency in 1989**
Monochoria vaginalis	61.7	9.20
Fimbristylis miliacea	44.7	8.21
Cyperus spp.***	38.9	11.83
Ludwigia adscendence	36.2	1.30
Eleocharis ochrostachys	25.5	1.64
Sagittaria quyanensis	25.5	5.60
Marsilea crenata	23.4	3.29
Eleocharis acutangula	21.3	0.33
Ludwigia spp.****	17.0	6.90
*Scirpus juncoides******	12.7	6.25
Limnocharis flava	5.1	8.21
Scirpus grossus	5.1	5.60
Salvinia cuculata	5.1	0.33

* : quoted from Khalid (1988)

$$\text{Frequency} = \frac{\text{number of plots in which species occurs}}{\text{Total number of plots (47 quadrats)}} \times 100$$

** : quoted from Azmi Man (1990), 56 quadrats samples were obtained.

$$\text{Relative frequency} = \frac{\text{frequency value for a species}}{\text{total frequency value for all species}} \times 100$$

*** : annual sedges (*C. iria*, *C. difformis* and *C. digitatus*)
**** : *L. hyssopifolia* and *L. octovalvis*
***** : The species includes *S. lateriflorus* (*S. supinus*)

Table 8. Weed shift tendency from transplanting method to wet seeding method under puddled field condition, Muda field, Malaysia

Rainfed transplanting (past)	Irrigated transplanting (past)	Extensive direct seeding (past and now)	Intensive direct seeding (now and future)
Grasses (*Echinochloa colona*)		Grasses (*Echinochloa crus-galli*)	Herbicide Resistant Biotypes (*Sphenoclea zeylanica*)
Broadleaf weeds (*Limnocharis flava*)	Broadleaf weeds (*Monochoria vaginalis*)		Herbicide Tolerant Species (*Sagittaria guyanensis*)
Sedges (*Cyperus pilosus*)	Sedges (*Cyperus difformis*)	Sedges (*Fimbrystylis miliacea*)	Perennial Weeds (*Echinochloa stagnina*)

WEED CONTROL METHODS UNDER WET SEEDED RICE

Cultural Methods

Rice fields rotovated twice under inundated condition and subsequently puddled reduced the sprouting ability of stolons of perennial weeds (*Echinochloa stagnina*, *Ischaemum rugosum*, *Paspalum distichum*) which were fragmented (Ho and Itoh, 1990). Laboratory study revealed that buds of *E. stagnina* sprouted readily on moist soil surfaces. However, the buds failed to sprout when fully submerged or buried in the puddled soil. Hence, soil puddling after rotovation is a possible method of controlling the spread of *E. stagnina* under wet seeded condition (Table 9).

Table 9. Sprouting ability of *Echinochloa stagnina* 15 days after treatment (quoted from Ho and Itoh, 1990)

Treatment	% of dead nodes	% of living nodes	% of sprouting nodes	No. of leaves/ plant	No. of roots/ plant
Nodes placed vertically on soil surface with axillary buds above water surface	0	100	100	2.61	2.50
Nodes placed horizontally on soil with axillary buds submerged in water	43	57	57	2.15	1.25
Nodes embedded in the soil and submerged with water	100	0	0	-	-

Chemical Control

Low cost herbicides, such as 2,4-D, were widely used in the paddy fields and they are not effective in curbing the grassy weed menace (Table 10). As a result, the application of alternative herbicides is necessary in the adoption of wet seeded rice culture. The spectrum of weeds in the wet seeded rice is much wider than those in the transplanted rice (Lo, 1988b). Combined mixture of herbicides or sequential application are more effective than treatment with only one type of herbicide.

Table 10. Estimated herbicides usage in the Muda Irrigation Scheme, Malaysia (in metric tons)

YEAR	1980	1983	1985	1986	1987	1988
TYPES OF HEBICIDES						
2,4-D IBE	100	180	250	280	250	250
2,4-D Sodium salt	50	20	N.A.	N.A.	N.A.	30
2,4-D Amine	5	20	150	150	140	130
MCPA	1	N.A.	N.A.	1	1	1
Molinate	-	10	110	195	265	380
Molinate + Propanil	-	-	-	-	-	10
Oxadiazon	-	-	10	10	6	6
Propanil	-	-	-	2	14	20
Thiobencarb	-	-	-	-	-	50
Paraquat	10	80	300	320	320	320
Others	N.A.	N.A.	1	2	3	6
Total	165	310	821	960	999	1,203

N.A. - Not available
Source : Division of Agriculture, MADA

Timely application of effective concentrations of molinate, quinclorac, propanil, fenoxaprop-ethyl, pretichlor or benthiocarb are able to reduce losses when there is an occurrence of grassy weeds in the fields. Likewise when there is an infestation of sedges and broadleaf weeds, timely treatment with bensulfuron or 2,4-D herbicides has proven to be able to reduce losses inflicted by them (Azmi and Supaad, 1990; Azmi and Anwar, 1989; Lo, 1988a). In addition, the application period of herbicides is very wide now. For instance fenoxaprop-ethyl can be used from 25 DAS to just before the heading of *E. crus-galli* (Table 11).

The strategic extension campaign (SEC) for integrated weed management (IWM) were carried out by MADA in 1989 - 1990. During the campaign the farmers were trained by MADA staff with a package of simplified technology. The technology included proper land preparation, seed selection, filling up of the vacant areas in the field, good water management, appropriate chemical control and hand weeding (Ho *et al.*, 1990).

Table 11. Relationship between treatment time of fenoxaprop-ethyl and percentage of matured (survived) seeds of *Echinochloa crus-galli*

Fenoxaprop-ethyl treatment	Total number of seeds	Percentage of germination	Number of mature seeds	Percentage of mature seeds
Before heading stage of *E. crus-galli* (9th June 1990)	382	0	5	1.3
At heading stage stage *E. crus-galli* (16th June 1990)	656	0.5	56	9.0
After heading stage of *E.* crus-galli (23rd June 1990)	573	0	127	22.2
Control (non-treatment)	873	1.0	288	34.0

* Germinated and survived seed 70 days after germination test. The seeds were collected 15-25 days after heading stage of *E. crus-galli*.

Surveys conducted by MADA showed that IWM had significantly minimized weed infestation in the campaign area. Although grassy weeds still remained as the most predominant group, their dominance had decreases. It was also noted that *Echinochloa crus-galli* and *E. colona* were effectively was also noted that *Echinochloa crus-galli* and *E. colona* were effectively controlled. Molinate/propanil (Arrosolo) treated areas increased from 5.3 to controlled. Molinate/propanil (Arrosolo) treated areas increased from 5.3 to 19.3%, molinate (Odram 10 G) from 28.7 to 51.6 % and propanil (Stam F 34) from 4.8 to 16.7 % respectively. While the population of *E. crus-galli* and *E. colona* had declined, the infestation of *Leptochloa chinensis* and *Ischaemum rugosum* escalated by 52 % and 870 % respectively (Fig. 4).

Molinate application was carried out on half of the campaign area for two consecutive seasons. It is a highly selective herbicide and was able to control *E. crus-galli* while leaving other perennial or perennial-like grassy weeds uncontrolled. The result suggests that the continuous use of the same herbicides leads to an undesirable shift of weeds.

It is noted that the water retained in the field just and after the application of herbicides is most important. If an effective herbicide is obtained then the continuous utilization has to be averted. Due to the repetition of a herbicide, weed shift problems are encountered (Itoh, 1988; Ho, 1991). In addition, herbicide resistant problem was also experienced (Itoh and Matsunaka, 1990; Itoh *et al.*, 1990).

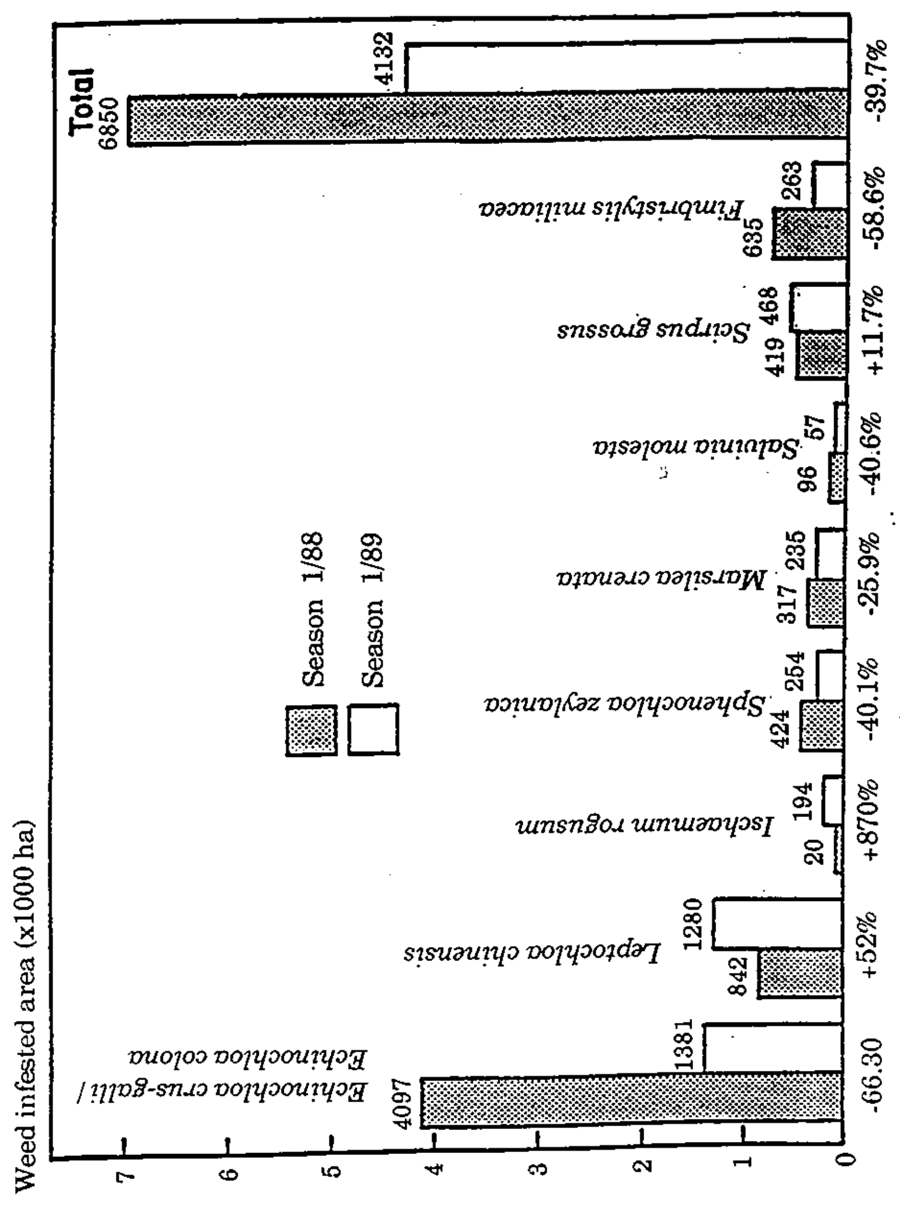

Figure 4. Weed group profile in campaign area, expressed in terms of weed hectarage and proportion of total infestation (adapted from Ho *et al.*, 1990)

Biological Control

The starting point for biological control is to find a selective biological agent against the weeds, leaving the rice crop intact. In order to achieve this, a multi-disciplinary task force involving entomologists, weed scientist, fisheries experts, plant pathologists and extension workers is required. Grass Carp (*Ctenopharyngodon idella*) and Red Tilapia (*Tilapia mossambica* X *T. nilotica-aurea*) have potentials to be used in tropical zone rice fields as biological agent to control weeds (Itoh, unpublished). Nevertheless due to the extensive use of herbicides, insecticides, fungicides and fertilizers, the fishes may be adversely affected (Tan, 1977).

A selective stemborer species (*Emmalocera* sp.) which feeds only on *E. crus-galli* has been discovered (Goto, personal communication). Further studies concerning this stemborer is needed in the future.

CONCLUSION

The principle of Integrated Weed Management (IWM) is easy to understand but implementing the technology is complicated. The Strategic Extension Campaign for IWM by MADA was successful but weed shift problem is still a menace and required continuous monitoring. Hence a good crop establishment and a healthy environment for rice growth is the best way, not only for rice growing but also for weed control.

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CHARACTERISTICS OF PYRIBUTICARB, A NEW HERBICIDE FOR PADDY RICE

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ABSTRACT

Pyributicarb, a new paddy herbicide developed by Tosoh Corporation, was evaluated in greenhouse about its characteristics and factors which might affect its herbicidal efficacy and rice injury. Pyributicarb showed excellent herbicidal activity against annual paddy weeds, especially barnyardgrass (*Echinochloa oryzicola* Vasing.), one of the most important weeds in paddy field, from its emergence to two leaf stage under flooded condition. But it showed almost no injury againts the transplanted young rice seedlings. Herbicidal efficacy of pyributicarb was slightly affected by water over-flow. The movement of pyributicarb in paddy soil was very little, and the safety of pyributicarb against transplanted rice was slightly influenced by application time, water leaching, and water depth. While its safety was not affected by transplanting depth, except 0 cm transplanting.

INTRODUCTION

Pyributicarb is a now paddy herbicide which was developed by Tosoh Corporation. Pyributicarb has been produced as a herbicide against annual paddy weeds, especially barnyardgrass (*Echinochloa oryzicola* Vasing.), one of the most important weeds of paddy rice.

Pyributicarb can be put to practical use in flowable, new type formulation for paddy herbicide. Its characteristics as a paddy herbicide was studied by using both flowable and granule formulations. This paper will discuss the results.

MATERIALS AND METHODS

The experiments were conducted in a greenhouse. In experiment(1) and (2), 10% wettable powder (W.P.) of pyributicarb and butachlor were used. Experiment (3) to experiment (8) used 5.7% flowable (FL) and 3.3% granule (G) formulation of pyributicarb and 2% granule of pretilachlor (Solnet®) were applied.

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(1) **Herbicidal Spectrum and Safety to Rice Plants of Pyributicarb**

Various kinds of seeds and rhizomes of paddy weeds were sowed or transplanted into ceramic pots (180 cm) filled with paddy soil (clay loam). One rice seedling (Yamahoushi, two leaf stage) was transplanted per pot. The pots were flooded to give a water depth of 2 cm. Suspension of pyributicarb W.P. was added dropwise on the surface of water on the next day. The water depth was kept at 2 cm throughout the study period. Herbicidal efficacy and rice injury were evaluated 20 days after application.

(2) **Influence of Application Time Against Herbicidal Efficacy**

Seeds of barnyardgrass were sowed into 1/5000 are plastic pots filled with paddy soil (clay loam). Water was kept at 3 cm depth throughout the study period. Each herbicide was applied at the prescribed stage, and water leaching of 2 cm/day was given for two days from the next day of the application. The dry shoots were weighed 30 days after application.

(3) **Influence of Water Overflow Against Herbicidal Efficacy**

Bach herbicide was applied in the same condition as experiment (3) at 1.5-2 leaf stage of barnyardgrass. Six hours after application, at first 375 ml water and then 230.9 ml water in pots was exchanged with tap water. These exchanges of water were equivalent to rainfall of 100 mm in all, and was continued for 1, 3, and 5 days. The dry shoots were weighed 30 days after application.

(4) **Mobility of Pyributicarb in Paddy Soil**

A plastic column, which consisted of ten rings (10 cm diameter, 1 cm height) and was filled with paddy soil (clay loam), was placed into water pool. Water depth from soil surface was kept at 3 cm, and each herbicide was applied. Leaching of 1 cm per three hours was given on the next day of the application until there was no water in the pool. The soil was divided every 1 cm and put into a plastic pot (60 cm). Seeds of barnyardgrass were sowed into these pots and the pots were placed in greenhouse. Herbicidal efficacy was evaluated 20 days after sowing.

(5) **Influence of Application Time Against Rice Injury**

Ten pairs of two rice seedlings (Yamahoushi, two leaf stage) were transplanted in each of the plastic containers (60 cm x 30 cm, two replications) filled with the same soil as experiment (1).

Water depth was kept at 3 cm throughout the study period. Each herbicide was applied at the prescribed stage, and leaching of 2 cm/day was given for two days from the next day of the application. The dry shoots were weighed 30 days after application.

(6) **Influence of Transplanting Depth Against Rice Injury**

Two pairs of two rice seedlings (Yamahoushi, two leaf stage) were transplanted with two transplanting method: 1) whole root was buried into the soil, 2) root tip was exposed over the soil), and 0 cm depth per one plastic container (60 cm x 30 cm, two replications), filled with the same soil as experiment (1). Each herbicide was applied three days after transplanting. Water management and evaluation were conducted in the same way as experiment (4).

(7) **Influence of Water Leaching Against Rice Injury**

Ten pairs of two rice seedlings (Yamahoushi, two leaf stage) were transplanted per one plastic container (60cm x 30cm, two replications), filled with the same soil as experiment (1). Each herbicide was applied three days after the transplanting. Leaching of 0, 2, and 4 cm/day was given for two days from the next day of the application. Then, the water depth was kept at 3 cm after the leaching. The dry shoots were weighed 30 days after the application.

(8) **Influence of Water Depth Against Rice Injury**

Three pairs of two rice seedlings (Yamahoushi, two leaf stage) were transplanted per one plastic pot (1/5000 are, three replications) filled with the same soil as experiment (1). The water depth was arranged to three depths namely, 1, 3, and 8 cm. These water depths were kept throughout the test period. Each herbicide was applied three days after transplanting. The dry shoots were weighed 30 days after the application.

RESULTS AND DISCUSSIONS

(1) **Herbicidal Spectrum and Safety to Rice Plants of Pyributicarb**

Pyributicarb showed excellent herbicidal efficacy against annual paddy weed such as barnyardgrass, smallflower umbrella sedge (*Cyperus difformis* L.), *Monochoria vaginalis* (Burm.f.), and annual broad leaved weeds. And the safety of pyributicarb against transplanted young rice seedlings was very high even at the dosage of 10 kg a.i./ha (Fig 1).

(2) **Influence of Application Time Against Herbicidal Efficacy**

Flowable and granule formulations of pyributicarb showed excellent efficacy against barnyardgrass from pre-emergence to two leaf stage. Considering

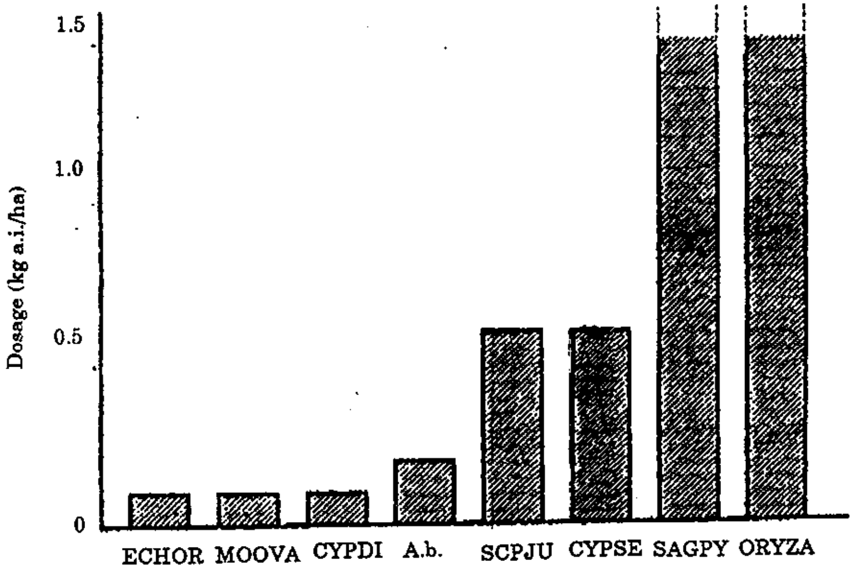

Figure 1. Dosage of pyributicarb for 80 % growth inhibition of weeds and transplanted rice

Abbreviation of plant name

ECHOR	: *Echinochloa oryzicola,*	MOOVA	: *Monochoria vaginalis,*
CYPDI	: *Cyperus difformis,*	A.b.	: Annual broadleaved weeds,
SCPJU	: *Scirpus juncoides,*	CYPSE	: *Cyperus serotinus,*
SAGPY	: *Sagittaria pygmaea,*	ORYSA	: *Oryza sativa*

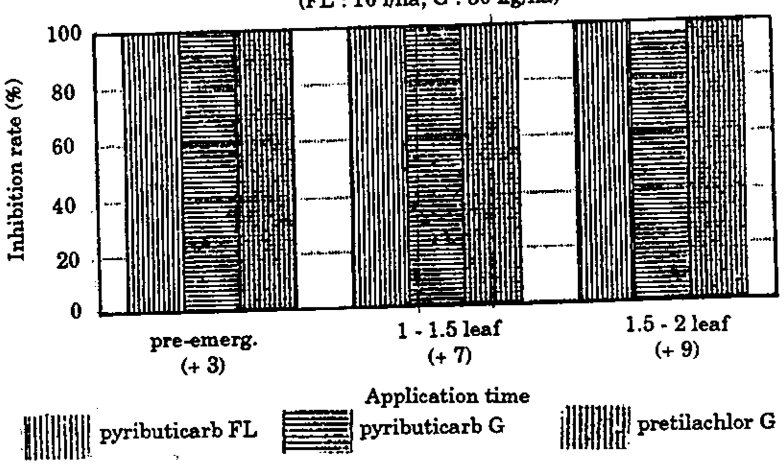

Figure 2. Herbicidal efficacy against barnyardgrass in some growth stages

the contents and application dosage of each formulation, the rate of pyributicarb could be decreased by changing its formulation from granule to flowable (Fig 2).

(3) Influence of Water Overflow Against Herbicidal Efficacy

Flowable formulation of pyributicarb showed excellent efficacy against barnyardgrass at 1.5-2 leaf stage independently of overflow and its extent. The efficacy of pyributicarb granule at 1.5-2 leaf stage was reduced a little by overflow for long days (Fig. 3).

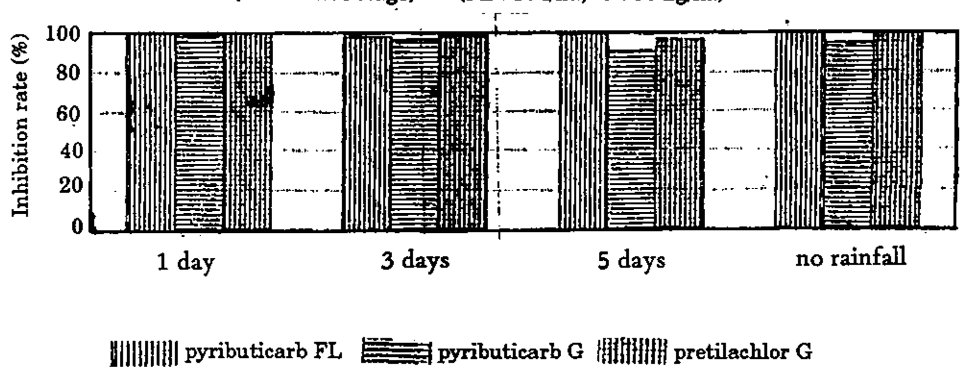

Figure 3. Effect of water overflow on efficacy

(4) Mobility of Pyributicarb in Paddy Soil

Pyributicarb was not moved to more than 1 cm from the soil surface. The mobility of pyributicarb in soil was extremely little (Fig. 4).

(5) Influence of Application Time Against Rice Injury

Neither flowable nor granule formulation of pyributicarb showed any rice injury with pot-transplanting application. With pre-transplanting application, granule formulation made slight growth inhibition against rice, but the plant recovered by the time of evaluation. Pyributicarb would have large application period from pre-transplanting to post-transplanting (Fig. 5).

(6) Influence of Transplanting Depth Against Rice Injury

Growth of the rice seedlings put on the soil surface was inhibited by flowable and granule formulations of pyributicarb. However, when they were transplanted under the soil, neither flowable nor granule formulation affected their growth, independently of root exposition and transplanting depth (Fig. 6).

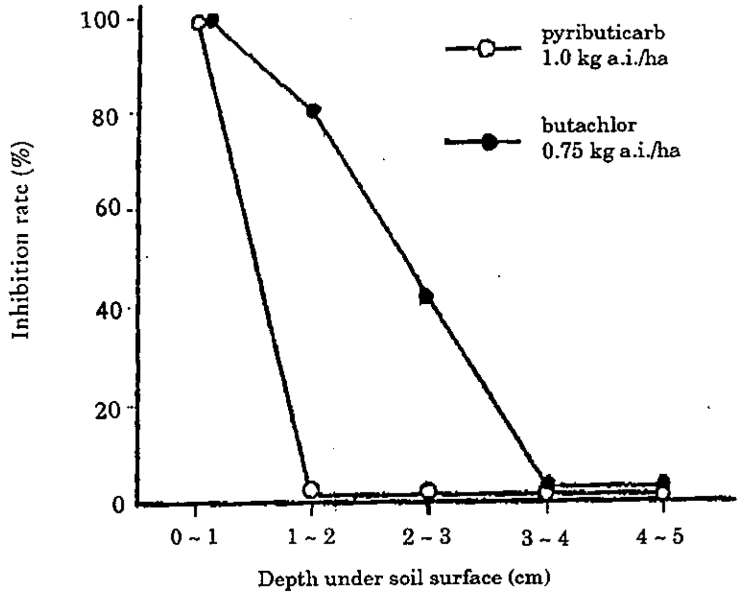

Figure 4. Herbicidal activities in each soil layer of column against barnyardgrass

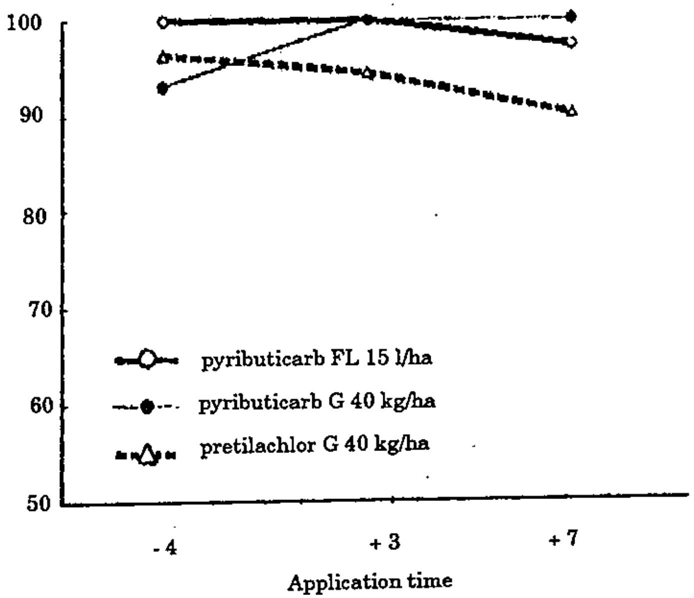

Figure 5. Effect of application time on rice injury

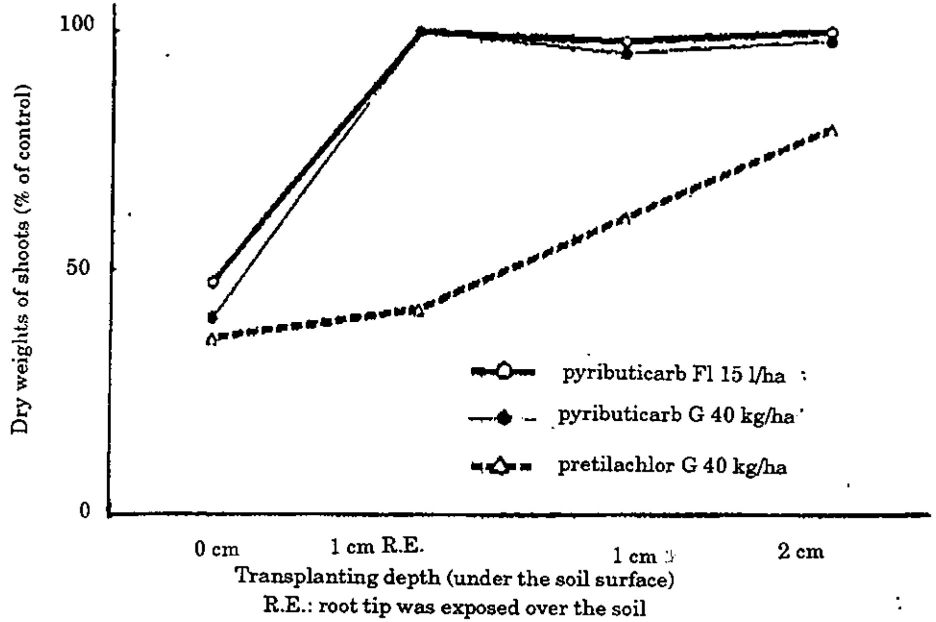

Figure 6. Effect of transplanting depth on rice injury

(7) Influence of Water Leaching Against Rice Injury

Neither flowable nor granule formulation of pyributicarb showed any injury against tranplanted rice independently of leaching. This was due to the little mobility of pyributicarb (Fig. 7).

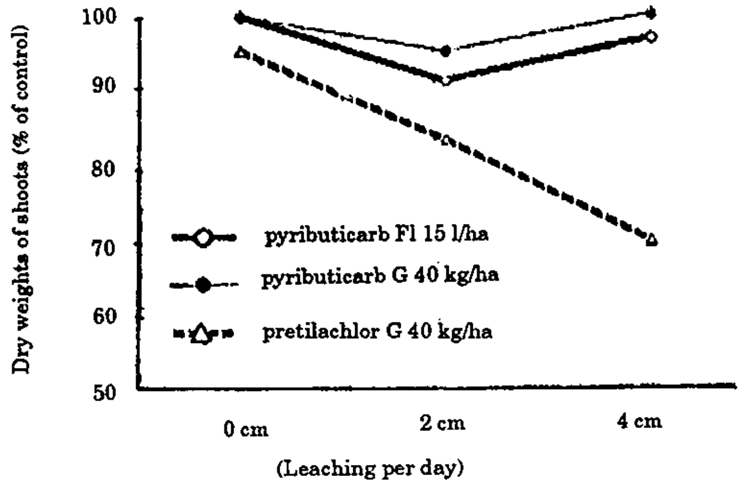

Figure 7. Effect of leaching on rice injury

(8) Influence of Water Depth Against Rice Injury

Neither flowable nor granule formulation of pyributicarb showed any injury against transplanted rice independently of water depth. Pyributicarb was safe to transplanted rice even at high concentration in water (Fig. 8).

Pyributicarb has excellent selectivity between barnyardgrass and transplanted rice, and flowable formulation made it possible to decrease rate of pyributicarb while keeping its herbicidal efficacy and safety to rice.

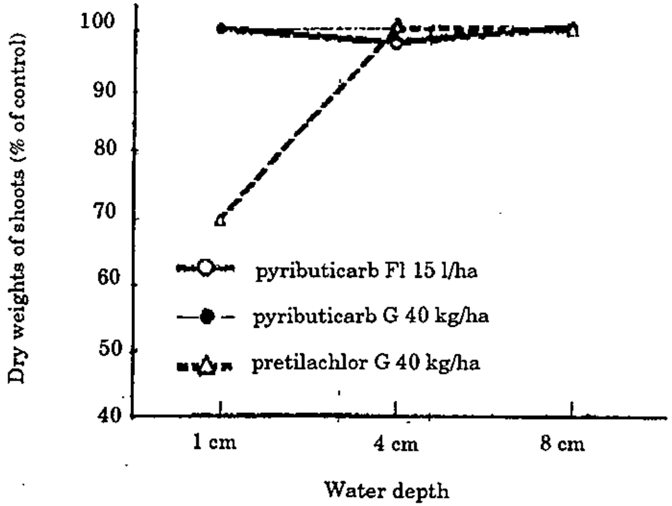

Figure 8. Effect of water depth on rice injury

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DIFFERENCES IN SELECTIVITY AND PHYSIOLOGICAL EFFECTS OF QUINCLORAC BETWEEN RICE AND BARNYARDGRASS COMPARED WITH 2,4-D

KOO, S.J.[1], Y.W. KWON[1] AND K.Y. CHO[2]

ABSTRACT

The selectivity of quinclorac (BAS 514H; 3,7-dichloro-8- quinolinecarboxylic acid) and 2,4-D (2,4-dichlorophenoxyacetic acid) between rice and barnyardgrass was quantified after foliar spray of the herbicides on seedlings of 1-leaf stage. The selectivity of quinclorac is 934-fold greater than that of 2,4-D between the two species. To examine the physiological basis of selectivity, the effects of quinclorac on respiration, RNA and protein contents, and electrolyte leakage of rice and barnyardgrass seedlings were compared with those of 2,4-D. Rice did not show any significant responses to both herbicides, however, barnyardgrass responded differentially. The application of 2,4-D increased respiration, RNA and protein content, all auxin-like physiological responses, but, had no effect on electrolyte leakage in barnyardgrass tissue. Quinclorac did not affect respiration, but it decreased RNA content slightly and increased protein content and electrolyte leakage in barnyardgrass tissue. The physiological effects of quinclorac on barnyardgrass is different from those of 2,4-D, auxin-like ones. It was suggested that the basis of the high selectivity of quinclorac between rice and barnyardgrass might be due to differential mode of action in the two species.

INTRODUCTION

Quinclorac has been used mainly for the control of barnyardgrass in paddy fields since its first introduction by BASF Atkiengesellschaft in 1985 (Wuerzer and Berghaus 1985). The high selectivity of quinclorac between rice and barnyardgrass was reported (Kibler *et al.* 1987; Wuerzer and Berghaus 1985), but the quantitative selectivity was not clearly demonstrated.

Auxin activity was proposed to be main mode of action of quinclorac based on auxin bioassay, but its selectivity between rice and barnyardgrass has not been fully understood despite of studies on uptake, translocation and metabolism (Berghaus and Wuerzer 1987; Berghaus and Wuerzer 1989). Recently, Koo *et al.* (1991) reported that grass species could be divided into tolerant and sensitive groups to quinclorac. The tolerant group including rice showed auxin-like responses, but the sensitive group to which barnyardgrass belonged did

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not show auxin-like ones. Quinclorac had no auxin activity in barnyardgrass mesocotyl elongation assays. Based on these results, it was proposed that auxin activity of quinclorac varied among plant species, and the mode of action in barnyardgrass might not be related to auxin activity (Koo *et al.* 1991). Whether quinclorac acts as an auxin-like substance or not in barnyardgrass is not clear.

The auxin activity of quinclorac could be determined by investigating auxin-induced physiological phènomena. There were many reports on physiological and biochemical effects of IAA or 2,4-D (Chrispeels and Hanson 1962; Davies 1973; Hanson and Slife 1969; Key 1964; Key and Hanson 1961; Key and Ingle 1964; Key *et al.* 1967; West *et al.* 1960). The increase in the contents of RNA and protein, and cell wall acidification were reported as the major mode of action. Besides, increase in respiratory rate was also regarded as a physiological response depending on plant species and tissues (Fedtke 1982; Moreland 1985). The effects of 2,4-D on various respiratory enzymes were also investigated (Mostafa and Fang 1971). A hypothesis (Theologis 1987) is that auxin regulates gene expression, which includes stimulation of RNA and protein loosening, wall stretching and cell elongation. These reactions were continuous and occured very rapidly within 5 and 15 minutes in pea tissues. Increase in respiratory rate might be due to the stimulation of ATP-dependent proton excretion, and RNA and protein synthesis. For the verification of auxin activity of other auxin-type herbicides such as dicamba or picloram, the contents of RNA and protein were investigated (Arnold and Nalewaja 1971; Chen *et al.* 1972; Chen *et al.* 1973; Malhorta and Hanson 1970).

In this paper, the responses of plant growth to quinclorac and 2,4-D were measured to quantify the selectivity between rice and barnyardgrass. The effects on the contents of RNA and soluble protein, respiratory rate, and electrolyte leakage of two species were also compared to know whether quinclorac act as an auxin-like substance like 2,4-D.

MATERIALS AND METHODS

Quantification of Selectivity between Rice and Barnyardgrass

Twenty or thirty seeds of rice (*Oryza sativa* cv. Dongjin) and barnyardgrass (*Echinochloa crusgalli* var. *formosensis*) were placed in pots and covered with a sandy loam soil and the pots were kept in a greenhouse. Quinclorac and 2,4-D were then foliar applied at various concentrations in a spray volume of 4,000 L/ha when the first leaf of the plants was fully expanded. The shoot fresh weight was measured at 2 weeks after application.

The 50% inhibitory doses (ID50s) were calculated from the linear regression equations between dose and fresh weight. The selectivity index (SI) was calculated as follows: SI=ID50 (rice)/ID50 (barnyardgrass).

Physiological Effects on Rice and Barnyardgrass

The cultivation of rice and barnyardgrass and herbicides application except concentration were same as above. The concentration of quiclorac and 2,4-D was 1 mM.

Respiratory rate was measured 6, 12, 24, 48 and 72 h after herbicide application. The content of RNA and protein was measured 12, 24, 48 and 72 after application. The respiratory rates were determined with a Clark-type oxygen electrode (Rank Brothers Bottisham Cambridge England) using the meristematic tissues of shoots (basal portion of shoot 1 cm from the ground), which were excised to 2 mm long. The respiratory rates were estimated by the oxygen consumption of the tissues in 4 ml of air saturated distilled water for 15 min.

The content of RNA and soluble protein, and electrolyte leakage of the entire shoot except for the first leaf blade were investigated. RNA and soluble protein were extracted using the method used by Chen *et al.* (1972; 1973) with slight modification. The tissues were homogenized with a mortar grinder and pestal in 0.2 M K-Phosphate buffer (pH 7.5), and centrifuged at 25,000 g for 10 min. The supernatant was used to measure the content of soluble proteins by Bradford method (Bradford 1976) using bovine albumin as a standard. The sediments were washed by centrifugation twice with 80% ethanol at 2,800 g and then once with 5% trichloroacetic acid at 20,000 g. The resulting sediments were disolved in 1 N KOH for 24 hours and centrifuged at 25,000 g for 5 min. and the RNA contents in the supernatant were measured by orcinol reaction (Dawson *et al.* 1986).

The amount of electrolyte leakages were determined by measuring the conductivities with a conductivity meter (Denki Kakaku Keiki Co,, Ltd., Model AOC-10) as described by Vanstone and Stobbe (1977). The tissues were suspended in 20 ml distilled water and inubated on an orbit shaker with 250 rpm for 1 h at 25° C and the electrolyte conductivity was measured.

Chemical Preparation

Quinclorac (3,7-dichloro-8-quinolinecarboxylic acid, a.i. 98%, Oriental Chem. Co. Ltd.) and 2,4-D (2,4-dichlorophenoxyacetic acid, Sigma Chem. Co.) were dissolved in 50% acetone containing 0.2% Tween 20. All experiments were replicated three or four times and the data were subjected to one-way analysis.

RESULTS AND DISCUSSIONS

1. Quantification of Selectivity Between Rice and Barnyardgrass

The fresh weights of rice and barnyardgrass are shown in Figure 1. The application of 2,4-D reduced fresh weight of rice more than that of barnyardgrass. Where as, quinclorac was much safer than 2,4-D to rice in inducing growth reduction, and showed complete control of barnyardgrass at a low concentration (0.3 mM). As shown in Table 1, ID50s of quinclorac and 2,4-D in rice were 26.81 and 0.92 mM, and those in barnyardgarss were o.07 and 2.26 mM, respectively. The selectivity index of quinclorac between rice and barnyardgrass (SI) was 383.00, but that of 2,4-D was 0.41.

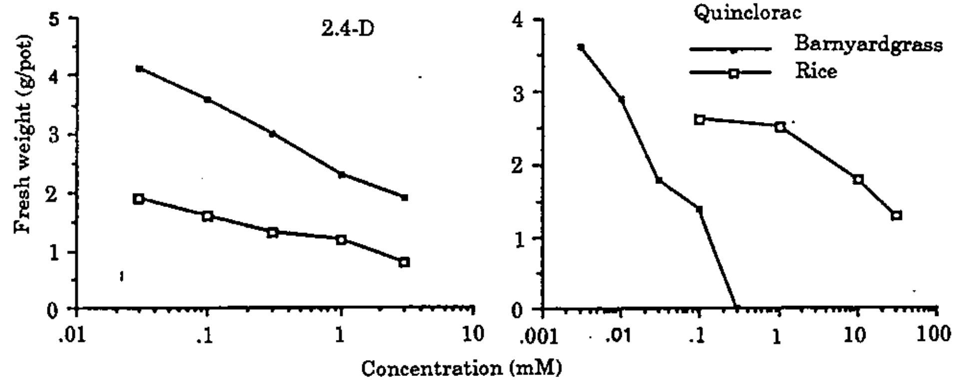

Figure 1. Selectivity between rice and barnyardgrass of foliar- sprayed quinclorac and 2,4-D

Table 1. Selectivity indices between rice and barnyardgrass of quinclorac and 2,4-D foliar-sprayed.

	Quinclorac (Q)	2,4-D (D)
ID50 (rice)	26.81	0.92
ID50 (barnyardgrass)	0.07	2.26
SI (R/B)	383.00	0.41

Note : The selectivity were foliar applied that at the 2 leaf stage. After 2 wks. remained green parts were harvested and weighed. The fifty percent inhibition doses (ID50) were calculated based on linear the regression equations:

2,4-D on rice	y = 1.6208-0.29434x	R2 = 0.773*
2,4-D on barnyardgrass	y = 2.4846-0.04233x	R2 = 0.918**
quinclorac on rice	y = 3.5278-0.61827x	R2 = 0.722*
quinclorac on barnyardgrass	y = 2.8375-10.1300x	R2 = 0.818**

In these equations, x represents dose (mM) and represents fresh weight. The selectivity indices (SI) are the ratio of ID50 between treatments.

*, **: statistically significant at 5 and 1% level, respectively.

From these result indicated that quinclorac appear to have high selectivity between rice and barnyardgrass. The difference in selectivity between quinclorac and 2,4-D was 934.1 (383.0/0.41). The difference in selectivity between two herbicides was so marked that the selectivity of quinclorac might be qualitatively different from that 2,4-D.

Therefore it is supposed that the studies on uptake, translocation and metabolism could not explain the selectivity of quinclorac between rice and barnyardgrass (Berghouse and Wuerzer 1989). Besides these results, the morphological responses of barnyardgrass induced by quinclorac were not auxin-like as described in the previous report (Koo *et al.* 1991).

2. Physiological Effects On Rice and Barnyardgrass

Whether quinclorac acts as an auxin-like substance in rice and barnyardgrass was further examined on physiological basis.

Neither herbicides affected respiration of rice. The respiration of barnyardgrass treated with 2,4-D increased from 28 to 50% at 21 to 48 h after application compared to untreated check, but with quinclorac was not affected (Figure 2).

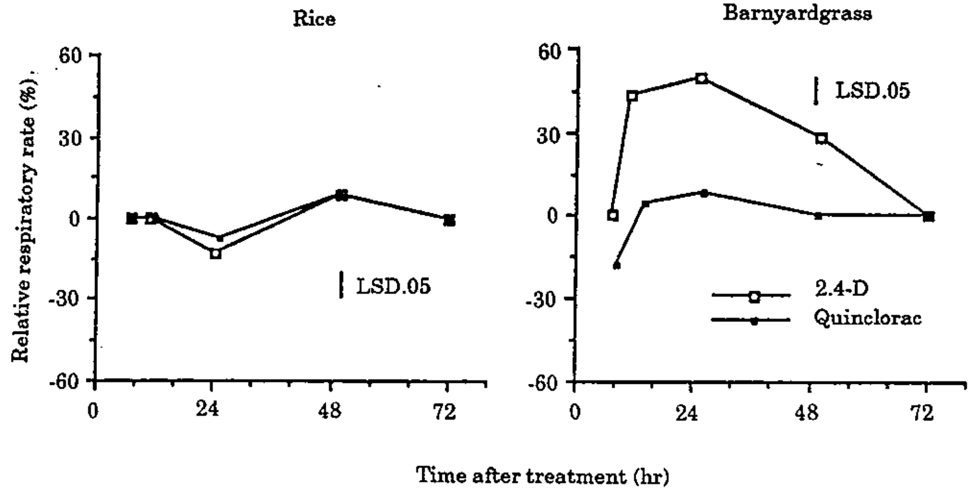

Figure 2. Change in respiratory rate of the shoot of the young seedlings of rice and barnyardgrass sprayed with 1 mM of quinclorac or 2,4-D. Respiratory rate was estimated by the oxygen consumption of the meristematic portion of shoot, basal 1 cm part from the ground. Each respiratory rate was converted to percentage value against untreated check at each time of measurement

The application of 2,4-D increased the content of RNA of barnyardgrass by 49%, but quinclorac decreased 35% at 72 h after application. However, both herbicides did not affect the content of RNA of rice (Figure 3). Similarly, both herbicides did not affect the content of soluble protein of rice. However, 2,4-D and quinclorac increased protein content of barnyardgrass 148 and 67%, respectively, at 72 h after application (Figure 4). The increase of RNA and protein content of barnyardgrass by 2,4-D was pronounced between 24 and 48 after application. The increase of protein content of barnyardgrass by quinclorac continued between 24 and 72 h after application.

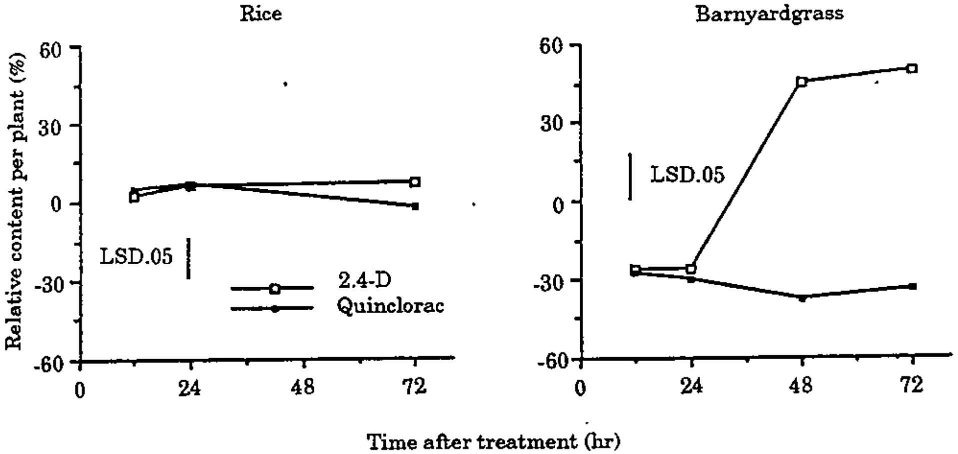

Figure 3. Change in RNA content of the shoot, except for leaf blade, of the young seedlings of rice and barnyardgrass sprayed with 1 mM of quinclorac or 2,4-D

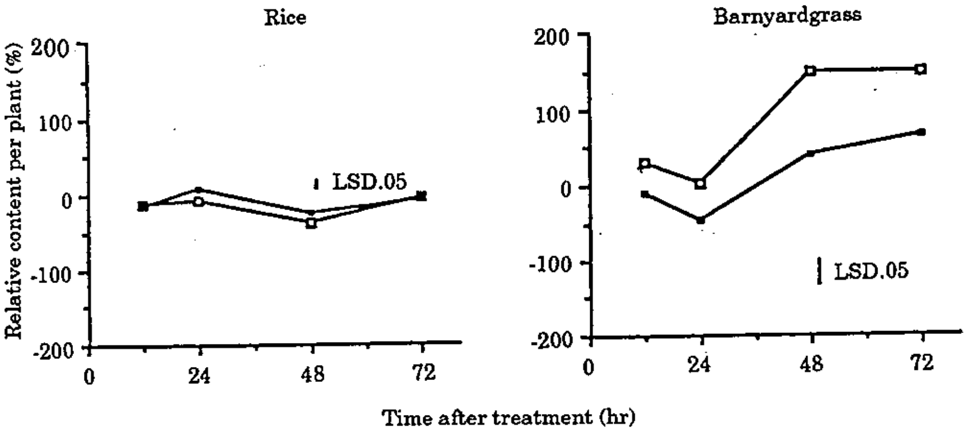

Figure 4. Change in protein content of the shoot, except for leaf blade, of the young seedlings of rice and barnyardgrass sprayed with 1 mM of quinclorac or 2,4-D.

Quinclorac and 2,4-D had no influence on electrolyte leakage between 24 and 72 h after application in barnyardgrass comparing to control or 2,4-D (Figure 5).

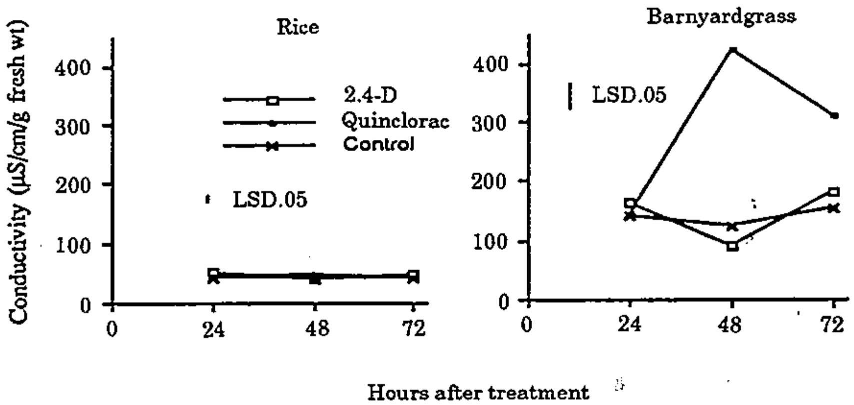

Figure 5. Electrolyte leakage of shoot, except for leaf blade, of the young seedlings which were sprayed with 1 mM of 2,4-D or quinclorac.

Among many reports on the physiological effects of IAA or auxin-type herbicides, rice or barnyardgrass tissue had not been used for these studies. In this study, both herbicides had no significant effects on respiration, RNA and protein contents. Rice tissues might not be affected by quinclorac because of lower application concentration (1 mM) than ID50 as shown Table 1. Whereas rice was not affected by 2,4-D even though the application concentration was high enough to inhibit growth. However, because both herbicides showed auxin-like symptoms including shoot curvature and root growth inhibition, they seemed to act as auxin-like substances in rice plant. Therefore, the relative safety of quinclorac in rice plant might be due to dose response, uptake or metabolism.

Barnyardgrass, however, was affected by both herbicides and physiological responses were shown. Respiratory rate, RNA and protein contents were increased by 2,4-D application. Therefore, the auxin-like physiological effects of 2,4-D on barnyardgrass were well demonstrated according to the hypothesis (Theologis 1987). Treatment of quinclorac increased protein content, but decreased RNA content and did not affect respiration of barnyardgrass. Because the soluble protein content increased without increase in RNA content, it was thought that increased protein by quinclorac might not be originated from gene expression, which is a mode of action of auxin. Quinclorac increased eletrolyte leakage, which is induced by membrane disruption.

Whether solubilization of membrane bound protein is a caused of protein increase or not should be investigated.

Quinclorac did not affect the elongation of barnyardgrass mesocotyl, and showed symptoms different from auxin-like ones (Koo *et at.* 1991). The marked difference in selectivity and physiological effects further suggest that the action of quinclorac in barnyardgrass may not be related to auxin-like mode of action.

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INFLUENCE OF DIFFERENT SITES OF TREATMENT ON ABSORPTION AND TRANSLOCATION OF DITHIOPYR IN RICE VARIETIES AND *ECHINOCHLOA* SPECIES

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ABSTRACT

Nutrient solution assays were conducted to investigate the distribution of ^{14}C-dithiopyr applied on roots, basal stems or shoots, related to absorption and translocation in rice varieties and *Echinochloa* species. *Echinochloa* species were significantly greater than rice varieties in the total amount of absorption which was highest at *E. crus-galli* Beauv. var *typica* Honda followed by *E. crus-galli* Beauv. var *caudata* Kitagawa, rice cultivar Sumjin (Japonica) and rice cultivar Poongsan (Indica x Japonica). The total amount of translocation from roots to shoots was slightly greater in rice than in *Echinochloa* species. The amount of absorption in rice was highest in basal stem followed by root and shoot treatments. However, in *E. crus-galli* it was highest in roots followed by basal stems and shoot treatments. Since rice absorbed dithiopyr more in basal stem than roots, phytotoxicity on rice can be significantly reduced if absorption from basal stem was restricted as much as possible.

INTRODUCTION

Dithiopyr (S. S-dimethyl 2-difluoromethyl-4-(2-methylpropyl)-6- trifluoromethyl-3-5-pyridine dicarbothioate) has newly been developed by Monsanto Company for paddy rice, and known to have excellent weeding effect on annual weeds, specially *Echinochloa* species and *Monochoria vaginalis* Presl, when applied at a rate as low as 0.06-0.12 kg ai/ha by pre or early post-emergence of soil application (Fujiyama *et al.* 1987). Herbicidal activity had narrow variation, regardless of soil type, leaching amount, standing water, and temperature. Residual effect in soil was 40 to 70 days. Treated rice had a good safety even at four fold recommended rate, provided the basal stem of rice was buried in soil (Ryang *et al.* 1989). Since absorption and translocation of herbicide in plant is very important for verification of mechanisms of selectivity and phytotoxicity between crops and weeds a lot of studies have been carried out in the world (Dixon, and Staller 1982, Pyon and Kwon 1989, Kobayashi and Ichinose 1984, Ma, *et al.* 1986).

However, few studies on absorption and translocation of dithiopyr in plants were reported.

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Accordingly, Kang *et al.* (1990) investigated the rate of growth inhibition in rice and *E. crus-galli* as affected by different concentration of dithiopyr and the amounts of absorption and translocation of ^{14}C-dithiopyr in shoots and root for the intergeneric selectivity between rice and *E. crus- galli*, where at the same concentration of dithiopyr, the growth of *E. crus-galli* was more inhibited than rice. *E. crus-galli* has absorbed dithiopyr more and faster than rice. In dithiopyr soaking treatment in rice and *E. crus- galli*, absorption quantity of both shoot and root was greater than that of root only, regardless of test plants, but total absorption quantity in each plant were similar (Ryang *et al.* 1991).

The objectives of this study were to investigate the differential amount of absorption and translocation of dithiopyr between rice varieties and *Echinochloa* species to define the mechanisms of selectivity and phytotoxicity and to characterize and contrast the pattern of absorption and translocation at different treatment sites i.e. root, basal stem or shoot.

MATERIALS AND METHODS

1. Absorption and Translocation of ^{14}C-dithiopyr at Different Rice varieties and *Echinochloa* species

Rice plants, cv. Sumjin (Japonica) and cv. Poongsan (Indica X Japonica), and *E. crus-galli* var. *caudata* Kitagawa and *typica* Honda were selected at 3 leaf stage. To determine the amounts of absorption and translocation of ^{14}C-dithiopyr in nutrient solution, test plants were grown in Kasugai nutrient solution adjusted to 7 x 10^{-9} M of ^{14}C-dithiopyr for 24 hours. After dithiopyr treatment, plants were washed with distilled water, then transferred to dithyopyr-free Kasugai nutrient solution and again grown in the growth chamber for 1, 3, 5 and 8 days. The plants were sectioned into shoots and roots after harvest, then oven-dried at 90°C for 24 hours and weighed.

The samples were combusted by the sample oxidizer (Packard 306) for 30 seconds, and were added in to 12 ml of Carbosorb V cocktail, CO_2 absorbent. The radioactivity was quantified using the liquid scintillation counter (Beckman LS 5801). Translocation rate of ^{14}C-dithiopyr was calculated by the ratio of radioactivity in the shoots to that in the whole plants. Each treatment was replicated 3 times each using 2 plants.

2. Differential Amount of Absorption at the Different Sites of ^{14}C-dithiopyr treatment

Test plants, 2 leaf stage of cv. Poongsan, cv. Sumjin, *E. crus-galli* var. *caudata* Kitagawa, and var. *typica* Honda were selected through preliminary experiments. Plants were cultured and treated as shown in Fig. 1. Plastic pot (diameter 13.7 cm and height 3.8 cm) was divided into two separate compart-

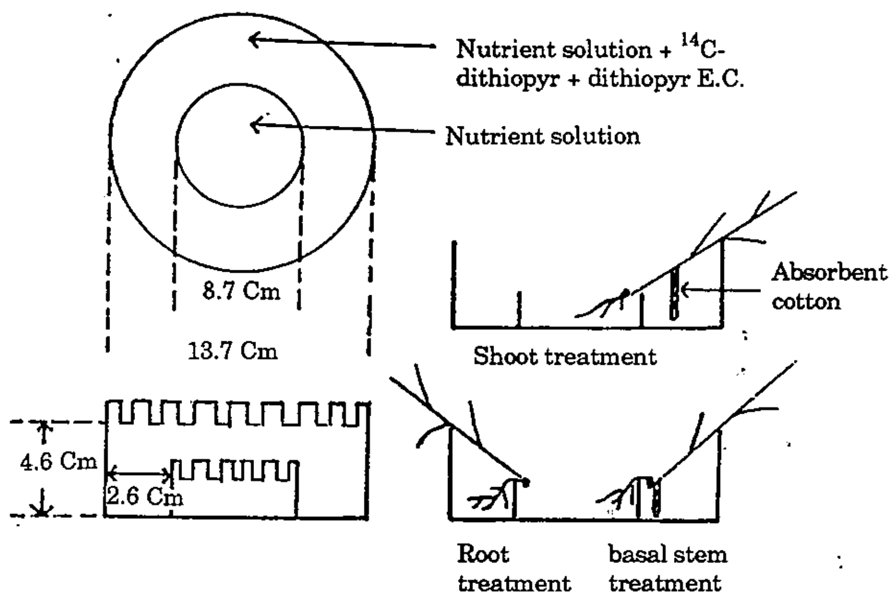

Figure 1. Treatment methods of ^{14}C-dithiopyr.

ments, the inner compartment contained pure nutrient solution and the outer compartment contained 10^{-8} M of ^{14}C-dithiopyr, 1.2 ppm of unlabelled dithiopyr and nutrient solution. Root treatment with ^{14}C- dithiopyr was done by soaking root only in the outer nutrient solution at uniform depth. In ^{14}C-dithiopyr treatment at basal stem, after soaking root and shoot in the inner solution, basal stem was contacted to cotton inside absorbing the outer solution. While in shoot treatment, shoot was contacted to cotton absorbent after soaking root and basal stem in the inner solution. Radioactivity of treated plants was quantified for 3, 6, 12 and 24 hours after treatment as previously described.

RESULTS AND DISCUSSION

1. Absorption and Translocation of ^{14}C-dithiopyr in Different Rice varieties and *Echinochloa* Species

Ryang *et al.* reported that ^{14}C-dithiopyr absorption rate of *E. crus-galli* was faster and greater than that of rice cultivar. Therefore, this study was conducted to investigate the ratio of absorption between root and shoot and translocation rate of ^{14}C-dithiopyr between rice varieties and *Echinochloa* species.

After test plants were grown in nutrient solution adjusted to $7x10^{-9}$ M of ^{14}C-dithiopyr for 24 hours, the absorption of ^{14}C-dithiopyr between roots and shoots was higher at roots than at shoots in the test plants. When test plants were grown in ^{14}C- dithiopyr free nutrient solution for 1, 3, 5 and 7 days after soaking in dithiopyr nutrient solution, the amounts of ^{14}C-dithiopyr absorbed in roots of test plant species gradually decreased as time passed by. After 7 days in ^{14}C-dithiopyr free nutrient culture the amount of absorption in roots remained about 1/2 in two rice cultivars, and 2/3, 1/3 in *E. crus-galli* var. *typica* Honda and var. *caudata* Kitagawa, respectively. When compared to the roots, however, no significant reductions were observed in shoots of four test plants. The reasons why absorption quantity in roots was significantly decreased during ^{14}C-dithiopyr free nutrient culture for 7 days, were not clear but it may be related to decomposition and leakage by basipetal translocation as explained by Dixon (1982), Oyamada (1985), and Pyon (1989).

Total absorption of roots and shoots was highest at *E. crus-galli* var. *typica* Honda followed by var. *caudata* Kitagawa, cv. Sumjin and cv. Poongsan (Figure 2). Ryang *et al.* (1990) reported similar results where dithiopyr absorption of *E. crus-galli* was greater about one and a half times than that of rice. The absorption rate of *E. crus-galli* var. *typica* Honda was higher than that of

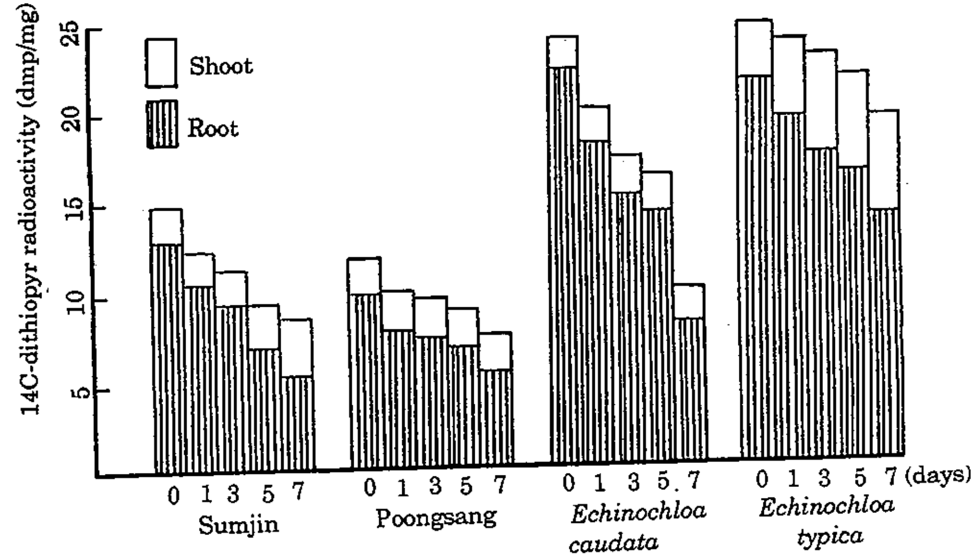

Figure 2. Distribution of ^{14}C-dithiopyr activity in two rice varieties and two *Echinochloa* species grown in nutrient solutions after 24 hours absorption in ^{14}C-dithiopyr ($7x10^{-9}$ M).

var. *caudata* Kitagawa, which may be related to herbicidal sensitivity. This was evident at the results of Ryang (1989) where herbicidal tolerance in dithiopyr among *Echinochloa* species was not observed from just after emergence to 0.5 leaf stage, but as leaf age developed the tolerance was highest at *E. crus-galli* var. *caudata* Kitagawa followed by var. *typica* Honda and var. *oryzicola* Ohwi.

Absorption of dithyopyr by cv. Sumjin was slightly greater than that of cv. Poongsan in this study, though differential dithiopyr sensitivity between rice cultivars was not observed even at four fold of recommended rate (Ryang *et al.* 1988). However, this difference in absorption between rice cultivars may gradually be reduced because of growth recovery as dithiopyr decomposed.

Figure 3 shows translocation from root to shoot among test plants grown in nutrient solution for 7 days after soaking at nutrient culture adjusted to 7 x 10^{-9} M ^{14}C-dithiopyr for 24 hours. Although dithiopyr in plants was only slightly translocated from roots to shoots, translocation in all test plants were gradually increased as time passed by and in particular, cv. Poongsan (Indica x Japonica) was about 10% higher than *E. crus-galli* Beauv var.

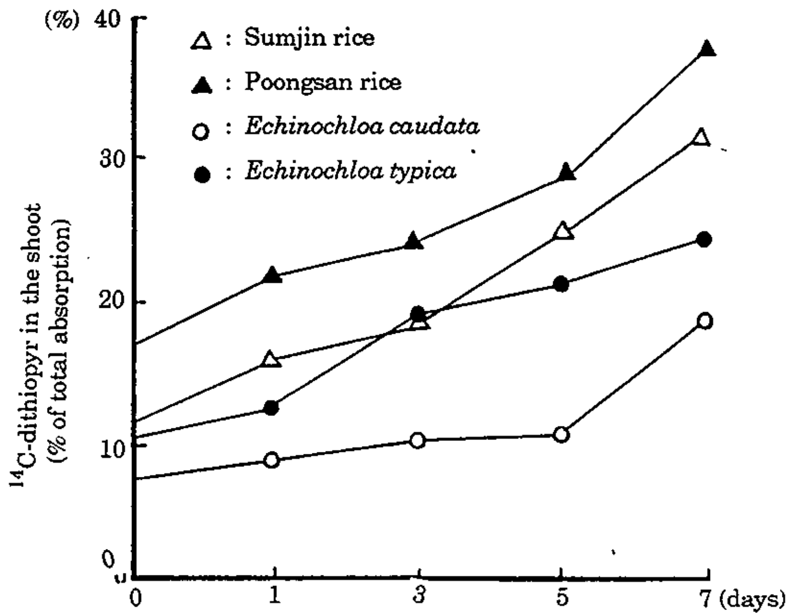

Figure 3. Translocation rates (%) of PT14PTC-dithiopyr from root to shoot in 4 test plants grown in dithiopyr free nutrient solution for 0, 1, 3, 5 and 7 days after soaking test plants in 7 x 10^{-9} M of ^{14}C-dithiopyr nutrient solution for 24 hours.

caudata Kitagawa, but no difference was obtained between cv. Sumjin (Japonica) and *E. crus-galli* Beauv var. *typica* Honda. Total translocation however, was higher at cv. Poongsan followed by cv. Sumjin, *E. crus-galli* Beauv var. *typica* Honda and *E. crus-galli* Beauv var. *caudata* Kitagawa. Difference in translocation rate between rice cultivar was becoming narrower with time, but cv. Poongsan was slightly higher than cv. Sumjin. A similar result was obtained by Kang *et al.* (1990), where ^{14}C-dithiopyr in cv. Choocheong (Japonica) and *E. crus-galli* was only slightly translocated from root to shoot, and differences in translocation between test plants were not significant in this experiment.

This indicates that roots of these test plant was the primary site of action of dithiopyr. A little difference in absorption quantity between rice cultivar was shown in this study, where cv. Poongsan was slightly greater than cv. Sumjin. This difference of absorption quantity in the field condition, however, may gradually be reduced with time because of growth recovery due to the decomposition of herbicide.

2. Difference in Absorption of ^{14}C-dithiopyr by Different Treatment Sites.

In order to investigate the mechanism of phytotoxicity and selectivity between rice and *E. crus-galli*, two leaf stage of cv. Poongsan (Indica x Japonica) and *E. crus-galli* were grown in nutrient solution adjusted to 10^{-8} M of ^{14}C-dithiopyr and unlabelled 120 g ai/ha dithiopyr for 3, 6, 12 and 24 hours, then the absorption quantities were determined (Figure 4).

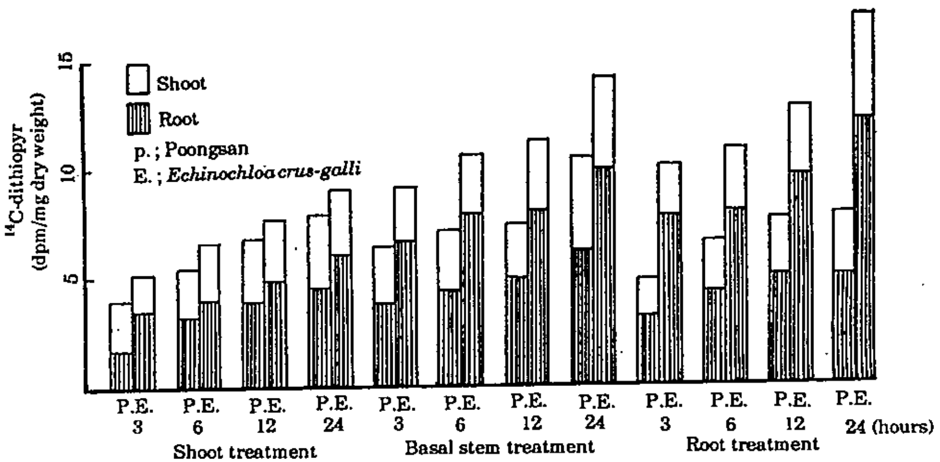

Figure 4. Distribution of ^{14}C-dithiopyr activity on the different absorption sites and hours in nutrient solution with dithiopyr (0.12 kg ai/ha) + ^{14}C-dithiopyr (10^{-8} M).

Whether dithiopyr was applied at roots, basal stems or shoots of rice, absorption was shown in all treatment sites even at only 3 hours after application, and highest was at basal stems followed by roots and shoots. As time passed, the absorption gradually increased up to 24 hours after application. Distribution of ^{14}C-dithiopyr was significantly higher at root than at shoot regardless of sites and times of treatment. In *E. crus-galli* the distribution was similar to that of rice. The total translocation was highest when applied through roots followed by through basal stems and through shoots, and in *E. crus-galli* was significantly greater than in rice. This observation indicated that differential amount of absorption and translocation in dithiopyr was resulted in selectivity between rice and *E. curs-galli*. Similar results in ^{14}C-naproanilide were reported by Oyamada *et al.* (D (1985), where absorption quantity of *Sagittaria pygmaea* Miquel was greater about 2 times than that of rice. Herbicide was mostly absorbed from root and basal stem and translocation from root and basal stem to shoot was significantly restricted in rice, whereas in *S. pygmaea* Miquel herbicide was evenly distributed at shoot, tuber and root.

Fujiyama *et al.* (1987) and Ryang *et al.* (1989) reported that if rice transplanted properly, dithiopyr was safe even at four fold of the recommended rate, but resulted in phytotoxicity when basal stem was in the flooded water in paddy field. Although root was in the flooded water, phytotoxicity on rice could significantly be reduced if basal stems were buried in soil.

It is concluded that in rice, dithiopyr was absorbed more at basal stem than at root, and phytotoxicity was significantly reduced if absorption from basal stems was restricted as much as possible. As absorption quantity in *E. crus-galli* was significantly higher than that of rice at any application sites, dithiopyr seemed to control efficiently *E. crus-galli* which emerged at soil surface.

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THE USE OF TREE LEGUMES AS FALLOW CROPS TO CONTROL WEEDS AND PROVIDE FORAGE AS A BASIS FOR A SUSTAINABLE AGRICULTURAL SYSTEM

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ABSTRACT

Crop fallows for weed control are widely practised throughout the Asia-Pacific region. The fallow crop normally consists of perennial trees and shrubs that colonise the cropping area during the fallow. With increasing demand for land as populations rise the length of the fallow is shortening, reducing its value for weed control and the restoration of soil fertility. One option to overcome this problem is to introduce tree legume as fallow crops that provide forage or fuelwood, and to control weeds.

INTRODUCTION

Upland cropping systems based on annual crops are important throughout the Asia-Pacific region and provide subsistence farmers with food crops to supply household needs. These farmers who are often resource poor with the exception of household labour, and fallow farming systems are common in order to restore soil fertility and to control weeds.

Where land is not scarce a bush fallow provides opportunities to utilise available resources more efficiently, but as populations increase the fallow period is reduced, placing greater stress on the system and threatening its sustainability. Improved fallows consisting of an economic crop may enable farmers to more efficiently utilise available resources without stressing the system. The improved fallow not only provides benefits during the fallow stage but also benefits the subsequent cropping phase, further enhancing the acceptability of the system.

The development of appropriate vegetation management strategies for sustainable development could be based on existing systems that have evolved in the region. By examining existing farming systems throughout Asia and the Pacific we will probably identify innovative weed control practices and are compatible with the existing resource base. One such system, which forms the basis of this paper, is the improved bush fallow system, which was developed by farmers in the kingdom of Amarasi, in the mid 1930's. Amarasi is located in the province of Nusa Tenggara Timur, in eastern Indonesia.

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TRADITIONAL WEED CONTROL PRACTICES

In annual cropping systems based on shifting cultivation the farmer cultivates an area for two or three seasons before abandoning it and moving on. The area is abandoned when yields do not compensate for the increased costs of production. Crop yields decline as soil fertility diminishes, while labour inputs rise as weed populations increase.

If an area is continuously cropped weed populations increase and actively compete with crops for resources. Annual weeds are the greatest problem as they establish more quickly than perennial weeds and provide a challenge to crops, especially during dry spells at the beginning of the rainy season. It is important therefore to have crops weeded within four weeks of planting; if weeding is delayed, crop yields are significantly depressed (Field and Yasin, 1990). Weeding takes longer as weed populations increase and weeds have to be individually removed. In the province of Nusa Tenggara Timur in Eastern Indonesia weeding is labour intensive because the soils have a high clay content and weeding implements are not very effective if the soil is still moist. Farmers abandon areas which are uneconomical to weed and move onto a new plot.

The abandoned area is fallowed and over time perennial plants become the main vegetation and displace the annuals. Trees assist in depleting the seed reserves of annual weeds, as their canopy reduces the amount of incident light reaching the ground (Nye and Greenland, 1960), shading out annual weeds which may establish at the start of the wet season and preventing them from flowering. Soil fertility and organic matter are restored through nutrient recycling, reduction in erosion and deposition of canopy litter. The longer the fallow is allowed to persist the more efficient it is in depleting weed seed reserves, and fallow periods of over ten years used to be common in parts of the Asia-Pacific region.

Farmers are forced to reduce the length of the fallow as human populations increase and the demand for land rises. Tall trees of the secondary forest became less common, and are replaced by perennial grasses and shrubs. Grasses pre-dominate in areas exposed to regular dry season burning, especially alang-alang (*Imperata cylindrica* (L.) Rauschel), *Themeda* spp. and *Heteropogon* spp. In other areas of higher rainfall bamboo (*Bambusa* spp.), damar (*Jatropha gossypifolia* L.), lantana (*Lantana camara* L.) and chromolaena (*Chromolaena odorata* (L.) K.&R.), are the main perennial plants occupying the fallow. They are widely accepted by farmers as a fallow crop because they provide the same benefits as the trees of the original shifting cultivation system.

Although some of the plants which now colonise abandoned gardens are considered weeds by some people, they are often beneficial to resource poor farmers (Field, 1991). A plant should only be considered a weed if it is causing either an economic or a social problem within the whole system. The weed may impose costs on a component of the system, but the costs may be negated by benefits if the system is considered as a whole. Too often only one component of a system is considered since few studies have examined the impact of weeds on whole systems. The authors believe that research into controlling weeds should look at the whole system rather than its components, if sustainable agricultural systems are to be developed.

Consideration needs to be given to the impact of various types of fallow plants on the crop. Perennial weeds are generally preferred to annual weeds if the main constraint is labour for weeding, since they are more readily controlled by pre-plant cultivation during the dry season. Once a crop has been planted it must be weeded within a limited period, otherwise crop yields are depressed. The cost of weeding is significantly higher than that of cultivating because of the necessity to direct resources at a defined time. As resource poor farmers are dependent on their family's labour, they cannot afford to provide further inputs and prefer systems that allow them to better allocate resources over those that concentrate activities within short periods. For this reason farmers prefer to have perennial rather than annual plants colonising the fallow, even if the perennial competes with the crop.

Land preparation is either by pre-plant cultivation or by cut-and-burn, depending on the plants dominating the fallow. Grassy fallows have to be cultivated, which involve significantly higher labour inputs than cutting and burning. In eastern Indonesia cultivation of grasses takes 150 man days/ha, whilts cutting and burning takes only 30 man days/ha (Field, unpublished data), making perennial shrubs and bamboo the preferred fallow vegetation. They also shade out perennial grasses like alang-alang (Field, 1991). Under these circumstances lantana and chromolaena should not be considered a weed, since they facilitate land cultivation rather than pose a threat to crop production, especially for resource poor farmers.

In areas where the demand for land is high farmers are forced to implement continuous cropping systems, some of which may not be sustainable. Without the fallow there will be erosion and no replenishment of nutrients and organic matter as crops are harvested, unless inputs are provided. Fertiliser is required to replace nutrients removed by the crop and the farmer is forced to spend most of the labour during the early wet season controlling weeds. Under these circumstances, resource poor farmers with no access to credit can only intensify land degradation and rural poverty.

THE USE OF IMPROVED FALLOWS FOR WEED CONTROL

To overcome these problems farmers have identified innovative approaches to reduce the deleterious effects of continuous cropping. One such innovation is the use of tree legumes as an improved fallow crop, which was developed by the farmers of Amarasi in the Nusa Tenggara Timur (NTT) region in the early 1930's. The tree legume lamtoro (*Leucaena leucocephala* (Lam.) de Wit) was originallly planted in three meter rows along the contour to form terraces to reduce soil erosion (Metzner, 1981, 1983). By the 1960's most of the Kingdom was planted to the tree lagume. The system not only reduced land degradation, but also provided increased cattle fodder and food crop production.

The livestock industry is a major component of the economy in parts of eastern Indonesia. Farmers raise and fatten 1-10 cattle on lamtoro depending on the availability of feed, labour, water and capital to purchase an animal. Each animal may generate a return of Rp 150,000 significantly increasing farmer's in- come (Subandi and Akil, 1990). It became apparent that native bush and perennial weed fallows were inefficient since they only benefitted the food crop. Adoption of the system was also aided by the need to control free ranging cattle, as the herds had been allowed to increase in size and accelerate land degradation as the rangelands became over-stocked. To overcome the problem lamtoro had been extensively planted in the cropping areas of NTT by 1986 (Piggin and Parera, 1987).

The plant provides similar benefits to the food crop, to those the traditional fallow, including weed control. The tree legume shades out most plants, including lantana. Soil fertility is also maintained through nutrient recycling, nitrogen fixation and organic matter return. Under the tree legume system farmers can allocate resources more efficiently and significantly increase income through livestock production, making them less dependent on annual crops for income. Moreover they only need to crop 0.25 ha compared to the normal 0.5-1.0 ha (Jones, 1983), thereby reducing the pressure on the system (Field *et al*., 1990).

Similar improved fallows based on tree legumes have been developed in other parts of eastern Indonesia. In western Flores farmers plant calliandra (*Calliandra calothyrsus* Meissn.) for shading coffee and have noticed that it can also shade out chromolaena, which is the dominant fallow crop in the region (Field, 1991). Farmers also plant calliandra as a support for vanilla vines and forage for cattle. In other areas the tree legumes lamtoro merah (*Acacia villosa*) and gamal (*Gliricidia sepium* (Jacq.) Walp.) are becoming important fallow crop to replace lamtoro which has been badly affected by the psyllid, *Heteropsylla cubana* Crawford (Piggin and Parera, 1987).

MANAGEMENT OF THE TREE LEGUME FALLOW

As with most intercropping systems, consideration should be given to appropriate management both crops. Resource poor farmers are often dependent on the food crop, and are reluctant to implement intercropping systems that compete with the food crop for resources. The tree legume should be grown at a spacing that minimises competition with the food crop and optimises both forage production and canopy during the fallow. The closer the spacing the more efficient it is at shading out weeds, but also the greater the competitive effects on the food crop. Pruning back the tree legume during the cropping phase minimises competition by the tree legume (Field and Oematen, 1990). Pruning to ground level is recommended, as it decreases both evapotranspiration and light competition. Under this system the tree legume can be planted in rows, two meters apart without reducing maize yields.

Both spacing and management can be changed to meet the needs of the farmer who prefers to increase cash income rather than produce staple food crops. For example opportunities exist to incorporate other intercrops in the system that area compatible to the needs of the individual farmer. Farmers may also grow tree crops more intensively so as to rear more cattle as a source of income.

CONCLUSIONS

If sustainable farming systems are to be identified, consideration should be given to more efficient utilisation of existing resources and opportunities. Tree legumes are one option. Other perennial crops such as trees for timber, food or fuelwood or alternative forage crops could be appropriate depending on the needs and resources of the farmer. Research and extension agencies will be better equipped to identify sustainable farming systems when they understand the system better.

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CONTROL OF *STENOCHLAENA PALUSTRIS* WITH HERBICIDES UNDER RUBBER PLANTATION

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ABSTRACT

The efficacy of selected herbicides in controlling *Stenochlaena palustris* (Burm.) Bedd. under mature rubber was evaluated. Comparison between the herbicides paraquat and glufosinate ammonium up to 1.2 kg and 2.4 ai/ha respectively showed that paraquat was more effective. Weed control was slightly improved when paraquat at 0.6 kg ai/ha was mixed with 2,4-D amine at 1.0 kg ai/ha. However, paraquat mixed with sodium chlorate at 15 kg ai/ha resulted in reduced percentage control. Mixtures of glufosinate ammonium at 1.0 kg ai/ha with 2,4-D amine at 1.0 kg ai/ha or sodium chlorate at 15 kg ai/ha showed almost comparable control. Mixture of glufosinate ammonium at 1.0 kg ai/ha with paraquat at 0.6 kg ai/ha however showed enhanced control.

The addition of cationic surfactants Hyspray 52 or Ethokem, anionic surfactant Teepol or nonionic surfactant Polypol Ace to paraquat at 0.6 kg ai/ha in 1:1 ratio by volume of product did not show significant improvement on weed control. However the addition of the same cationic surfactants in similar ratio to glufosinate ammonium resulted in slight improvement in control.

S. palustris can also be controlled with other herbicides such as 2,4-D amine + sodium chlorate at 1.0 + 15 kg ai/ha, paraquat + diuron at 0.6 + 0.6 kg ai/ha, paraquat + MCPA + diuron + amitrole at 0.3 + 0.48 + 0.72 + 1.425 kg ai/ha and imazapyr at 1.0 or 1.2 kg ai/ha. Glyphosate applied up to 4.32 kg ai/ha was ineffective on this weed.

INTRODUCTION

Stenochlaena palustris (Burm.) Bedd. is a fern which can be found in lowland areas in either open or lightly shaded conditions particularly where there is sufficient moisture (Holttum, 1969). It is an important weed under mature rubber especially in moist, low-lying areas. It had been reported that *S. palustris* prefers open rather than shaded conditions (RRIM, 1966). If it is allowed to establish under rubber, it can develop into a dense thicket and hinder accessibility along the planting strips. This situation is further aggravated by the sharp toothed margins of the leaflets which can cause unpleasant effects to the unprotected human skin. In addition, it was reported that natural covers which include *S. palustris* resulted in poor tree growth (RRIM, 1963). Slashing the weed may not give effective control since the

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remaining stems can regenerate new shoots. Its creeping stems can also give rise to new shoots and help in its propagation. Earlier studies reported that the weed was susceptible to the herbicide paraquat (Riepma, 1968). It has also been reported to be susceptible to MSMA + 2,4-D amine + sodium chlorate (RRIM, 1968). These herbicides, however do not provide persistent control and furthermore paraquat has a high mammalian toxicity and alternative herbicides are necessary. A relatively new herbicide, glufosinate ammonium had shown some potential against this weed (Langeluddeke *et al.*, 1983). This herbicide is mainly a contact herbicide with limited systemic activity (Kocher and Lotzsch, 1985). Trials were conducted under rubber to evaluate this herbicide alone and in mixtures with other herbicides or surfactants and its effectiveness with paraquat. Other herbicides and herbicide mixtures were also evaluated against this weed.

MATERIALS AND METHODS

Trials were conducted in the interrows under partial shade of about 70% light transmission at the fringes of a mature rubber area in Rubber Research Institute Experiment Station, Sungai Buloh, Selangor. The height of the weeds was 50 to 80 cm and they were quite densely populated. The soil texture was sandy clay loam. The experimental design was a randomized complete block with 3 or 4 replicates. The plot size was 20 m^2. A Solo knapsack sprayer fitted with a fan jet nozzle of 0.20 cm nozzle orifice was used to spray the herbicides. Volume rate of water used was about 500 l/ha. Control of weeds was visually assessed using a 0 to 100 rating, where 0 = no effect and 100 = total kill. Results of trials on percentage control of the weeds were transformed to arcsin percentage where necessary and analyzed statistically to detect differences between treatment means. The herbicides used were Gramoxone (paraquat dichloride - 24.64 % w/w), Basta (glufosinate ammonium 20 % w/w), 2,4-D Amine E' (dimethylamine salt of 2,4-D - 60.2 % w/w), Sodium chlorate (sodium chlorate - 99 % w/w), Assault 100A [imazapyr with isopropylamine (1:1)], Para-col (paraquat dichloride - 24.64 % w/w + diuron 17.86 % w/w), Roundup (isopropylamine salt of glyphosate - 41 % w/w) and Ustinex special (MCPA - 16 % w/w + diuron - 24 % w/w + amitrole - 47.5 % w/w).

Efficacy of Glufosinate Ammonium and Paraquat

The efficacy of glufosinate ammonium, paraquat and mechanical slashing in controlling *S. palustris* was compared (Trial 1). The efficacy of different rates of glufosinate ammonium (Trial 2) and paraquat (Trial 3) was also evaluated. The details of the treatments are given in Table 1.

Table 1. Efficacy of glufosinate ammonium and paraquat on *S. palustris* under mature rubber

TRIAL 1		TRIAL 2		TRIAL3	
Treatment	Rate (kg ai/ha)	Treatment	Rate (kg ai/ha)	Treatment	Rate (kg ai/ha)
Glufosinate ammonium	0.5	Glufosinate ammonium	0.4	Paraquat	0.2
Glufosinate ammonium	1.0	Glufosinate ammonium	0.8	Paraquat	0.4
Paraquat	0.5	Glufosinate ammonium	1.2	Paraquat	0.6
Paraquat	1.0	Glufosinate ammonium	1.6	Paraquat	0.8
Slashing	-	Glufosinate ammonium	2.0	Paraquat	1.0
		Glufosinate ammonium	2.4	Paraquat	1.2

Herbicide Mixtures with Glufosinate Ammonium and Paraquat

A trial was conducted to determine whether the addition of 2,4-D amine, sodium chlorate or paraquat enhance control as compared to glufosinate ammonium alone (Trial 4). A similar trial was also conducted comparing paraquat alone and in mixtures with 2,4-D amine, sodium chlorate or glufosinate ammonium (Trial 5).

In another trial, mixtures of glufosinate ammonium and paraquat were evaluated at lower rates to determine whether enhancement in control of the weed could also be achieved (Trial 6). Details of the treatments are shown in Table 2.

Table 2. Effect of glufosinate ammonium or paraquat and its mixture with herbicides on *S. palustris* under mature rubber

TRIAL 4		TRIAL 5		TRIAL 6	
Treatment	Rate (kg ai/ha)	Treatment	Rate (kg ai/ha)	Treatment	Rate (kg ai/ha)
Glufosinate ammonium	1.0	Paraquat	0.6	Paraquat	0.2
Glufosinate ammonium +	1.0+	Paraquat+	0.6+	Glufosinate ammonium	0.2
2,4-D amine	1.0	2,4-D amine	1.0	Glufosinate ammonium+	0.2+
Glufosinate ammonium+	1.0+	Paraquat+	0.6+	paraquat	0.2
$NaClO_3$	15	$NaClO_3$	15	Glufosinate ammonium+	0.4+
Glufosinate ammonium +	1.0+	Paraquat+	0.6+	paraquat	0.2
paraquat	0.6	Glufosinate ammonium	1.0		

Mixtures of Glufosinate Ammonium or Paraquat with Surfactants

The effectiveness of paraquat (Trial 7) or glufosinate ammonium (Trial 8) alone and in mixtures with surfactants were compared. The cationic surfactants used were Hyspray 52 and Ethokem, the ionic surfactant was Teepol and the nonionic surfactant was Polypol Ace. The mixtures were in the ratio of one part by volume of the herbicide to one part of the surfactant. Details of treatments are provided in Table 3.

Table 3. Effect of glufosinate ammonium or paraquat and its mixtures with surfactants on *S. palustris* under mature rubber

TRIAL 7		TRIAL 8	
Treatment	Rate (kg ai/ha)	Treatment	Rate (kg ai/ha)
Paraquat	0.6	Glufosinate ammonium	1.0
Paraquat+Hyspray 52	0.6+3 l	Glufosinate ammonium+ Hyspray 52	1.0+5 l
Paraquat+Teepol	0.6+3 l	Glufosinate ammonium+ Ethokem	1.0+5 l
Paraquat+Ethokem	0.6+3 l	Glufosinate ammonium+ Teepol	1.0 + 5 l
Paraquat+Polypol Ace	0.6+3 l	Glufosinate ammonium+ Polypol Ace	1.0 + 5 l

Efficacy of Other Herbicides

The efficacy of several other herbicides on this weed was also evaluated (Trial 9). In addition, different rates of 2,4-D amine mixed with sodium chlorate was also tested to determine whether an improvement in weed control could be obtained (Trial 10).

Trials were also conducted to compare the effectiveness of imazapyr (Trial 11) and glyphosate (Trial 12) on this weed. Details of the treatments are given in Table 4.

Table 4. Effect of herbicides and herbicide mixture on S. palustris under mature rubber

TRIAL 9		TRIAL 10	
Treatment	Rate (kg ai/ha)	Treatment	Rate (kg ai/ha)
Paraquat	0.5	2,4-D amine + $NaClO_3$	0.66+10
Paraquat+diuron	0.6+0.6	2,4-D amine + $NaClO_3$	0.66+15
2,4-D amine+$NaClO_3$	1.0+20	2,4-D amine + $NaClO_3$	0.66+20
Paraquat+MCPA+diuron+amitrole	0.3+0.32+0.48+0.95	2,4-D amine + $NaClO_3$	1.0 +10+1.0+15
Paraquat+MCPA+diuron + amitrole	0.6+0.48+0.72+1.425	2,4-D amine + $NaClO_3$	1.0 +20

TRIAL 11		TRIAL 12	
Treatment	Rate (kg ai/ha)	Treatment	Rate (kg ai/ha)
Imazapyr	0.2	Glyphosate	0.72
Imazapyr	0.4	Glyphosate	1.44
Imazapyr	0.6	Glyphosate	2.16
Imazapyr	0.8	Glyphosate	2.88
Imazapyr	1.0	Glyphosate	3.60
Imazapyr	1.2	Glyphosate	4.32

RESULTS AND DISCUSSION

Efficacy of Glufosinate Ammonium and Paraquat

Results showed that paraquat at 0.5 or 1.0 kg ai/ha was more effective than glufosinate ammonium, also at 0.5 or 1.0 kg ai/ha (Figure 1). The initial activity of paraquat and glufosinate ammonium at 1.0 kg ai/ha was rapid. Weed control declined to 80% between 4 to 5 weeks after treatment with paraquat at 0.5 kg ai/ha or glufosinate ammonium at 1.0 kg ai/ha. The most effective control was obtained with paraquat at 1.0 kg ai/ha where weed control declined to 80% at about seven weeks after treatment. The least effective treatment was glufosinate ammonium at 0.5 kg ai/ha. Slashing resulted in

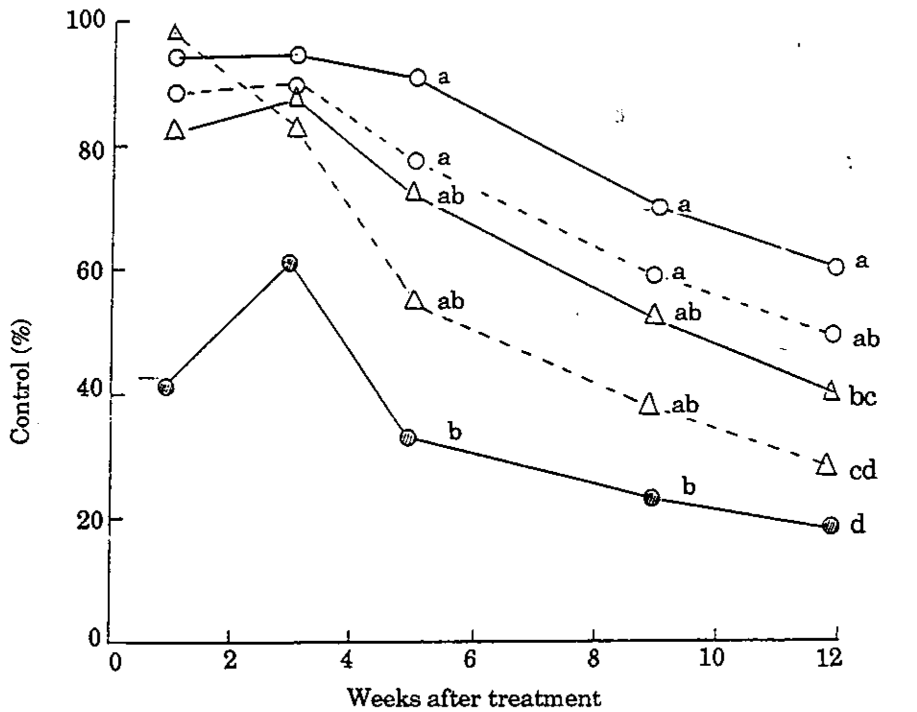

Figure 1. Effect of glufosinate ammonium, paraquat and slashing on control of *S. palustris*. Treatments were glufosinate ammonium at 0.5 kg ai/ha (●—●) and 1.0 kg ai/ha (Δ—Δ), paraquat at 0.5 kg ai/ha (O---O) and 1.0 kg ai/ha (O—O) and slashing (Δ---Δ). Same letter within the same period of observation indicates non-significant difference in percentage control at 5% level of significance.

fast regeneration but was more effective than glufosinate ammonium at 0.5 kg ai/ha. The susceptibility of this weed to paraquat as shown here agrees with an earlier report (Riepma, 1968). Its susceptibility to the contact herbicides such as paraquat or glufosinate ammonium could be due to the fern being a lower class plant and having a simple vascular system. Glufosinate ammonium, apart from its contact action, possesses some systemic activity, however, its performance was not better than paraquat.

In the trial with different rates of glufosinate ammonium, more than 80 % control was obtained with glufosinate ammonium at 1.2 to 2.4 kg ai/ha at two weeks after treatment Figure 2). However, by four weeks after treatment similar percentage control was only obtained with 2.0 and 2.4 kg ai/ha. Nine weeks after treatment, control decreased to less than 80 % and the maximum rate of 2.4 kg ai/ha gave about 60 % control only.

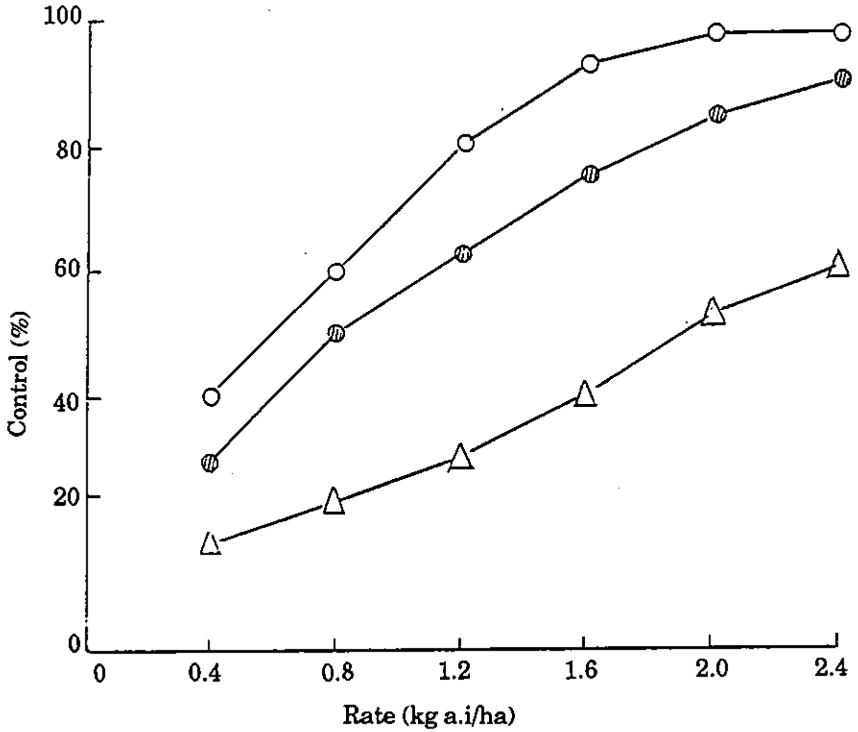

Figure 2. Control of *S. palustris* with different rates of glufosinate ammonium. Observations were made at 2 weeks(○–○), 4 weeks (⊘—⊘) and 9 weeks after treatment(Δ—Δ)

Control of this weed was increasingly better with increasing rates of paraquat (Figure 3). At three weeks after treatment, more than 80 % control was achieved with paraquat at 0.2 to 1.2 kg ai/ha. Percentage control declined in later weeks and more than 80 % control was obtained with paraquat at 0.8 to 1.2 kg ai/ha at ten weeks and at only 1.0 and 1.2 kg ai/ha by seventeen weeks after treatment.

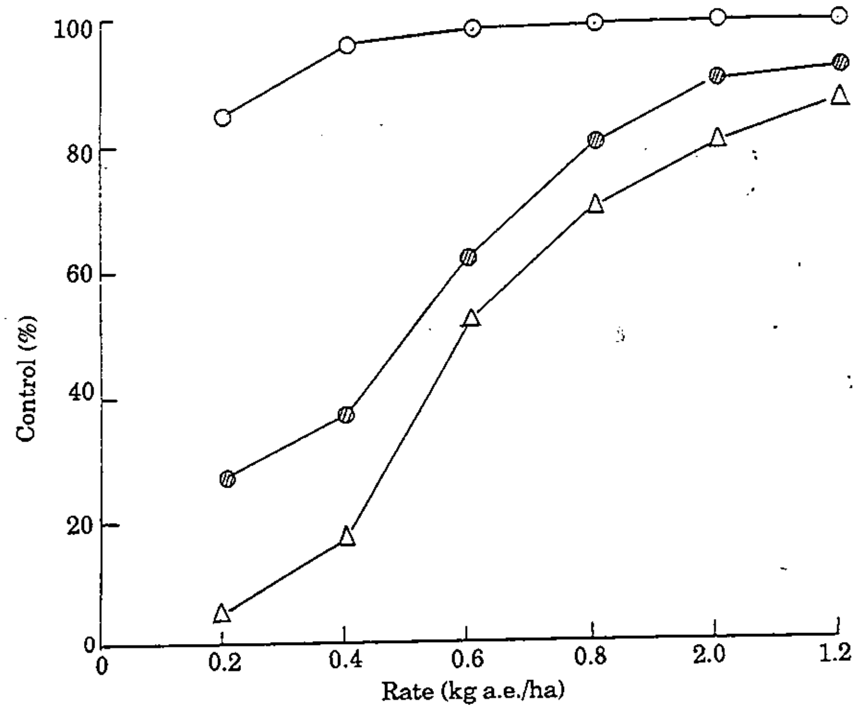

Figure 3. Control of *S. palustris* with different rates of paraquat. Observations were made at3 weeks (○—○), 10 weeks (⊘—⊘) and 17 weeks after treatment (Δ—Δ).

The results of these trials confirmed the better efficacy of paraquat over glufosinate ammonium. Even the high rates of glufosinate ammonium. Even the high rates of glufosinate ammonium did not provide persistent control.

Herbicide mixtures with glufosinate ammonium and paraquat

The addition of 2,4-D amine to glufosinate ammonium slightly improved control, however the difference was not significant (Figure 4). The addition of paraquat however showed significant improvement in weed control. Adding sodium chlorate, on the other hand, resulted in faster regeneration and also some reduction in control.

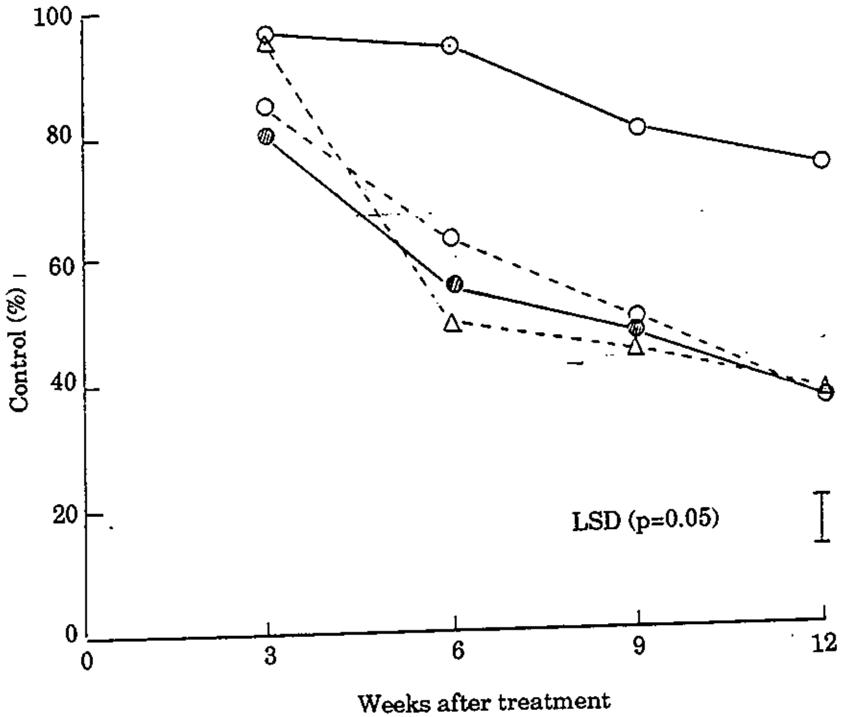

Figure 4. Effect of glufosinate ammonium alone and in mixtures with 2,4-D amine, sodium chlorate or paraquat on control of *S. palustris*. Treatments applied were glufosinate ammonium at 1.0 kg ai/ha (O—O), glufosinate ammonium + 2,4-D amine at 1.0 + 1.0 kg ai/ha (O---O), glufosinate ammonium + sodium chlorate at 1.0 + 15 kg ai/ha (Δ--Δ) and glufosinate ammonium + paraquat at 1.0 + 0.6 kg ai/ha (●—●).

In the case of paraquat mixtures, 2,4-D amine slightly improved control while sodium chlorate showed reduced control (Figure 5). The addition of glufosinate ammonium also enhanced control.

Paraquat or glufosinate ammonium mixtures showed almost similar pattern of control. The addition of 2,4-D amine did not enhance control of the weed. The addition of sodium chlorate, a contact herbicide, to paraquat or glufosinate ammonium, also contact herbicides, probably caused rapid scorching of the weed tissues and thus, reducing herbicidal activity. Faster regeneration occurred from the unaffected parts of the weed. An improvement in control with glufosinate ammonium plus paraquat is probably due to their different mechanism of action. Glufosinate ammonium inhibits the activity of glutamine synthetase responsible for the synthesis of glutamine (Kocher and

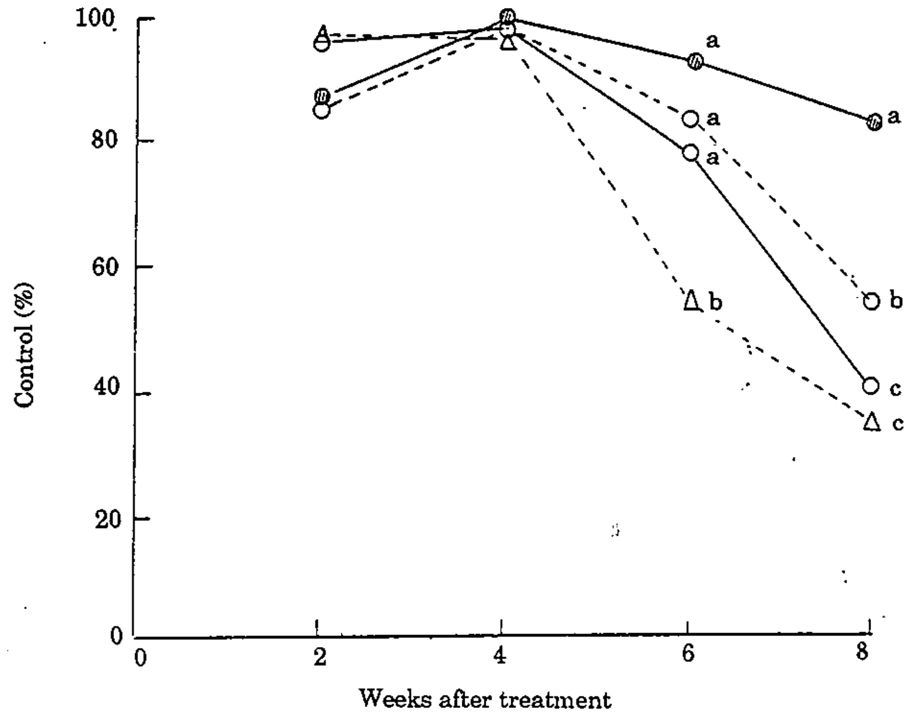

Figure 5. Effect of paraquat alone and in mixtures with 2,4-D amine, sodium chlorate or glufosinate ammonium on control of S. palustris. Treatments applied were paraquat at 0.6 kg ai/ha (O---O), paraquat + 2,4-D amine at 0.6 + 1.0 kg ai/ha (O—O), paraquat + sodium chlorate at 0.6 + 15 kg ai/ha (Δ----Δ) and paraquat + glufosinate ammonium at 0.6 + 1.0 kg ai/ha (●—●). Same letter within the same period of observation indicates non-significant difference in percentage control at 5% level of significance.

Lotzsch, 1985). Inhibiting this enzyme cause the accumulation of ammonia which is phytotoxic to the leaf cells, and hence affects photosynthesis. Paraquat phytotoxic activity depends on the presence of photosynthetic activity of the plant (Ashton and Crafts, 1973). The inhibition of photosynthesis by glufosinate ammonium probably reduced contact activity of paraquat and resulted in increased uptake and translocation of paraquat and hence increased phytotoxicity on the weed.

Mixtures of paraquat + glufosinate ammonium at lower rates of 0.2 + 0.2 and 0.2 + 0.4 kg ai/ha respectively also resulted in enhancement of weed control (Figure 6). The higher rate of glufosinate ammonium showed significant improvement in control.

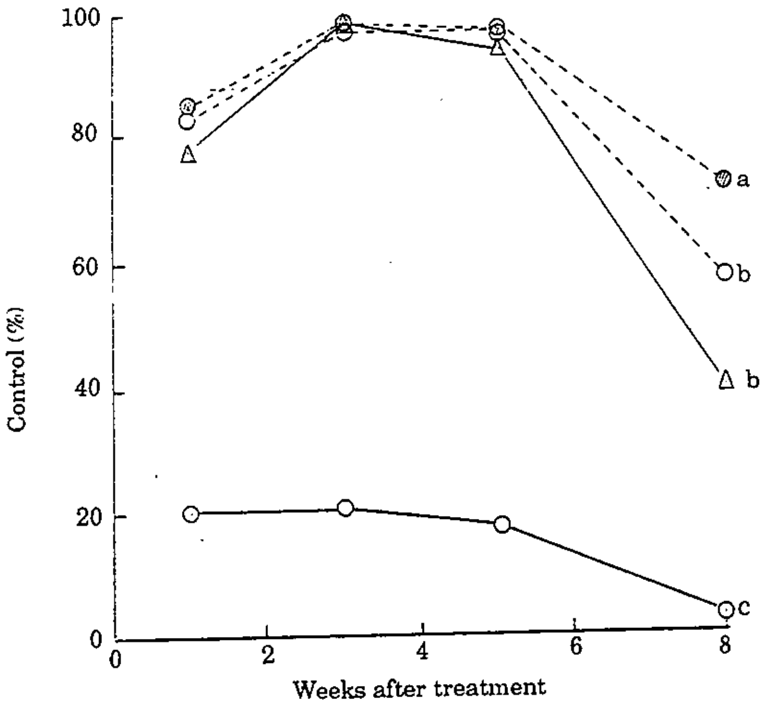

Figure 6. Effect of glufosinate ammonium or paraquat alone and in mixtures on control of S. palustris. Treatments applied were glufosinate ammonium at 0.2 kg ai/ha (O–O), paraquat at 0.2 kg ai/ha (Δ–Δ), paraquat + glufosinate ammonium at 0.2 + 0.2 kg ai/ha (O- -O) and paraquat + glufosinate ammonium at 0.2 + 0.4 kg ai/ha (◍---◍). Same letter within the same period of observation indicates non-significant difference in percentage control at 5% level of significance.

Glufosinate Ammonium or Paraquat Plus Surfactants

The addition of the cationic surfactants Hyspray 52 or Ethokem, the anionic surfactant Teepol or the nonionic surfactant Polypol Ace to paraquat did not significantly improved control (Table 5). The cationic surfactants added to glufosinate ammonium showed some improvement in control of the weed but the anionic or nonionic surfactant produced either comparable or slight reduction in control (Table 6).

Table 5. Effect of surfactants with paraquat on *S. palustris* under mature rubber

Treatment	Rate/ha (kg ai/ha)	Mean percentage control 2 wks	5 wks	10 wks
Paraquat	0.6	96	97	48
Paraquat + Hyspray 52	0,6 + 3 l	98	97	45
Paraquat + Ethokem	0.6 + 3 l	97	97	47
Paraquat + Teepol	0.6 + 3 l	98	87	48
Paraquat + Polypol Ace	0.6 + 3 l	97	89	50
LSD	(p=0.05)	NS	NS	NS

Table 6. Effect of surfactants with glufosinate ammonium on *S. palustris* under mature rubber

Treatment	Rate/ha (kg ai/ha)	Mean percentage control 2 wks	5 wks	10 wks
Glufosinate ammonium	1.0	72	70	20
Glufosinate ammonium+ Hyspray 52	1.0+5 l	75	80	28
Glufosinate ammonium+ Ethokem	1.0+5 l	75	77	25
Glufosinate ammonium+ Teepol	1.0+5 l	70	58	20
Glufosinate ammonium+	1.0+5 l	70	63	20
LSD	(p=0.05)	NS	7.5	NS

Effect of Other Herbicides

S. palustris was also susceptible to paraquat + amitrole + diuron + MCPA, paraquat + diuron and 2,4-D amine + sodium chlorate (Figure 7). In the case of paraquat + MCPA + diuron + amitrole, the lower rate of 0.3 + 0.32 + 0.48 + 0.95 kg ai/ha was ineffective, but better control was obtained with the higher rate of 0.6 + 0.48 + 0.72 + 1.425 kg ai/ha of the mixture. The initial activity of paraquat + diuron at 0.6 + 0.6 kg ai/ha was slower than paraquat at 0.5 kg ai/ha, but control was almost comparable. Treatment with 2,4-D amine + sodium chlorate at 1.0 + 20 kg ai/ha showed rapid initial activity, however, weed regeneration was fast as control dropped to 50% about 5 weeks after treatment. The susceptibility of the weed to this mixture agrees with the earlier finding by Sheperd *et al.*, (1970).

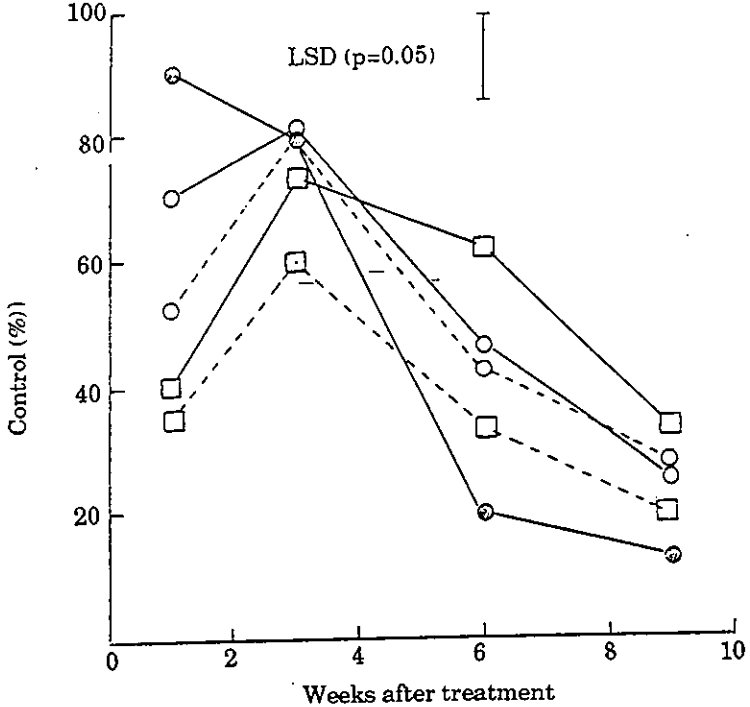

Figure 7. Effect of herbicide on control of *S. palustris* under rubber. Treatments applied were paraquat at 0.5 kg ai/ha (○—○), paraquat + diuron at 0.6 + 0.6 kg ai/ha (○—○), paraquat + MCPA + diuron + amitrole at 0.3 + 0.32 + 0.48 + 0.95 kg ai/ha (□---□) and 0.6 + 0.48 + 0.72 + 1.425 kg ai/ha (□—□), 2,4-D amine + sodium chlorate at 1.0 + 20 kg ai/ha (⊘—⊘).

Different rates of 2,4-D amine + sodium chlorate was also evaluated (Table 7). Increasing rates of sodium chlorate mixed with a fixed rate of 2,4-D amine resulted in the increase in percentage control. Increasing the rate of 2,4-D amine at a fixed rate of sodium chlorate also improved control, however, the increase was generally insignificant.

S. palustris was also susceptible to imazapyr (Figure 8). Control increased with increasing herbicide rates, however, effective control was achieved at 12 l/ha. Imazapyr is a systemic herbicide but showed very slow activity. Imazapyr at 1.0 and 1.2 kg ai/ha resulted with about 70 % and 90 % control respectively at about 11 weeks after treatment. The mechanism of action of this herbicide is through inhibition of acetohydroxyacid synthetase which inhibit synthesis of the amino acids valine, leucine and isoleucine (Shaner *et al*., 1985). This could probably be the main reason for the very slow herbicidal activity of imazapyr.

Table 7. Effects of 2,4-d amine plus sodium chlorate on *S. palustris* under mature rubber

Treatment	Rate/ha (kg ai/ha)	Mean percentage control 1 wks	2 wks	4 wks
2,4-D amine + sodium chlorate	0.66 + 10	50	85	30
2,4-D amine + sodium chlorate	0.66 + 15	65	87	42
2,4-D amine + sodium chlorate	0.66 + 20	77	88	52
2,4-D amine + sodium chlorate	1.0 + 10	52	90	35
2,4-D amine + sodium chlorate	1.0 + 15	72	92	45
2,4-D amine + sodium chlorate	1.0 + 20	83	95	53
LSD	(p=0.05)	6.3	5.1	6.8

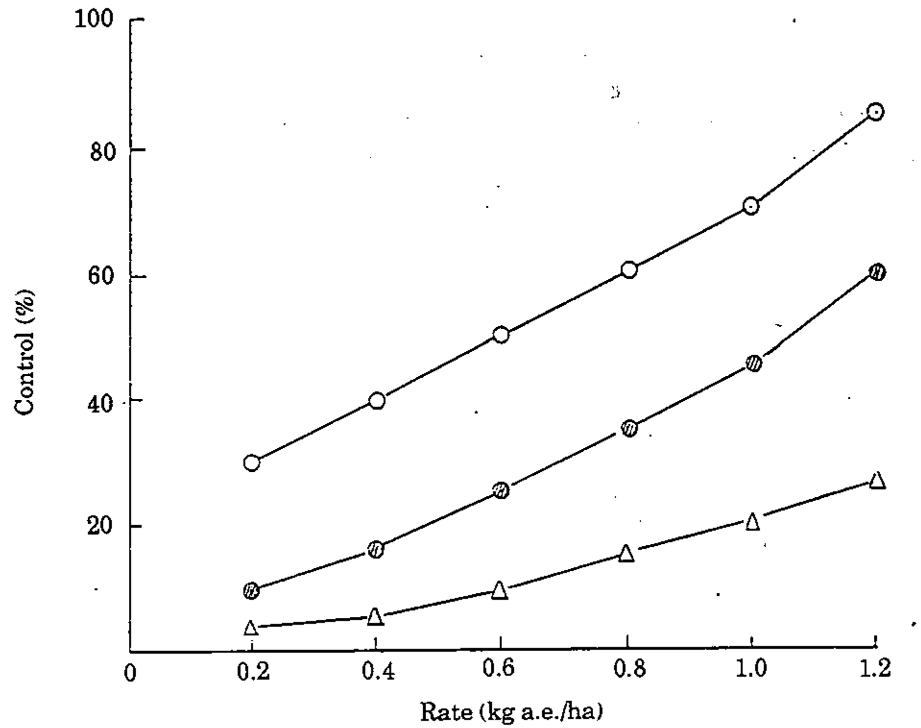

Figure 8. Effect of different rates of imazapyr on control of *S. palustris* under rubber. Observations were made at 4 weeks (△—△), 11 weeks (○—○) and 27 weeks after treatment (⊘—⊘).

Different rates of glyphosate up to 12 l/ha, hardly had any effect on the weed. This weed was thus not susceptible to this herbicide.

CONCLUSIONS

S. palustris is susceptible to glufosinate ammonium but this herbicide produced inferior control as compared to paraquat. Increased rates of these herbicides did not provide persistent control. The addition of paraquat to glufosinate ammonium significantly enhanced control as compared to the addition of 2,4-D amine or sodium chlorate. The cationic surfactants Hyspray 52 or Ethokem, the anionic surfactant Teepol or the nonionic surfactant Polypol Ace did not improve weed control with paraquat but the cationic surfactants slightly improved control with glufosinate ammonium. This weed was also susceptible to 2,4-D amine + sodium chlorate, paraquat + diuron, paraquat + MCPA + diuron + amitrole as well as imazapyr while glyphosate was ineffective at the rates tested.

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NOXIOUS SUBMERGED WEEDS OF PENINSULAR MALAYSIA

MASHHOR MANSOR[1]

ABSTRACT

To date, approximately more than five species of submerged plants could be catergorized as the noxious and serious submerged weeds in Peninsular Malaysia. These weeds thrive in various freshwater habitats ranging from rivers, irrigation and drainage canals to man-made lakes and inundated ricefields.

From the field assessments, it can be concluded that among the weeds, *Hydrilla verticillata* Royle. is rated to be the most undesirable submerged weed. This species is widely distributed and it also cused massive problems particularly to an irrigation system.

For example, in Krian rice growing area, *H. verticillata* is generally found in most of the main irrigation canals and on several occasions the fresh weight could reach 6 kg per square meter. In addition, this weed species is also found to be growing very well in disused minning pools, lakes and along the slow moving rivers.

Lake Chenderch and Lake Bukit Merah in Perak have a high populationof *H. verticillata*. To a certain extent, a lake in a remote area like Lake Chini in the state of Pahang is not free from the invasion of this submerged weed. Unlike the one which is found in a canal or flowing water, the hydrilla that grow in the lake normally produce white floating flower at certain times of the year.

Ceratophyllum demersum L. could be ranked the second most troublesome submerged weed in Peninsular, Malaysia. This species generally found in irrigation and drainage canals. The massive growth of this species could severely clog and subsequently block the canals.

Besides the two species described, *Ceratopteris thalicoides*L., *Najas graminae* Del.,*Utricularia aurea*Lour.,*Ottelia alismoides*L. and *Najas indica* Willd. are also rated as noxious submerged weeds. Most of these species are generally found in ricefields and also canals particularly in rice growing areas.

Most of this submerged weeds generally obtain adequate supply of nutrients especially fertilizer leaching from adjoining agricultural areas. In the laboratory experiment, *H. verticillata* and *C. demersum* were observed to absorb nutrients not only from the sediment but also from the water.

INTRODUCTION

It is safe to consider only submerged and floating plants as true aquatic plants. This is mainly because their life-cycle completely takes place in water.

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For example, a submerged plant anchors itself firmly on the bottom sediment and except for the flowering part, most parts including the leaves are totally submerged in the water. Therefore, the process of photosynthesis of this group of plants, unlike their terrestrial counterparts, takes place in water. Unfortunately, some of the species especially the introduced one could propagate very fast and subsequently well adapt to their surroundings. Consequently, they interfere with human activities and occasionally have caused severe problems. Therefore, in this case they are categorized as weeds, specifically aquatic weeds.

Baki and Md. Khir (1986), Mansor (1986) and Mansor (1987) have documented works on aquatic weeds of Peninsular Malaysia. However, informations on submerged weeds are limited. Like most countries in the tropics, Malaysia is not totally free from the invasion of submerged weeds. In fact several localities particularly the irrigation and drainage canals are facing serious aquatic weed problems. Millions of Malaysian ringgits have been wasted in order to eradicate these unwanted weed species.

Several control methods have been employed including mechanical, chemical, manual and biological methods. However, most of these methods do not seem to be very effective. Few species like *Hydrilla verticillata* are rated as the most undesirable submerged weeds and are fairly difficult to control. In order for an effective control, a target species should be known first. Therefore, this study could be considered an attempt to discuss and described the target species of submerged weeds which are noted as the most problematic weed species in Peninsular, Malaysia.

SURVEY

The survey of aquatic weeds around Peninsular Malaysia was conducted almost every year starting from the year 1987. The survey was generally done on the month of June each year. Places which are accessible by roads are visited and due to the limitation of time, visual observations of weed species in aquatic habitats were recorded. To substantiate the observations, water and also soil samples were taken from each locality. Samplings were relatively easy for the rivers and canals, however rubber dingy and sampan were used in the lakes and disused mining pools. Hundred sampling areas were located in this study.

The main rivers visited included Sungai Perak, Sungai Pahang, Sungai Kerian, Sungai Kelantan, Sungai Johor, Sungai Terangganu and Sungai Endau. In addition several upstream rivers which are located in the interior like Sungai Pergau, Sungai Beriyah and Sungai Rui were visited. Surveys were also conducted at irrigation and drainage canals in major rice growing areas in the Peninsula. The major rice growing areas are KADA in the States of Kelantan and Terangganu, MADA in the states of Kedah and Perlis, Kerian

district in Perak, Tanjung Karang in Selangor and Balik Pulau/Seberang Prai in Penang.

Among the lakes, Tasik Bukit Merah and Tasik Cherendoh were intensively studied. Tasik Kenering and Tasik Kenyir were observed. In addition several disused mining pools in Perak and Selangor were visited.

Habitat

Figure 1 shows that 58 sampling areas is only made up of one species. This monospecific stand is mainly due to the characteristic of a particular weed species. In man-made lake and disused mining pools only one species monopolized the whole habitat. In this case, the opportunistic species which has a broad dispersal powers and rapid growth could take advantage of the empty niche provided. Once a robust species like *Hydrilla verticillata* has colonized an area, it is rather difficult for other species of submerged plants to survive in the same locality. However few species like *Ceratophyllum demersum* and *Utricularia aureas* could co-exist with *Hydrilla verticillata*. In a stretch of canal in Simpang Lima, Kerian, it was observed that six species of submerged weeds were thriving in the same locality. Incidentily, most canals in Kerian are known to habour than three species.

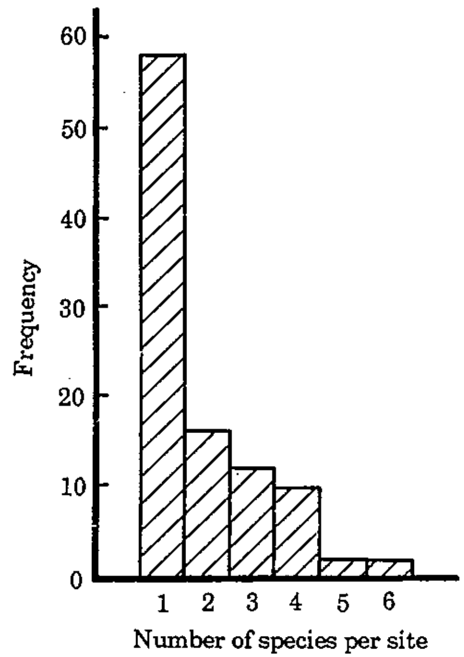

Figure 1. The frequency of species found in the 100 sampling sites

According to Radosevich and Holt (1984) in the natural system, weeds including aquatic weeds would probably be classified as pioneers, invaders or increasers. Generally, the man-made canals and lakes serve as conducive habitats for most species of aquatic weeds. Therefore, it is not surprising that these types of habitats are frequently being invaded by several species of aquatic weeds. In a secluded place like Langkawi Island where rice cultivation still follows the traditional method, except for *Utricularia aureas*, other noxious submerged weeds are unheard of. As this island is relatively isolated from the mainland, perhaps noxious weeds like *Hydrilla verticillata* and *Ceratophyllum demersum* do not reach the island.

On the contrary, Penang Island which is relatively developed and considerably higher in human population, *Hydrilla verticillata* are found in most of the small rivers on the island.

Hydrilla verticillata

Approximately 74% of the freshwater habitats visited were comprised of *Hydrilla verticillata* (Table 1). Therefore, hydrilla is singled out to be the most dominant submerged weed in Peninsular Malaysia. They are found in almost every freshwater habitats ranging from rivers, canals, lakes to fish ponds. Evidently, about twice the number of hydrilla roots were found embedded in the muddy substrates rather than the sandy sediments. The one that grows in the river is generally found on the sand. According to Hutchinson (1975), hydrilla grows faster when its roots is embedded in mud compared to the sand. Perhaps this may be one of the reason why hydrilla could propagate very fast in muddy substrate canals and lakes. However Mansor and Hifni (1990) have indicated that hydrilla could not survive in highly polluted water; for example, in the middle section of Sungai Pinang, the plant was observed to be gradually killed in this polluted water.

Table 1. The eight noxious submerged weeds found in 100 sampling sites

No.	Species	Family	%
1	*Hydrilla verticillata*	Hydrocharitaceae	74
2	*Ceratophyllum demersum*	Ceratophyllaceae	30
3	*Utricularia aurea*	Lentibulariaceae	28
4	*Najas graminea*	Najadaceae	16
5	*Ottelia alismoides*	Hydrocharitaceae	14
6	*Ceratopteris thalicriodes*	Parkeriaceae	8
7	*Vallisneria gigantea*	Hydrocharitaceae	6
8	*Najas indica*	Najadaceae	4

In Tasik Chenderoh, *Hydrilla* was found not more than 2 m deep. Perhaps the lake was turbid and light penetration could not reach a much deeper part. *Hydrilla* was found to grow deeper in a relatively clear lake like Tasik Bukit Merah. According to Den Hartog (1957) this weed could grow to the depth of seven meters in water of high clarity. These two lakes seemed to be suitable for the tremendous growth of *Hydrilla*, therefore, some of the water quality parameters of both lakes are shown in Table 2. Apparently, both of the lakes were considerably high in nutrient concentration particularly soluble phosphate. Many man-made lakes in Malaysia like Tasik Kenyir and Tasik Temenggor are still new, therefore they are virtually free from the invasion of aquatic weeds like *Hydrilla*.

Table 2. Some physico-chemical properties of Tasik Chenderoh and Tasik Bukit Merah (range; taken from 1988 to 1990)

Parameter	Tasik Chenderoh	Tasik Bukit Merah
PO4-P mg/l	0.20 - 0.40	0.06 - 0.19
Alkalinity meq/l	1.13 - 3.04	1.07 - 2.51
pH	6.36 - 6.79	5.60 - 6.80
Conductivity µS/cm	35.40 - 40.91	19.30 - 65.10

Hydrilla is widely distributed in Peninsular Malaysia. They are found in habitats with pH ranging from 4.0 to 9.2 and alkalinity values ranging from 0.1 meq/l to 3.2 meq/l. Based on this evidence, it can be postulated that this species could thrive in acidic as well as alkaline waters. They are also dominant in the canals along the coastal areas where the water conductivity values were comparatively high, sometimes reaching a maximum value of 800 µS/cm. The high reading may be due to the effect of sea water especially during high tide. However most of the time, they are found in water with less than 50 µS/cm.

Hydrilla is also known to absorb nutrient particularly phosphate directly from the water, besides absorbing it through a root system via sediment. Therefore high soluble phosphate in the water generally helps to substantiate the massive growth of *Hydrilla*. In turn, the massive growth of *Hydrilla* has created problem especially in blocking and subsequently clogging the irrigation and drainage canals. One of the worst *Hydrilla* affected areas in Peninsular Malaysia is Kerian rice growing district in which case, most of the canals were heavily infested with this submerged weed.

Apparently, *Hydrilla* found in flowing water do not produce flower unlike those found in the lakes which generally produce white flower. In Malaysia, hydrilla seldom produce seeds, even though they produce flower. Therefore, sexual reproduction seldom takes place and most of the time they produce by vegetative means. *Hydrilla* could produce by fragmentation of its parts, axillary turions and underground tubers. In fact because of this vegetative reproduction, *Hydrilla* could propagate very fast and it is very difficult to control.

According to Haller (1978), *Hydrilla* originated from Central Africa and currently causes severe problems throughout the tropical regions of the world. Swarbrick *et al.* (1982) also added that this perennial submerged aquatic herb is a weed in Australia and also southeastern Asia. It is a member of the Hydrocharitaceae and its chromosome numbers were given as 16 and 24 by Subramanyam (1962). Grass carp (*Ctenopharyngodon idella*) is known to feed heavily on this weed and Alvin (1990) stated that among the weeds, *Hydrilla* was the best feed in terms of the fish growth. Perhaps from the aspect of aquaculture, *Hydrilla* could be utilized as a grass carp feed and indirectly the fish could be used as an effective biological agent to control this weed.

Other weeds

In addition to *Hydrilla verticillata*, there are seven plants which could be considered as weeds. Table 1 shows there was 30% occurence of *Ceratophyllum demersum* and 28% *Utricularia aurea* at the sampling sites. *Najas graminae* was observed at 16 (16%) sampling sites and *Ottelia alismiodes* was observed at 14 (14%) sites. Among the ferns, by far *Ceratopteris thalicroides* was considered the most dominant aquatic fern in the Peninsular. Like Ottelia, *Vallisneria gigantea* is an annual plant from the family Hydrocharitaceae and these plants seem to be dominant at certain times of the year. *Najas indica* has shown an impact on several lakes and to a certain extent, they are also found in the rice paddies.

Rataj and Horeman (1977) stated that the family Ceratophyllaceae is composed exclusively of perennial plants includes only the genus ceratophyllum with two species. However, only *Ceratophyllum demersum* L. is known to be a weed which is widely distributed all over the world. According to Pip and Philip (1990), this submerged weed can grow at a variety of depths ranging from just below the surface to 14 m. It should be noted that true roots are absent and are replaced by short rhizoid and the plant could absorb nutrient from other parts. Propagation is mainly by stem breakage. Nik Noraini (1989) had shown that under a shaded condition with relatively low light intensity 400 lux *Ceratophyllum demersum* could grow very fast and outclass the massive growth of *Hydrilla.*

CONCLUSION

It is interesting to note that out of the eight submerged weed species, three species are from the family Hydrocharitaceae and two species are from Najadaceae. The rest are made up of one family, Ceratophyllaceae (*Ceratophyllum demersum*), Lentibulariaceae (*Utricularia aurea*) and Parkeriaceae (*Ceratopteris thalictroides*).

It can be concluded that currently *Hydrilla verticillata* is the most noxious submerged weed in the Peninsula. Although *Ceratophyllum demersum* is rated to be the second noxious weed, however, this weed has a potential of becoming the most noxious weed. Another potential submerged weed to be watch is *Najas graminae*, so far it has shown good growth in some parts of a lake. Although *Ottelia alismoides* and *Vallisneria gigantea* have shown tremendous grow rate, since they are annual plants, they are generally absent certain times of the year and these do not pose much danger compare to their perennial counterparts.

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THE EFFECT OF WEED CONTROL PRACTICES AND RATE OF NITROGEN FERTILIZER ON YIELD AND NITROGEN UPTAKE BY UPLAND RICE AND WEEDS

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ABSTRACT

Field experiments were conducted over three years in West Bengal, India with 0, 36, 54 and 72 kg/ha of applied nitrogen and unweeded and manually, physically and chemically (butachlor) weeded upland rice crops to determine the interactions of these treatments on rice and weed yields and nitrogen content.

Increasing rates of nitrogen promoted weed growth and dry matter. Nitrogen uptake by weeds increased with increasing levels of nitrogen applied to the soil. Two hand weedings was the most effective method of weed control and produced the highest yields of rice grain and straw, followed by the physical and chemical methods. Nitrogen uptake by rice was fairly constant between 36 and 72 kg nitrogen/ha and varied considerably between years.

INTRODUCTION

Nitrogen application is essential for increasing the production of modern rice varieties, but high levels of nitrogen increase weed growth (Wankhede, 1970). In upland rice weeds generally emerge simultaneously with direct seeded rice and compete for applied nutrients with the crop plants, reducing the efficiency of the applied nitrogen and adversely affecting both crop growth and yield. The magnitude of yield reduction, however, varies with input management, weed species, and weed density (Pandey *et al.*, 1980). Since yield loss of direct seeded rice is primarily due to competition by the weeds for nutrients, it's necessary to adopt suitable weed control practices in order to realize the yield potential of modern rice genotypes.

Herbicide usage in rice growing areas is increasing with butachlor being widely applied as an effective pre-emergence herbicide for controlling annual grasses and broadleaf weeds. Mechanical devices are also available for controlling weeds very effectively in line sown crops.

For chemical weeding butachlor (Machete 50 EC) was applied @ 1.5 kg ai/ha as a pre-emergence herbicide two days after sowing by knapsack sprayer. A uniform application of 45 kg P_2O_5 and 30 kg K_2O per hectare was incorporated into the soil at the time of sowing. Nitrogen was applied as pre-treatment in two equal splits at sowing and at tillering stage. The present

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investigation studied the influence of different weed control methods on the yield performance and nitrogen use and economy of upland rice.

MATERIALS AND METHODS

The investigation was carried out at the Indian Institute of Technology, Kharagpur, West Bengal, India during the wet seasons of 1987, 1988 and 1989.

The soil at the experimental site was an acidic lateritic sandy-clay-loam with a pH of 5.2, organic carbon content of 0.38%, available P_2O_5 of 0.0004%, available K_2O of 0.1%, and CEC of 8.3 me/100g. A uniform application of 45 kg/ha of P_2O_5 and 30 kg/ha K_2O was incorporated into the soil at planting.

The rice variety used was NW-10 (Mtu 15 x Yaikoku) and was sown at 20 cm row spacing at the beginning of the monsoon rains.

The treatments consisted of four rates of applied nitrogen and four weed control practices. Zero, 36, 54 and 72 kg of nitrogen/ha were applied.

The four weed control practices were an unweeded check, two hand weedings, mechanical interrow weeding with the IITWAM-82 weeder-cum-herbicide applicator developed at the Institute, and butachlor (as Machete 50 EC) applied at 1.5 kg ai/ha two days after sowing with a knapsack sprayer.

The predominant weed species and total weed dry matter were recorded at harvest, as were the grain (at 14% moisture) and straw yields of the rice. The total nitrogen content in weed, rice grain and rice straw samples was determined by the Kjeldahl method (Jackson, 1973) and nitrogen uptake was calculated from the percentage nitrogen and total drymatter weights of weeds, rice grain and rice straw.

RESULTS AND DISCUSSION

The predominant weed species were *Echinochloa crusgalli* (L.) Beauv., *Digitaria sanguinalis* (L.) Scop., *Cyperus rotundus* L., *Cyperus iria* L., *Cynodon dactylon* (L.C. Rich.) Pers., *Fimbristylis miliacea* (L.) Vahl, *Ludwigia perennis* L. and *Cleome viscosa* L.

Drymatter of Weeds

The weeds were effectively controlled by all weed control practices (Table 1). Hand weeding was the most effective treatment and reduced the drymatter of weeds by 84% compared to the unweeded check. Mechanical weeding was inferior to hand weeding (reducing drymatter by 46% compared to unweeded check) as it could control the weeds growth only in the interrow spaces. Although butachlor initially controlled all weeds at later stages the grassy

weeds (particularly *Cyperus rotundus* and *Cynodon dactylon*) reinfested and the drymatter of weeds at harvest was only 48% less than the unweeded check.

Table 1. Effect of Weed Control Practices and Nitrogen Levels on Drymatter Production and Nitrogen Uptake of Weeds

Treatments	Drymatter, t/ha				N-uptake, kg/ha			
	1987	1988	1989	Mean	1987	1988	1989	Mean
Unweeded check	2.8	2.6	1.5	2.30	51.1	40.6	19.0	36.9
Hand weeding	0.3	0.6	0.2	0.36	4.7	9.7	2.0	5.5
Mechanical weeding	2.0	1.0	0.7	1.23	28.4	15.3	9.1	17.6
Butachlor @ 1.5 kg ai/ha	2.1	0.9	0.6	1.20	32.0	16.8	8.5	19.1
CD at 5%	0.5	0.9	2.3	-	-	-	-	-
N-levels, kg/ha								
0	1.5	0.8	0.7	1.00	25.1	12.0	8.4	15.2
36	1.9	1.4	0.7	1.33	27.6	22.3	9.0	19.6
54	1.9	1.6	0.8	1.43	30.1	28.2	10.5	22.9
72	1.9	1.4	0.8	1.37	32.6	20.3	10.7	21.2
CD at 5%	0.5	0.9	-	-	-	-	-	-

Application of varying doses of nitrogen had marked effects on the growth and population of weeds with increases in drymatter being recorded with increasing nitrogen levels upto 56 kg/ha in each years. A positive correlation (r=0.89) was observed between nitrogen levels and drymatter of weeds. Gautam *et al.* (1981) reported similar increases in the drymatter of weeds with increasing levels of nitrogen fertilizer.

Grain Yield of Rice

The grain yield of rice was significantly increased by all weed control treatments as compared to the unweeded check except mechanical weeding (Table 2). Maximum yield was obtained under hand weeding treatment which averaged 50% higher yield than the unweeded check, primarily due to less crop-weed competition which was apparent from the reduced drymatter of the weeds (Table 1). Mechanical weeding increased grain yield by only 32%, due to the competition of weeds with the crop in the intrarow spaces. Under chemical weeding though the crop-weed competition was less initially, at later stages the weeds competed with the crop due to regeneration of sedges and grassy weeds, hence the average increase in yield over the unweeded check was only 26%.

Table 2. Effect of weed control practices and nitrogen levels on yield and uptake of nitrogen by rice

Treatments	Yield, t/ha								N-uptake (grain + straw) kg/ha			
	Grain				Straw							
	1987	1988	1989	Mean	1987	1988	1989	Mean	1987	1988	1989	Mean
Unweeded check	0.96	1.73	3.65	2.11	1.84	2.97	4.72	3.18	20.7	15.0	80.9	38.9
Hand weeding (twice)	2.45	2.63	4.43	3.17	2.84	2.73	5.72	3.76	44.1	61.6	104.9	70.2
Mechanical weeding	2.19	2.04	4.12	2.78	2.91	2.87	4.97	3.58	45.2	27.4	94.9	55.8
Butachlor @ 1.5 kg a.i./ha	1.59	2.22	4.18	2.66	2.26	2.73	5.37	3.45	32.8	25.4	99.0	52.4
CD at 5%	0.31	0.39	0.42	-	0.65	0.29	0.85	-	-	-	-	-
N-levels, kg/ha												
0	1.04	1.65	3.34	2.01	1.54	2.08	4.30	2.64	19.7	19.6	80.3	39.8
36	1.79	1.93	4.19	2.64	2.50	2.64	5.33	3.49	36.2	36.6	95.4	56.1
54	1.95	2.39	4.33	2.89	2.54	3.12	5.43	3.69	38.2	39.0	98.7	58.6
72	2.40	2.65	4.52	3.19	2.52	3.46	5.70	3.89	49.7	34.2	104.5	62.8
CD at 5%	0.31	0.39	0.42	-	0.65	0.29	0.85	-	-	-	-	-

The straw yield rice was also higher under hand weeding followed by mechanical and chemical weeding than the unweeded check (Table 2). There was substantial increase in straw yield when nitrogen was applied at 36 kg/ha but further increases upto 72 kg/ha produced only marginal increases in straw yield.

Nitrogen Uptake by Weeds and Crop

The depletion of nitrogen by crop and weeds was significantly affected by different weed management practices and nitrogen treatments. The removal of nitrogen by weeds was considerably reduced by various weed control practices and was at a minimum after hand weeding (Tables 1 & 2 and Fig. 1). Similar findings were also reported by Singh *et al.* (1987). The contribution of nitrogen uptake by weeds to total nitrogen uptake (weed + crop) was estimated to be 48% in the unweeded check, and only 7% after hand weeding, 22% after mechanical control and 26% after chemical control, 22%-41% of nitrogen could be saved through the adoption of weed control practices.

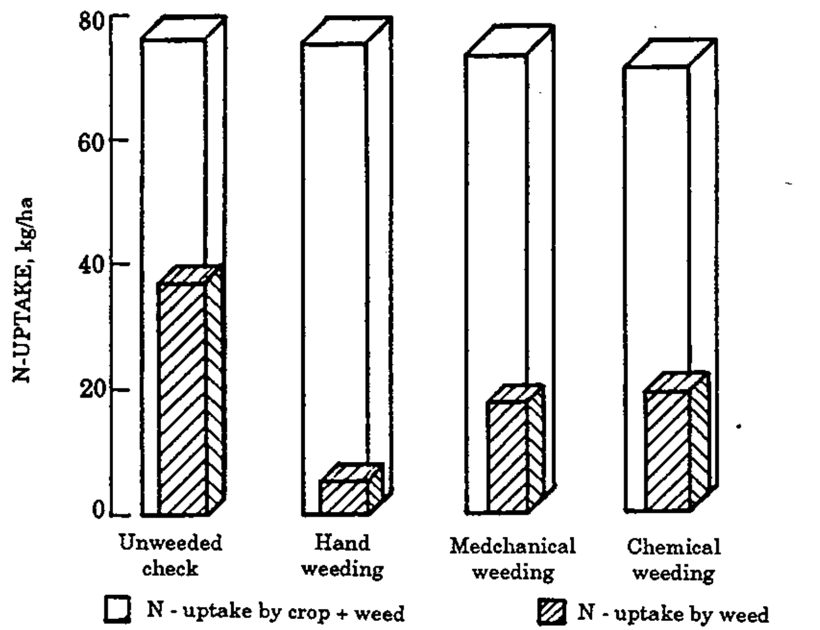

Figure 1. Nitrogen uptake by crop and weed under different weed management practices

Losses of nutrients to weeds was increased with increasing levels of nitrogen. At 36 kg and 54 kg N/ha, the uptake of nitrogen by weeds was 29%

and 50% higher than in unfertilized treatment. Further increase in nitrogen did not cause additional weed incidence or nitrogen uptake by the weeds. A positive correlation (r=0.9) was observed between nitrogen levels and nitrogen uptake by the weeds.

The uptake of nitrogen by rice was mainly governed by its dry matter production. It is apparent from Tables 1 & 2 that whenever the removal of nitrogen was higher through weeds, the corresponding up take by rice was less and vice versa. Therefore, for efficient utilization of applied nitrogen fertilizers, the weeds should be kept under check. The nitrogen uptake by the rice plant (grain and straw) was significantly higher after hand weeding (70 kg/ha) followed by mechanical (55 kg/ha) and chemical methods (52 kg/ha). Further nitrogen uptake increased substantially upto the 36 kg N/ha level, beyond which the increase was marginal. A positive correlation (r=0.97) between nitrogen levels and nitrogen uptake by rice (grain + straw) was further confirmed in the above observation.

Applied nitrogen can only be efffectively used by a crop if appropriate weed control practices are adopted. Hand weeding was found to be most effective in reducing nitrogen losses to weeds followed by mechanical weeding and chemical weeding. The selection of the weed control method will, however, depend upon the availability of manpower and the cost effectiveness of each practice. The level of fertilizer input should also take into account the type of weed infestation.

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METSULFURON, CHLORIMURON AND TRIBENURON-LOW DOSE HIGH EFFICIENCY HERBICIDES FOR WEED CONTROL IN TRANSPLANTED RICE

S.K. MUKHOPADHYA AND R.B. MALLICK[1]

ABSTRACT

Metsulfuron methyl at 2, 4 and 8 g ai/ha, chlorimuron ethyl at 6, 12 and 24 g ai/ha and tribenuron methyl at 7.5, 15 and 30 g ai/ha as well as some combinations of pairs of these herbicides were tested for post transplanting weed control in rice in standing water in the kharif (warm-wet) season in West Bengal, India. Butachlor at 1500 g ai/ha was used as a standard herbicide with hand weeded and unweeded controls. The weed flora consisted of grasses (especially *Echinochloa colona* (L.) Link), broad leaves (mainly *Ludwigia parviflora* Roxb. and *Sphenoclea zeylanica* Gaertn.) and sedges (dominated by *Fimbristylis miliacea* (L.) Vahl).

All rates of all three herbicides killed all weeds within ten days and kept the plots weed free until harvest. Grain yield factors and grain and straw yields were similar in all herbicide treatments and the hand weeded control.

INTRODUCTION

In India, transplanted rice crop with standing water has the largest area, mostly grown in kharif (warm-wet) rainy season. In the traditional rice belt of Eastern India this crop is mostly rainfed and grown on medium or low land with standing water.

Transplanted rice has considerable weed problems, with average losses in yield in India estimated as 11-20% (Mukhopadhyay, 1978; De Datta, 1981; Mukhopadhyay, 1981; Mukhopadhyay, 1983). Considering the very large area under transplanted rice the total yield reduction due to weed infestation becomes very high. In some areas algal (Characeae) weed problems are very acute whilst where maintenance of constant standing water is not possible and fields become dry, weeds come up vigorously in large numbers and if effective measures are not taken to control them yield losses in transplanted rice become quite heavy.

Furthermore, due to continuous use of herbicides and the introduction of intensive cropping practices with high yielding varieties of crops some weeds have become common and serious even in transplanted rice in standing water, including *Sphenoclea zeylanica* Gaertn., *Ludwigia parviflora* Roxb., *Monochoria vaginalis* Burnf. and *Marsilea quadrifolia* L.

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Over the last few decades many herbicides have been used to control weeds in transplanted rice in India, with different degrees of success. Butachlor has become one of the most effective and widely accepted rice herbicides.

In this investigation three new herbicides were tested to find out the nature and extent of their weed control and their effect on growth and yield of transplanted rice.

MATERIALS AND METHODS

The field experiment was conducted at the Intitute of Agriculture, Palli Siksha Bhavana, Sriniketan, Birbhum, Visva-Bharati University, West Bengal, India during kharif (warm-wet) season of 1990. The area is situated 23°39' N and 87°42' E at an altitude of 60 m above sea level in a sub-humid climate with an average rainfall of 1200-1400 mm, most of which is received during June to September. The soil of the experimental field is lateritic, light textured and slightly acidic in nature (pH 5.5).

The experiment was carried out in Randomised Block Design with 17 treatments (Table 1) replicated thrice. The rice cultivar was IR-36. The herbicides tested were metsulfuron methyl, chlorimuron ethyl and tribenuron methyl supplied by Du Pont Far East Inc. as Ally, Classic and Express respectively. The standard rice herbicide butachlor was included for comparison as well as a weed free check and an unweeded control. The herbicides were mixed with sand and spread evenly over each plot in which standing water 5 cm deep was maintained for 7 days after application.

Observations were taken of weed density and dry weight, crop toxicity at 30, 50 and 75 days after transplanting and at harvest, rice tillers/m^2, filled grains/panicle, 1000 grain weight and grain and straw yield/ha at harvest, and weed densities and dry weights 5, 10, 15 and 50 days after herbicide application and at harvest.

Characteristics and Mode of Action of The Herbicides

Metsulfuron methyl (Ally) is methyl 2 [[[[4 methoxy - 6 methyl - 1, 3, 5 triazine - 2-yl) amino] carbonyl] amino] sulfonyl] benzoate with molecular formula $C_{14}H_{15}N_5O_6S$. It is available as 20% WP from Du Pont Far East Inc.

Chlorimuron ethyl (Classic) is 2(([4-chloro - 6 methoxy-pyrimidine-2-yl) amino carbonyl] amino sulfonyl)) benzoic acid, ethyl ester with molecular formula $C_{15}H_{15}Cl_1N_4O_6S$. It is available as 25% WP from Du Pont Far East Inc.

Tribenuron methyl (Express) is methyl 2[3-(4 methoxy - 6 methyl - 1, 3, 5 triazine 2-yl)-N-methyl-amino] carbonyl] amino] sulfonyl] benzoate with molecular formula $C_{15}H_{17}N_5O_6S$. It is available as 10% WP from Du Pont Far East Inc.

Tabel 1. Particulars of Treatments.

Sl. No.	Herbicides: Common Name	Dose g ai/ha	Trade Name	% a.i.	dose/ha	Time of Application
T1	Metsulfuron methyl	2 g	Ally	20%	10 g	12DAT
T2	Metsulfuron methyl	4 g	Ally	20%	20 g	12DAT
T3	Metsulfuron methyl	8 g	Ally	20%	40 g	12DAT
T4	Chlorimuron ethyl	6 g	Classic	20%	24 g	12 DAT
T5	Chlorimuron ethyl	12 g	Classic	20%	48 g	12 DAT
T6	Chlorimuron ethyl	24 g	Classic	20%	96 g	12 DAT
T7	Tribenuron methyl	7.5 g	Express	10%	75 g	12 DAT
T8	Tribenuron methyl	15 g	Express	10%	150 g	12 DAT
T9	Tribenuron methyl	30 g	Express	10%	300 g	12 DAT
T10	Metsulfuron methyl + Chlorimuron ethyl	2 + 6 g	Ally / Classic	20% / 25%	10 g + 24 g	12 DAT
T11	Metsulfuron methyl + Chlorimuron ethyl	4 + 4 g	Ally / Classic	20% / 25%	20 g + 16 g	12 DAT
T12	Metsulfuron methyl + Chlorimuron ethyl	4 + 12 g	Ally / Classic	20% / 25%	20 g + 48 g	12 DAT
T13	Tribenuron methyl + Chlorimuron ethyl	7.5 g + 6 g	Express / Classic	10% / 25%	75 g + 24 g	12 DAT
T14	Tribenuron methyl + Chlorimuron ethyl	15 g + 12 g	Express / Classic	10% / 25%	150 g + 48 g	12 DAT
T15	Butachlor	1500 g	Tear	50%	3000 g	3 DAT
T16	Weed free check					
T17	Un-Weeded control					

DAT = Days After Transplanting; g = gram; ai = active ingredient

All three herbicides stop cell division by inhibiting biosynthesis of the essential amino acids valine and isoleucine. They are absorbed by plant foliage and roots and translocated throughout the plant. Susceptible plants cease growth almost immediately after post emergence treatment and are killed in 7-21 days.

Weed Flora

The weed flora in the experimental field consisted of grasses, broad leaves and sedges of which the predominant weed species were *Echinochloa colona, Ludwigia parviflora, Sphenoclea zeylanica* and *Fimbristylis miliacea* (Table 2).

Table 2. Weed Flora in the Experimental Field

Species	Family	Life cycle
Echinochloa colona (L.) Link	Poaceae	Annual
Cynodon dactylon (L.) Pers.	Poaceae	Perennial
Ludwigia parviflora Roxb.	Onagraceae	Annual
Sphenoclea zeylanica Gaertn.	Sphenocleaceae	Annual
Alternanthera sessilis (L.) DC.	Amaranthaceae	Annual
Lindernia ciliata (Colsm) Pannel	Scrophulariaceae	Annual
Cyperus iria L.	Cyperaceae	Annual
Fimbristylis miliacea (L.) Vahl	Cyperaceae	Annual

RESULTS AND DISCUSSION

Effects on Yield Component of Rice

Among the yield attributing characters, the number of effective tillers/m^2 and number of filled grains/panicle showed statistically significant increase in all other treatments over the unweeded control although the 1000 grain weight did not differ significantly between treatments (Table 3) with no significant differences between them.

Effects on Grain Yield of Rice

All rates of all four herbicides alone and in combinations resulted in insignificant yield differences to the weed free check (Table 3). The herbicides thus proved to be efficient at low doses in achieving effective weed control in transplanted rice.

Effects on Straw Yield of Rice

All rates of all herbicides and the weed free check gave similar yields of rice straw, all of which were significantly more than that of the unweeded control (Table 3).

Table 3. Effect of Herbicides on Yield and Yield Attributing Characters of Transplanted Rice

Treatments	Dose g ai/ha	No. of Effective tillers/m^2	No. of filled grains/ panicle	1000 grain weight (g)	Grain yield t/ha	Straw yield t/ha
Metsulfuron methyl	2	445.00	68.67	21.65	3.81	5.90
Metsulfuron methyl	4	441.66	68.33	22.25	3.84	6.02
Metsulfuron methyl	8	433.33	67.00	21.95	3.71	5.97
Chlorimuron ethyl	6	413.33	69.33	22.17	3.92	5.90
Chlorimuron ethyl	12	420.00	67.33	21.83	3.83	5.85
Chlorimuron ethyl	24	391.66	64.67	21.00	3.24	5.75
Tribenuron methyl	7.5	471.67	67.33	21.25	4.04	5.94
Tribenuron methyl	15	451.66	69.33	21.75	3.64	6.11
Tribenuron methyl	30	411.66	73.35	22.00	3.99	5.96
Metsulfuron methyl + Chlorimuron ethyl	2 + 6	470.00	66.33	21.25	3.74	5.72
Metsulfuron methyl + Chlorimuron ethyl	4 + 4	453.33	70.00	21.33	3.67	5.68
Metsulfuron methyl + Chlorimuron ethyl	4 + 12	400.00	66.67	21.70	3.58	5.89
Tribenuron methyl + Chlorimuron ethyl	7.5 + 6	471.67	70.67	21.50	3.55	5.82
Tribenuron methyl + Chlorimuron ethyl	15 + 12	453.33	70.33	21.83	3.82	5.68
Butachlor	1500	408.33	68.67	21.83	3.89	5.94
Weed free check		435.00	70.00	21.75	3.64	5.70
Un-weeded control		283.00	45.00	20.00	2.27	4.40
S. Em. = ±		26.76	3.57	NS	0.23	0.23
C. D. =		76.37	10.13		0.66	6.68

Effects on Weeds

All three new herbicides even at the lowest doses killed all weeds of all categories within 10 days after application and kept the plots weed free throughout the growth period of rice crop. The number of weeds in the control plots increased up to 50 days after transplantating then declined due to loss of annual weeds (Table 4).

Table 4. Weed Counts and Weed Dry Weight in Control Plots

Weeds/m^2	30 DAT	50 DAT	75 DAT	At harvest
Grasses	8.00 (1.16)	18.67 (9.33)	3.00 (0.84)	2.33 (0.66)
Broad leaved	119.00 (18.44)	181.33 (36.67)	73.67 (14.50)	9.33 (4.00)
Sedges	54.33 (11.33)	131.67 (45.00)	26.33 (12.60)	11.67 (8.50)
Total	181.33 (30.93)	331.67 (91.00)	103.00 (27.94)	23.33 (13.16)

N.B. : Figures in parenthesis indicate the dry weights of weeds/m^2.

Since all doses of the new herbicides showed the same high efficacy, only lowest doses needed to be considered as the recommended effective dose for efficient weed control in transplanted rice.

Toxicity

Toxicity was observed 5, 10, 15 and 50 days after herbicide application and at harvest. No phytotoxicity was observed on crop plant on any occassion even at the highest rates.

Potato was planted after harvesting the rice crop in the same experimental plot. Observations were taken on germination and phytotoxicity on the potato crop if any. Germination percentage was 100% and no phytotoxicity developed in the potato crop from early vegetative stage to harvesting.

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EDUCATION, TRAINING, RESEARCH AND EXTENSION

INFORMATION IN WEED SCIENCE

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ABSTRACT

An overview is presented of the development of information sources and information technology in weed science internationally. The information requirements of those actively angaged or interseted in weed science are considered in relation to the available literature and other sources of information, including bibliographic databases, and the role of international weed societies and information services. Future prospects for wed-related information dissemination are discussed against a background of increasing interest in CD-ROM for stand-alone retrieval and in knowledge-based expert systems for decision making and prediction.

INTRODUCTION

The disparate nature of early work on weeds and control made the task of tracing information in the literature difficult and chancy. However, ever since the recognition of weed science as a multi-disciplinary entity, information presentation and dissemination procedures have progressively developed to meet the wide variety of user requirements.

The establishment of academic, public and commercial organisations dedicated to weed-related activities has provided the impetus for the coordination and production of a whole new section of the scientific literature. This ranges from local extension leaflets aimed at the farmer to extensive and authoritative textbooks covering all aspects of the science together with regulatory and legislative aspects and numerous other topics influencing the sociological, economic, environmental and agronomic impact of weeds and their control.

Moreover, the conderable increases in the number of personnel actively engaged or interested in weed-related work over the past 30 years, the increased interest in vegetation manipulation as a means of enhanching the environment, and the recent moves towards integration of crop protection initiatives have served to maintain the demand for information and documentation, to extend the area of interest, and to encourage the information technologist to use the new opportunities currently available for information management.

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INFORMATION REQUIREMENTS

The importance of information for on-farm management decisions is beyond dispute and it is as relevant for small-scale subsistence farming in Developing Countries as it is for intensively managed large arable farms with a range of control options at their disposal. Local information needs, which will vary from farm to farm, can be provided by regional extension workers, by commercial advisory personnel or by recourse to a file of data built up by the farmer himself, frequently in conjunction with a PC and floppy disks.

As weed information users, farmers and growers are joined by vast number of botanists, ecologist, agronomists, chemists, biochemists, plant physiologists, toxicologists, soil scientists and agricultural engineers. Their information needs are truly diverse with much reliance being placed on the primary literature and conference material.

The collection, management and distribution of relevant information for all these user groups may serve many purposes ranging from the provision of overviews or responses to specific requests for assistance with decision making (Putter and Van der Graaff, 1989). It is the aim of this paper to identify some of the available literature and other sources of information on weed science and to discuss the ways in which this information can most effectively be imparted.

THE LITERATURE

Primary Journals

The literature of modern weed science is extraordinarily diverse for a subject area capable of relatively clear lines of demarcation. Before the advent of growth regulator herbicides, the majority of papers on the biology and control of weeds was published in serials devoted to general aspects of biology and agronomy. But it was the appearance and widespread availability of these selective compounds that led to a dramatic increase in interest in weeds. Initaially, while many of the results were of significance to agronomists, the publication of research findings was frequently confined to regional conference proceedings, particularly in USA (Ivens, 1980). With the publication of research papers of more permanent significance, serial devoted exlusively to publishing original papers in weed science emerged. Frequently, these are the official publications of weed science societies, such as: **Weed Science**, USA; **Weed Research**, UK; **Weed Research**, Japan; **Indian Journal of Weed Science**; they reflect current research trends.

Reviews and papers in the various herbicide-related areas concerning chemistry, physiology and soil behaviour and the environmental impact of

herbicides appear frequently in **Pesticide Science, Journal of Agricultural and Food Chemistry** and **Pesticides Biochemistry**, and **Physiology**.

These primary journals cater for the academic and research community having a considerable input from university and official research workers, while industry appears now to be less inhibited by commercial constraints and publishes work associated with herbicide products freely in those serials. Those who have an interest in a particular proprietary product, however, may well find a direct approach to the manufacturer or formulator worthwhile.

Vegetation management and weed population dynamics are well represented in the literature following the vast proliferation of environmental titles. These include **Environmental Science and Technology, Journal of Environmental Management** and **Journal of Environmental Quality**.

Monograph and Extension Documents

There is a vast range of floras, handbooks and guides for weed identification and management. The majority of countries produce their own practical hanbooks on the identification and control of weeds. These are auqmented by extension leaflets distributed by official agencies and innumerable leaflets and brochures giving guidance on various crop/weed situations and in the use of manufactures' products.

NOMENCLATURE

The weed scientist is faced with a confusing variaton in weed nomenclature resulting from, in many cases, unresolved synonymies in scientific names and from the many common names given to the same weed species in different countries. The composite list of major weed species, their synonyms, common names and abbreviations produced by Bayer (Bayer, 1986) goes some way towards achieving coordination, but the matter remains largely unresolved. For herbicides, on the other hand, effective directories of approved products, with details of their chemistry, uses and nomenclature, are widely available in most countries and regions. **The European Directory of Agricultural Products, Herbicides** (Royal Society of Chemistry, 1991) is a paticularly valuable guide to the extensive range of herbicide products in Europe.

More detailed information on the chemistry and properties of herbicides is contained in the **Pesticide Manual** (Worthing, 1990), while a list of currently used common names and ebbreviations for herbicides and selected plant growth regulators is given in **Weed Abstracts.**

SECONDARY SOURCES AND BIBLIOGRAPHIC DATABASES

The weed scientist wishing to keep abreast with the latest developments reported throughout the primary literature has at his disposal abstract citation journals, bibliographies and computerized information services, all of which, if used diligently, are capable of saving the searcher time and money.

To this end the major bibliographic databases, such as **AGRICOLA, AGRIS, BIOSIS Previews** and **CAB ABSTRACTS**, have highly effective search facilities which can be easily restricted to the weed science field (Gouch and Cowie, 1989). Of these, **CAB ABSTRACTS** holds a predominant position in its coverage of world agricultural documentation. The weed science subfile of the **CAB ABSTRACTS** databise is pubiished in the CABl journal Weed Abstracts, produced by weed specialists in the Department of Crop Protection. It features approximately 4500 recods per year obtained from scanning 4000 titles from of some 120 countries in more than 50 languages.

As part of its commitment to provide information to the international scientific community in the most convenient and cost-effective form, CAB International has now made its database from 1984 onwards available on CD-ROM, which, in conjunction with a suitable PC, provides stand-alone retrieval. All the indexing, bibliographic details and abstracts that are available on the database and in the printed products are presented in this convenient form. Its independence of telecommunications makes it particularly suitable for use indeveloping countries.

INFORMATION SERVICES

The researcher frequently works in isolation and, despite being remarkably well served by the latest information technology, he may be oblivious of activities in other parts of the world which are related to his work; the establishment of contacts may be of vital importance to his project. Fortunately, weed scientists are well placed in having a number of regional organisations which represent the interests of their members and assocites. These include: the International Weed Science Society (Oregon, USA), European Weed Science Society, Weed Science Society of America, Asociacion Latinoamericana de Malezas (Colombia), West African Weed Science Society (Nigeria), Weed Science Society of East Africa (Kenya) , Asia-Pacific Weed Science Society (Australia), and the Southeast Asian Weed Science Society (Indonesia).

Regional weed science centres usually have availabie lists of research and extension workers in weed science and related activities. The CAB International **Directory of Research Workers in Agriculture and Allied Sciences** (CABl, 1989) lists the names, institutions and subject specialization of over 29,000 agriculturalists.

Apart from these institutions, PUDOC, administered by the Agricultural Research Division of the Netherlands Ministry of Agriculture and Fisheries, provides a unique documentation, information and current awareness service. This organization has built up a liaison with European and international bodies concerned with standards in writing, editing, publishing, documentation and dissemination of scientific information.

FUTURE PROSPECTS

It can be predicted with some degree of certainty that applications of information technoiogy for weed science will closely follow the innovations and developments constantly being produced for the scientific community as a whole, but the justification for this must be found by an examination of the changing concepts and attitudes towards weeds themselves. When weed control was the priority, it might have been sufficient to obtain from the source literature a suitable range of options for given weed/crop situations. Today, however, the emphasis has turned from weed control as such toward vegetation management, using environmentally acceptable yet economically effective remedies for the presence of weeds, resulting from integrating management strategies.

To meet these changes there will be increased scope for knowledge-based decision-support approaches such as exped systems and simulation models. Expert systems have many predictive and diagnostic applications in weed management (Tjitrosoedirjo and Djojomartono, 1990), particularly in the development of integrated approaches to crop management. Weed population shifts have been successfully simulated by mathematical models (Schmid, 1990).

In this context the disappointing lack of cohesion in the provision of weed taxonomic information is likely to receive attention with a view to clarifying some of the ambiguity in weed identification and nomenclature, so improving the accuracy of distribution maps and the formulation of control strategies.

The appeal of CD-ROM as an inexpensive, timely and secure way of distributing large amounts of information is likely to increase (Lindsey and Novak, 1989). Already CAB International is developing a specialist CD-ROM containing bibliographic information for all the crop protection disciplines, including weed science. A single disk will cover the period 1973-1991 . But CD-ROM possibilities do not end there. Information on an international scale on the identification, characteristics, distribution, economic and agronomic significance and control of major weeds and pests could be assembled in a compendium of databases involving bibliographic references, world distribution maps, scientific descriptions, taxonomic data, illustrations and quarantine information. The exploitation of information technology in interactive systenms of this sort aims to provide economic benefits as a result of more effective information management, leading to improved crop protection.

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WEED ECOLOGY, POPULATION DYNAMICS, VEGETATION SUCCESSION, COMPETITION AND PROBLEMS

GERMINATION PATTERNS OF *PENNISETUM POLYSTACHION* SEEDS ACCORDING TO DIFFERENT COLLECTION PERIODS AND SEED PRODUCTION IN THAILAND

VERAPONGS KIATSOONTHORN[1]

ABSTRACT

Seed germination of the yellowish spike strain of *Pennisetum polystachion* increased to 90.7 % after 2-month storage and gradually decreased after 4-month storage. Twelve months after storage, the germination decreased to 28 %. Seeds collected from November 1988, December 1988 and January 1989 showed different germination. Those collected in December had higher germination rate than the ones collected in November and January, respectively. Seed sizes of 0.64-0.76 mm and more than 0.76 mm had higher germination than those of 0.56-0.64 mm. Fertile seed production in spike gradually decreased from 62.4% in the early part of January to 3.4 % in the mid of April; although the number of spikelets gradually decreased from the early part of January to the mid of February and increased again till the mid of April.

INTRODUCTION

Pennisetum setosum (Swartz) L.C. Rich, or Yaa khachyon job dook rueng (in Thai), is one of the noxious weeds found in the South and North-East of Thailand, especially in the abandoned and perennial crop cultivated areas. Reasons for its recognition as noxious weed may be due to its perenial characteristic which showed the tendency to replace *Imperata cylindrica* in rubber plantation (Tjitrosoedirdjo, 1990). Another may be due to its high production of spikelets and fertile seeds (Noda *et al.*, 1985; Yamchong and Kiatsoonthorn, 1989). Since the report of this weed by Weed Science Society of Thailand (Anonymous, 1984), there were controversies about its scientific name whether *P. polystachon* (L.) Schult. (Bakar, *et al.*, 1990) or *P. polystachion* (Lee, 1988). However in order not to make any confusion, the *P. setotum* mentioned in the author's previous paper as well as this paper will be named as the yellowish flower strain of *P. polystachion*.

Biological studies of this strain in the Thailand have been reported by Noda *et al.* (1985 and 1987), Suppaphon *et al.*, (1987) and Arunpu *et al.* (1991). According to its characteritics as a short-day plant, flowering will be found

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during the end of the year from October to March. In spite of its ability to produce a lot of inflorescence, the amount is not the same throughout the year (Suppaphon *et al.*, 1987). It is dependent on the sizes of vegetative growth (Yamchong and Kiatsoonthorn, 1989). Suppaphon *et al.* (1987) reported that in dry season this plant had lower seed germination and less spikelets than that collected in rainy season. This may be due to the amount of empty seeds that were unequal in the spike. In order to clarify this matter, this study was conducted.

MATERIALS AND METHODS

1. Pattern of Seed Germination

P. polystachion seeds collected from its natural habitat at Kao Kaelae, Pananikom district, Amphur Bankai, Rayoong province, Thailand were shown in the experimental field of the Srinakharinwirot University (Prasanmitr). On 6th December 1989, spikelets were collected from the growing plants, separated from bristles by hand rubbing and gauged through a mesh to obtain the 0.64-0.76 mm size of seeds. These seeds were kept at room temperature (27°-32°C) until testing period. On each month, one hundred seeds were placed on filter paper, moistened with 3 ml of distilled water, in a 9-cm glass Petri-dish and kept at 30°C under controlled dark condition (Arunpu *et al.*, 1991). Seed with small root protrusion was assumed to be germinated and removed after counting. During the testing period, distilled water was added when neccesary. Germinated seeds were accumulatively 2-day counted under light condition for 12 days. Experiment was conducted for one year with four replicates and the data of germination percentages were arcsin transformed before they were statistically analyzed.

2. Seed Sizes and Seed Collecting Periods

Spikelets were collected monthly from the same natural habitat, as stated in the first experiment on 5 November 1988, 4 Desember 1988 and 5 January 1989. The seeds were then separated from the bristles by hand rubbing and selected by mesh into three categories of seed sizes, i.e. 0.56-0.64, 0.64-0.76 and >0.76 mm by mesh. These seed batches were kept at room temperature (25°- 30°C) until the germinating time on 5 August, 4 September and 2 October 1989. In each germinating test, 100 seeds were used, and following the same method stated in the first experiment. Germinated seeds were accumulatively counted every day interval for 12 days. Experiment was replicated four times and designed in factorial design with 2 factors, each with three levels (three months of seed collection and three seed sizes). Data from the 9-month testing period were arcsine transformed and statistically analyzed.

3. Spikelet and Seed Production

P. polystachion, planted in the same site as stated in the first experiment, were marked for their heading every two weeks. Five of those having brownish colour and the spikelet nearly shedding were randomly harvested each time from 1 January 1990 until 18 April 1990. Spike length was measured and the number of spikelets and fertile seeds were counted. Fertile seeds are those containing stout brown caryopsis.

RESULTS AND DISCUSSION

1. Pattern of Seed Germination

In the first month of storage, seeds of *P. polystachion* had low germination percentage (27.2%) but it increased since the second month and reached the highest percent of germination in the fourth month and then gradually decreased till the end of the experiment (Figure 1). This result is similar to that of Noda *et al.* (1985) and Pemadasa and Amarasinghe (1982); but the former authors mistook the species of *P. polystachion* yellowish inflorescence strain as *P. purpureum* (Noda *et al.*, 1987). It seemed that seeds kept at room temperature (27°-32°C) would lose their germinatability at last. This result is similar to the research result of Pemadasa and Amarasinghe (1982) which took about 16 months. The difference may be due to the lower temperature of seed storage of the mentioned authors, which was about 23°-27°. Moreover even if seeds were kept at 5°C condition the germinatability would be lost too (unpublished data). This means that the germinatability of burial seeds in the natural soil condition will be lost at last.

2. Seed Sizes and Seeds Collecting Period

Pattern of seed germination tested for three continuous months (August 1989 to October 1989) is shown in Figure 2. From this figure, it seems that seed germination will decrease, similar to the result of the first experiment. Different batches of seeds collected in different months showed the same trend of decreasing germination with time, except the seeds collected in November which showed only a little decrease. Comparing to the equal time of storage (9 months), the accumulated germination pattern of seed during the 12-day testing period is shown in Figures 3 and 4. In Figure 3, seeds collected in different periods showed significantly different pattern of germination. Those collected in December 1988 had higher germinatability than those collected in November 1988 and January 1989 respectively (Figure 3). This result is similar to that of Suppaphon *et al.* (1987), although the authors assumed every spikelet contains only one seed. The difference may be caused by the different

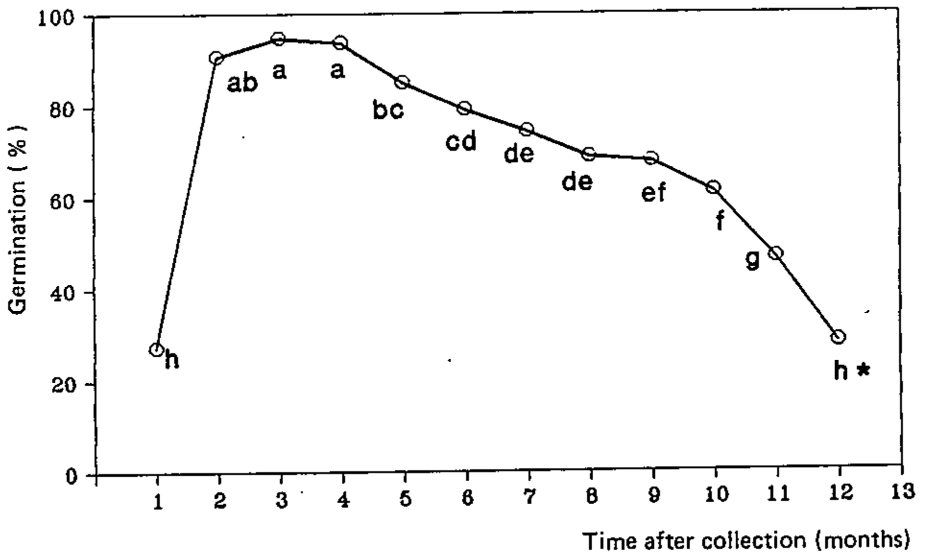

Figure 1. Germination of *P. polystachion* seeds (collected on 6 December).
*: values followed by the same letter are not significantly different at 5 % level.

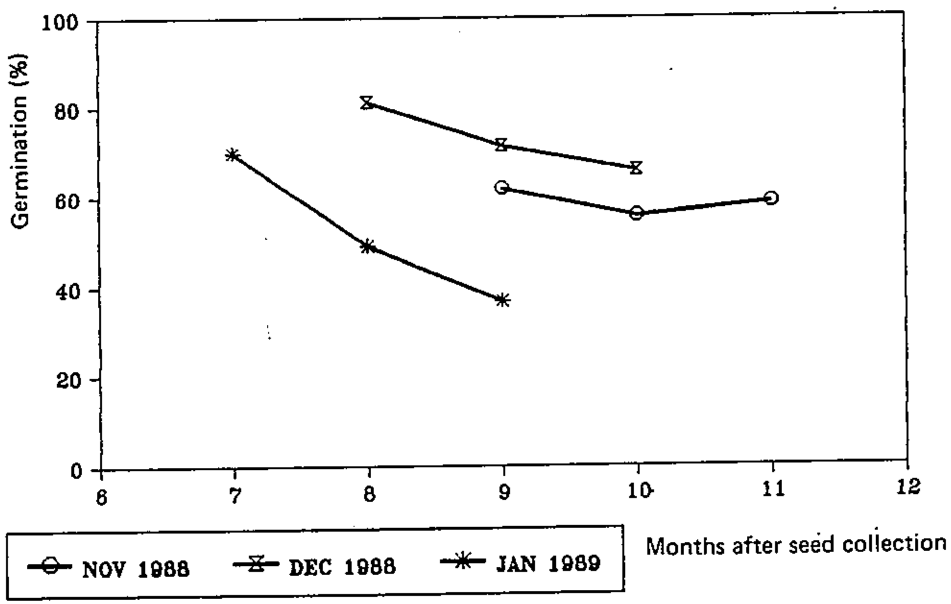

Figure 2. Germination pattern of *P. polystachion* seeds colected in different months.

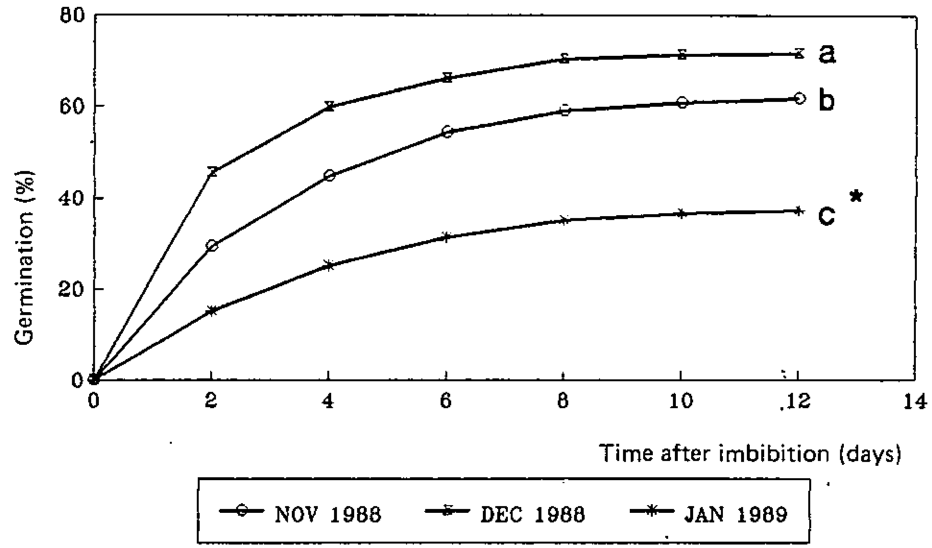

Figure 3. Germination pattern of *P. polystachion* seeds colected in different months.
*: the same as Figure 1.

enviromental conditions occurring at the time of seed maturation and caused different germination (Sawhey and Naylor, 1982). Difference in seed size is also caused various patterns of seed germination, especially those having larger seed sizes. However, seed sizes larger than 0.76 mm and those of 0.64-0.76 mm did not show any difference (Figure 4) (Younger and Mckell, 1972).

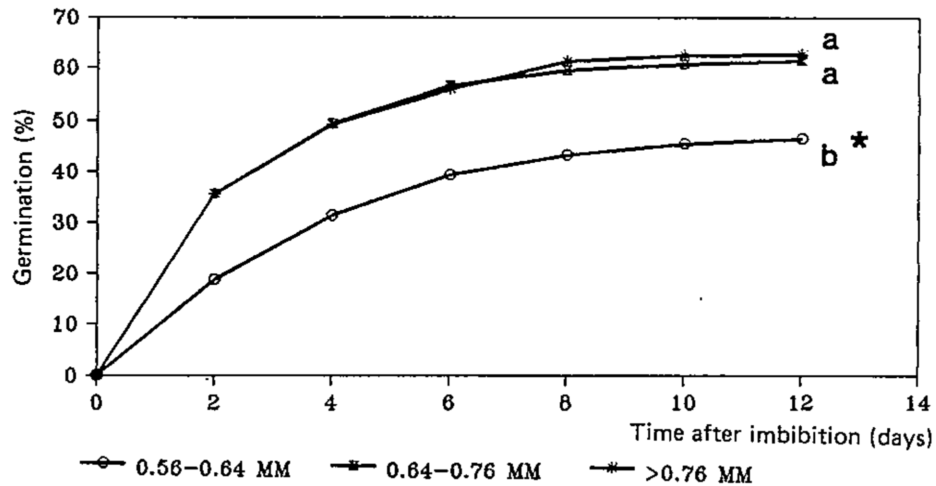

Figure 4. Germination pattern of different seed sizes of *P. polystachion*.
*: the same as Figure 1.

Figure 5 shows the interaction of seed size and collection period. Seed size greater than 0.76 mm collected in December showed significantly higher germination percentage, while seed sizes 0.56-0.64 mm showed the lowest germination percentage.

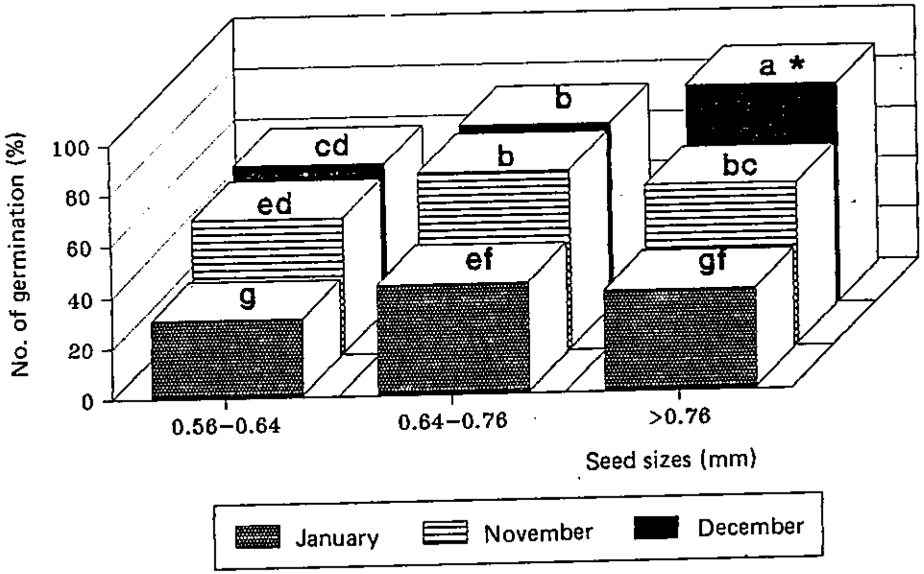

Figure 5. Interaction of seed sizes of *P. polystachion* and months of collection.
*: the same as Figure 1.

3. Spikelet and seed production

In Figure 6, spike length was very uniform in January, but variations can be seen from 19 February to 18 April. This means that most of the spikes produced by the plant in January had the same length as well as in November and December (data were not shown). This was caused by the flowering pattern of the plant. In general, first heading of *P. polystachion* begins at the main culm and the secondary etc. from the distal node to the lower. The spike length in the distal position of the culm will be longer than that of the lower part of the same culm. The spike length and the number of spikes in one culm, decreased from 1 January until 19 February and reincreased again from 1 March and then dropped down on 18 April, except for the number of spikelets in the spike, which still increased (Figure 7). The percentage of the fertile seed decreased gradually from 62.4 % in 1 January to 31.2 % in 2 April and

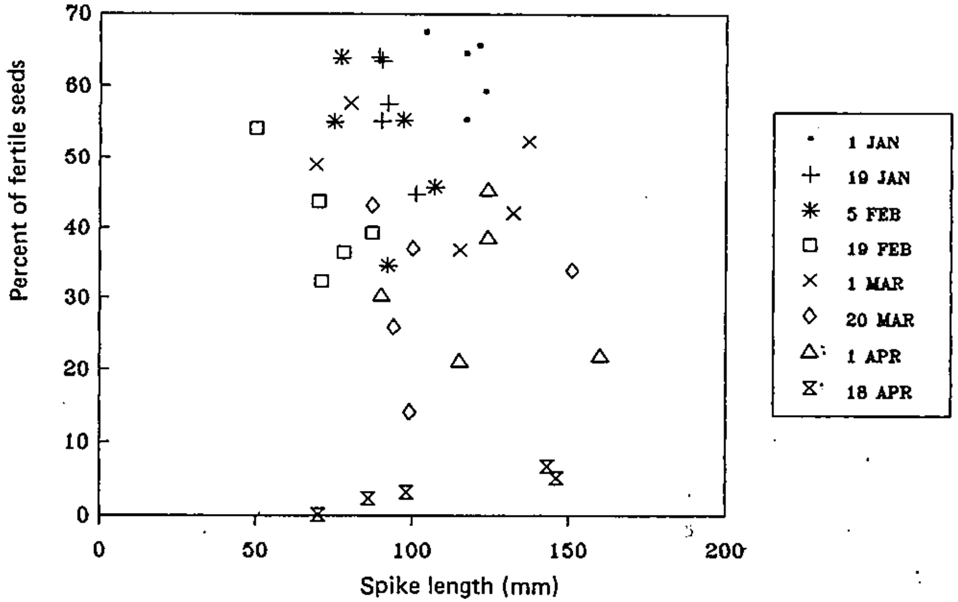

Figure 6. Correlation between spike length and percent fertile seeds.

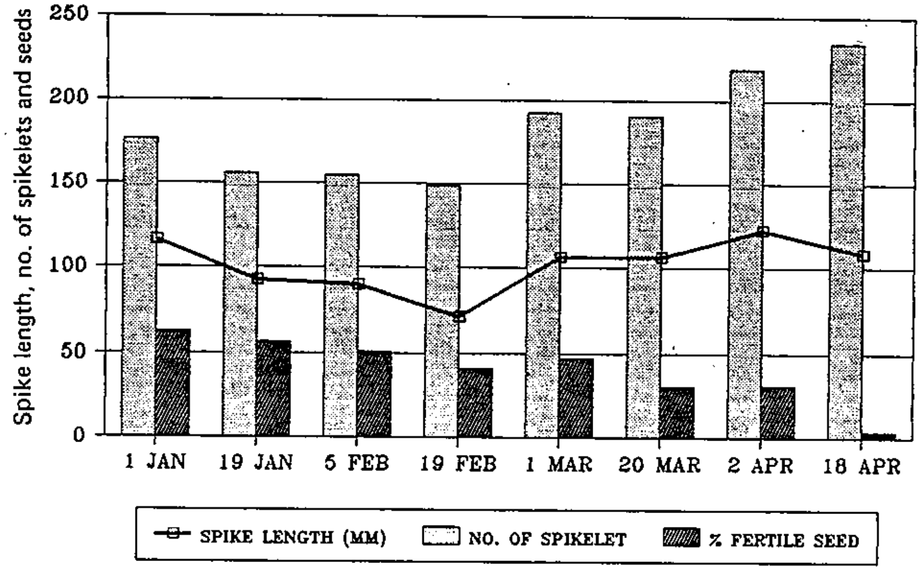

Figure 7. Spike length, number of spikelets and seeds in spike of *P. polystachion* collected in different months.

drastically decreased again to 3.4% in 18 April. In this month, flowering is scarcely observed in the field due to the long photoperiod.

From the above result, it is understandable why *P. polystachion* is recognized as a noxious weed. This plant can produce an immense amount of inflorescences for 5-6 months per year, and the percentage of fertile seeds in one spike is rather high, ranging from 30.7 to 62.4 % or more, although there is variation of seed germination among the months. Germination percentage of these seeds are also high up to 94 % after 3-4 months of storage. In order to control the distribution of this weed, studies should be done to decrease inflorescence production between October till March.

ACKNOWLEDGMENT

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INTER - AND INTRASPECIFIC VARIATION IN CYPERACEOUS WEEDS[1]

M.A. CHOZIN[2], S. YASUDA[3] AND K. NAKAGAWA[4]

ABSTRACT

Inter- and intraspecific variation was investigated among strains of *Cyperus iria* L., *C. microiria* Steud. and *C. amuricus* Maxim. (Cyperaceae) collected from different habitats. Observations were made of morphological characters, biomass, seed production, heading time and isozyme banding patterns.

The three species were similar in most of the characters tested, but could be separated well by means of principal components analysis and cluster analysis of 21 characters including morphology, biomass and seed production, and by variation of aspartate aminotransferase and peroxidase isozyme banding patterns. Based on cluster analysis and the similarities in isozyme banding patterns, *C. microiria* was more similar to *C. iria* than to *C. amuricus*.

Intraspecific variation in heading time and morphological characters was found in *C. microiria* strains, which differentiated into two types. The early type showed early heading, small growth habit, high reproductive allocation and low photoperiodic response. The late type showed late heading time, tall and big growth habit and low reproductive allocation and was largely influenced by photoperiod.

INTRODUCTION

The three species of *Cyperus* namely *C. iria* L., *C. microiria* Steud. and *C. amuricus* Maxim. are recognized as weeds. *C. iria* is a principal weed in paddy fields throughout the world and is also a common weed of upland fields in many countries (Holm *et al.*, 1977). *C. microiria* and *C. amuricus* are endemic to upland fields in East Asia (Makino,1964; Holm *et al.*, 1977; Ohwi, 1981); although Kasahara (1982) classified *C. microiria* and *C. amuricus* as weeds of both types of fields. Since *C. microiria* in general appears as an intermediate in morphological characters, its taxonomic status arises confusion.

In Japan, *C. microiria* (kayatsurigusa) is classified as one of the most harmful weeds in upland fields (Holm *et al.*, 1977) and is found in arable fields, gardens, road sides, border of paddy fields, wastelands and grasslands as both

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agrestal and ruderal. Many authors have reported that weedy species show differences in morphological and physiological responses to different habitats (Matsumura, 1967; Gadgil and Solbirg, 1972; Law *et al.*, 1977; Warwick and Briggs, 1978, 1979), and thus, other biological studies on weeds are necessary to gain basic knowledges for weed management strategy.

MATERIALS AND METHODS

During 1985 - 1988 mature seeds of 120 strains of *C. iria*, *C. microiria* and *C. amuricus* were collected from 16 localities throughout Japan. Twelve strains each of *C. iria* and *C. microiria* from Okayama and Tottori prefectures, and six strains of *C. amuricus* from Tokyo were used for these experiments (Table 1). In order to investigate differentiation between species and variation within species, and also to identify relationships between them, five plants of each strain were grown in pots in a glasshouse under natural photoperiod of summer in Okayama. Observation was made on phenology, morphology and biomass. Mature seeds (achenes) were harvested for the investigation of seed production, seed morphology and seed weight.

Morphology, Biomass and Seed Production

Twenty one characters including morphology, biomass and seed production (Table 2) were observed on the five individuals of each strain. The data were analyzed in one way analysis using Student Newman Keul's test for differences between strains, and in multivariate analysis using principal components analysis (PCA) for differences between species, and by the centroid method of cluster analysis for relationships between strains and species.

Electrophoresis

Electrophoresis was carried out to identify isozyme banding patterns of the three species at the seedling stage, using the procedure of Davis (1964). Staining for aspartate amino transferase (AAT), acid phosphatase (ACP), esterase (EST) and peroxidase (PRX) followed the recipes of Nielsen and Jorgensen (1986).

Heading Time

Heading time was the number of days between seed germination and emergence of the first inflorescence. The present study investigated heading time variations among the strains of *C. iria* and *C. microiria* collected from different habitats in a latitudinally narrow belt of Okayama (34°39'N) and Tottori (35°31'N) prefectures.

Table 1. Localities and habitats of strains

No.	Species/ strain	Locality	Habitat
	C. iria		
1.	IOk-1	Kurushiki, Okayama	fallow paddy field
2.	IOk-2	Kurushiki, Okayama	wasteland
3.	IOk-3	Niimi, Okayama	border of paddy field
4.	IOk-4	Ikura, Okayama	wasteland formerly paddy field
5.	IOk-5	Ikura, Okayama	konjak field
6.	IOk-6	Ikura, Okayama	grassland
7.	ITo-1	Kamiiwami, Tottori	wasteland
8.	ITo-2	Kamiiwami, Tottori	paddy field
9.	ITo-3	Yonago, Tottori	roadside by paddy field
10.	ITo-4	Hikona, Tottori	roadside
11.	ITo-5	Osinozu, Tottori	fallow paddy field
12.	ITo-6	Osinozu, Tottori	buckwheat field
	C. microiria		
13.	MOk-1	Kurushiki, Okayama	kitchen garden
14.	MOk-2	Kurushiki, Okayama	kitchen garden
15.	MOk-3	Ikura, Okayama	wasteland
16.	MOk-4	Ikura, Okayama	wasteland formerly corn field
17.	MOk-5	Ikura, Okayama	konjak field
18.	MTo-1	Kamiiwami, Tottori	fallow paddy field
19.	MTo-2	Kamiiwami, Tottori	wasteland
20.	MTo-3	Yonago, Tottori	roadside, sandy soil
21.	MTo-4	Hikona, Tottori	roadside
22.	MTo-5	Osinozu, Tottori	buckwheat field
23.	MTo-6	Amariko, Tottori	shady grassland
24.	MTo-7	Sakai Minato, Tottori	railway
	C. amuricus		
25.	ATk-1	Ishikawa, Tokyo	botanical garden
26.	ATk-2	Ishikawa, Tokyo	botanical garden
27.	ATk-3	Ueno, Tokyo	home garden
28.	ATk-4	Ueno, Tokyo	home garden
29.	ATk-5	Obadai, Tokyo	wasteland
30.	ATk-6	Obadai, Tokyo	wasteland

In another experiment to investigate the effect of photoperiod on heading time, nine plants of each of four strains of *C. iria* and three strains of *C. microiria* which were considered as early and late types, respectively, were grown in growth chambers under 12 and 14 hours photoperiods.

RESULTS

Morphology, Biomass and Seed Production

Variation within species and significant differences between strains were found in most morphological characters, with the range of the variation overlapping among the species (data not presented).

Principal component analysis on the 21 characters showed that 83% of the total variation could be explained by the first three components (Table 2): the first component (Z_1) accounting for 37% of the total variation was due to factors concerning spikelet and seed production, the second component (Z_2) accounting for 28% of the total variations was due to factors concerning growth size (leaf, leaf bract, stem and stalk), and the third (Z_3) was largely affected by seed weight and floret density.

Table 2. Cumulative variance of the first three principal components and the loadings of 21 characters on each principal component

	Z_1	Z_2	Z_3
Cumulative variance	37%	65%	83%
Characters		Eigenvectors	
1. Leaf length (LL)	0.127	0.352	0.238
2. Leaf width (LW)	-0.025	0.366	-0.127
3. Leaf bract length (LBL)	-0.130	0.290	-0.230
4. Leaf bract width (LBW)	-0.224	0.254	-0.084
5. Culm/stem length (CL)	-0.003	0.342	-0.070
6. Stalk length (SL)	-0.207	-0.250	-0.313
7. Ratio stalk/stem (CL/SL)	-0.110	-0.320	0.174
8. Number of tillers (NTL)	0.179	0.173	0.261
9. Number of inflorescences/panicle (NI)	0.104	0.242	0.313
10. Number of spikelets/inflorescence (NS)	-0.294	0.068	-0.247
11. Number of florets/spikelet (NF)	0.318	-0.134	-0.035
12. Spikelet length (SPL)	0.323	-0.225	0.183
13. Floret density (NF/SPL)	-0.120	-0.169	-0.397
14. Seed length (SEL)	-0.228	0.156	0.275
15. Seed width (SW)	-0.232	0.007	0.363
16. Seed shape (SW/SEL)	-0.109	-0.142	0.215
17. 1000 seed weight (WS)	-0.188	0.016	0.422
18. Number of seeds/plant (NOS)	-0.330	-0.006	-0.120
19. Seed production/plant (SP)	-0.344	0.005	0.086
20. Biomass (BIO)	-0.224	0.293	0.098
21. Reproductive allocation (RAL)	-0.282	-0.227	0.062

Projection of the 30 strains on the first and third components is presented in Fig. 1a. The thirty strains divided distinctly into three groups: the first group consisted of *C. amuricus* strains (■), while the second and third consisted of *C. microiria* (▲) and *C. iria* (●) strains respectively.

Fig. 1b shows the projection of the 30 strains on the second and third components of PCA. Three groups of *C. microiria* strains are recognized: A, B, and C. Group A consists of strains 13 and 14 from Okayama and 21 from Tottori clustered on the negative zone of Z_2, while the others are on the positive zone. The strains of group A are considered as dwarf plants as expressed by the low scores mainly of the leaf and bract size, stem length and biomass, especially in contrast to the strains of group C having high scores for those characters. Group C consists of the strains 15, 16 and 17 from Okayama and strain 22 from Tottori. All of the strains of group B were from Tottori, considered as plants having intermediate scores between group A and C in these characters.

A cluster analysis expressing phenetic similarity of the 30 strains performed on the 21 characters is shown in Fig. 2. The strains are divided into two clusters at a level of 42.1; one is composed of *C. amuricus* strains 25 to 30, and the other of *C. microiria* and *C. iria* strains. In the latter cluster, the Okayama strains 13 and 14 and Tottori 21 of *C. microiria* differ distinctly from the others at a level of 35.8. The remaining strains make two subclusters at a level of 25.2; one is composed of all strains of *C. iria* and the other of the remaining strains of *C. microiria*.

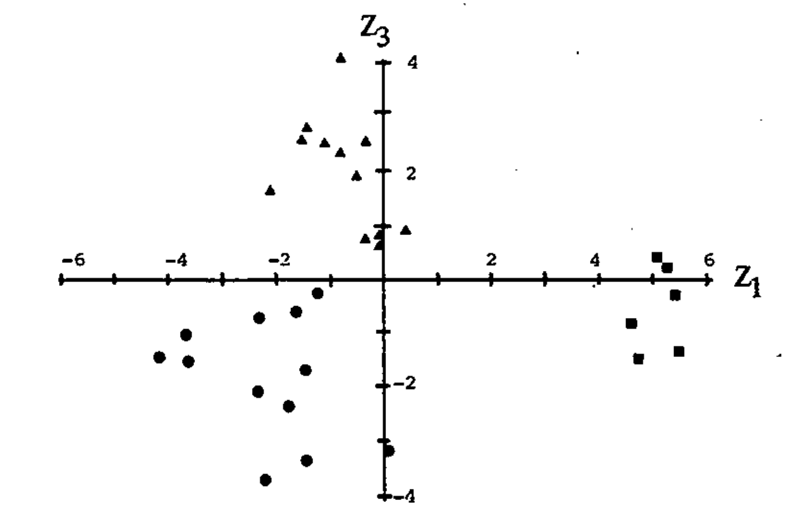
Isozymes Banding Patterns

The strains of *C. iria*, *C. microiria* and *C. amuricus* varied in isozyme banding patterns. However, the three species could be clearly identified by aspartate amino transferase (AAT) and peroxidase (PRX) banding patterns.

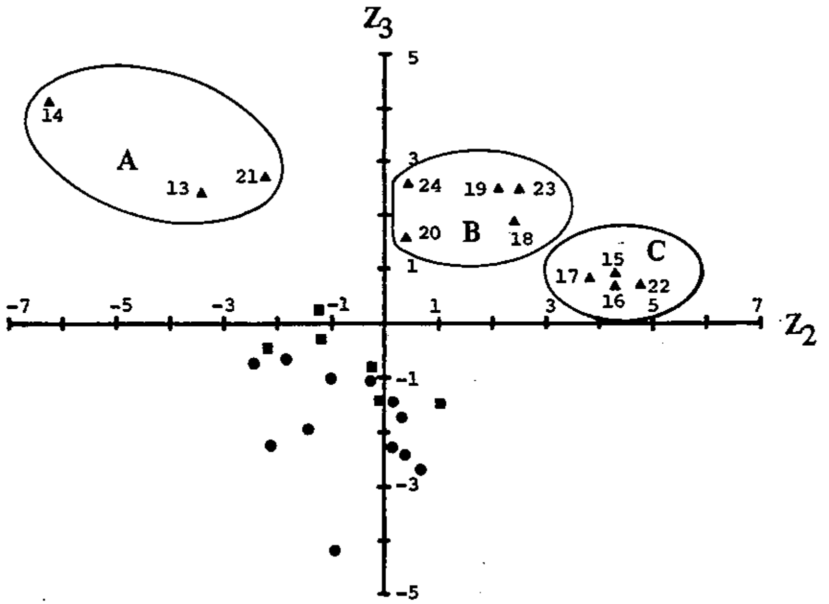
Based on the similarity index values following a formula used by some authors (Whitney *et al.*, 1968; Vaughan and Denford 1968, Zigenfus and Clarkson, 1971; Schechter and De Wet, 1975; Yadava *et al.*, 1979), *C. microiria* is more similar to *C. iria* than to *C. amuricus* (Table 3).

Heading Behaviour

Fig. 3 shows heading time (mean and standard deviation) of *C. iria* and *C. microiria* strains collected from different habitats grown in pots under the natural summer photoperiod in Okayama. Heading time of *C. microiria* varied more widely than that of *C. iria* strains. Differentiation of *C. microiria* was found even among the strains collected from the same locality: MOk-1 and MOk-2 strains headed very early in contrast to the other strains from Okayama, whilst MTo-3, MTo-4 and MTo-7 headed earlier than the others from Tottori.



a. Projection of Z_1 and Z_3 components



b. Projection of Z_2 and Z_3 components

Figure 1. Principal components analysis of 21 characters of *C. iria* (●), *C. microiria* (▲) and *C. amuricus* (■) strains. See Table 1 for no. of strains.

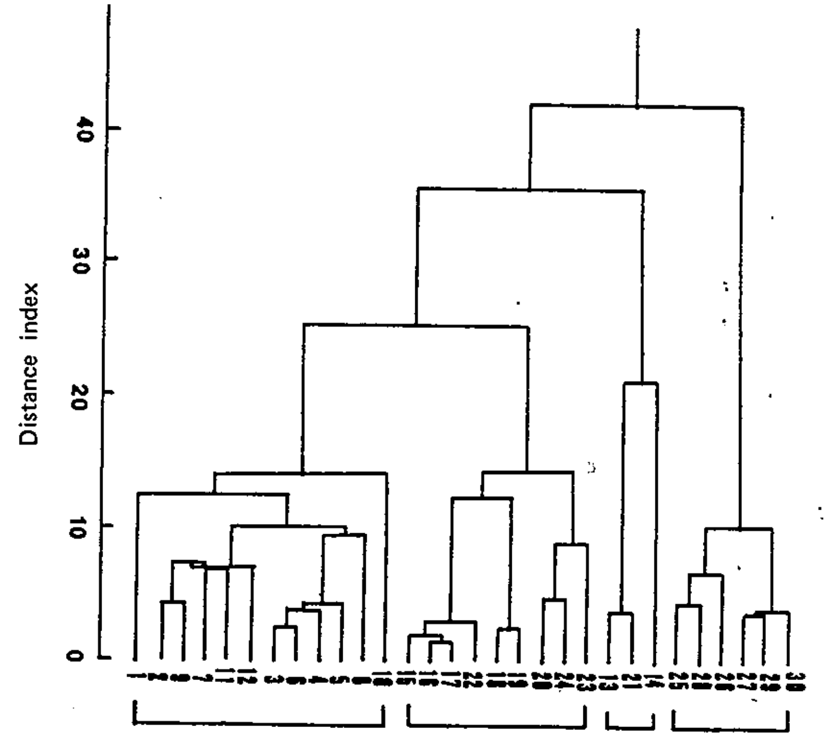


Figure 2. Dendrogram by cluster analysis based on the distance of 21 characters among *C. iria*, *C. microiria* and *C. amuricus* strains. See Table 1 for no. of strains.

Table 3. Similarity index value (%) between species based on homologous bands in AAT, PRX and EST zymograms

Species	i	m	a	d	b	s
i	-					
m	50.0	-				
a	14.3	28.6	-			
d	5.0	5.9	5.9	-		
b	12.0	12.5	13.6	9.5	-	
s	12.0	13.6	4.3	10.5	20.8	-

i = *C. iria*
m = *C. microiria*
a = *C. amuricus*
d = *C. difformis* L.
b = *C. brevifolius* (Rottb.) Hask.
s = *C. serotinus* Rottb.

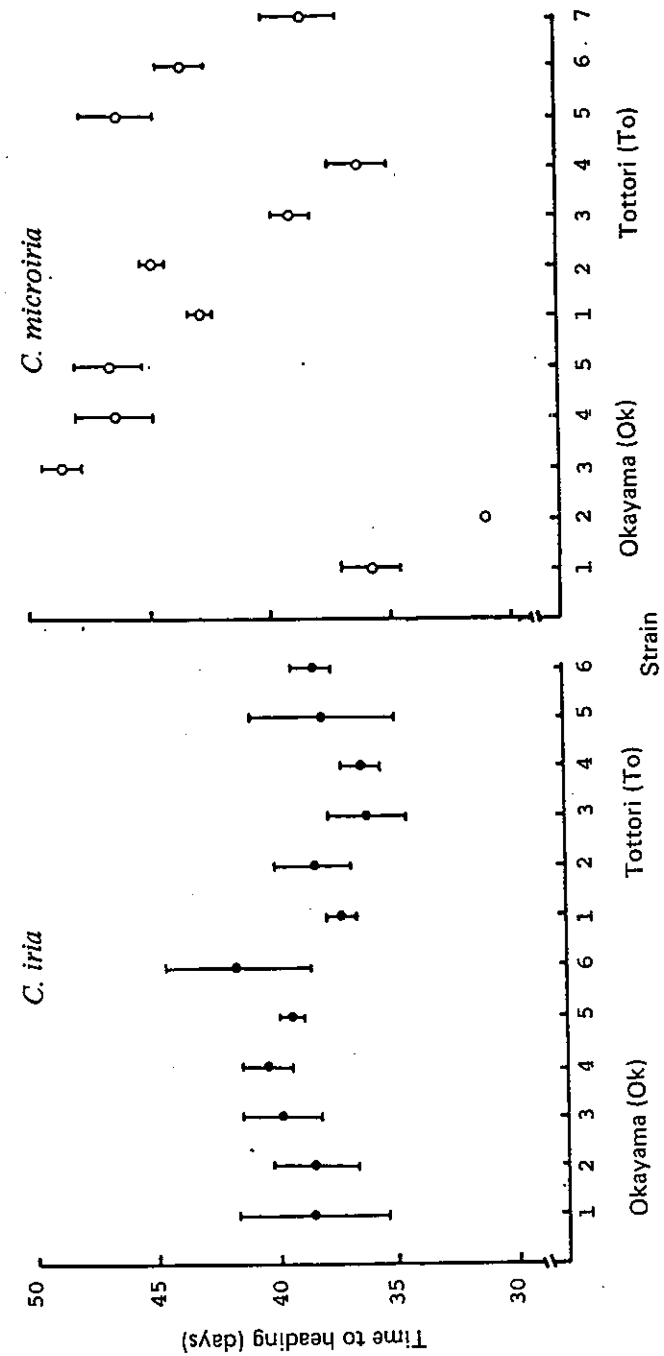


Figure 3. Time to heading of *C. iria* and *C. microiria* strains collected from Okayama and Tottori Prefectures (mean and standard deviation). Habitats of the strains are shown in Table 1.

Morphological observation on the strains of *C. microiria* showed that the early strains were different from the late ones in many morphological traits as well as in biomass and reproductive allocation. Table 4 shows that the mean values of leaf length, leaf width and number of tillers of the early type was significantly lower than those of the late one. The early type was also characterized by a low biomass and a high reproductive allocation.

Table 4. Differences between early and late types of *C. microiria* in plant size and seed production

Character	Early (n=5)	Late (n=7)	Significant difference
1. Leaf length (cm) (20.5 - 29.4)	24.8 (29.8 - 37.8)	34.0	**
2. Leaf width (cm) (0.34 - 0.80)	0.64 (0.90 - 1.00)	0.93	**
3. Stem length (cm) (19.3 - 32.7)	27.0 (37.0 - 52.2)	47.9	**
4. Stalk length (cm) (12.6 - 15.6)	13.9 (7.00 - 9.40)	7.8	**
5. Number of tillers (12.4 - 13.8)	13.4 (14.2 - 17.8)	14.7	*
6. Biomass (g/plant) (10.22-17.40)	14.49 (18.76-21.02)	20.03	**
7. Seed production (g/plant)	5.172 (4.268-6.104)	4.615 (3.588-5.566)	ns
8. Reproductive allocation (7/6x100%)	36.6 (30.9 - 41.7)	23.1 (18.5 - 28.2)	**

n : number of strain tested
(-) : range
ns : not significant
**, * : significant at 1% and 5%, repectively.

All of the strains showed significant differences in heading time when they were grown under different photoperiods; they headed earlier under 12 hours than 14 hours (Table 5). If different day-numbers of heading time are regarded as photoperiodic response, variation of photoperiodic response was found among the strains. The range of photoperiodic response in *C. iria* was from 7.3 days (IOk-1) to 15.0 days (IOk-2), and that of *C. microiria* was from 3.9 to 12.1 days and 16.8 to 19.3 days for early and late types respectively.

Table 5. Heading time of strains of *C. iria* and *C. microiria* under two different photoperiods at 20°/30°C (mean and standard deviation)

Species/strain[1]	12 hours	14 hours	Difference (14 - 12)
C. iria:			
IOk-1	39.3 ± 1.3	46.6 ± 2.6	7.3**
IOk-4	40.7 ± 1.1	55.7 ± 3.6	15.0**
ITo-1	40.0 ± 0.0	50.2 ± 0.8	10.2**
ITo-6	39.3 ± 0.7	47.5 ± 3.4	8.2**
C. microiria:			
MOk-2[e]	36.3 ± 0.5	40.2 ± 0.8	3.9**
MTo-4[e]	35.0 ± 0.0	47.1 ± 2.8	12.1**
MTo-7[e]	36.5 ± 0.5	48.6 ± 4.4	12.1**
MOk-3	36.7 ± 0.5	56.0 ± 2.6	19.3**
MTo-2	35.8 ± 0.7	52.6 ± 1.5	16.8**
MTo-5	36.8 ± 0.7	54.6 ± 1.7	17.8**

1 Sites and habitats of the strains are presented in Table 1
e Early type
** Significant at 1% level.

DISCUSSION

Three species of the series Iriae (Cyperaceae) namely *C. iria, C. microiria* and *C. amuricus* have similarities in morphological features. In general, *C. microiria* shows an intermediate form between the two others. For this reason, probably Franchet and Savattier (1877) treated *C. microiria* as a variety of *C. iria*, while Kukenthal (1935) attributed it to *C. amuricus* (Koyama, 1961). Recent authors have treated it as independent species, differentiating the three species by the characteristics of branching pattern of the spike, spikelet length, number of florets and shape of floral scale (Koyama, 1961; Makino, 1964; Ohwi, 1981). The present study showed that variation within species was found in most of those characters, that the variation was overlapping among the species, and that there were difficulties in identifying the species using any one of these characters alone. To distinguish one species from the others requires a combination of two or more characters.

Multivariate analyses such as principal components analysis and cluster analysis are effective methods for taxonomic studies in plant species (Namkoong, 1966; Flake *et al.*, 1969; Wells, 1980; Standley, 1987; Menadue and Crowden, 1988; Ohara, 1989). Table 2 showed that in principal components analysis, characters LL, LB, SPL, FD and SW give high contributions to postulate the general features of each species. Using the Z_1 and Z_3 of principal

components analysis the three species could be clearly differentiated; *C. amuricus* has longer spikelets with more florets and produced fewer seeds/plant than the two other species, and *C. iria* can be separated from *C. microiria* since it has higher floret density with smaller seeds than the another one (Fig. 1a). Further, by means of a projection of the Z_1 and Z_3 of principal component analysis, three groups of *C. microiria* strains were recognized (Fig. 1b). Group A consisted of two strains from Okayama and one strain from Tottori and is considered to be dwarf plants, especially in contrast to group C which is considered to be big plants with higher biomass. The same result was found in cluster analysis showing *C. microiria* strains distinctly separated at a level of 35.8 (Fig. 2).

Recently, methods of gel electrophoresis have been frequently applied to many types of scientific inquiry with plants, especially isozyme variations which are useful for species and cultivar identification and for observation on species relationships (Wilkinson and Beard, 1972; Ungar and Boucaud, 1974; Wehner *et al.*, 1976; Quiros, 1980; Wu *et al.*, 1984). The present study showed that isozyme banding pattern of AAT and PRX could be used for species identification of the morphologically similar species *C. iria*, *C. microiria* and *C. amuricus*. On the other hand, based on the similarity of AAT, PRX and esterase isozyme banding patterns some degree of relationships between the species were recognized; *C. microiria* was more similar to *C. iria* than to *C. amuricus* (Table 3). The result corresponds to that of principal components analysis (Fig. 1a) and of cluster analysis (Fig. 2). *C. iria* and *C. microiria* are also able to intercross and produce fertile hybrids (Chozin, 1990).

Intraspecific variations in heading time have been reported in many plant species and the adaptive significance of the variation has been discussed. Some cases were explained as clinal variation along environmental gradients or broad geographical scales (Cooper, 1954; Oka, 1958), whilst others were explained as ecotypic differences caused by adaptation to different habitats (Matsumura, 1967; Law *et al.*,1977; Tsuyuzaki, 1989). The differentiation of *C. microiria* probably could not be explained as clinal variation since there were no close relationships between latitude of the locality of the strains and their heading time (Chozin, 1990). Furthermore, the present study showed that *C. microiria* strains collected from different habitats in the same locality was different in earliness and dwarfness. Another experiment (Chozin, 1990) indicated that the earliness and dwarfness of *C. microiria* were heritable characters. Cooper (1954) and McNelly and Antonivics (1976) noted that one of the physiological responseses of plant species to different habitats was expressed by heading time; such a difference was inherited (Cooper, 1954).

It is interesting to note that *C. microiria* strains collected from different habitats showed differences in reproductive allocation. Such differentiation has been a focus of studies on adaptive strategies of plants (Abrahamson and

Gadgil, 1973; Turkington and Carvers, 1978; Pitelka, 1977; Oka, 1988). In general, plants growing in disturbed habitats or at an early stage of secondary succession have a high rate of reproductive allocation (Abrahamson, 1979). This is predicted by the theory of r vs K-selection (Pianka, 1970; Gadgil and Solbirg, 1972).

Taking the habitat origins of the strains (Table 1) as a consideration, the intraspecific differentiation in *C. microiria* is thought to be an adaptation to different habitats. The strains collected from habitats such as garden and roadside were different from those from wasteland and grassland in heading time, morphological traits, reproductive allocation and response to photoperiods. The two types of habitats are considered different in environmental condition as well as in management. *C. microiria* is one of the most harmful weeds in Japan, and is often found even in well managed habitats like gardens, roadsides and railways. Generally the owner of the place makes it weed-free and well managed. *C. microiria* would show morphological and physiological responses toward this condition. Therefore, management of habitats including cultivation and application of weed control is suggested as one which favours selection pressure. This type of selection has been reported in some graminaceous species (Law *et al.*, 1977; Warwick and Briggs, 1978, 1979; Tsuyuzaki, 1989).

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THE OCCURRENCE OF PENNY FERN (*DRYMOGLOSSUM PILOSELLOIDES* PRESL.) AS A WEED OF COCOA IN INDONESIA

ZAENUDIN[1] AND ACHMAD SOEDARSAN[2]

ABSTRACT

A preliminary survey evaluated the occurrence of penny fern (*Drymoglossum piloselloides* Presl.) in cocoa plantations, in Java, Sumatera and Sulawesi.

75% of government cocoa plantations in Java and North Sumatera are infested by penny fern. Planters considered this is a serious problem since it reduces the growth rate and in some cases causes dieback. Manual control of penny fern is widely practised in plantations but needs a great number of labours and consequently increases production cost.

INTRODUCTION

Penny fern (*Drymoglossum piloselloides* Presl.) was mentioned by Ruinen (1953) as an epiphyte harmful to host plants in the Bogor Botanical Garden. Later studies by Partomihardjo (1980) defined the plant as a pathogen, but unfortunately there is no further information available.

Many cocoa plantations in Java and Sumatera have problems caused by heavy infestations of penny fern during the past five years. A great deal of man power is needed every year to control the weed, thus increasing production cost. A preliminary study proved that penny fern can adversely affect growth and health of cocoa trees (Zaenudin, 1986).

This paper presents the results of a survey aimed at evaluating the problem as well as the occurrence of penny fern in many cocoa area. Such information is important to ascertain its control measures.

MATERIALS AND METHODS

A questionnaire was distributed to government cocoa plantations in Java, Sumatera and Sulawesi requesting the following information:

1. General information of the plantation such as location, acreage, age and condition of cocoa, and environmental description.

1 Research Institute for Estate Crops, Jl. P.B. Sudirman 90 Jember, Indonesia.
2 Indonesian Planters Association for Research and Development, Jl. Tanjungkarang 5, Jakarta, Indonesia.

2. The occurrence of penny fern on cocoa, intensity of infestation and its population dynamics.
3. Planters view on the effect of penny fern on aspects of cocoa growth and production.
4. Control activities.

Forty questionnaires were distributed to 40 cocoa plantation belonging to five estate enterprises in Java, two estates in Sumatera and one estate in Sulawesi. Thirty six questionnaires were returned, covering more than 27 thousand ha of cocoa plantations. From the questionnaires a lot of information could be analysed.

RESULT AND DISCUSSION

The Occurrence of Penny Fern

Information about the occurence of penny fern is presented in Table 1. Seventy five percent of planters stated that some parts or even all plantations were infected by penny fern. Most of these answers mentioned came from East Java, West Java, and North Sumatera, indicating that most cocoa plantations in the regions were infested by penny fern.

Table 1. The occurrence of penny fern on cocoa plantations

No.	Number of cocoa plantations	%
1. Questionaires returned	36	90
2. There is penny fern infestation		
27	-	-
75	-	-
100	-	-
3. Distribution of penny fern:		
- entirely	9	33.3
- in spots/partially	16	56.3
4. Ages of infested cocoa		
- less than 10 years	12	44.4
- ten years or more	13	48.5

Epiphytes including moss and fern have been recognized as pest on cocoa by some authors (Urquhart, 1961; Thorold, 1976; Kodera *et al.*, 1984), but none of them refers to penny fern. This means that so far information about the plant is lacking.

According to the data presented in Table 1, penny fern should be considered as important weed of cocoa and thus needs more attention.

Geographical Distribution

Cocoa is distributed in almost all provinces but the greater part are in Java, Sumatera and Sulawesi. Old cocoa plantations are found in Java and Sumatera but not in Kalimantan and Sulawesi.Economic Importance

Ruinen (1953) concluded that penny fern was not a common epiphyte because it showed noxious effects on its susceptible host. For such noxious epiphyte-host interaction, Ruinen proposed the term **epiphytosis**.

The effect of penny fern on its host is different depending on the susceptibility of the host. The general symptoms of the effect are lower growth rate, reduction of leaf size, and dieback. In a susceptible host such symptoms appear a few months after the first infestation, but in resistant hosts it will not appear after a few years.

The importance of the weed according to planters' opinion is presented in Table 2.

Table 2. Assessment of the importance of penny fern and its control

No.	Number of cocoa plantations	%
1. Total answers	27	-100
2. Penny fern harmful to cocoa	27	100
3. Types of interference		
- Flower interference	27	100
- Shoot growth interference	13	48
- Weakend the tree and dieback	20	74
4. Manual control	22	81.5

Field assessment of the effect of the weed had been done at Kaliwining Experimental Garden, East Java. The result showed that abundant growth of penny fern can reduce leaf size of cocoa as much as 30% (Zaenudin, 1986).

Manual control of the weed has been widely practised in many plantations. The average labour consumption ranged from 20 until 40 mandays per ha. However, planters still have problems eradicating the weed manually.

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BIOMASS PRODUCTION AND COMPETITIVE ABILITY OF TWO NUTSEDGE (*CYPERUS ROTUNDUS* L.) ECOTYPES, GROWN WITH SUGAR CANE

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ABSTRACT

An ecological study to clarify the differences in growth characters of nutsedge plants from Pasuruan and Jatiroto, took place in both locations from February 15 until July 23, 1987. Treatments consisted of soils from both locations, three levels of initial nutsedge densities, two levels of nitrogen fertilizer and the two ecotypes. They were assigned to a Randomised Block Design with four replications at each locality. The susceptible cane variety of HJ 5741 was planted together with nutsedge in drums of 100 l capacity.

The nutsedge plants differed significantly in growth variables. Nutsedge from Jatiroto produced more basal and dormant tubers than nutsedge from Pasuruan. Consequently the weight of basal and dormant tubers and roots were higher for the Jatiroto nutsedge. The Pasuruan nutsedge showed larger number of living shoots at the termination of the experiment.

Sugarcane grown with the Jatiroto nutsedge had lighter weight of shoots, leaves and roots, shorter shoot height and smaller leaf area, than cane grown with the Pasuruan nutsedge. Thus, the former nutsedge competed more severely than the latter and the differences may lead to the conclusion that they are distinct ecotypes.

Beside the inherently different growth characteristics, the nutsedges reacted differently to environmental conditions. The Jatiroto nutsedge showed higher environmental responses, and at Jatiroto this weed competed more vigorously.

INTRODUCTION

Purple nutsedge (*Cyperus rotundus* L.) growing with sugarcane and prevalent in wet and fertile lands, showed differences in competitive abilities to cane plants. Big differences of cane yield reduction due to nutsedge competition were shown in experimental plots at several locations (Kuntohartono and Tarmani, 1980; Kuntohartono and Sasongko, 1983).

Different responses to herbicides by *Cyperus esculenthus* L., a closely related species, have been reported elsewhere (Costa and Appleby, 1976; Yip, 1978). The same happened to the purple nutsedge toward 2,4-D applications: the purple nutsedge growing at Jatiroto cane area was more tolerant to 2,4-D at 1.44 kg a.e./ha than the nutsedge from Pasuruan cane area (Kuntohartono

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et al., 1988). Both observations imply the occurrence of different kinds of purple nutsedge at those locations.

Different ecotypes of weed species were reported by Yip (1978) for *Cyperus esculenthus* in the United States, *Echinochloa colonum* L. in rice by Chun and Moody (1987) in the Philippines, and *Cynodon dactylon* L. Pers. in Mauritius (Rochecouste 1962). Different biotypes of purple nutsedge have been reported by Wills (1978) in North America after he observed differences in growth habits and growth measurements of the weed.

Explanation of the differences in growth as well as competitive responses of purple nutsedge is therefore needed. Whether the characteristic differences originate as inherent species traits or are due to the differences in the growing conditions, remains to be elucidated. The objective of this experiment was to study different conditions of growth and "types" of the nutsedges of Pasuruan and Jatiroto, and the responses of nutsedge-sugarcane interactions.

MATERIALS AND METHODS

The experiment consisted of two identical sets of treatments carried out in two locations where purple nutsedge was found. Each set consisted of the combinations of: two nutsedge types from Pasuruan and Jatiroto, two alluvial topsoils from both places, three levels of initial nutsedge density (0,50 and 100 basal tubers per m^2) and two nitrogen rates of 80 and 160 kg ha^{-1}.

These treatment combinations plus one bud set of HJ 5741 cane variety were planted in 100 l containers. In each location the treatment sets were replicated four times with the treatments randomized and assigned as sub-plots. The whole experiment which was of split-plot design, was carried out from February 14 until July 23, 1987.

Each container was irrigated daily (except when rain fell), weeds other than nutsedge were hand weeded, insecticides were sprayed several times to combat top and stem borer infestations, and the old and dying nutsedge foliage was left to rot in the containers and weighed at the end of the experiment.

The nutsedge and sugarcane biomass were collected 140 days after planting. Nutsedge data collected were as follows: the number of life and dead shoots, the number of dormant tubers and basal tubers, fresh and dry weight of the leaves, roots (including rhizomes) and tubers. Sugarcane data observed were the height and total leaf area of the mother stalk, fresh and dry weights of its shoots, roots and leaves, average height of the tillers, and fresh and dry weights of shoots, roots and leaves. Preparation of the plant parts for weighing was carried out by washing in running tap water, blotting to remove excess water, weighing in an analytical balance, then oven-drying at 105° C for 24 hours.

The climatic conditions at Pasuruan and Jatiroto are shown in Table 1. Distinct differences in climatic data were observed; Jatiroto had lower average temperatures than Pasuruan but larger diurnal temperature fluctuations, while the air humidity was slightly higher than at Pasuruan, with substantially lower sunshine percentage and higher monthly rainfall.

Table 1. Meteorological data of Pasuruan and Jatiroto, from January to July 1987

Location	Month	Temperature °C			Humidity (%)	Monthly rainfall (mm)	Evaporation (mm/day)	Sunshine (%)
		Max	Min	Average				
Pasuruan	Jan.	30.8	24.1	26.9	82	185.3	5.07	-
	Feb.	31.1	23.2	26.5	85	376.8	5.43	54
	Mar.	31.4	22.4	27.8	82	93.3	6.32	79
	Apr.	31.7	23.9	28.5	75	82.2	6.80	87
	May.	31.0	22.8	28.0	75	59.1	6.04	89
	June	31.0	22.8	27.6	74	0.2	5.67	82
	July	30.5	21.6	26.5	73	0.0	5.96	79
Jatiroto	Jan.	31.8	23.5	27.1	85	288	nd*	33
	Feb.	31.8	23.0	26.3	88	329	nd	45
	Mar.	33.3	22.5	26.6	88	265	nd	58
	Apr.	33.3	22.7	27.3	86	27	nd	55
	May.	33.0	22.5	27.1	86	55	nd	69
	June	31.5	22.4	26.0	88	107	nd	21
	July	31.3	21.1	25.5	84	0.0	3.60	61

*nd data not available

Soil samples from both places were analysed (Table 2). Soil pH, organic matter content, Na_2O, MgO and Cu were higher in Pasuruan soils. However, Jatiroto soil had a higher P_2O_5 content. Similar amounts of N, K, Mn, Zu and Fe were present in both soils.

Table 2. Analytical data for Pasuruan and Jatiroto soils

Soil samples	Soil layers (cm)	pH (H_2O)	N (%)	OM (%)	P_2O_5	K_2O	Na_2O	CaO	MgO	Fe	Mn	Cu	Zn
					ppm								
Pasuruan	0 - 30	6.90	0.10	2.45	76	467	214	6274	5209	2	50	121	16
	30 - 60	7.30	0.08	1.34	77	397	218	5752	5209	2	42	121	16
Jatiroto	0 - 30	5.80	0.10	0.15	106	493	118	6141	4164	2	57	38	16
	30 - 60	6.50	0.70	0.15	203	266	197	6254	4752	1	32	39	17

Data from both experiments were analysed in a single analysis of variance. Several data were logarithmically transformed, while the dry weight of nutsedge foliage, roots and tubers and the height of cane shoots and leaf-area of the primary cane stalks were not transformed. The Fischer test was used in the combined analysis, and the Least Significant Difference means were determined.

RESULTS

Nutsedge Growth Measurements

Eight growth measurements of nutsedge were observed at 140 days after planting. Significant (>P0.05) and highly significant (>P0.01) values were obtained for different treatments and their interactions. Significant figures were shown for location, soil from both locations, nitrogen rates, and nutsedge densities. Particularly important are the significant and highly significant differences of nutsedge growth figures derived from nutsedge grown in Pasuruan and Jatiroto. From eight growth observations, six were significantly different, as can be seen in Table 3.

Table 3. Different growth measurements of nutsedge grown at Pasuruan and Jatiroto

Growth measurements	Pasuruan	Jatiroto
Total alive nutsedge shoot numbers	144.83*)	64.54
Total dead nutsedge shoot numbers	47.54	64.03*)
Total number of dormants tubers	126.15	186.09*)
Total number of basal tubers	286.74	319.73*)
Dry weight of nutsedge leaves (g)	139.0	131.94
Dry weight of dormant tubers (g)	51.86	69.54*)
Dry weight of basal tubers (g)	175.74	170.28
Dry weight of roots (g)	123.61	144.52*)

*) LSD 0.01

Table 3 shows that Jatiroto nutsedge produced more dormant and basal tubers than Pasuruan nutsedge and higher dry weights of dormant tubers and roots. At the termination of the trial, the Pasuruan nutsedge had higher number of living shoots, while the Jatiroto nutsedge had more dead shoots.

Both nutsedges grew better at Pasuruan suggesting that the physical conditions at Pasuruan support better growth and development of the weed. At Pasuruan, the Pasuruan nutsedge possessed only heavier weight of leaves, while the number and weight of dormant tubers were smaller and lighter than the Jatiroto nutsedge. In Jatiroto the local nutsedge grew better and had significantly better and higher growth figures. Hence the Jatiroto nutsedge grew more vigorously than the Pasuruan nutsedge at both locations, and we suspected that both nutsedges have different growing characters irrespective of the local environment.

Sugar Cane Growth Measurements

The sugarcane growth and biomass as observed at the termination of the trial were the outcome of various growth factors. The nutsedge which competed with sugarcane to obtain such growth factors showed a strong negative correlation with sugarcane biomass and other growth parameters (Kuntohartono and Sasongko, 1983). Therefore the differences in sugarcane growth parameters and biomass could be an indication of the magnitude of nutsedge competition.

Calculation of the mean differences of cane growth and biomass affected by various treatments showed that there were distinct and significant differences among the values due to location of trial, nutsedge origins, and nitrogen rates. No significant differences occurred due to soil origin and nutsedge densities. Of particular importance are the significant differences between various growth and biomass parameters of the sugar cane, due to the different nutsedge origins, as can be seen in Table 4 below.

Table 4. Growth parameters and weights of various cane parts, as affected by nutsedge competitions

Data measured		Cane grown with nutsedge from	
		Pasuruan	Jatiroto
Mother stalk			
height	(cm^2)	118.38*	98.77
leafes area	(mm^2)	217.93*	187.55
stalk weight	(g)	75.37*	46.52
foliage weight	(g)	42.02*	37.95
roots weight	(g)	28.03*	21.67
Tillers			
height	(cm)	41.24*	10.01
leafes area	(mm^2)	65.03*	13.86
stalk weight	(g)	20.0 *	12.71
foliage weight	(g)	13.74*	3.97
roots weight	(g)	16.18*	5.00
Total weight of cane	(g)	275.43*	144.23

*) Least significant different at P0.01

Interaction of treatment responses occured for locations versus nitrogen rates and nutsedge origins. A positive interaction occurred for location and nutsedge origins. There is a general tendency for the sugar cane growth parameters to follow a significantly decreasing magnitude from Pasuruan location - Pasuruan nutsedge, through Pasuruan location - Jatiroto nutsedge, followed by Jatiroto location - Pasuruan nutsedge, and finally the lowest sugar cane growth was with Jatiroto location - Jatiroto nutsedge (Teble 5). Hence the Jatiroto nutsedge competed more strongly than the Pasuruan nutsedge at both experimental sites and the conditions at Jatiroto provided heavier competition toward sugarcane growth.

Table 5. Cane growth parameters as affected by nutsedge origin and experimental locations

	Pasuruan location		Jatiroto location	
Cane growth parameters	Pasuruan nutsedge	Jatiroto nutsedge	Pasuruan nutsedge	Jatiroto nutsedge
Average height of tillers (cm)	69.54*)	34.13b	24.30c	2.45d
Weight of tillers leaves (g)	30.25e	14.34f	5.95g	0.61h
Weight of tillers roots (g)	47.86i	26.52j	5.04k	0.311
Total leaf area of tillers leaves	148.52m	84.89n	57.52o	13.27p

*) Figures followed with the same letters are not significantly different according to the Duncan multiple range test at P0.05

DISCUSSION

Heavier and bigger basal and dormant tubers and roots, suggested that the Jatiroto nutsedge is indeed a different ecotype than the Pasuruan nutsedge. Due to bigger underground organs, the Jatiroto nutsedge has a more severe competitive ability toward HJ 5741 sugarcane variety than the Pasuruan nutsedge. Hence they can be considered as two distinct nutsedge ecotypes.

The trials conducted in pots, however, provide different results compared to the former field trials. Nutsedge competition to sugarcane and the reduction of its growth resulting from it were higher at Pasuruan than at Jatiroto (Kuntohartono and Tarmani, 1980; Kuntohartono and Sasongko, 1983). Assuming that the nutsedge ecotypes used were similar to the ones used in these trials, it might be suspected that nutsedge sugarcane interaction is much influenced by different environmental conditions at both locations, as was shown in this trial.

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PLANT INVASION AND SUCCESSION OF CLEAR FELLING SITES WITH WEEDING IN THE COOL-TEMPERATE PRIMEVAL MIXED FOREST ON THE PACIFIC SIDE OF HONSHU, JAPAN

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INTRODUCTION

In the cool-temperate zone of the Pacific side of Honshu, Japan, the natural forests are composed of many species of coniferous trees and deciduous broad-leaved species, although in that of the Japan Sea side only beech (*Fagus crenata* Blume) trees usually dominate, occasionally mixed with oak trees (*Quercus mongolica* var. *grosseserrata*). Many studies on the regeneration of beech forest were carried out and a few methods of natural regeneration were proposed. However, studies on that of mixed forest are limited (Tanaka 1985). The undergrowth of these cool-temperate forests usually consists of thick dwarf- bamboo, although there is a difference of species between the two sides of Honshu. On the Pacific Ocean side there are usually *Sasa borealis* (Hack.) Makino and/or *S. nipponica* (Makino) Makino, whereas on the Japan Sea side *S. palmata* (Bean) Nakai, *S. senanensis* (Franch. et Sav.) Behd. and *S. kurilensis* (Rupr.) Makino et Shibata occur widely throughout the zone.

Since dwarft-bamboo grows profusely in an opening, it prevents the invasion and growth of trees (Tanaka 1986, 1987). The dwarft-bamboo undergrowth is undoubtedly the greatest hindrance to reforestation in this zone (Shidei 1974).

Since 1986 the natural regeneration management consisting of clear felling and pre-felling weeding has been adopted by the Misakubo District Forestry Office. We studied the invasion of plants consisting of useful tree and weed species and the development of the communities after felling by recording species, size and growth process of the plants to estimate the possibility of the management.

STUDY AREA

The study area is located at 1,300 to 1,400 m a.s.l. in Akaishi Mountains on the Pacific side of Honshu (35°13'N, 138°1'E). The bedrocks consist of sandstone, slate, etc. of Paleozoic origin, with partial cover of volcanic loam.

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There are narrow valleys, steep slopes and rather gentle ridges. The study plots were set up in the four management blocks of the Reagional Forestry Office. The blocks 95g and 96g were felled in 1986 with cutting dwarft-bamboo before the felling and with an application of the herbicides, tetrapion, effective of Gramineae perennial in the following year. The block 86e was felled in 1956 with cutting dwarft-bamboo before the felling and larch (*Larix leptolepis* (Sieb. et Zucc.) Gordon was planted at the density of 3,000/ha.

In the block 90a there is a primeval forest. According to the records of regional Forestry Office, tree volume of the intact before felling in the blocks 95c, 96g and 86e, and that of the block 90a were shared at the rate of 65:35 by coniferous species and deciduous broad-leaved species respectively. This record indicates the felled forests is similar to the existing intact forest in the block 90a.

METHODS

Placing 16 plots (2m x 2m) in the block 95c, we recorded every saplings of useful tree species by species name and height and also recorded all plant species by species name and coverage. Placing 10 plots (2m x 2 m) in the blocks 96g, we did the same measurement for every saplings of useful tree species. Placing two plots (5m x 5m), we recorded every trees by species name, diameter at breast height (DBH) and height, and cut two sample trees for each of five species to analyze the stem growth with annual rings. Placing one plot (50m x 30m), we recorded evry trees by species name, DBH and height. All these measurements were carried out in summer, 1990.

RESULTS

In the block 95c and 96g, where four years had passed after the felling, the saplings of tall tree species such as cherry birch (*Betula grossa* Sieb. et Zucc.), monarch birch (*B. maximowicziana* Regel) and cork-tree (*Phellodendron amurense* Rupr.) grew in high density, while some shrub species such as bramble (*Rubus crataegifolius* Bunge, *R. palmatus* Thunb., *R. microphyllus* Linn., etc.) and *Styrax shirasawana* Makino showed high density and coverage.

In the block 86e, where 34 years had passed after the felling, there was a secondary forest composed of larch, cherry birch, cork-tree, stewartia (*Stewartia monadelpha* Sieb. et Zucc.) in the overstory, while in the understory there were *Styrax shirawasana and Parabenzoin praecox* (Sieb. et Zucc.) Nakai. The dwarft-bamboo is dominant but less dense the primeval forest. There were almost no saplings of tree species in the understory.

According to the stem analysis, the broad-leaved trees such as cherry birch, cork-tree and stewartia were established one to four years after the felling and grew steadily at the height increment of 38 to 42 cm/yr. The *S. shirasawana* grew more quickly than the other trees at the initial phase and was outran by them thereafter due to the reduction of height growth.

The primeval forest in the block 90a was dominated by coniferous trees, i.e. hemlock (*Tsuga sieboldi* Carr.) and fir (*Abies homolepis* Sieb. et Zucc.) and by deciduous broad-leaved trees, i.e. beech, cherry birch, stewartia and *Acer palmatum* Thunb. in the overstory, with the dense undergrowth of drawft-bamboo (*S. borealis*). The height class distribution showed that there were only canopy trees for dominant broad-leaved trees such as beech and cherry birch, whereas two coniferous tree species had individuals at almost every height class. However, in the lowest layer covered with dense dwarft-bamboo, almost no saplings of the tree species were found.

DISCUSSION

Since a large number of saplings of useful tree species, the preceding weeding of dwarft-bamboo and an application of herbicide are effective to the invasion of some useful tree species. Invading tree species into the felling sites have small seeds disseminated by wind or bird except for stewartia and *S. shirasawana* that have no special modification for dissemination, which might be regenerated from buried dormant seeds. However, the established saplings of hemlock, fir and beech, which are dominant in the original forests, were very few.

In the block 95c and 96g, sufficient density of sapling of useful tree species were established for the successful reforestation, mixed with weeds such as bramble and dwarft-bamboo. However, most saplings were lower than 50 cm in height so that their number will decrease mainly due to the intra- and inter-species competition. We are going to investigate the number and survival of the established plants at the interval of five years in the plots thereafter.

The facts that the sufficient density of saplings of useful tree species in the sites of felling four years later and that the dominance of broad-leaved tree species in the site of felling 34 years later showed that cutting of dwarft-bamboo was effective methods to allow the useful tree species to invade into the felling sites. However extra weeding may be necessary to accelerate the invasion of useful tree species in patchy thickets of weeds formed after felling. It is also important to plant saplings of valuable timber species such as *Zelkova serrata* (Thunb.) Makino in adequate sites for economically enrich the composition of regenerated forests.

The natural regeneration methods consisting of clear felling and weeding of dwarft-bamboo allowed light-demanding tree species such as cherry birch, cork-tree and stewartia to grow, whereas shade-tolerant tree species such as hemlock, fir and beech, which dominate in intact forests, hardly regenerated. Therefore, the application of this methods to the extensive area will lead to the dominance of light-demanding species and the reduction of shade-tolerant species. In order to promote the regeneration of the shade-tolerant species, ensuring seed supply from mother trees and control the illuminance in the felling sites may be necessary either by the reduction of felling area or by more residual mother trees. It may be also important to reserve coniferous trees in the understory of the intact forests when felling. Further study is necessary to accelerate the regeneration of the shade-tolerant tree species.

SOIL SEED BANKS OF WEEDS AND OTHER SPECIES IN A RAIN FOREST COMMUNITY

ROCHADI ABDULHADI[1]

ABSTRACT

The soil seed bank of a rain forest community was assessed. Twenty soil samples of 20 x 50 x 5 cm were randomly collected within a one ha plot beneath subtropical rain forest in Southeast Queensland.

The density of viable seeds was 560 seeds m^{-2} composed of 70 species. Most seeds were herbaceous weeds and other rain forest pioneers. The pattern of seedling emergence is discussed, and the possible role of the seed bank on vegetation succession is reviewed.

INTRODUCTION

Weeds are usually known as unexpected plants which occur in a certain area (Holm *et al.*, 1977). They are, in agricultural practices, considered as competitors with crop plants for nutrients, water, space and light. During the recovery process following forest disturbances, however, weeds often play an important role by providing the initial vegetation, even though they are rarely or never found under the closed canopy forest. These species may be recruited from the viable seeds that are stored in the soil or from seeds that have recently arrived (Abdulhadi 1989).

The present study assesses the size and composition of a soil seed bank under rain forest with special reference to weeds and pioneers.

STUDY AREA AND METHODS

The study was conducted in the Lamington National Park of South East Queensland, Australia (28° 14' S, 153° 7' E). The forest is an undisturbed subtropical rain forest, classified as Complex Notophyll Vine Forest (Webb 1968).

A plot of 100 x 100 m was established, and divided into 100 subplots of 10 x 10 m. Twenty 50 x 25 x 5 cm soil samples were taken randomly in August 1984 using a metal sampling frame. These samples were placed in marked plastic bags and transported directly to the glass house. Each sample was then spread out on a layer of vermiculite in two germination trays of 34 x 28 cm

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respectively and placed in the glass house. All live vegetative material was removed carefully to prevent any probability of vegetative sprouting.

Six trays of steam sterilized soils were placed among the sample trays for estimating any contamination from seed sources adjacent the glass house. The soil was watered twice daily and seedling emergence was monitored weekly for 17 weeks.

RESULTS

Seedlings of *Portulaca oleracea* L. came up in the control trays, which were probably contaminated by local seeds from surrounding trays in the glass house. In fact, this plant was found in the glass house and was flowering during the period of observation. Seedlings of this species were therefore eliminated from recording of the seed bank as contaminants.

Size and Composition of Seed Banks

A total of 1335 seedlings (536 seedlings m^{-2}) were recorded. The pattern of seedling germination is given in Figure 1. The number of seedling coming up increased sharply during the first six weeks, after which it decreased slowly until the curve finally become roughly stable.

Seventy species belonging to 56 genera and 33 families were recorded. Most species were weeds and other secondary forest species, and only 5% of species (five species) and 2% of seedlings (11 seeds m^{-2}) were primary forest tree species.

The Importance Value Index (IV) was calculated based on the relative density and relative frequency of each species (Table 1). It can be seen that 14 species have importance values greater that 5, most of which were herbaceous weeds and secondary forest species. Nineteen species have importance values between 1 and 5 whilst the remaining 36 species have the importance values of less than 1.00.

Seedling Emergence

Bray-Curtis dissimilarity measure (Clifford and Stevenson 1975) and flexible clustering strategy (Lance & William 1966) were both used for grouping the species by the times of seedling appearance. The result of the clustering analysis is given in Figure 2.

It can be seen that three major species groups are formed and that they are apparently allied to the species functional group. The first group is confined to pioneer species which are herbaceous weeds which germinate immediately after sowing and continue to do so for the relatively short period ie., less than 6 weeks (Table 2).

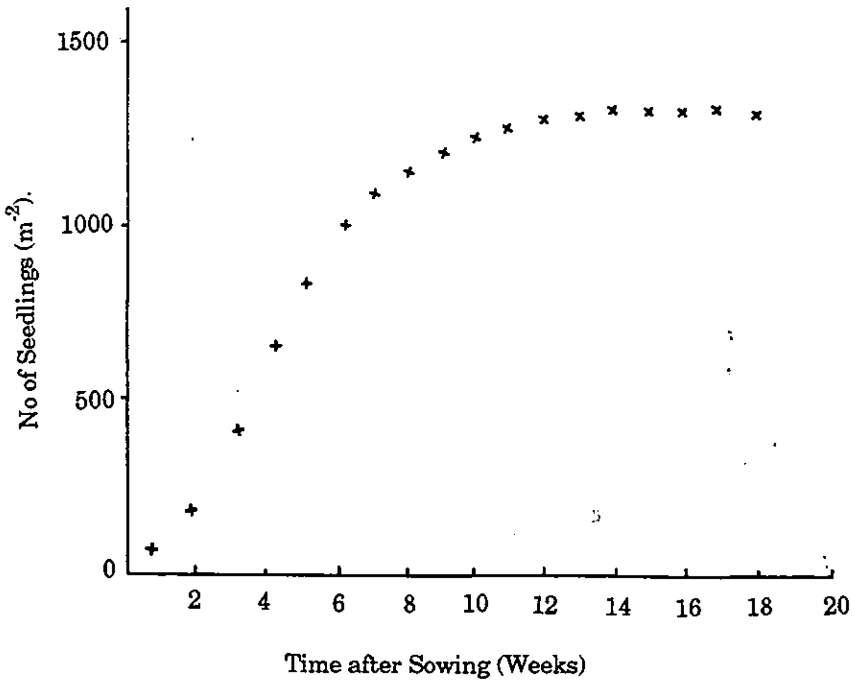

Figure 1. The cumulative numbers of seedlings observed over a period 17 weeks

Table 1. List of the 14 prevalent species with the Importance Values (Relative Dominance + Relative Frequency) greater than 5

Species	LF	RF	RD	IV
Clematis glycinoides	V	5.90	12.24	18.14
Rubus rosiifolius	V	5.31	9.30	14.61
Duchesnea indica	H	5.60	7.88	13.48
Dendrocnide excelsa	T	4.72	7.06	11.78
Conyza canadensis	H	5.90	5.40	11.30
Caldcluvia paniculosa	T	4.13	7.13	11.26
Urtica incisa	H	3.83	7.43	11.26
Cephalaralia cephalobotrys	V	2.95	5.25	8.20
Eupatorium adenophorum	H	3.54	3.08	6.62
Euphorbia hysoppifolia	H	2.95	3.38	6.33
Solanum americanum	H	3.24	2.70	5.94
Ficus platypoda	T	3.24	2.25	5.49
Solanum stelligerum	S	3.54	1.58	5.34
Hydrocotyle pedicellosa	H	2.65	2.40	5.05

LF.= Life Forms, RF.= Relative Frequency, RD.= Relative Dominance, IV.= Importance Value, V.= Vines, H.= Herbs, T.= Trees, S.= Shrubs

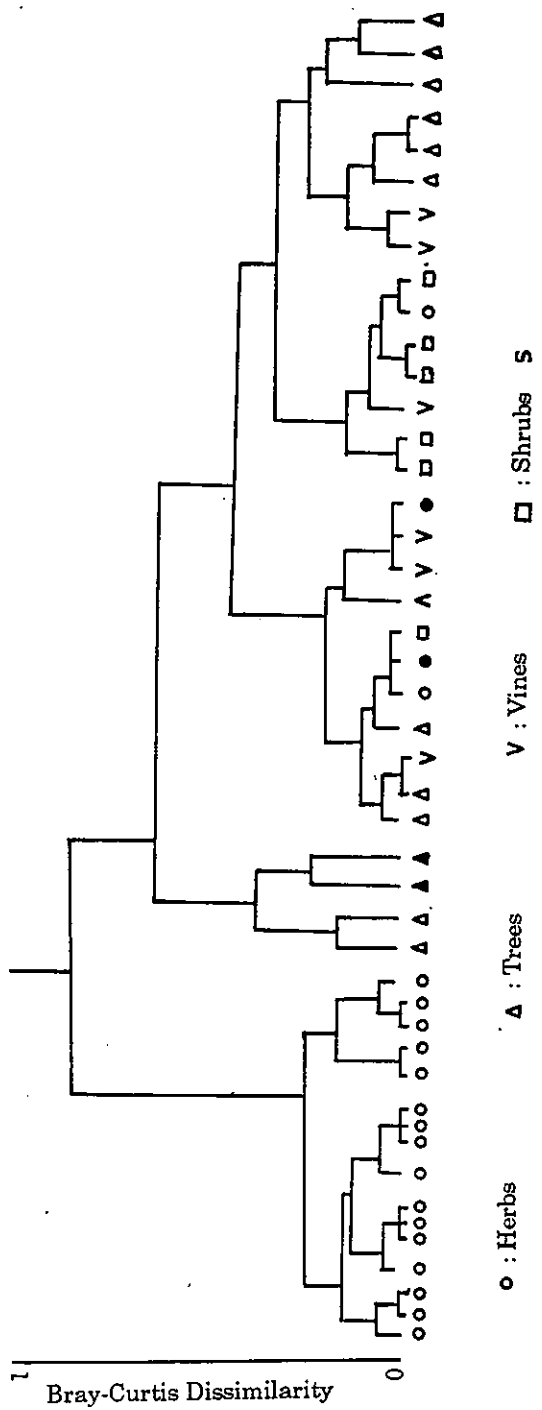

Figure 2. Selected species grouped according to germinating times, using Bray-Curtis dissimilarity index and the flexible clustering strategy

Table 2. Selected species sorted into groups by weeks of germination using the Bray-Curtis dissimilarity index and the flexible sorting strategy

Species	Time (weeks (s))																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Group I																	
Conyza canadensis	+	+	+	+	+												
Duchesnea indica	+	+	+	+													
Solanum nigrum	+	+	+	+													
Gnaphalium americanum	+	+	+		+												
Baccharis halimifolia	+	+	+														
Cirsium vulgare	+	+	+														
Crassocephalum crepidioides	+	+															
Sonchus oleraceus	+	+															
Erechtites valerianifolia	+	+															
Phytolacca octandra		+	+	+													
Deeringia amaranthoides		+	+		+												
Senecio lautus		+	+														
Siegesbeckia orientalis		+	+														
Gnaphalium pensylvanicum		+		+													
Wahlenbergia sp.		+		+													
Group II																	
Ehretia acuminata												+	+				
Endiandra sp.														+	+		
Pittosporum undulatum								+	+		+	+	+				
Euodia sp.											+		+				
Group III a.																	
Cephalaralia cephalobotrys		+	+	+	+	+	+	+		+	+	+					
Dendrocnide excelsa		+	+	+	+	+	+	+		+							
Rubus rosifolius		+	+	+	+	+	+	+		+							
Oxalis corniculata		+	+	+	+	+	+	+									
Urtica incisa		+	+	+	+	+	+	+									
Ficus platypoda		+	+	+	+		+	+	+								
Solanum stelligerum		+	+	+	+	+	+										
Hydrocotyle pedicellosa			+	+	+	+	+	+	+		+		+				
Caldcluvia paniculosa				+	+	+	+	+	+			+					
Clematis glycinoides					+	+	+	+	+		+	+	+	+			
Polyscias elegans						+	+	+	+		+						
Group III b.																	
Eupatorium adenophorum		+	+	+	+	+	+	+									
Euphorbia hysoppifolia		+	+	+	+	+	+	+									
Solanum aviculare			+	+	+	+	+										
Solanum semiarmatum			+	+	+	+	+										
Solanum mauritianum			+	+	+			+	+								
Rubus moluccanus			+	+	+		+										
Lophostemon confertus			+	+	+												

Table 2. (Continued)

Species	Time (weeks (s))																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Acronychia oblongifolia			+		+		+		+								
Zehneria cunninghamii			+	+		+											
Claoxylon australe				+	+	+		+	+								
Omalanthus populifolius				+	+	+											
Trema aspera				+	+	+											
Cayratia eurynema					+	+	+										
Duboisia myoporoides					+	+		+									
Zanthoxylum brachyacanthum						+	+										

In contrast to the first group, the second group represents the late secondary and primary tree species. These species do not all germinate immediately after sowing, but at least some germinate after 12 weeks.

The third group has a more widespread distribution of times for their germinations. It includes species that germinate and produce succesful seedlings in light gaps, some of which may be able to germinate and become seedlings in the mature forest. Thus, this group includes various plants ranging from herbaceous weeds to tree species. However, it seems that the herbaceous weeds mostly came up in the early period after sowing.

Phenological Behaviour of Weeds

An attempt to assess the phenology of weeds has been made by recording the number of weeks to appearance of first seedling, flower and fruit within the glass house. The results (Table 3) show that 15 of the 16 species coming into flower within 15 weeks are herbaceous weeds with one vine *Zehneria cunninghamii,* F. Muell.

The quick flowering and fruiting of those short lived pioneers may indicate a strategy for avoiding competition.

DISCUSSION

Sowing the forest soils in the glasshouse changed the environment of the buried seed. In contrast to the soil beneath the closed canopy of rain forest they received much more light and a higher level of temperature fluctuation (Abdulhadi 1990).

Increasing light or temperature, or may be both may stimulate seeds buried in the soil to germinate, particularly the seeds of pioneer species which are more sensitive to both factors (Bazaz & Picket 1980). The results show that the species coming up in the first forthnight are all herbaceous weeds (Table 2).

Table 3. Number of weeks to appearance of first seedling, flower and fruit

Species	Week (s)		
	Germinating	Flowering	Fruiting
Euphorbia hysoppifolia	1	6	8
Solanum nigrum	1	6	8
Sonchus oleraceus	1	8	10
Crassocephalum crepidioides	1	12	13
Duchesnea indica	1	12	*
Gnaphalium americanum	1	14	16
Conyza canadensis	1	17	*
Siegesbeckia orientalis	2	8	*
Phytolacca octandra	2	12	14
Solanum semiarmatum	2	14	17
Senecio lautus	2	15	17
Gnaphalium pensylvanicum	2	16	*
Wahlenbergia sp.	2	16	*
Deeringia amaranthoides	2	17	*
Oxalis corniculata	3	7	9
Zehneria cunninghamii	3	9	12

In the following four weeks many more seeds were stimulated to germinate including many vines, shrubs and trees. The cumulative number of seedlings coming up therefore increased sharply during this period. By contrast, in the later period of observation just a few remaining seeds germinated, particularly those of tree species, until eventually no more seedlings came up.

The number of species and seed densities found in this study are comparable with those found in other studies of rain forest soil seed banks (see Table 4). However, these numbers were much lower than the seed population in disturbed forests. Abdulhadi & Lamb (1987) noted that the number of seeds stored in the soil of a 20 year-old regrowth forest about 600 m from the study site was 3.5 times higher. Guevara & Gomez-Pompa (1972) and Kellman (1974) have suggested that seed densities in secondary forests can be 6.5 to 12.5 times higher than in undisturbed forests, mostly due to the increasing numbers of seed of pioneers.

Most pioneers rapidly established as mature plants and produced seeds, whilst some (mostly herbaceous weeds) such as *Euphorbia hysoppifolia* L., *Crassocephalum crepidioides* (Benth.) S. Moore, *Gnaphalium americanum* Miller, *Phytolacca octandra* L. and *Solanum nigrum* L. produced fruit under the glass house conditions within 15 weeks (Table 3). Abdulhadi & Lamb (1991) from their study on the seed bank development following a rain forest disturbance have shown that some pioneers such as *Solanum aviculare* Forster, *S. inaequilaterum* Domin, and *Hydrocotyle pedicellosa* F. Muell. soon released large numbers of seeds resulting in a continuous increase in the seed bank

Table 4. A comparison of soil seed banks in rain forest communities

Location	Vegetation type	Sample area (cm^{-2})	Number of species	Number of seeds (m^{-2})	Authors
Nigeria	LRF	5200	42	233	Keay (1960)
Mexico	LRF, site 1	640 (x8 repeats)	13	175-689	Guevara & Gomez-Pompa (1972)
	LRF, site 2	640 (x8 repeats)	26	344 - 862	
Thailand	LRF	1000	27	182	Cheke *et al.* (1979)
Ghana	SDF	1000	30 & 43	633 & 696	Hall & Swaine (1980)
	EF	1000	17 & 22	45 & 163	
Venezuela	LRF (mixed forest)	5200	13	180	Uhl & Clark (1983)
	LRF (caatinga)	1200	14	200	
North Queensland	CMVF,site 1	15000	64	588	Hopkins & Graham (1983)
	MMVF,site 2	15000	64	516	
	MVF,site 3	15000	79	1069	
	CMVF,site 4	15000	60	593	
Malaysia	LRF	4241	30	131	Puyz & Apannah (1987)
South-east Queensland	CMVF,	12500 (x3 repeats)	52 - 58	550-603	Abdulhadi (1991)
	CMVF,	25000	70	560	Present study

LRF. : Lowland rain forest
SDF. : Semideciduous forest
EF. : Evergreen forest
CMVF.: Complex Mesophyll Vine forest
NMVF.: Nothophyll-Mesophyll Vine forest

density in the following years. A similar phenomenon has been noted in North Queensland (Hopkins & Graham 1984) and in Papua New Guinea (Saulei 1985).

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THE DEVELOPMENT OF WEEDS UNDER *DENDROCALAMUS ASPER* (SCHULTZ. F.) BACK. EX HEYNE PLANTATION IN LAMPUNG, SUMATRA, INDONESIA

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ABSTRACT

Fifty four species of weeds were collected from a three months old bamboo plantation in Lampung (Sumatra) which was previously planted with cassava. The number of weed species decreased with the age of the bamboo plantation, from 28 at six months to ten under one year old bamboo plantation, probably due to crowding of the bamboo leaves, suppressing the weed growth. *Mikania micrantha* was the most dominant weed at one year because its climbing habit enables it to cover the bamboo plants, suppress their growth and even kill the bamboos. Another weed species which grows well under bamboo plantation is *Pennisetum polystachyon*. Some herbicides were used to control weeds under bamboo plantation, and herbicides are recommended when competition from weeds become serious.

INTRODUCTION

Many people in the Asia-Pacific region use bamboos for a thousand things, so that it is not surprising that they are cultivated in large plantations. Although Asian countries such as Japan, China, Thailand, Philippines, India and Taiwan produce bamboos in large plantations, there is no published report regarding weed problems in these plantations.

When a bamboo plantation is being developed in Lampung (Sumatra), weeds become serious problems especially during the early stages when bamboos suffer from weed competition, which may kill some bamboo plants. A weed inventory was made in a bamboo plantation to gain information and develop techniques to prevent or limit weed infestations.

MATERIALS AND METHODS

This study was conducted in Lampung, Sumatra where a bamboo plantation of *Dendrocalamus asper* (Schultz. f.) Back. ex Heyne was just started. The land was previously planted with cassava especially grown for a selection

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programme. Before planting the bamboo the soil was manually ploughed, and 1 x 1 x 0.75 cm holes at a spacing of about 5 x 5 m were prepared for the bamboo propagules. Planting occurred in November when the rainy season started, and the first inventory was performed 3 months later, followed by a second when the bamboos were 6 months old and a third when the plantation was 1 year old.

RESULTS AND DISCUSSION

The result of the three weed inventories are given in Table 1. Fifty four weed species were collected at three months, and the survival of the bamboo planting at this stage was very low because the propagules still needed a lot of water for vigorous development. Weeds may become serious at this stage so that if no weeding is undertaken the propagules which just manage to establish might die. During this young period *Imperata cylindrica* (L.) Raeusch., *Cynodon dactylon* (L.) Pers., *Axonopus compressus* (Swartz) Beauv., *Mimosa invisa* Mart ex Colla and *Starchytarpheta indica* (L.) Vahl. were the most common and dominant weeds. At this stage the bamboos had not developed their dense crowns, so that sunlight reached the ground and the weeds developed fully. *Mikania micrantha* H.B. & K. became the most difficult weed to handle, because of its climbing habit enabled it to cover and suppress the bamboo crowns. Manual weeding was necessary to prevent this, and after a long study using different herbicides we found that 2,4 - D Dimethylamin can be used at 1.44 kg/ha as a preventive measure to overcome *Mikania* infestation.

The number of weeds decreased under the six month old bamboo plantation, because the bamboos had developed their dense crowns. Some Cyperaceae and Poaceae were incapable of growing well at this stage but *Borreria* spp. and *Oxalis barrelieri* L. survived although manual weeding was done previously.

Only about ten weed species could grow in one year old bamboo plantation probably because the sunlight could reach the soil. *Mikania micrantha* H.B. & K. was still found and this weed could be a serious problem since it might cover the bamboo crowns if weeding and other control measures were not undertaken.

Although bamboo can grow anywhere, to obtain a high yield a proper management of the bamboo plantation should be undertaken since weeds are a serious problem in the early stages. *Mikania micrantha* H.B. & K. is the most dangerous weed for bamboo plantations. *Pennisetum polystachyon* Schult. was originally introduced into this areas as forage for cattle, and it is now widely spread all over the plantation, and can also develop very well under bamboo stands.

Table 1. List of Weeds in A Bamboo Plantation in Lampung, Sumatra

Species	3 months	6 months	1 year
Aeschynomene americana L.	+	-	-
Ageratum houstonianum Mill.	+	+	-
Amaranthus gracilis Desf.	+	-	-
Amaranthus hybridus L.	+	+	-
Axonopus compressus (Swartz.) Beauv	+	+	+
Borreria alata (Aub.) DC.	+	+	-
Borreria laevis (Lamk.) Griseb.	+	+	+
Brachiaria paspaloides (Persl.) C.E. Hubb.	+	-	-
Brachiaria distachya (L.) Stapf.	+	-	-
Calopogonium mucunoides Desv.	+	+	-
Cassia tora L.	+	-	-
Cleome rutidosperma DC.	+	+	-
Clibadium surinamensis L.	+	+	+
Cynodon dactylon (L.) Pers.	+	+	-
Cyperus cyperoides (L.) O. Kuntze	+	+	-
Cyperus halpan L.	+	-	-
Cyperus sphacelatus Rottb.	+	+	-
Dactyloctenium aegyptium (L.) Richt.	+	-	-
Desmodium heterophyllum (Willd.) DC.	+	+	-
Desmodium pulchrum	+	+	-
Digitaria ciliaris (Retz.) Keol.	+	-	-
Echinochloa colonum (L.) Link.	+	-	-
Eleusine indica (L.) Gaertn.	+	-	-
Eragrostis tenella (L.) Beauv. ex. R. & S.	+	-	-
Euphorbia geniculata Ortega	+	-	-
Euphorbia hirta L.	+	+	-
Fimbristylis griffithii Boeck.	+	-	-
Hyptis capitata Jacq.	+	-	-
Imperata cylindrica (L.) Raeusch.	+	-	-
Ipomoea trilobata L.	+	-	-
Leucas lavandulaefolia J.E.Smith	+	-	-
Malvastrum coromandelianum (L.) Garcke	+	-	-
Merremia sp.	+	+	-
Mikania micrantha H.B. & K.	+	+	+
Mimosa invisa Mart. ex Colla	+	+	+
Mimosa pudica L.	+	+	-
Mitracarpus villosus Chem. & Schlecht.	+	+	-
Ottochloa nodosa (Kunth.) Dendy	+	-	-
Oxalis barrelieri L.	+	+	-
Paspalum flaccidum Nees	+	-	-
Paspalum commersonii Lamk.	+	+	+
Paspalum conjugatum Berg.	+	-	-
Passiflora foetida L.	+	+	-
Pennisetum polystachyon Schult.	+	+	+
Phyllanthus urinaria L.	+	-	-
Poa annua L.	+	-	-
Polygala paniculata L.	+	+	-
Rhynchelytrum repens (Willd.) C.E. Hubb	+	+	-
Richardsonia brasiliensis Hayne	+	-	-
Scleria biflora Roub.	+	-	-
Sonchus oleraceus L.	+	-	-
Spigelia anthelmia L.	+	+	-
Stachytarpheta indica (L.) Vahl.	+	+	+
Vernonia cinerea (L.) Less.	+	+	+

MANAGEMENT OF BROME GRASS IN RELATION TO ITS POPULATION DYNAMICS

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ABSTRACT

The impact of treatments imposed to manage brome grass was measured by changes in populations over four years. The results have enabled the prediction of population movements within a range of crop and herbicide rotational systems and has facilitated decision-making with regard to the changes that could be made in the systems to reduce the abundance of brome grass in the most cost effective way.

INTRODUCTION

Bromus diandrus Roth and *B. rigidus* Roth, collectively referred to as brome grass, are the two major species in the genus causing concern to Australian agriculture, especially in wheat and other cereal crops. Both species were introduced into Australia from the Mediterranean region, apparently during the middle of the nineteenth century (Kloot 1983). *Bromus* spp. are aggresive and according to Kloot (1983), the time from introduction to naturalisation can be as short as one growing season.

B. diandrus and *B. rigidus* have only risen to prominence in recent years. Several reasons have been advanced to explain this rapid increase; the most important being the trend towards direct drilling which allows farmers to plant sooner than they would with conventional systems (Cheam 1986). While a large proportion of the brome grass seed bank germinates readily (Cheam 1987), early planting offers less opportunity to kill the resultant seedlings since selective post-emergent herbicides are not available for their control in wheat and other cereals. The use of selective herbicides in cereals against other major grass weeds including ryegrass (*Lolium rigidum* Gaudin) and wild oats (*Avena fatua* L.) as well as the broadleaved weeds in general, has resulted in a population shift to brome grass, barley grass (Hordeum leporinum Link) or silver grass (*Vulpia bromoides* (L.) S.F. Gray and *V. myuros* (L.) C.C. Gmelin). Of these three, Poole and Gill (1986) claim that brome grass is the most competitive.

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PRESENT STATUS OF BROME GRASS MANAGEMENT

Several methods are available for the management of brome grass in crop land, mostly based on the reduction of the brome grass seed bank in the previous season(s) or in the short period prior to sowing the cereal crop. The focus on seed bank reduction is based on the fact that the seed is the only source of infestations of brome grass and therefore it should be the ultimate target of control efforts (Cheam 1988). Current recommendations consequently include crop rotation, good land preparation prior to seedling, delayed planting, and planting clean seed. Chemical control of brome grass in the cereal crop itself is a last resort causes some crop damage since currently available herbicides lack complete selectivity.

Crop rotation is the most effective method because it enables selective in-crop grass herbicides to be used in the broadleaved crop or pasture phase. Cultivation on its own is less effective, even though it encourages brome grass germination which is further enhanced by delayed seeding. The good preparation of the seed bed through cultivation has the disadvantage of making the soil more prone to wind erosion as well as delaying the seeding operation which in turn can penalise crop yield.

The use of lupins (*Lupinus angustifolius* L.) in the rotation has been very successful in helping to reduce brome grass population in Western Australia. Several herbicides are available for controlling brome grass in lupins. Simazine, a soil incorporated pre-sowing herbicide, is the most commonly used, but is less effective than the grass-specific herbicides like fluazifop-p, haloxyfop and quizalofop all of which are currently registered for post-emergence brome grass control in lupins. Field peas (*Pisum sativum* L.s.lat.) is another broad-leaved crop commonly grown in rotation with wheat to enable successful control of brome grass, especially in South Australia.

Two methods are currently in use during the pasture phase of a pasture-wheat rotation to reduce brome grass seed carryover into the following wheat crop. Spray topping is achieved by using a non-selective herbicide such as paraquat or glyphosate in spring to reduce the flowering and/or seeding capacity of brome grass. The advantages of spray topping can be significant because the small cost input can lead to real economic gain, but it requires a high level of management skill because timing of the herbicide application is very critical. The other method for the control of brome grass in the pasture phase involves the use of a grass herbicide such as fluazifop-p, but this technique can only be recommended if there is a reasonable density of pasture legumes to ensure economic gains.

Despite the availability of several crop rotation strategies and other cultural practices, regeneration of brome grass in the cereal phase is quite common. Regeneration is entirely from seed, and knowledge of the seed dynamics is important since the annual rate of population change will be determined by the balance between the addition of new seeds and the losses of existing seeds from the system. This paper reports an analysis of patterns of demographic behaviour in brome grass in relation to available weed control methods and enable the prediction of population movements within a particular cropping system.

BROME GRASS POPULATION DYNAMICS IN CROPPING SYSTEMS

The population dynamics of brome grass are clearly influenced by the use of various crop management and weed control programmes, as was shown by the evaluation of 16 rotational systems over four years (Table 1). The herbicide rates were: glyphosate at 0.25 kg ai/ha (as Roundup CT, 45% ai), fluazifop-p at 0.106 kg ai/ha (as Fusilade 212, 21.2% ai), simazine at 0.75 kg ai/ha (as Gesatop 500 FW, 50% ai) and paraquat dichloride and diquat dibromide at 0.125 + 0.075 kg ai/ha (as Spray. Seed, 12.5 + 7.5 % ai).

The 16 rotational systems can be considered as components on nine basic treatments (Table 2). Detailed censuses were made of buried seeds, seedling emergence, plant survivorship and plant reproduction in each of the nine basic treatments between 1986 and 1990, and the calculated annual percentage rate of change of the brome grass seed bank, effective seedling recruitment and adult fecundity for each of these treatments are shown in Table 2.

Seed Bank

The data show that as much as 98% annual decrease in the brome grass seed bank occurred under lupins treated with glyphosate tankmixed with simazine presowing followed by the application of fluazifop-p. In contrast, an annual increase in seed population of about 559% was recorded in early-seeded wheat. Of the wheat cropping treatments, only the late-seeded wheat receiving two kills of brome grass before crop seedling led to an annual decrease in the seed bank. The seed bank increased about 78% annually in the absence of brome grass control during the pasture phase. However, approximately 75% annual decrease in the seed reserves occured in fluazifop-p treated pasture, with a corresponding figure of 35% decrease in spraytopped pasture.

The seed bank is a useful population parameter due to the fact that it is buffered againts annual variations in weather or experimental conditions giving a good measure of long-term tendencies (Fernandez-Quintanilla 1988), and monitoring the soil seed bank is therefore a useful approach to determining population trends and annual rates of change for the various treatments.

Table 1. The 16 rotational systems and the respective herbicide programme for two full cycles of the rotational treatments

Rotational system 1986-87-88-89	Herbicide programme*	
	1986	1987
Continous pasture		
P-P-P-P	Nil	Nil
P-P-P-P	glyphosate (SPT)	paraquat dichoride+ diquat dibromide (SPT)
P-P-P-P	fluazifop-p (POE)	fluazifop-p (POE)
Pasture-wheat		
P-W-P-W	glyphosate (SPT)	paraquat dichloride+ diquat dibromide, once (PS)
P-W-P-W	fluazifop-p (POE)	paraquat dichloride+ diquat dibromide, once (PS)
Wheat-pasture		
W-P-W-P	paraquat dichloride+ diquat dibromide, once (PS)	paraquat dichloride+ diquat dibromide (SPT)
W-P-W-P	paraquat dichloride+ diquat dibromide, once (PS)	fluazifop-p (POE)
Lupin-wheat		
L-W-L-W	simazine (PS)	paraquat dichloride+ diquat dibromide, once (PS)
L-W-L-W	simazine (PS), fluazifop-p (POE)	paraquat dichloride+ diquat dibromide, once (PS)
L-W-L-W	glyphosate (PS), simazine (PS), fluazifop-p (POE)	paraquat dichloride+ diquat dibromide, once (PS)
L-W-L-W	glyphosate (PS), simazine (PS), fluazifop-p (POE)	Nil
Wheat-lupin		
W-L-W-L	paraquat dichloride+ diquat dibromide, once (PS)	simazine (PS)
W-L-W-L	paraquat dichloride+ diquat dibromide, once (PS)	simazine (PS) fluazifop-p (POE)
W-L-W-L	paraquat dichloride+ diquat dibromide, once (PS)	glyphosate (PS) simazine (PS) fluazifop-p (POE)
W-L-W-L	Nil	glyphosate (PS), simazine (PS) fluazifop-p (POE)
Continuous wheat		
W-W-W-W	paraquat dichloride+ diquat dibromide, twice (PS)	paraquat dichloride+ diquat dibromide, twice (PS)

* Herbicide programme for 1988 and 1989 was the same as in 1986 and 1987, respectively. P = pasture, W = wheat, L = lupins, (SPT) = spraytopping, (POE) = post-emergent, (PS) = pre-sowing. Fluazifop-p was applied at the 3-5 leaf stage of the brome grass.

Table 2. Influence of four years of cropping and herbicide treatments on the annual percentage rate of change (decline (-) or increase (+)) of brome grass seed banks, effective seedling recruitment and adult fecundity

Basic treatments	Seed banks	Seedling recruitment	Adult fecundity
1. Pasture (no spray)	+78	+18	18
2. Pasture (spraytopped)	-35	+20	17
3. Pasture (fluazifop-p)	-75	+5	19
4. Lupins (simazine)	-69	+8	19
5. Lupins (simazine, fluazifop-p)	-94	+0.6	12
6. Lupins (glyphosate, simazine, fluazifop-p)	-98	+0.7	9
7. Standard wheat (1 kill of brome grass)	+170	+22	45
8. Early wheat (no control of brome grass)	+559	+30	40
9. Late wheat (2 kills of brome grass	-31	+17	29

Although several processes (removal with the harvested crop, predation from the soil surface, failure to emerge, decay, etc) may be involved in the overall loss of seeds, no attempt was made in this particular study to determine the relative contribution of each of these factors. There is complete loss in innate dormancy by the break of the season, which with the shallow seed bank associated with reduced tillage and adequate soil moisture led to rapid decline in the number of viable seeds in the soil between the end of one growing season and the start of the next and during the first four weeks after sowing. Because germination is the fate of most seeds in the soil, it is suggested that attempts to stimulate brome grass germination are rational approaches to depleting the soil of weed seeds. The best time to manipulate the seed bank should correspond to the times of germination and seedling emergence under natural conditions in the field.

Seedling Recruitment

The rates of effective seedling recruitment (Table 2) were calculated as the proportion of the seed bank that emerged and survived throughout the growing season. These rates ranged from 0.6 - 30% depending on environmental hazards such as tillage, herbicides and climatic stress during emergence and establisment. The results showed that there was a 30% effective seedling recruitment in early-sown wheat in the absence of herbicide treatments. Delayed sowing (treatment 9) which allowed two kills of brome grass with a knockdown herbicide resulted in a lower seedling recruitment of 17%. The recruitment rate in wheat sown at standard seeding time with one kill of brome grass using a knockdown herbicide was 22%. Overall, the lowest recruitment rates, ranging from 0.6 to 0.7%, were recorded in lupin plots treated with simazine and fluazifop-p. The recruitment rates in pasture ranged from 5 to 20%.

Adult Fecundity

Adult fecundity was obtained by dividing total seed production m^{-2} by the number of mature plants m^{-2} present at harvest. Fecundities during the four-year period were quite variable even within the same treatment, mainly because of differences in rainfall between seasons. There were also large differences between treatments. Generally the lowest fecundities were recorded in lupin plots, averaging 9 seeds/plant in plots treated with glyphosate, simazine and fluazifop-p. Fecundities in wheat plots were the highest, but ranged from 1-57 depending on the time of emergence of the plants, declining progressively in the successive cohorts (Table 3).

Table 3. The pattern of brome grass emergence and reproductive capacity of each cohort in the wheat crop following lupins

Emergence group (cohort)	Emergence period (weeks after crop seeding)	Emergence		Seed/plant
		No. m^{-2}	% of total	
1	1-4	36	87.8	57
2	5-8	4	9.8	3
3	9-12	1	2.4	1

The first cohorts which emerged with the wheat crop were generally the most successful and produced on average 93% of the total seed rain. Timely control of the first cohort is therefore important. The later cohorts were less competitive and produced fewer seeds.

PREDICTION OF INFESTATIONS AND DEPLETION OF SEED RESERVES

The acquisition of detailed demographic data for brome grass for each of the treatments, has enabled the prediction of population movements within a particular cropping system. It is possible to evaluate different cropping sequences and to select the one the gives the best control of brome grass by combining the values for the various parameters of the different treatments.

Considering the sixteen rotational systems under investigation, it is possible to calculate the number of years to deplete the soil of the brome grass seed reserves. Working on an average initial seed bank of about 1,000 seeds m^{-2} it would take five years to exhaust the seed bank in the lupin-wheat rotation using the most effective control strategy. The use of simazine alone in the lupin-wheat sequence would require over 60 years to exhaust the seed bank.

Considering the reinfestation potential of brome grass and the potential grain yield increase of wheat and lupins following its control, the greatest net return over the standard simazine treatment was given by the lupin-wheat sequence incorporating the use of glyphosate, simazine and fluazifop-p. A net return of $A 58/ha has been calculated based on a wheat price of $A 150/t, lupin price of $A 165/t, and herbicide prices at recommended retail prices for the 1990 growing season.

CONCLUSIONS

It is concluded that if a rational approach is to be taken in the management of a persistent annual weed like brome grass, it is important to analyse patterns of demographic behaviour of the weed and to compare strategies of controlling the production of seeds with currently available weed control methods. Weeds should be controlled to avoid the future build-up of weed populations, it is not enough to control weeds in the year of application. Thus action against the passive seed reserves should be given some priority in the management of such a weed but this approach is only possible with a proper understanding of its seed dynamics under different crop and herbicide rotations.

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HERBICIDES TECHNOLOGY

HERBICIDE APPLICATION TECHNIQUES USED IN PLANTATION CROPS IN MALAYSIA - AN UPDATE

TEOH CHENG HAI[1]

ABSTRACT

Although the conventional knapsack sprayer continues to be the main equipment for weed control in plantation crops, there had been more extensive use of alternative techniques such as controlled droplet application, Mistblower ULV spraying and semi-mechanised hydraulic spraying (SHS) systems during the last decade. The comparative merits of these techniques in relation to worker productivity, cost of weed control and occupational safety of workers are discussed in this paper.

INTRODUCTION

At the Workshop on Pesticide Application Technology in 1982 in Malaysia, the current methods of herbicide application and possible areas of improvement were discussed by Teoh *et al.* (1983). The prospects of using newer application techniques such as controlled droplet application (CDA) were also considered. In Malaysia, the conventional knapsack sprayer (CKS) has been used extensively since the introduction of chemical weeding in the 1950s. Although a recent survey (Teoh & Chung, 1991) showed that the knapsack sprayer remains the most commonly used spraying equipment on estates, there has been a major shift towards very low volume (VLV) and ultra low volume (ULV) application using CDA applications and mistblowers. Semi-mechanised spraying with hydraulic nozzles has also been employed more widely where terrain is suitable. This paper discusses the major changes in herbicide application techniques since 1982, with particular reference to weed control in plantation crops such as rubber (*Hevea brasiliensis*) and oil palm (*Elaeis guinensis).*

FACTORS THAT INFLUENCED CHANGE

Among various factors that could have influenced the recent changes, the labour situation in Malaysia and developments in the agrochemical industry had the most significant impact.

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Labour

As Malaysia develops, there has been a progressive shift of workers to the industrial sector, resulting in labour shortages in estates as well as smallholdings. In 1989, 204 out of 511 estates surveyed reported labour shortages, total deficit being 9600 workers which was equivalent to 7.61 % of the workforce. Among these, 2620 workers or 27.3 % were required for weed control operations (UPAM, 1989). The survey also reported a decline in the proportion of workers in the younger age groups. Besides labour shortages, the cost of wages continues to rise as workers expect a better standard of living. Although migrant workers have been employed by numerous estates, the industry is expected to continue to face labour shortages. In view of this, there is an urgent need to increase the productivity of workers as well as to reduce the dependence on labour through mechanisation.

Herbicide

The herbicide market in Malaysia grew from about M$ 128 million in 1983 (Teoh, 1985) to about M%250 million in 1990 (MACA, 1991). The top selling active ingredients in 1990 are listed in Table 1.

Table 1. Top Selling Herbicides Active Ingredients in 1991 in Malaysia.

Ranking	Oil Palm	Rubber	Cocoa
1	paraquat	paraquat	paraquat
2	glyphosate	glyphosate	glyphosate + ammonium
3	glyphosate +	2,4-D	glyphosate

Source: MACA, 1991

Paraquat has been widely used in estates for general weed control on account of its cost-effectiveness and rapid contact action. In 1983, about 50 % of the total herbicide expenditure was on paraquat (Teoh, 1985) and it has maintained its market share up to the present. However, the most significant changes had been.

(i) the increased use of glyphosate for general weed control following substantial price reductions. For instance, in mid-1987, there was at 45 % reduction in the end-user price of the glyphosate formulation (Teng, Y.T., 1991, pers. comm.). The overall use of glyphosate increased from about 9 % of the total market value in 1983 to about 30 % in 1990. Taking into consideration the decline in prices, the growth in the quantity of glyphosate used would be considerably higher.

(ii) the introduction of new herbicides and herbicide mixtures such as glufosinate-ammonium (Purusotman *et al.*, 1985), fluroxypyr (Sabudin & Bakar, 1985), metsulfuron methyl (Ackerson and Davis, 1987) and the glyphosate + dicamba formulation (Teng and Teh, 1987). The new herbicides combined well with glyphosate, either as tank mixes or sequential sprays to control a broad-spectrum of grasses and broadleaf weeds. The wider range of herbicides provided the agrochemical and plantation industries the impetus to seek more cost-effective and safer alternatives to paraquat-based treatments. In this endeavour, greater emphasis has been given to improving the efficiency of applying these herbicides.

RECENT DEVELOPMENTS IN HERBICIDE APPLICATION TECHNIQUES

Conventional Knapsack Spraying

Although the need to improve the design and efficiency of lever-operated hydraulic knapsack sprayers had been well documented and suggestions have been made for improvements (Teoh *et al.*, 1983, Thornhill, 1989, Jusoh *et al.*, 1990 and Jusoh & Anas, 1990), there had been no major changes in this traditional method of herbicide application. Nevertheless, effort had been directed at reducing the volume of application to increase worker productivity and development of aids to improve the precision of knapsack spraying.

In the control of *Imperata cylindrica*, a low volume spraying (LVS) system of glyphosate in 220 litres water per hectare was cheaper and more efficient than conventional spraying (Teng & Teh,1986). The reduction in volume of application could also lower the cost of general weed control through better worker productivity (Table 2). This is achieved by using LVS nozzles such as Cross Mark LVS 1/16 hollow cone tip and Cooper Pegler's VLV 50, 100 and 200 nozzles designed to deliver 50, 100 and 200 l/h respectively. Although it is feasible to apply spray solutions at 100 to 200 l/ha, depending on the weed density and type of herbicide used, low volume spraying has not been widely practised on estates. A plausible reason is that general weed control is often done by contract workers who have not been adequately trained. On estates

Table 2. Labour Cost Comparison between CDA and CKS

Equipment	Spray volume (l/ha)	Relative labour cost	
		Estate A	Estate B
CKS	400	100%	100%
CKS	200	80%	61%
CKS	100	70%	62%
Micro Herbi	25	59%	39%
Birky	25	49%	43%

who employ their own workers for spraying, they may opt for ULV spraying with either CDA equipment or mistblowers which could provide better cost savings than low volume spraying.

In the effort to increase the efficiency of knapsack spraying, various aids have been introduced to simplify calibration such as Hardi Kalibottle[R] and Monsanto's LVS calibration kit which includes a calibration slide rule. Spray pressure is often difficult to monitor and it is impractical to fit spray lances with pressure gauges. To overcome this problem, a few sprayer manufacturers have incorporated an internal pressure regulator, for example, to control the pressure up to one bar ('L' setting) or three bars ('H' setting) (Anon, undated - a). Unfortunately, these imported sprayers are considerably more expensive than those manufactured locally. An external pressure regulating device that could be fitted on to the lance of any hydraulic knapsack sprayer would be a better alternative. The Spray Management Value (SMV) introduced recently (Anon., 1991a) has been developed to maintain spray pressure at one, two and three bars. The SMV has been designed to operate at the pre-set pressure and it will not open until the pressure is attained while excess pressure will be automatically regulated to the pre-set level. Preliminary assessments show that with the SMV, it is possible to obtain the rated flow rate of the nozzles under field operating conditions particularly the nozzles with higher outputs (Table 3). When the knapsack sprayers were operated without SMV, the flow rate of the test nozzles increased from 6 % to 65 %.

Table 3. Effect of the Spray Management Value (SMV) Set at 1 Bar on the Flow Rate of Lurmark Deflector Nozzles

Nozzle (Rated Flow @ 1 bar)	Sprayer	Flow rate (Mean of 6 determinations)			
		With SMV		Without SMV	
		ml/ min	% of rated flow	ml/ min	% of with flow rate
AN 1.0	CKS1	507	110	839	165
Orang	CKS2	520	520	792	152
(460 ml/min)	CKS3	485	105	708	146
AN 2.0	CKS1	950	103	1201	126
Cambridge Blue	CKS2	945	103	1134	120
(920 ml/min)	CKS3	915	99	1079	118
AN 3.0	CKS1	1396	100	1527	109
Lime Green	CKS2	1373	99	1493	109
(1390 ml/min)	CKS3	1357	98	1432	106

CKS1 & CKS2 = Crossmark 18 l knapsack sprayer
CKS3 = Solo 15 l knapsack sprayer

Controlled Droplet Application (CDA) - Hand-held Equipment

CDA application of herbicides in Malaysia was initially evaluated for weed control in rubber estates by Liu and Faiz (1981). Results of their small scale trial demonstrated the potential use of the Micron Herbi 77® for low volume application (15-55 l/ha) of translocated herbicides. Han and Maclean (1984) who tested this technique on a commercial scale obtained 30-50 % savings for tree row/path and circle spraying in rubber and oil palm areas. Labour output was increased significantly, average coverage per manday for rubber tree rows and oil palm circles spraying being 3.3 ha while 7.8 ha could be achieved for spraying of oil palm harvesters' paths. The CDA technique has also been found to cost-effective for controlling perennial weeds such as *Imperata cylindrica* and *Ischaemum muticum* (Teo and Maclean, 1990). Controlled droplet application has been adopted as the standard method for application of herbicides in the 26 oil palm estates covering about 65,000 ha in Eastern Plantation Agency (Johore) Sdn. Bhd. The average output per manday for CDA on a commercial scale was about 40 % higher than that of knapsack spraying (Table 4) (Teo, L., 1991, pers. comm.).

Table 4. Worker Output from CDA and Knapsack Spraying on a Commercial Scale (ha/manday)

Sprayer	Oil Palm Circles	Harvesters' Path
CDA	3.15 ha (141%)	5.46 lha (139%)
CKS	2.23 ha (100%)	3.93 ha (100%)

Source: Teo Leng, 1991 pers. comm.

The CDA technique has also been used extensively in plantation crops in Indonesia and Papua New Guinea and 40 % to 60 % savings over conventional knapsack spraying had been obtained. Besides reducing the water carrier rate from 400 - 600 l/ha to 14 - 110 l/ha, the CDA technique made it possible to reduce the dosage of translocated herbicides by up to 50 % (Jollands, *et al* 1983, Turner, 1985, Bakri *et al*, 1986). According to Bakri, A.H. (pers. comm., 1991), CDA has been used for general weed control in about 35,000 ha of oil palm and rubber for the past eight years. Average worker output was 5 ha/manday for oil palm circle spraying and 8 ha/manday for rubber tree row spraying (flat terrain) compared with 1 ha/manday for knapsack spraying.

With the growing interest in CDA, various types of applicators such as the Birky® (Ciba Geigy - Birchmeier, Switzerland), Berthoud H2 CDA® (Berthoud, France) and Turbair Weeder® (Turbair Ltd., U.K.) were introduced into the Malaysian market (Chung & Lee, 1985). However, in commercial herbicide application, the most commonly used is the Micron Herbi 77® (Micron Ltd., U.K.). As this equipment was designed for temperate agriculture, several modifications had been made to adapt it for use in plantation crops (Jollands *et al.*, 1983, Han, 1985 and Bakri *et al.*, 1986). Notable changes include

- replacement of the 2.5 l spray container with bigger spray tanks from knapsack sprayers or used 5 l herbicide containers.
- use of a 12V motorcycle battery instead of eight 1.5V size D batteries.
- fabrication of a double-headed sprayer to obtain a wider swathe for oil palm circle spraying. By using a blue "nozzle" in the inner head or spinning disc and a yellow "nozzle" in the outer head, it is possible to achieve a spray volume of 20 l/ha (Jollands *et al.*, 1983).

In Indonesia, locally available materials except for the in-line filter and the spray head have been used to assemble a simple CDA equipment (Bakri *et al.*, 1986). Prompted by the modifications made by end-users, the manufacturers incorporated several improved features in their new range of CDA equipment using the Microfit® system (Anon, 1987). This included the production of the Herbi Twin with double spray heads.

Although trial and commercial experiences have shown that the CDA technique of herbicide application can give significant improvement in labour productivity, possible reduction of some herbicide active ingredients that would result in substantial reduction in the cost of weed control, its adoption as a commercial practice has been slower than expected. Apart from some inherent deficiencies in the standard Micron Herbi, there was concern over the potential hazards of chemical contamination to operators especially if paraquat was used, bearing in mind that up to 1:25 dilution had been used with CDA compared with 1:80 to 1:160 dilutions recommended for knapsack sprayers (Tan *et al.*, 1988). As a precaution, the Pesticides Board in 1985 did not allow the use of paraquat with CDA equipment while the major paraquat manufacturer stipulated on the product label that dilution of paraquat should not exceed 1:40.

Mistblower ULV Application

This ULV technique was evaluated by Monsanto in 1988 for the application of glyphosate at 10 to 50 l/ha for general weed control. Compared with knapsack spraying which has an output of 1.5 - 2.5 ha/manday, mistblower ULV spraying could cover 5-6 ha/manday. With this method, labour input is havled while water requirement is reduced by 90% and the overall treatment cost could be reduced by 30% (Chew *et al.*, 1990).

Monsanto uses a modified Solo Model 412 Mistblower, the main adaptations being.

- a ULV dosage selector plate with 4 orifices of 0.5, 0.8, 1.0 and 1.2 mm diameter fitted at the end of the pleated hose.
- a spray deflector made of a circular plate with grills.

A spray volume of 30 to 35 l/ha for general weed control could be obtained by operating the mistblower at the second throttle speed and setting the dosage selector plate at 1.0 mm diameter. The Maruyama Mistblower MD 300 could also be used for ULV herbicide application. This machine has a fixed discharge orifice of 1.0 mm diameter and a propeller at the nozzle to break up the spray solution (Anon, 1991b). Besides glyphosate, the mistblower ULV technique is being evaluated for applying other chemicals such as glufosinate-ammonium and a DSMA + diuron + 2 4-D Na formulation (Purusotman *et al*, 1991.

In spite of its recent introduction in Malaysia, the mistblower ULV technique has gained wide acceptance. Since its launch in 1988 until July 1991, it has been reported that Monsanto sold 1517 untis of the modified Solo Model 412 Mistblower, more than 80% of which was supplied to the plantation sector. The rapid adoption of this technique could be attributed to

- active promotion by the herbicide company.
- estates familiarity with the machine as mistblowers are commonly used for pest control.
- significant reduction in labour input, water and overall cost.

However, with continued use of the technique, several disadvantages have become apparent. The most common complaint was the mistblower was prone to frequent breakdown and its life span is unlikely to exceed six months of regular use. In view of its narrow spray swathe, it is necessary to swing the pleated hose 'lance'. As a large proportion of the droplets produced are less than 50 microns, concern has been raised over the potential chemical contamination of spray operators. With this in mid, same plantation companies have adopted a cautious approach to adoption of the mistblower ULV technique.

Mechanised Herbicide Application-Hydraulic Nozzles

In 1976, Anderson proposed the Integrated Mechanical Upkeep (IMU) Concept of herbicide spraying using an imported tractor-mounted sprayer until fitted with a P.T.O. shaft driven diaphragm pump, booms and distribution lances. The machine could either be used for fully mechanised boom spraying or hand lance spraying, the latter being a mechanically assisted operation. Although fully mechanised or 'automatic' spray could give a coverage of 20 to 25 ha/manday (Anderson, 1976; Bloomfield and Khoo, 1979), its commercial utilization had been very limited. On the other hand, the mechanically assisted approach has received wider acceptance and is currently used on a large scale in many estates, particularly those in coastal areas. The sprayer unit which could be tractor-drawn or tractor-mounted basically consists of a tank, a piston or plunger pump, a pressure control valve and usually two ordinary knapsack sprayer lances fitted to long (about 100m) acrylic or rubber hoses. The pumps could be powered by 5HP engines or by the P.T.O. shaft of the tractor. Based on cost consideration, many estates fabricate their own sprayer units using locally available materials where possible. For instance, the tanker could be made from 200-l oil or herbicide drums or old latex tankers of up to 4000 l capacity. However, fully assembled units such as the ACM Spray System SS-A1[R] are also available (Yang, 1989).

The area covered by the mechanically assisted system of hydraulic spraying varies from 3-5 per day to 10-13 ha per day depending on terrain (Table 5). Trial and commercial experience have shown that the semi-mechanised approach is more cost-effective than knapsack spraying. For example, the cost of rubber tree row spraying with the glyphosate + picloram formulation and a tank mix of paraquat + 2,4-D Amine could be reduced by 25% and 42% repsectively (Yeoh, 1986), the saving being mainly attributed to the improved worker productivity. Another benefit from this system is bulk preparation of the field strength herbicide solutions which will eliminate the risk of contamination of workers by herbicide concentrates in the field.

Table 5. Output of Semi-Mechanised Hydraulic Spraying System in Relation to Ground Condition

Ground condition and accessibility	ha/day	ha/manday
Flat to slightly undulating; fully accessible to trailed tank	10 - 13	3.3 - 4.3
Flat to undulating; not fully accessible to trailed tank	7 - 10	2.3 - 3.3
Undulating; not very accessible to trailed tank	5 - 6	1.7 - 2.0
Steep terrain; inaccessible to trailed tank	3 - 5	1.0 - 1.7

Source: Neoh, 1986

This method of hydraulic spraying has been called by various names such as "trailer power sprayer systems" (Teoh *et al.*, 1983), "motorised power spraying" (Neoh, 1986), "motorised sprayer" (Yeoh, 1986), tractor-mounted sprayers and mechanical sprayers. As the method is widely used on estates, it would be appropriate to standardise the terminology. Being a mechanically assisted method that uses hydraulic nozzles, it would be appropriate to call it SEMI-MECHANISED HYDRAULIC SPRAYING (SHS) system. The reference to "power spraying" should be discontinued as it implies spraying at high pressure which could give rise to problems associated with small droplets (spray drift, operator safety etc). For general weed control, a pressure of 1-2 bars would be adequate.

Mechanised Herbicide Application - CDA

The prospects of using boom-mounted CDA atomisers such as the Micron Micromax[R] were investigated by Khairudin *et al.* (1986). The Micromax atomiser which is operated by a 12V, 2 amp power source can be set at three operating modes for different pesticide applications. For herbicides, the atomiser is operated at 2000 rpm to produce droplets of a volume median diameter of about 250 microns (Anon, undated - b).

A large scale legume purification trial in a one-year old oil palm planting showed that from Micromax atomisers mounted on a boom behind a Yanmar YM 155DT mini tractor to apply selective herbicides increased worker output 25-fold and reduced application cost by 90%.

Encouraged by the results of this trial, a prototype boom sprayer was fabricated for rubber tree row spraying. Two spring loaded booms are fitted at the back of a mini-tractor. The booms are movable so that they could deflect when they come into contact with a rubber tree. Although only one atomiser is required for tree row spraying, two are fitted for better manoeuvrability. A switch is located at the console for the driver to operate either atomisers independently. The tractor is driven close to the trees with an atomiser directly above the strip to be sprayed. With the spring-loaded boom, the atomiser is able to 'move around' the trees. Travelling at 3 to 5 km/hr, an area of 15-24 ha could be covered in an 8-hour day, provided that there is ground access. As rubber is usually grown in less favourable terrain and trees are planted on narrower terraces than oil palm, the tractor access paths would have to be prepared before mechanised CDA herbicide application could be done.

SAFETY ASPECTS OF HERBICIDE APPLICATION

Concern over operator safety led to the conduct of several studies to determine the potential exposure associated with application of herbicides with new application techniques (Lee & Chung, 1985, Tan *et al.*, 1988, Lee & Yang, 1991 and Manning *et al.*, 1991). Although the contamination patterns for CKS and CDA sprayers indicate that the whole body could be exposed to spray solutions, extensive contamination occurred mainly on the lower limbs unless overhead spraying of weeds on oil palm trunks was done (Lee & Yang, 1991). Tan *et al*, 1988 observed that relative exposure of the legs was significantly higher for the CDA operator (86.1 %) than those using knapsack sprayers (58.7 %). The high level contamination of the leg region can be attributed to the fact that operators walked through the sprayed vegetation. While Lee & Yang (1991) confirmed that herbicide contamination was mainly the lower limbs, their studies indicated lower exposure with CDA than CKS.

When CDA sprayers were introducted to estates concern was raised over the potential hazard to operators particularly as more concentrated spray solutions are applied. However, results from the studies by Lee & Chung, 1985 and Tan *et al.*, 1988 showed potential inhalational exposure to be minimal.

In their study on the occupational exposure of workers to ULV application of glyphosate, Manning *et al.* (1991) concluded that the mistblower application was safe to the workers when spraying was done according to label instructions. However, it should be noted that the spraying was closely supervised and the study was limited to a 4-hour period. Considering that mistblowers produce a much higher proportion of spray droplets of less than 50 microns compared with hydraulic nozzles and CDA, it would be prudent to repeat these exposure studies for a longer duration and with a wider range of herbicides such as 2,4-D amine which has been reported to cause nose bleeding when applied by mistblowers.

As all methods of herbicide application could give rise to herbicide exposure to operators, it is important that guidelines on safe and proper use of the equipment and use of protective clothing (Lee & Chung, 1985, Jusoh and Anas, 1990) are followed. In this context, the need for adequate training of spray operators and their supervisors cannot be over-emphasised.

DISCUSSIONS AND CONCLUSIONS

Although the conventional knapsack sprayer continues to be the most common equipment for applying herbicides in estates, shortages of labour and increasing cost of wages have led to the adoption of alternative techniques such as controlled droplet application, ultra low volume spraying with mistblowers and semi-mechanised systems. These techniques have given significant improvements in worker productivity resulting in considerable savings in the cost of weed control. The CDA and ULV techniques also provide substantial reduction in water requirement as well as the prospect of lowering the dosages of herbicide active ingredients.

The CDA technique was initially evaluated in Malaysia in 1981 but its commercial development had been slower than anticipated. This was to a large extent due to the concern over potential hazards of contamination of operators since more concentrated herbicide spray solutions would be used, particularly paraquat - the most hazardous and widely used herbicide in plantation crops. Furthermore, the adoption of CDA in estates was overshadowed by the introduction of the mistblower ULV technique about four years ago.

Despite the fact that the mistblower ULV technique also involves the application of concentrated spray solutions, there had been no undue concern over its potential hazards to operators and it gained wide acceptance in estates. A likely explanation is that the technique was promoted for the application of glyphosate which is regarded as a relatively non-toxic herbicide. A recent study on occupational exposure indicated that the mistblower ULV technique was

safe to workers if spraying of glyphosate was done **according to label instructions** (Manning *et al.*). However, it should not be assumed that this is also applicable for other herbicides and similar operator exposure studies under field conditions would have to be undertaken on herbicides that are likely to be used eg. glufosinate- ammonium, 2,4,D-amine and component herbicides in glyphosate-based products and mixtures.

Comparing the two methods, CDA is inherently safer as it designed to produce spray droplets within a narrow size range that is considered suitable for the target, 150 to 300 microns in the case of weeds. The proportion of droplets within this desired range is about 75 % for a spinning disc operated at 2000 RPM while the number of small droplets (50 microns) that are prone to drift is significantly lower than that produced by mistblowers. As trials and commercial experiences have demonstrated that CDA spraying of herbicides could give similar worker output and cost savings as the mistblower ULV technique, consideration ought to be given to wider usage of controlled droplet application.

The last decade had also seen more extensive semi-mechanised or mechanically assisted application of herbicides using tractor-drawn or tractor-mounted spraying units. A team comprising a tractor driver and two operators using hydraulic lances could cover an average area of 10-13 ha per day (3.3 - 4.3 ha per manday), on flat to undulating terrain. However, the output per day could be increased to 20-30 ha with fully mechanised spraying using only a tractor driver. For mechanised spraying to succeed, it is necessary to provide vehicle access paths. During land preparation, mechanical "harvesters' paths" could be prepared in oil palm plantings while wide terraces (3.0-3.5 m) could be constructed in undulating to hilly rubber areas to facilitate herbicide spraying as well as other mechnaised field operations (eg. fertilizer application, crop evacuation).

In spite of the advances in herbicide application technology, continued usage of the conventional knapsack sprayer can be expected particularly among smallholders as it is the cheapest spraying equipment. However, consideration ought to be given to improve the design for locally manufactured sprayers, particularly on aspects that would enhance the safety and comfort of the operators. The efficiency of using knapsack sprayers should also be examined. For instance, worker output could be increased through low volume spraying, particularly as a wider range of translocated herbicide is now available.

Irrespective of the application technique, due attention must be given to operator safety and every effort should be made to minimise potential herbicide contamination. Training of operators and their supervisors is essential so that they could follow the recommended guidelines of the safe and effective use of herbicides (GIFAP, 1983; UPAM, 1989). Adequate occupational exposure studies should be undertaken by agrochemical companies before they recommend new application techniques such as mistblower ULV application for their products.

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EFFECT OF TANK-MIXING OF GLUFOSINATE-AMMONIUM AND IMAZAPYR FOR LALANG (*IMPERATA CYLINDRICA* (L.) BEAUV) CONTROL IN RUBBER PLANTATIONS

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ABSTRACT

Three experiments were designed and carried out to investigate the effect of tank-mixing of glufosinate ammonium and imazapyr, for lalang control in rubber plantations, during June 1989 - January 1991. The herbicides were studied using two different spray volumes, both currently practised in Thailand. Low volume (50-300 l/ha) and high volume (1,000 L/ha) were sprayed using a modified mistblower and a knapsack sprayer, respectively. The results indicated that glufosinate ammonium tank-mixed with imazapyr could be applied effectively using either one of the aforementioned spray volumes. Glufosinate-ammonium + imazapyr 0.38 + 0.35, 0.45 + 0.3 and 0.6 + 0.2 kg a.i./ha gave an effective control of lalang which was comparable to glyphosate at 2.25 - 3.0 kg ai/ha. (However for consistent lalang control, 0.45 + 0.3 kg ai/ha glufosinate-ammonium + imazapyr should generally be recommended). In addition, the combination of glufosinate- ammonium + imazapyr could also give the same quick knock-down action as glufosinate-ammonium alone and quicker than either glyphosate or imazapyr alone. Moreover, the combination could provide a longer term suppression of regrowth of other weeds, after lalang decay. After the effective dosages of glufosinate-ammonium + imazapyr for lalang control were determined, phytotoxicity of the combinations was also studied. The data from 2 trials showed that glufosinate-ammonium + imazapyr at the normally recommended rate of 0.45 + 0.3 kg ai/ha, could be used in rubber plantations without any phytotoxicity on immature rubber plant even only 1 year-old.

INTRODUCTION

Lalang, *Imperata cylindrica* (L.) Beauv is considered as the worst perennial weed in South-east Asia (Eussen and Wirjahardja, 1973). It's the most troublesome weed found in cultivated and non-cultivated areas. Thus, effective control of lalang becomes imperative and can be achieved by the use of appropriate chemicals.

Glufosinate ammonium (Basta®) and imazapyr (Arsenal®) are non-selective post-emergence herbicides developed by Hoechst AG and American Cyanamid Company, respectively. Both chemicals were reported to control lalang (Langelueddeke *et al* ., 1983; Lee, 1985). Recent studies in Malaysia reported

[1] Plant Protection Division, Hoechst Thai Ltd., Bangkok, Thailand.

that the tank-mixture of glufosinate-ammonium (Basta® 200 g a.i./l and imazapyr (100 g ai/l) at 1.0 kg ai/ha + 0.25 kg ai/ha and glufosinate-ammonium at 0.5 kg ai/ha + special adjuvant, Genapol® LRO at 2.5 l/ha + imazapyr at 0.25 kg ai/ha, produced better control of lalang compared to the current commercial standard, glyphosate at 2.15 kg ai/ha (Kuah and Strilchuk, 1989).

In Thailand, glufosinate-ammonium has been marketed since 1989 as the new formulation of glufosinate-ammonium 150 g ai/l + special adjuvant, Genapol LRO 44 % (using the tradename of Basta®-X). This formulation had already been found to be equally effective, as the standard formulation (Basta® 200 g ai/l) on the basis of equal rates of formulated product (Langelueddeke *et al.*, 1989).

Three experiments using tank-mixtures of glufosinate-ammonium 15 g ai/l (Basta-X®) and imazapyr 10 g ai/l (Arsenal®) were carried out to determine the efficacy of the combination for lalang control in rubber plantations. Different spray volumes (varying from 50-1,000 l/ha) which were in current use by local rubber growers (Boonsrirat *et al.*, 1987; Khattiyakarun and Katanyukul, 1988) were used. Additionally, phytotoxicity of the combination to rubber plants under Thai conditions was also studied.

MATERIALS AND METHODS

Experiment I: Effect of glufosinate-ammonium + imazapyr for lalang control using high spray volume

The experiment was carried out in two locations, namely Chantaburi and Trad provinces. Shading conditions in the rubber plantation were 25% in 2.5 year-old rubber, and 40% in 4 year-old rubber. The experiment was designed in a randomized complete block (RCB) with 4 replications and the plot size was 5 x 5 m. The herbicides were applied in high volume at 1,000 l/ha by a conventional knapsack sprayer fitted with a T-jet 8004 nozzle. Herbicide application was made on 21/6/1989 and 15/5/1990 in Chantaburi and Trad, respectively. The treatments are shown in Tables 1 and 2. Weed control was evaluated by a visual rating system, where 0% means no control and 100% complete control, at 15, 30, 45 and 60 days after application (DAA) and at 1 month-intervals thereafter for a period of one year.

Experiment II: Effect of glufosinate-ammonium + imazapyr for lalang control using low spray volume

Four trials were carried out in Chumporn and Surathani provinces. In the first two trials (located in both provinces), the tested chemicals were sprayed by a conventional knapsack sprayer fitted with D-2 nozzle, delivering a spray volume of 300 l/ha. The other two trials (in both provinces) were

sprayed using a modified mistblower delivering 50 l/ha. RCB designs were employed with 4 replications, plot size was 5 x 5 m for the trials applied by knapsack sprayer and 8 x 5 m for the trials applied by mistblower. The spraying was done on 19-20/6/1990 and 18-19/7/1990 at Surathani and Chumporn, respectively. The treatments are shown in Tables 3, 4, 5, and 6. Assessments were made in the same way as in Experiment I.

Experiment III: Study of phytotoxicity of glufosinate-ammonium + imazapyr on rubber plants

Two trials were conducted under field conditions in 1-1.5 year-old rubber. The variety, RRIM 600, was the same in both provinces. Four replications of all treatments were arranged using a RCB layout. Each plot measured 2 m wide x 9 m long and the distance between the trees was 3 m. Thus in every plot there were three rubber plants. The treatments were applied on 17/6/1990 at Surathani and 19/7/1990 at Chumporn, by a conventional knapsack sprayer, delivering a spray volume of 1,000 l/ha. Normal rates of glufosinate-ammonium + imazapyr and a 2X rate were tested compared to glyphosate. Phytotoxicity was assessed by a visual rating where 0% = no sign of phytotoxicity, and 100% = complete crop destruction.

RESULTS AND DISCUSSION

Experiment I: Effect of glufosinate-ammonium + imazapyr for lalang control using high spray volume

In Chantaburi, before herbicide application, the lalang was 120 cm high and covered about 100% of the area. After spraying, the results showed that all glufosinate-ammonium + imazapyr treatments gave more than 80% control (burning effect) at 15 days after application (DAA) while imazapyr alone at 0.25 and 0.5 kg ai/ha gave only 30% control (Table 1). Glyphosate at 3.0 kg ai/ha also showed much quicker burning effect than imazapyr alone but could produce only 70% control. All dosages of glufosinate-ammonium alone reached the maximal control level at 45 DAA and lalang regrowth occurred thereafter. On the other hand, glufosinate-ammonium + imazapyr at all dosages reached the maximal control 95-98% at 90 DAA and remained at this control level up to 420 DAA. The improved control of these tank-mixes maybe due to a synergistic effect. Especially when considering the percentage control achieved by glufosinate-ammonium + imazapyr compared to glufosinate-ammonium and imazapyr applied alone and bearing in mind the dosages used in the various treatments. Similar phenomena were reported earlier by Kuah and Sallehhudin (1988). In glufosinate-ammonium + imazapyr treated plots broadleaf weed succession was less and regrowth slower, after lalang decay,

Table 1. Efficacy of glufosinate-ammonium plus imazapyr for lalang control in 2.5 year-old rubber applied in high spray volume (June 1989-August 1990. Chantaburi, Thailand)

Treatment[2/]	Rate kg ai/ha	Percentage of lalang control after herbicide application[1/] (days)														
		30	45	60	90	120	150	180	210	240	270	300	330	360	390	420
Glufosinate-amm.	0.38	83	88	80	57	50	33	42	56	61	65	48	48	30	27	26
Glufosinate amm.	0.56	85	88	80	66	60	50	55	61	61	61	57	55	33	27	22
Glufosinate amm.	0.75	90	95	85	80	75	72	71	68	67	70	63	62	58	55	52
Imazapyr	0.25	37	40	60	73	87	87	93	97	97	97	97	94	94	94	93
Glufosinate-amm.+ imazapyr	0.38+0.25	85	86	86	95	95	95	94	96	97	97	99	98	97	97	95
Glufosinate-amm.+ imazapyr	0.56+0.25	86	88	88	97	98	99	99	100	100	100	100	100	99	99	99
Glufosinate-amm.+ imazapyr	0.75+0.25	93	95	95	98	98	98	98	99	99	99	99	100	100	100	100
Imazapyr	0.5	38	42	62	80	97	96	100	100	100	100	100	100	100	100	100
Glyphosate	3	77	88	83	98	99	99	99	100	100	99	99	99	99	99	99
Glufosinate-amm.	1.5	95	98	92	90	90	82	80	78	76	75	75	72	67	65	65
Untreated	-	(100[3/])	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)

Remark :

1/ Lalang control was evaluated by visual rating form 0-100% where 0% = no control and 100% completely killed

2/ Herbicides were applied by knapsack sprayer fitted with T-Jet nozzle at 1,000 l/ha

3/ The figure in bracket was presented as % weed coverage

which may be caused by the soil residual effect of imazapyr. Glyphosate gave a similar lalang control and the effect was camparable to glufosinate-ammonium + imazapyr at 90 DAA, however faster weed succession and many broadleaf weeds especially *Borreria latifolia* were found after 120 DAA.

In Trad province, the lalang was 140 cm high and covered about 100% of the area. Similar results were found to those in the trial at Chantaburi (1989). Glufosinate-ammonium + imazapyr at 0.45 + 0.3 and 0.6 + 0.2 kg ai/ha could provide an acceptable control of lalang (>95%) at 60-90 DAA (Table 2). The tank-mix of glufosinate-ammonium + imazapyr and glufosinate-ammonium alone showed initial control (burning) even at 2 DAA and both treatments were clearly faster than those treated by glyphosate at 2.25-3.0 kg ai/ha and imazapyr alone at 0.5 kg ai/ha. Glufosinate-ammonium + imazapyr at 0.45 + 0.3 and 0.6 + 0.2 kg ai/ha could maintain control levels at 97% and 99% until 180 DAA as did glyphosate at 2.25 and 3.0 kg ai/ha. The lower tested dosage of glufosinate-ammonium + imazapyr at 0.45 + 0.15 kg ai/ha reached a peak of control of 92% at 60 DAA and regrowth of lalang occurred gradually thereafter. Imazapyr at the recommended dosage of 0.5 kg ai/ha also reached an acceptable control level (98%) at 180 DAA, despite the slower killing action which was noticeable at the early stages.

Experiment II : Effect of glufosinate-ammonium + imazapyr for lalang control using low spray volume

Two different types of low volume sprayers, knapsack sprayer fitted with low volume nozzle (D-2) and a modified mistblower (MD 300) were used for lalang control in 2 and 4 year-old rubber plantations at Chumporn and Surathani, respectively. The results from a total of 4 trials are shown in Tables 3 to 6.

Knapsack sprayer : The trial conducted in Surathani revealed that glufosinate-ammonium tank-mixed with imazapyr could be applied in low spray volume at 300 l/ha performing similar to the standard, glyphosate. Glufosinate-ammonium + imazapyr at 0.38 + 0.25, 0.45 + 0.3 and 0.6 + 0.2 kg ai/ha gave 97%, 98% and 99% lalang control levels at 180 DAA, respectively (Table 3). Glyphosate even at the low recommended dosage, 2.25 kg ai/ha gave 98% control at the same time, however, greater numbers of other weeds regerminating was observed after lalang decay. Glufosinate-ammonium + imazapyr at 0.45 + 0.15 kg ai/ha however could produce a control level equal to other combination rates in the early days after application but eventually regrowth of lalang was found after 90 DAA. This result confirmed the results from the first experiment where lalang regrowth occurred, due to the imazapyr dosage being too low. Imazapyr at the recommended rate, of 0.5 kg ai/ha gave a slow killing action, however complete control was found at 180 DAA. Similar

Table 2. Efficacy of glufosinate-ammonium plus imazapyr for lalang control in 4 year-old rubber applied in high spray volume (May-November 1990, Trad, Thailand)

Treatment[2/]	Rate kg ai/ha	Percentage of lalang control after herbicide application[1/] (days)				
		60	90	120	150	180
Glufosinate-amm.	0.75	68	65	60	47	42
Imazapyr	0.25	48	50	55	70	77
Glufosinate-amm.+ imazapyr	0.45+0.15	92	90	88	82	76
Glufosinate-amm.+ imazapyr	0.45+0.3	94	94	96	97	97
Glufosinate-amm.+ imazapyr	0.6+0.2	96	98	99	99	99
Imazapyr	0.5	60	60	67	90	98
Glyphosate	2.25	81	94	98	98	99
Glyphosate	3	97	98	99	99	98
Untreated	-	(100)[3/]	(100)	(100)	(100)	(100)

Remark :

1/ Lalang control was evaluated by visual rating form 0-100% where 0% = no control and 100% completely killed

2/ Herbicides were applied by knapsack sprayer fitted with T-Jet nozzle at 1,000 l/ha

3/ The figure in bracket was presented as % weed coverage

Table 3. Efficacy of glufosinate-ammonium plus imazapyr for lalang control in 4 year-old rubber applied in low spray volume (June-December 1990, Surathani, Thailand)

Treatment[2/]	Rate kg ai/ha	Percentage of lalang control after herbicide application[1/] (days)					
		30	60	90	120	150	180
Imazapyr	0.25	31	56	62	77	90	95
Glufosinate-amm.+ imazapyr	0.38+0.25	95	98	97	97	97	97
Glufosinate-amm.+ imazapyr	0.45+0.15	94	98	93	94	94	90
Glufosinate-amm.+ imazapyr	0.45+0.3	95	98	98	98	99	99
Glufosinate-amm.+ imazapyr	0.6+0.2	95	99	98	98	99	99
Imazapyr	0.5	40	66	73	89	98	100
Glyphosate	2.25	96	100	98	99	98	98
Glyphosate	3.0	97	100	99	99	98	98
Untreated	-	(95)[3/]	(100)	(100)	(100)	(100)	(100)

Remark :

1/ Lalang control was assessed by visual rating from 0-100% where 0% = no control and 100% completely killed

2/ Herbicides were applied by knapsack sprayer fitted with D-2 nozzle at spray volume 300 l/ha

3/ The figure in bracket was presented in % weed coveraged.

Table 4. Efficacy of glufosinate-ammonium plus imazapyr for lalang control in 2 year-old rubber applied in low spray volume (July 1990 - January 1991, Chumporn, Thailand)

Treatment[2/]	Rate kg ai/ha	Percentage of lalang control after herbicide application[1/] (days)						
		7	30	60	90	120	150	180
Imazapyr	0.25	0	35	41	57	71	85	77
Glufosinate-amm.+ imazapyr	0.38+0.25	65	87	91	94	95	97	95
Glufosinate-amm.+ imazapyr	0.45+0.15	65	91	91	95	95	95	88
Glufosinate-amm.+ imazapyr	0.45+0.3	60	91	94	97	97	98	97
Glufosinate-amm.+ imazapyr	0.6+0.2	61	91	91	94	95	98	97
Imazapyr	0.5	0	45	50	62	76	90	92
Glyphosate	2.25	21	91	94	98	99	99	98
Glyphosate	3.0	23	92	96	98	99	99	99
Untreated	-	(100)[3/]	(100)	(100)	(100)	(100)	(100)	(100)

Remark :

1/ Lalang control was assessed by visual rating from 0-100% where 0% = no control and 100% completely killed

2/ Herbicides were applied by knapsack sprayer fitted with D-2 nozzle at spray volume 300 l/ha

3/ The figure in bracket was presented in % weed coveraged.

Table 5. Efficacy of glufosinate-ammonium plus imazapyr for lalang control in 4 year-old rubber applied in low spray volume (June-December 1990, Surathani, Thailand)

Treatment[2/]	Rate kg ai/ha	Percentage of lalang control after herbicide application[1/] (days)					
		30	60	90	120	150	180
Imazapyr	0.25	35	60	57	82	95	97
Glufosinate-amm.+ imazapyr	0.38+0.25	92	93	95	97	98	98
Glufosinate-amm.+ imazapyr	0.45+0.15	92	95	94	94	89	90
Glufosinate-amm.+ imazapyr	0.45+0.3	90	93	95	97	97	98
Glufosinate-amm.+ imazapyr	0.6+0.2	91	95	94	95	97	98
Imazapyr	0.5	38	53	73	82	92	100
Glyphosate	2.25	92	97	97	98	98	98
Glyphosate	3.0	97	99	99	99	99	99
Untreated	-	(100)[3/]	(100)	(100)	(100)	(100)	(100)

Remark :

1/ Lalang control was assessed by visual rating from 0-100% where 0% = no control and 100% completely killed

2/ Herbicides were applied by a modified mistblower at spray volume 50 l/ha

3/ Figure in bracket was presented in % weed coveraged.

Table 6. Efficacy of glufosinate-ammonium plus imazapyr for lalang control in 2 year-old rubber applied in low spray volume (July 1990 - January 1991, Chumporn, Thailand)

Treatment[2/]	Rate kg ai/ha	Percentage of lalang control after herbicide application[1/] (days)						
		7	30	60	90	120	150	180
Imazapyr	0.25	0	47	52	66	80	90	89
Glufosinate-amm.+ imazapyr	0.38+0.25	56	88	85	89	90	90	89
Glufosinate-amm.+ imazapyr	0.45+0.15	57	92	87	91	93	90	90
Glufosinate-amm.+ imazapyr	0.45+0.3	55	92	93	96	93	95	99
Glufosinate-amm.+ imazapyr	0.6+0.2	60	94	96	95	96	97	99
Imazapyr	0.5	0	46	52	67	81	95	99
Glyphosate	2.25	23	92	96	99	100	100	99
Glyphosate	3.0	21	92	96	100	100	100	99
Untreated	-	(100)[3/]	(100)	(100)	(100)	(100)	(100)	(100)

Remark :

1/ Lalang control was assessed by visual rating from 0-100% where 0% = no control and 100% completely killed

2/ Herbicides were applied by a modified mistblower at spray volume 50 l/ha

3/ Figure in bracket was presented in % weed coveraged.

results were derived from the trial conducted in Chumporn (Table 4). Some lalang regrowth (1-2%) occurred in the glufosinate-ammonium + imazapyr and even in the glyphosate treated plots which may have resulted from low soil moisture during application.

Modified mistblower : Similar results were found when the products were applied by a modified mistblower. This indicated that glufosinate-ammonium could either be sprayed by a knapsack sprayer or at even lower volumes such as 50 l/ha by modified mistblower. The data also pointed out that glufosinate-ammonium + imazapyr at 0.38 + 0.25, 0.45 + 0.3 and 0.6 + 0.2 kg ai/ha could produce an effective lalang control the same as glyphosate at 2.25 kg ai/ha (Table 5). However, in unfavourable conditions such as low moisture content, glufosinate-ammonium + imazapyr at 0.38 + 0.25 kg ai/ha was less effective than the others (Table 6).

Experiment III : Study of phytotoxicity of glufosinate-ammonium + imazapyr on rubber plants

The studies were conducted to investigate phytotoxicity of glufosinate-ammonium + imazapyr under field conditions in immature rubber plantations (1-1.5 years-old). At both locations it was shown that application of glufosinate-ammonium + imazapyr at application rates of 0.45 + 0.3 and 0.6 + 0.2 kg ai/ha sprayed using high water volumes of 1,000 l/ha did not produce any adverse effect on the rubber plants. The same was valid for glufosinate-ammonium at 0.9 kg ai/ha and glyphosate at 3.0 kg ai/ha (Tables 7,8). However, application of a 2X dosage of glufosinate-ammonium + imazapyr ie. 0.9 + 0.6 kg ai/ha., could induce slight phytotoxic symptoms on the rubber plants, as could imazapyr used alone at 0.6 kg ai/ha. Such symptoms were appeared on the young leaves and caused curling, twisted, narrow and elongated leaves (similar to healthy mango leaves). The phytotoxic symptoms were seen from 60-120 DAA, but could not be found on the other new young leaves which developed later.

Table 7. Phytotoxicity of glufosinate-ammonium plus imazapyr on 1 year-old rubber[3/] (June 1990 - January 1991, Chumporn, Thailand)

Treatment[2/]	Rate kg ai/ha	Percentage of phytotoxicity control after herbicide application[1/] (days)				
		15	30	60	120	180
Gulfosinate-amm.	0.9	0	0	0	0	0
Imazapyr	0.6	0	0	10	10	0
Glufosinate-amm.+ imazapyr	0.6+0.2	0	0	0	0	0
Glufosinate-amm.+ imazapyr	0.45+0.3	0	0	0	0	0
Glufosinate-amm.+ imazapyr	0.9+0.6	0	0	10	10	0
Glyphosate	3	0	0	0	0	0
Untreated	-	0	0	0	0	0

Remark :

1/ % Phytotoxicity was evaluated from visual rating from 0-100% where 0% = no sign of phytotoxicity and 100% complete crop destruction.

2/ Herbicides were applied by a knapsack sprayer fitted with T- Jet nozzle No. 8004 at spray volume 1,000 l/ha

3/ Soil texture was 8.7% sand, 11% silt, 2% clay, pH = 4,6 and 1.9% organic matter.

Table 8. Phytotoxicity of glufosinate-ammonium plus imazapyr on 1.5 year-old rubber[3/] (July 1990 - January 1991, Surathani, Thailand)

Treatment[2/]	Rate kg ai/ha	Percentage of phytotoxicity after herbicide application[1/] (days)					
		15	30	60	90	120	180
Gulfosinate-amm.	0.9	0	0	0	0	0	0
Imazapyr	0.6	0	0	10	10	0	0
Glufosinate-amm.+ imazapyr	0.6+0.2	0	0	0	0	0	0
Glufosinate-amm.+ imazapyr	0.45+0.3	0	0	0	0	0	0
Glufosinate-amm.+ imazapyr	0.9+0.6	0	0	10	10	0	0
Glyphosate	3	0	0	0	0	0	0
Untreated	-	0	0	0	0	0	0

Remark :

1/ % Phytotoxicity was evaluated from visual rating from 0-100% where 0% = no sign of phytotoxicity and 100% complete crop destruction.

2/ Herbicides were applied by a knapsack sprayer fitted with T- Jet nozzle No. 8004 at spray volume 1,000 l/ha.

3/ Soil texture was 39% sand, 39% silt, 32% clay, pH = 4,3 and 1% organic matter.

CONCLUSION

The following can be concluded from the results :

1. Glufosinate-ammonium at 1.5 kg ai/ha produced quick killing action on lalang but did not provide sufficient long lasting control.
2. Imazapyr at the recommended dose of 0.5 kg ai/ha gave a very slow killing action on lalang up to 120-150 DAA, when complete control could be seen.
3. The tank-mix of gulfosinate-ammonium + imazapyr at 0.38 + 0.25, 0.45 + 0.3 and 0.6 + 0.2 kg ai/ha could provide quick killing action as weel as a long lasting control on lalang which was comparable to glyphosate at 2.25-3.0 kg ai/ha. In addition, this combination could provide longer term control and better regrowth suppression of other weeds after the lalang had decayed.
4. Glufosinate-ammonium + imazapyr at 0.38 + 0.25, 0.45 + 0.3 and 0.6 + 0.2 kg ai/ha could be sprayed using different water volumes, and using different equipment viz. a knapsack sprayer (300-1,000 l/ha), and a modified mistblower (50 l/ha).
5. To ensure effective lalang control in most conditions for example: dense lalang mixed with other tough weeds, or plants under moisture stress, the rate of 0.45 + 0.3 of glufosinate-ammonium + imazapyr should generally be recommended.
6. Glulosinate-ammonium + imazapyr at 0.45 + 0.3 and 0.6 + 0.2 kg ai/ha did not produce any adverse effect on immature rubber plants, even when applied to 1 year-old rubber. Neither did glyphosate at 3.0 kg ai/ha. However, application rates as high as 0.9 + 0.6 kg ai/ha of glufosinate-ammonium + imazapyr could induce slight phytotoxicity on young leaves.

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THE NECESSITY OF RHIZOME OBSERVATION IN THE ASSESSMENT OF ALANG-ALANG (*IMPERATA CYLINDRICA*) CONTROL

SUMARYONO AND BASUKI [1]

ABSTRACT

Data from three glyphosate efficacy experiments were used to examine the importance of rhizome observation in alang-alang (*Imperata cylindrica* (L.) Raeuschel) control assessments. There was a significant correlation between herbicide rate and shoot dry weight and mortality: as the glyphosate rate increased, the dry weight of living shoots decreased and the percentage of dead shoots increased. However, the effect of glyphosate rate on dry weight and mortality of rhizomes varied considerably, with only one experiment showing a close correlation between rate of glyphosate and rhizome mortality. The results indicated that it is not necessary to assess rhizome data in field trials with alang-alang because of the high variability of the data and the difficulties in obtaining and separating rhizomes in the field. The viability of alang-alang rhizome could be predicted by clipping the shoot and then observing the shoot regrowth.

INTRODUCTION

Alang-alang or cogongrass (*Imperata cylindrica* (L.) Raeuschel) is an aggresive rhizomatous perennial weed. According to Holm *et al.* (1977) alang-alang is an important weed of 53 different crops in 73 countries, especially in the tropics. In Indonesia, alang-alang is one of the most troublesome weed mainly in the plantation crops (Soerjani, 1970; Soedarsan *et al.*, 1977), upland food crops (Soerjani, 1970), and deforested areas (Eussen & Wirjahardja, 1973).

Various methods have been used to control alang-alang, including the application of herbicides. Since this weed has an extensive rhizome system (Eussen, 1981) and the rhizomes have both apical and axillary buds that can grow out (Lee, 1985), the herbicides must be translocated into and kill the underground rhizomes. The most important criterion in controlling alang-alang is the amount of shoot regrowth from the rhizomes. The less the shoot regrowth, the better the control will be. Consequently, the death of rhizomes should be the primary variable observed in alang-alang control trials. However, 5 out of 10 papers dealing with chemical control of alang-alang published in the Proceedings of Weed Science Society of Indonesia Conferences in 1988 and 1990 did not assess the effect of the herbicide on rhizome. All the papers

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reported that the degree of alang-alang control was determined by the percentage of drying shoot mainly observed visually.

There are some problems faced by researchers in assessing the viability of alang-alang rhizomes in field experiments, such as the technical difficulties in digging and separating the rhizomes from soils (especially those with a high clay content) and in separating the viable (living, undecayed) and dead (decayed) rhizomes. In addition, there are indications that data on rhizome observations have a high variability.

The objective of this paper is to examine the necessity of both shoot and rhizome observations in alang-alang control assessments by relating them to glyphosate rates and also to determine the variabilities of shoot and rhizome data.

MATERIALS AND METHODS

Data analyzed were derived from three field experiments of glyphosate efficacy on alang-alang (Basuki & Sumaryono, 1987; Sumaryono & Basuki, 1987; Basuki & Sumaryono, 1990), all conducted in estates near Bogor, West Java. In each case alang-alang was 1 - 1.5 m tall under 3-4 years old rubber plantations. Treatments used were rates of glyphosate ranging from 0 to 3.24 kg ae/ha. The treatments were arranged in randomized block design in each experiment with 3-4 replications. Individual plot sizes varied from 4 x 8 m to 2.4 x 28 m. The herbicide was applied using a knapsack sprayer with 400 l of water/ha as a carrier. There was no rain on the day of spraying.

Alang-alang response to the treatments was monitored by determining the dry weights of living and dead shoots, and living and dead rhizomes. Shoots were considered to be alive if they were green, whilst living (viable) rhizomes were white and fresh. The percentage of dead shoots or rhizomes was based on the dry weight. The data were obtained from two sample plots of 0.5 m x 0.5 m for each plot 4 months after herbicide application by digging up the soil of the sample plots to a depth of 50 cm. The rhizomes were gently removed and washed from the soil and then the decayed rhizomes were separated from the living rhizomes. The shoot and rhizome materials were then oven dried at 105°C for 48 hours and weighed for dry matter determination.

The data were subjected to analysis of variance. Comparisons among treatments were tested using Tukey's multiple range test at the 5% probability level. Correlations between glyphosate rate and observation variables were determined by a simple linear regression.

RESULTS AND DISCUSSION

Table 1 shows that all rates of glyphosate significantly decreased the dry weight of living shoots of alang-alang. The percentage of dead shoots correlated negatively with the dry weight of shoot biomass. Even though glyphosate decreased dry weight of fresh rhizome by approximately 50%, there was no significant difference between the rates. This might be due to the high variation of the rhizome data, indicated by the high coefficient of variation of the rhizome data (60-70%). The results also indicate that there was no correlation between glyphosate rate and percentage of dead rhizome.

Table 1. Effect of glyphosate rate on dry weights of living shoot and rhizome and percentages of dead shoot and rhizome of alang-alang, 4 months after treatment in Experiment 1.

Glyphosate rate (kg ae/ha)	Dry weight of shoot (g)	Dead shoot (%)	Dry weight of rhizome (g)	Dead rhizome (%)
0.00	119.0 a[1]	35.1 b	128.1 a	6.8 a
0.72	1.2 b	98.3 a	44.1 a	38.7 a
1.44	0.1 b	99.9 a	65.9 a	48.0 a
2.16	0.0 b	100.0 a	54.8 a	37.7 a
Coeff. var. (CV, %)	4.6	4.5	70.2	61.9
Coeff. corr. (r) vs rate	0.78 **[2]	0.78 **	0.42 NS	0.50 NS

Notes: 1 Figures within a column followed by the same letter are not significantly different at 5% level of probability according to Tukey's test.
2 ** = significant (1% level); NS = not significant

Results of Experiment 2 (Table 2) were similar to those of Experiment 1, except in rhizome data. Glyphosate significantly decreased the living rhizome of alang-alang. Both sets of rhizome data show significant correlations with gly-phosate rate, but the coefficient of variation of dead rhizomes is relatively high.

Results of Experiment 3 (Table 3) are somewhat different from those of the two previous experiments. As the rate of glyphosate increased, the dry weight of living shoot decreased and the percentage of dead shoot increased significantly. However, glyphosate application up to 3.24 kg ae/ha did not affect the rhizomes at all.

In Experiments 1 and 2 glyphosate at 2.16 kg ae/ha (the standard rate) killed more than 90% of shoots, while in the third experiment only 67% of shoots were killed, 4 months after application. This lower rate of control in Experiment 3 may be due to the better growth of alang-alang (see the dry weight of shoots in the untreated check in Table 3 compared to those of in Tables 1 and 2). In no case did glyphosate kill underground rhizomes completely. The results are in agreement with those obtained by Lee (1985) who stated that there is no problem in killing the aerial parts, but it is difficult to kill all the buds in the underground rhizomes, even at 10 kg ae of glyphosate per ha.

Table 2. Effect of glyphosate rate on dry weights of living shoot and rhizome and percentages of dead shoot and rhizome of alang-alang 4 months after treatment in Experiment 2.

Glyphosate rate (kg ae/ha)	Dry weight of shoot (g)	Dead shoot (%)	Dry weight of rhizome (g)	Dead rhizome (%)
0.00	116.6 a[1]	30.0 b	133.5 a	2.6 b
1.08	12.1 b	78.8 a	56.2 b	15.9 ab
1.44	8.0 b	83.2 a	63.5 b	8.4 b
2.16	2.7 b	93.4 a	33.6 b	27.7 a
Coeff. var. (CV, %)	37.5	9.7	18.3	46.7
Coeff. corr. (r) vs rate	0.88 **[2]	0.93 **	0.91 **	0.75 **

Notes: [1] Figures within a column followed by the same letters are not significantly different at 5% level of probability according to Tukey's test.
[2] ** = significant (1% level); NS = not significant

Table 3. Effect of glyphosate rate on dry weights of living shoot and rhizome and percentages of dead shoot and rhizome of alang-alang, 4 months after treatment in Experiment 3.

Glyphosate rate (kg ae/ha)	Dry weight of shoot (g)	Dead shoot (%)	Dry weight of rhizome (g)	Dead rhizome (%)
0.00	145.5 a[1]	33.6 c	164.5 a	5.3 a
1.08	81.8 b	48.7 bc	181.5 a	5.7 a
2.16	37.7 b	66.6 ab	138.4 a	6.2 a
3.24	29.4 b	78.0 a	118.7 a	6.7 a
Coef. var. (CV, %)	34.7	20.6	33.5	28.8
Coef. corr. (r) vs rate	0.86 **[2]	0.85 **	0.40 NS	0.32 NS

Notes: [1] Figures within a column followed by the same letters are not significantly different at 5% level of probability according to Tukey's test.
[2] ** = significant (1% level); NS = not significant

Results of the three experiments indicate that shoot data correlated closely with glyphosate rate, but the rhizome observation data varied greatly. The higher the glyphosate rates, the higher the percentages of dead shoots. In contrast, the higher rates of glyphosate were not always reflected by higher percentages of dead rhizome. However, it does not imply that there is no effect of herbicide on the regrowth from rhizomes, because living rhizomes which have been treated by herbicides have a lower germination percentage (Kusnanto & Nurdin, 1988). Regrowth of new shoots usually occurred from the apical

region of the primary rhizome (Lee, 1985), although according to Soerjani & Soemarwoto (1969) bud locations did not affect the germination of rhizome buds.

The above discussion suggests that data of dry weight of living rhizome and percentage of dead rhizome should not be used as observation variables for glyphosate efficacy with alang-alang. Furthermore, it is difficult to separate rhizomes from the soil and to distinguish living from dead rhizomes in the field. As an alternative, it is suggested that observations be made of the ability of rhizomes to regrow by clipping the shoot several centimeters above the ground and observing shoot regrowth (Moosavi-Nia & Dore, 1979). The size of sampling plots could be the same as the treatment plots, but the clipping time after herbicide application may depend on the type of herbicide, especially its translocation behavior. For glyphosate applied on alang-alang, one week after herbicide application is considered sufficient for clipping the shoot (Moosavi-Nia & Dore, 1979).

CONCLUSIONS

Four months after treatment the rhizome data (dry weight of living rhizome and percentage of dead rhizome) of alang-alang were more variable than those of the shoots and there was no consistent correlation between glyphosate rate and rhizome data. Therefore, it is not necessary to assess rhizome variables in glyphosate trials with alang-alang. Instead, viability of rhizome affected by herbicides might be predicted by observing shoot regrowth.

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APPLICATION TECHNIQUES OF ACETOCHLOR IN VEGETABLE FIELDS

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ABSTRACT

The field experiments showed that Acetochlor was a highly active herbicide, which could control annual grass weeds and a part of broadleaved weeds effectively when applied at 50-100 ml/mμ at the budding stage or one-leaf stage of weeds. It was found that the application of Acetochlor before or after transplanting of some vegetables and before emergence or during early seedling stage of direct-sowing soybean was highly safe to the crops. It was also found that the application of Acetochlor was safer at early seedling stage than before emergence. Acetochlor could keep its effect in soil over 70-80 days. The leaf age of weeds and soil moisture affected the weed control efficacy of Acetochlor significantly.

INTRODUCTION

Acetochlor is a selective herbicide for pre-emergence control of annual grass weeds and a part of broadleaved weeds. The detoxicating agents for Acetochlor and some other acetanilide herbicides applied in some direct-sowing crops like corn, sorghum, legumes and grape were also reported. In China it has already been applied in soybean and cotton fields (Shi *et al.*, 1990). Field plot experiments were carried out in transplanting rape-seed, Chinese wax-gourd, cowpea, cabbage and soybean fields with 50% Acetochlor EC in Shanghai during 1988-1989 by the authors. Some factors affecting the efficacy of the herbicide were studied and the weed-killing spectrum, efficacy, spraying time and dosage, persistence period were also investigated. Results showed that the spraying time of Acetochlor could be extended from pre-emergence to one-leaf stage of the weeds and not only confined to transplanting crops.

MATERIALS AND METHODS

Effect of Different Dosage on Weed Control Efficacy

The dosages of 0.45, 0.60, 0.75, 0.90, 1.20, 1.50 and 1.80 kg/ha of 50% Acetochlor EC mixed with 600 kg/ha water were applied in rapeseed, Chinese

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waxgourd, cowpea, cabbage and soybean at pre-transplanting, post-transplanting, pre-emergence and early seedling stages respectively. Herbicide was sprayed onto soil or onto leaves and stems. The area of each plot was 20-67 m^2. The experiment used the randomized design with three replicates. The species composition, number of surviving plants, biomass of upper part of weeds and the plant height, leaf age, biomass of crops were measured 30, 60 and 90 days after treatment respectively. Mature crops were sampled to calculate theoretical yield.

Factors Affecting the Efficacy of Acetochlor

The effect of leaf age of Alopecurus aequalis *on control efficacy*

Fifty percent Acetochlor EC 0.9 kg/ha mixed with 600 kg/ha water was sprayed in rapeseed fields at the pre-emergence, one-leaf and two-leaf satges of weeds. The number of surviving weeds was counted 30 days after treatment.

Soil moisture

Seeds of *Alopecurus aequalis* were sowed into soil of 20, 30 and 40% water content respectively. 0.9 kg/ha Acetochlor EC mixed with 60 kg/ha water was sprayed. Weight of soils were measured to supplement the water vapourated.

RESULTS AND DISCUSSION

Effect of Different Dosages on Weed Control Efficacy

The weed control experiments were conducted in transplanted rapeseed, Chinese waxgourd, cowpea, cabbage fields and direct- sowing soybean fields by 50% Acetochlor EC 0.45-1.81 l/ha in 1988-1989.

The results showed that Acetochlor EC exhibited an excellent weed control efficacy for annual grass weeds and to some degrees for a part of broadleaved weeds such as *Malachium aquaticum.*

In 1988, the control efficacy was 71.2-96.0% (weed number) and 87.4-97.0% (fresh weight) for *Alopecurus* spp. and also for *Malachium aquaticum*, when sprayed with the dosage of 0.6-0.9 l/ha. In 1989, it was 69.2-93.0% and 37.0-75.8% for *A. aequalis* and *M. aquaticum* respectively when sprayed with 0.6-0.9 l/ha in transplanting rapeseed fields (Table 1).

The control efficacy using 0.9 l/ha of Acetochlor EC (50%) was 100.0 and 78.4% for *Alopecurus aequalis* and *Malachium aquaticum* respectively in direct-sowing rapeseed fields before seedling emergence, however, it decreased to 76.6% and 39.4% for both weeds when 0.9 l/ha of 50% Acetochlor EC was applied at the seedling stage of rapeseed.

Table 1. Weed control efficacy of Acetochlor in transplanting rapeseed fields

Dosage (ml/0.07 ha)	*Alopecurus aequalis*				*Malachium aquaticum*			
	Plants/ 0.11 m^2	Control efficacy (%)	Biomass (g)	Control efficacy (%)	Plants/ 0.11 m^2	Control efficacy (%)	Biomass (%)	Control efficacy (%)
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	25.1	71.2	67.0	87.4	67.0	46.7	186.0	45.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	9.4	89.2	49.0	90.8	52.9	57.9	135.0	60.1
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
120	7.3	91.6	41.0	92.3	75.6	39.9	211.0	37.6
160	3.5	96.0	16.0	97.0	69.0	45.2	181.0	46.4
CK	87.3	--	533.0	--	125.8	--	338.0	--

In Chinese wagourd fields treated with 0.6, 1.2 and 1.8 l/ha 50% Acetochlor EC, the control efficacy was 72.4, 85.5 and 100.0% for *Digitaria sanguinalis* and 75.0, 80.0 and 95.0% for *Eleusine indica* respectively.

In cabbage fields, the controlling efficacy with 0.9 l/ha 50% Acetochlor EC was 100.0 and 45.0% for *Alopecurus aequalis* and *Malachium aquaticum* respectively but it showed a poor control efficacy for Portulaca oleracea, *Amaranthus ascendens* and *Chenopodium serotinum.*

The results in soybean and cowpea fields were similar to those in the cabbage fields.

The Persistence of Acetochlor in Fields

The persistence of herbicide in fields is one of the important parameters for the evaluation of herbicides. The persistence of a herbicide should be long enough to control weeds in the whole life period of the crop, but not too long to affect the plant emergence and growth of the next cropping. The results showed that Acetochlor EC began exerting its effect of weed control 10-20 days after treatment with a peak at 30-60th days and decreased at 90 days after treatment in transplanting rapeseed and cabbage fields. Such a persistence period ensured an excellent weed control during the critical period of weed-crop competition while it did not exert adverse effect on the next cropping (Figure 1).

The Effect of Acetochlor on Growth and Development of Rapeseed and Other Crops

The safety of Acetochlor in the fields of rapeseed and other crops

The results showed a high safety of Acetochlor for transplanting crops. Neither pre-transplanting soil treatment nor post- transplanting spraying onto

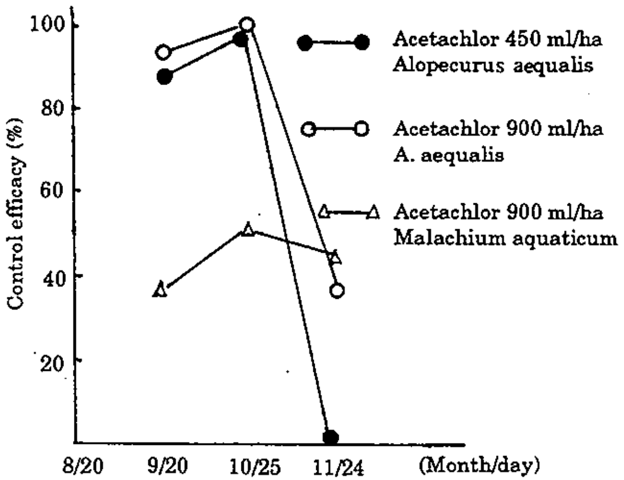

Figure 1. Efficacy of controlling *Alopecurus aequalis* and *Malachium aquaticum* different days after Acetochlor apllication

leaves and stems with a dosage of 0.6-1.8 l/ha 50 % Acetochlor EC exerted adverse influence on the leaf colour, growth, plant height, leaf age and biomass of rapeseed. Degreening occured in some leaves of crop 10 days after treatment when 3 l/ha 50% Acetochlor was applied but they got recovered 20 days later without influence on crop yield. In Chinese gourd, cowpea and cabbage fields, neither pre-emergence nor post-emergence soil treatment of 0.6-1.8 l/ha 50% Acetochlor affected the growth of the crops.

The safety of Acetochlor in transplanting crops fields

In direct-sowing rapeseed fields, 50% Acetochlor 0.45 l/ha did not affect the percentage of germination, plant height, leaf age and biomass of the crop. But when 0.9 l/ha was applied, it affected the growth of rapeseed to some degrees, when the dosage was up to 1.8 l/ha, it decreased the percentage of germination, plant height and biomass of the crop. Similarly 1.2 l/ha 50% Acetochlor affected the plant height and biomass of Chinese cabbage when it was applied post-sowing and before seedling emergence. No adverse influence was found in rapeseed when 0.45, 0.90 and 1.8 l/ha 50% Acetochlor were applied at the early seedling stage of the crop.

Acetochlor is highly safe for soybean crop. Neither 0.6, 1.2 or 1.8 l/ha of 50% Acetochlor applied pre-emergence nor 1.2 l/ha applied at the early seedling stage exerted adverse effect on the growth of the crop (Table 2).

Table 2. Effect of Acetochlor on soybean growth

Application time	Dosage l/ha	Plant height (cm)	Leaf-age (leaf number)	Biomass (g)
Pre-emergence	0.6	22.61a	4.10a	49.60a
	1.2	21.67a	4.00a	41.50a
	1.8	22.13a	3.94a	44.90a
Early seedling	1.2	21.04a	4.07a	51.95a
CK		23.31a	3.83a	48.43a

a Significance on 5% confidence level

The Effect of Acetochlor on Crop Yield

The yield of rapeseed increased to certain extent in the different treatments since Acetochlor could control the grass weeds and a part of broadleaved weeds effectively, so that the environments of crop growth were improved. The results implied that the increase in the yield was in the range of 5.3-16.2% for transplanting rapeseed crop (Table 3).

Table 3. Effect of different Acetochlor dosage on the yield of rapeseed

Treatment l/ha	Plants/ 0/06 ha (10,000)	Pod number/ plant	Pod/ 0.06 ha	Grains/ pod	Kilo-grain weight (g)	Theoretical yield (kg)	Increasing rate (%)
40	4.9	21.9	108.7	21.8	5.1	120.9	5.3
80	4.6	24.4	113.2	22.4	4.9	124.2	8.2
120	4.7	28.4	133.3	23.8	4.2	133.2	16.0
160	4.5	24.8	111.6	23.9	5.0	133.4	16.2
CK	4.6	21.4	98.5	24.8	4.7	114.8	---

Factors Affecting the Control Efficacy of Acetochlor

The effect of Acetochlor on control of Alopecurus *with different ages*

The result showed that the control efficacy was correlated negatively with the leaf ages of *Alopecurus*, i.e. it decreased with the increase of the leaf age. As 0.9 l/ha of 50% Acetochlor was used, the control efficacy was 98.2%, however, it decreased to 81.6 and 59.4% at the stages of one-leaf and two-leaf respectively. Hence Acetochlor should be applied before one-leaf stage.

The effect of soil moisture on the control efficacy of Acetochlor

Soil moisture played an important role in weed control as soil was treated with Acetochlor. As the soil containing 20% absolute water content was treated with 0.9 l/ha of 50% Acetochlor, the percentage of seedling emergence was 29.4% for *Alopecurus*. As the absolute water content was 30%, and increased to 40%, the percentage of weed seedling emergence decreased to 13.6% and further to 6.1% respectively.

Obviously, maintaining soil moisture will be beneficial for the weed control after application.

DISCUSSION

As mentioned above, Acetochlor is an ideal herbicide for controlling the grass weeds in the vegetable fields and highly safe for soybean and the transplanted vegetables. As Acetochlor was applied, the weed control efficacy is better before the seedling emergence for direct-sowing rapeseed, but the contrary for the safety. The application of Acetochlor favoured for the weed control at the early seedling stage of the crop is during the period from weed germination to one-leaf stage, using no less than 0.75 l/ha of 50% Acetochlor.

Acetochlor showed a certain control efficacy for *Malachium aquaticum* and a part of broadleaved weeds but quite poor for the majority of broadleaved weeds. Acetochlor is not safe for some direct-sowing crops, therefore further researches should be conducted on the mixed herbicides and the detoxicating agents.

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OCCUPATIONAL EXPOSURE OF PLANTATION SPRAY WORKERS TO GLYPHOSATE DURING MIST BLOWER APPLICATION

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ABSTARCT

A study was conducted to determine exposure of plantation workers to glyphosate while performing mist blower foliar application of Roundup® herbicide according to label directions and under actual use conditions. Exposure was determined by passive dosimetry techniques while workers sprayed weeds arround palm trees in a plantation in Malaysia. The workers were fitted with gauze patches at different locations on their clothing; air sampling was performed in the breathing zone and the workers's hands were washed at the end of the day. The mean body dose estimate for a fully clothed worker was 4.14×10^{-3} mg/kg/lb of glyphosate applied. This estimate is almost identical to that measured in a prior study of U.S.forestry workers applying Roundup® herbicide with backpack sprayers. Thus, mist blower application of Roundup®, which is very efficacious, is also very safe for the workers.

INTRODUCTION

In 1988/89, the ultra low volume technique using the modified mist blower for applying glyphosate herbicides was evaluated and recommended for general weed control in Malaysia. This technique had been reported by Chew *et al.* (1990) to provide effective and efficient weed control resulting in savings in herbicide application cost.

Occupational exposure of spray workers had been studied extensively in other countries (Crome, 1985). However in Malaysia, limited studies had been reported on occupational exposure to ultra low volume application of herbicides. Tan *et al.* (1987) had been reported on comparative study on the occupational exposure of spray workers using knapsack and spinning disc sprayers. In view of the above, this study was conducted under local conditions to determine the exposure of Malaysian workers to glyphosate while performing mist blower foliar application of Roundup® herbicide under actual use conditions.

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MATERIALS AND METHODS

Glyphosate is the active ingredient in Roundup®, which is a broad-spectrum, post-emergent herbicide used to control grasses, broadleaf and aquatic weeds. Roundup® would be used to control the weeds around palm trees to facilitate harvesting the palm fruit and application of fertilizers. Four workers were monitored with passive dosimetry techniques while spraying weeds around palm trees in a Malaysian plantation. Passive dosimetry was performed using cotton gauze patches, air sampling absorption media and hand washes as per EPA Assessment Guidelines.

This study was conducted at the Prang Besar Research Station, Kajang, Selangor, Malaysia with Malaysian workers in the fall of 1990. The Research Station is a very large plantation where cocoa plants, palm and rubbber trees are grown. Workers typically wear long sleeved shirts, long pants and rubber boots when applying pesticides. Background sampling and field fortifications with gauze patches, air sampling filters and hand wash solutions were performed at the field site, the day before the test. Before handling any spray solution, gauze patches were pinned to appropriate locations of the workers clothing to measure body exposure excluding hands (see Appendix 1). Air sampling filters connected to personal monitoring pumps were attached to the worker's collar to simulate respiratory intake. Each worker loaded the spray solution into a SOLO mist blower and performed the spraying operations with Roundup® herbicide under typical use conditions at a rate of 0.87 lb of active ingredient per acre. Each worker sprayed about 2.5 acres (7.5 planted acres). Finnaly, each worker's hands were washed after the loading and spraying operations were complete to determine hand exposure. All the field and study samples were analyzed and the estimated body dose calculated according to Subdivision U.

RESULTS AND DISCUSSION

Passive dosimetry body dose estimates were calculated for a fully clothed worker with a long sleeved shirt, long pants and rubber boots. The estimate corrected for clothing penetration, dermal penetration, transport/storage/analytical recovery and normalized for body weight and amount of chemical handled averaged 4.14 x 10^{-3}mg/kg/lb. In another exposure study by Cowell and Steinmentz (1990), estimates of forestry workers who applied Roundup® herbicide with backpack sprayers averaged 3.08 x 10^{-4}mg/kg/lb. Biological monitoring estimates of the same forestry workers, obtained by analysis of urine samples, averaged 3.08 x 10^{-4} mg /kg/lb (an order of magnitude lower). Body dose estimates achieved by biological monitoring are the most accurate because they account for exposure through all routes-oral, respiratory, and dermal. Passive dosimetry data indicate that workers applying Roundup® herbicide with either a mist blower or a backpack sprayer experience about the same exposure. The highest exposure was to the lower leg regions because the worker walked into the spray mist but these areas were protected by long pants and boots (Table 2). The data shows that the clothing protected the worker in the areas where there were gauze patches underneath the clothing. The actual amount of glyphosate absorbed by the body (biomonitoring) is very small because the inhalation exposure measure includes particles too large to be inhaled and the dermal penetration rate is only 1.8%. Due to the low toxicity and the low estimated exposure, application of glyphosate with a mist blower should result in a very low worker hazard.

Table 1. Glyphosate estimated body dose calculations from combined inhalation and patch/hand body dose calculations

Worker Number	Worker Wt.(kg)	Glyphosate Applied (lbs)	Inhalation Body Dose (µg)	Patch/Hand Body Dose (µg)	Total Est. Body Dose (µg)	Normalized mg/kg/hr	Normalized mg/kg/lb
1	38.6	2.14	69.0	351	420	1.36x10^{-3}	5.08x10^{-3}
2	40.5	2.14	87.1	487	574	1.77x10^{-3}	6.62x10^{-3}
3	44.1	2.14	81.0	226	307	8.70x10^{-4}	3.25x10^{-3}
4	54.5	2.14	73.9	113	187	4.29x10^{-4}	1.60x10^{-3}
					Average	1.11x10^{-3}	4.14x10^{-3}

Table 2. Glyphosate exposure to the applicator's body regions

	Worker Number 1	2	3	4	Average
neck(inside)	<1	<1	<1	<1	<1
chest (inside)	<1	<1	<1	<1	<1
back of head	3,396	4,587	1,465	475	2,481
chest	392	2,142	1,331	480	1,086
right shoulder	2,749	2,565	1,264	1,134	1,928
left shoulder	2,392	1,067	974	649	1,271
right forearm	2,736	2,476	1,296	1,853	2,090
left forearm	1,835	3,765	1,821	1,521	2,236
right thigh	6,055	7,339	6,017	4,285	5,924
left thigh	5,336	6,290	5,651	4,547	5,456
right shin	12,984	14,239	12,974	11,673	12,968
left shin	11,672	12,594	11,328	11,709	11,576
hands	633	1,927	649	553	941

The above values are µg of glyphosate.

All the values for exposure to the outside of the protective clothing unless noted otherwise ("inside" is underneath the clothing).

ACKNOWLEDGEMENT

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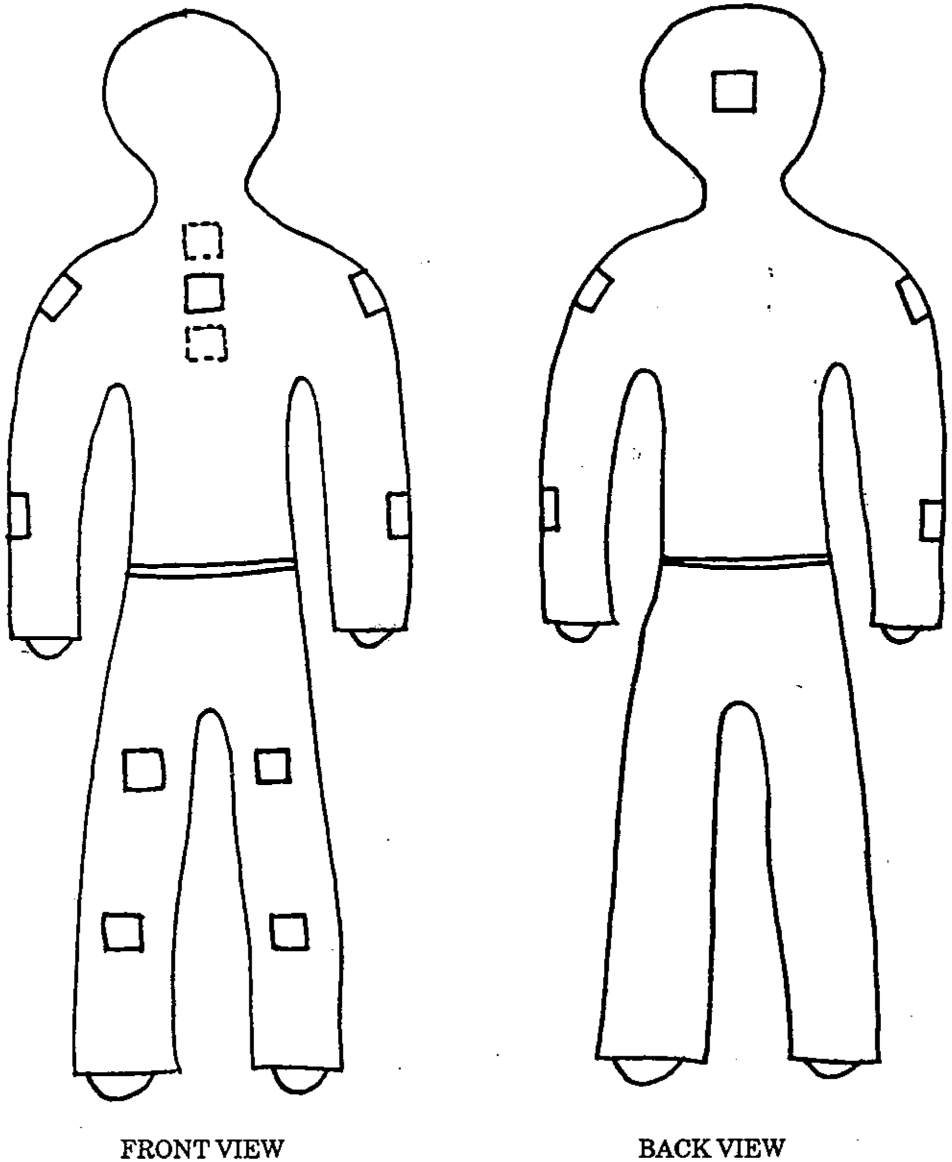
Appendix I. Position of patches on various parts of the body



Area of single patch = 100 cm^2
Number of patches = 12

ACTIVITY AND RETENTION OF GLYPHOSATE ON *IMPERATA CYLINDRICA* GROWN IN DIFFERENT SOIL TYPES

I.B. IPOR AND C.S. TAWAN[1)]

ABSTRACT

The activity and retention of glyphosate were determined on *Imperata cylindrica* (L) Beauv. grown in different soil types. *I. cylindrica* grown in sand was more susceptible to glyphosate than those in loam soil. Reduction of spraying volume tends to increase the control of *I. cylindrica* grown in sand and is vice-versa for those in loam soil. Regrowth of *I. cylindrica* after glyphosate treatment differed between soil types. The different effect of glyphosate was probably due to different trends of glyphosate retention, translocation, vegetative growth and allocation patterns of *I. cylindrica*.

INTRODUCTION

I. cylindrica (L) Beauv. is a tough perennial weed with a guerilla rhizomatous growth habits. It has an enormous regrowth capacity or high growth rate which makes it a strong competitor for common resources such as, water, light, nutrients and space (Holm *et al.*, 1977). Due to the high generative capacity of the weed from both rhizomes and seeds, the effective and prolonged control of *I. cylindrica* can only be obtained with knowledgeable understanding on the biology and physiology on this weed. Generally, growth rate, population growth, survival and response to herbicides of any weeds depend greatly on the suitability of particular type of soil. The present study is an attempt to determine the activity and retention of glyphosate on *I. cylindrica* from two types of soil.

MATERIALS AND METHODS

Control Study

I. cylindrica grown in both sand and sandy loam soil were sprayed with spinning disc (Micron Herbi) for 20 l/ha and solo sprayers for 105 and 211 l/ha. Glyphosate was sprayed at 2.16 kg a.i/ha. The phytotoxic effect of glyphosate on *I. cylindrica* was recorded as visual estimates of the percentage control

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relative to unsprayed: 0% indicates no effect and 100% complete dessication. Weekly assessment were made from 21 to 49 days after treatment.

Vegetative Parts of *Imperata cylindrica*

Vegetative composition of *I. cylindrica* grown in either sand or sandy loam soil was determined by using quadrats of one square meter with three replicates in each localities. Ten localities were selected to ensure the sites represented environmental variations. In another experiment, three-node long apical rhizome sections were planted 2.5 cm in 1.5 cm wooden boxes containing either porous sandy loam or sand. Rhizome fragments were also planted on undisturbed or compact sandy loam soil in the field. Six months after planting, six plants of each soil treatments were severed for vegetative assessment. Another group of plants were dug up carefully. They were kept intact as much as possible to facilitate classification of plant parts.

Retention Study

In this experiment, plants from both soil type were sprayed with spray solutions containing the water soluble dye lisamine (1% w/v) with glyphosate (2.16 kg a.i/ha) and distilled water. Solo sprayer and spinning disc (Micron Herbi) were used to deliver 211 and 20 l/ha respectively.

After the sprayed deposits dried, the whole plants (i.e 100 plants per square meter) were severed and the leaves weed cut into three sections i.e tip, middle and basal sections. The sprayed deposits were washed off with 20 ml of distilled water. The lisamine concentration was measured in a spectrophotometer at a wavelength of 460 μm. The value of the peak point was compared with a standard concentration curve for the calculation of the equivalent amount of herbicide in the sprayed deposit. Data was expressed in *ug* glyphosate per square centimeter of leaf surface.

Effect of Droplet Contact Period of Glyphosate on Control of *Imperata cylindrica*

Uniform plants of about two months old were selected from every soil treatments (sand, porous top sandy loam and undisturb sandy loam soil) and treated with five of one microlitre of glyphosate solution at 2.16 kg a.i/ha in 211 l/ha.

At 0, 1, 3, 6, 12 and 24 hours after treatment, the sites of droplet applications were stripped with cellulose acetate to remove surface deposits on the epicuticular layer. Treated plants without stripping the surface deposits were considered as control treatment. Assessment in term of percentage control as compared to untreated plants (0% control) was made five weeks after droplet application. Immediately after assessment, plants were severed for regrowth

assessment. Another portions of rhizomes were cut into single node fragment to determine their germination for viability study.

RESULTS

Control Study

The canopy of *I. cylindrica* from sandy loam soil was significantly more tolerant than those from sand (Figure 1). Phytotoxicity of glyphosate was considerably improved with decreasing volumes of spraying from sand.

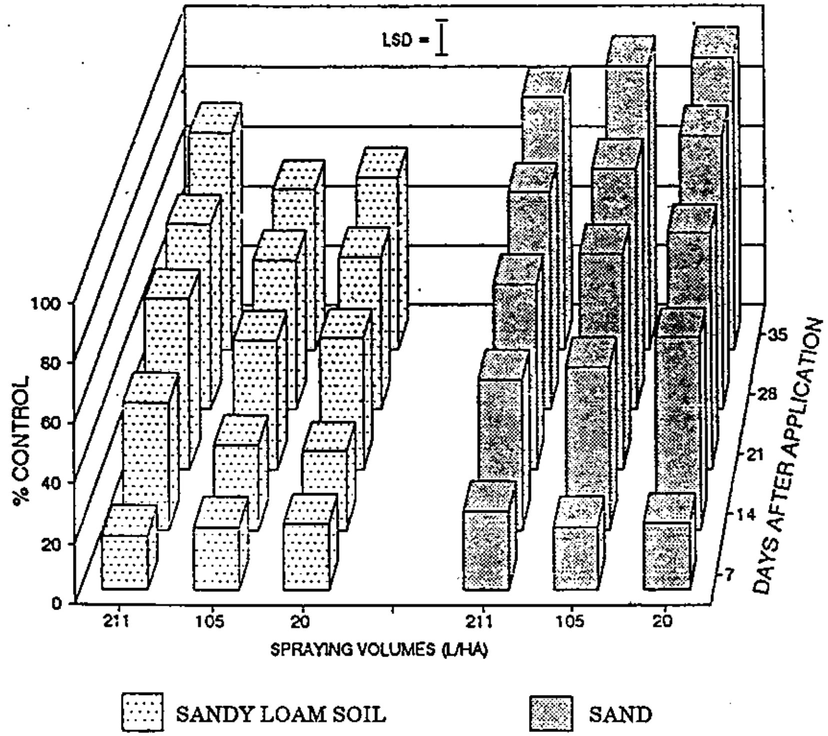

Figure1. Effect of spraying volumes on control *Imperata cylindrica* from two soil types by glyphosate

Control of *I. cylindrica* was ranged 85% to 98% for plants in sand compared with 58% to 73% from sandy loam soil, 49 days after spraying. In addition, the phytotoxic effect was comparably faster for plants from sand, ranging from 22% to 98% for 20 l/ha, in 21 and 49 days after application respectively, as compared with 22% and 58% for sandy loam soil.

However, spraying at 211 l/ha had significantly increased phytotoxicity of glyphosate for plants grown at sandy loam soil although for those in sand, the phytotoxicity had consistently increased with decreasing in spraying volumes.

Vegetative Assessment

I. cylindrica grown in sandy loam soil had significantly more tillers and leaves per meter square than those in sand (Table 1). Leaf area of the whole quadrat in sandy loam soil was almost six times larger than those from sand. *I. cylindrica* from sandy loam soil produced heavier dry weight of leaves, rhizomes and roots compared with those in sand (Table 2).

Table 1. Total number of tillers, leaves and leaf area per square metre of *I. cylindrica* from two soil types

Vegetative parts	Total number/square metre	
	Sand	Sandy loam soil
Tillers	396.7b	443.8a
Leaves	1249b	1679a
Leaf area (cm^2)	1257b	8464a

Within each column, values sharing the same letter are not significantly different at 5% level, according to DMRT.

Table 2. Total dry weight of mature *I. cylindrica* from two soil types

Vegetative parts	Dry weight (g)	
	Sand	Sandy loam soil
Leaves	807.5b	1177a
Rhizomes	612.5b	733.7a
Roots	57.5b	75.0a

Within each column, values sharing the same letter are not significantly different at 5% level, according to DMRT.

Growth and Development of *Imperata cylindrica* Grown in Different Soil Types

The total numbers of tillers, leaves, rhizomes and nodes were significantly more in sand and porous sandy loam than those from compact sandy soil (Table 3). Number of nodes was significantly greater in sand than those in porous sandy loam soil.

Table 3. Numbers of tillers, leaves, rhizomes and nodes per rhizomes of *I cylindrica* grown in three different soil types (six months after planting)

Soil type	Tillers	Leaves	Rhizomes	Nodes
Sand	43a	82a	42a	40a
Porous sandy loam	37a	80a	36b	22b
Compact sandy loam	8b	8b	6c	12c

Within each row, values sharing the same letter are not significantly different at 5% level, according to DMRT.

In sand and porous sandy loam soil, longer rhizomes and larger leaves were found compare with those in compact sandy loam soil (Table 4). Similar trend was also recorded in dry weight of both shoots and rhizomes. However, leaf length and area, dry weight of shoot and rhizomes were significantly more in porous sandy loam soil than those in sand.

Table 4. Total leaf area (TLA), length of rhizomes (LR) and leaves (LL), dry weight of shoot (DWS) and rhizomes (DWR) of *I. cylindrica* grown in different soil types

Soil type	LR (cm)	LL (cm)	TLA (cm^2)	DWS (gm)	DWR (gm)
Sand	57a	259a	5700a	57a	30a
Porous sandy loam	40a	160b	4480a	54a	23b
Compact sandy loam	25b	57c	1770b	8b	3c

Within each row, values sharing the same letter are not significantly different at 5% level, according to DMRT.

Retention Study

More retention of glyphosate on *I. cylindrica* from sandy loam soil was found at the tip section than those from middle and base section (Table 5). Least retention was quantified at the base section of both spray volumes. For

Table 5. Retention of glyphosate on *Imperata cylindrica* leaves grown in two soil types

Soil type	Retention (μg/cm^2)					
	Tip	Middle 20 l/ha	Base	Tip	Middle 200 l/ha	Base
Sandy loam	6.21	4.87	1.05	5.19	5.22	2.83
Sand	6.19	6.20	4.10	5.18	5.19	6.22
			LSD (0.05) = 2.74			

examples, retention was 1.05 and 2.83 μg/cm^2 at the base section for 20 and 211 l/ha respectively. However, retention of glyphosate was remarkably consistent on *I. cylindrica* grown in sand.

Effect of Droplet Contact Period of Glyphosate in Control of *Imperata cylindrica*

Figure 2 shows the effect of removing droplet deposits from leaf surface of *I. cylindric*a grown at different soil characteristics on the phytotoxi-city of glyphosate. Plants grown at compact sandy loam soil were significantly more tolerant to herbicide than those grown in sand and porous sandy loam soil. In addition, delaying the time of removing droplet deposits had increased the percentage control of *I. cylindrica*. At one hour interval for example, 27%, 35% and 41% control were recorded for compact sandy loam soil, porous sandy loam and sand respectively while plants without removing droplet deposits had 60%, 90% and 100% control respectively.

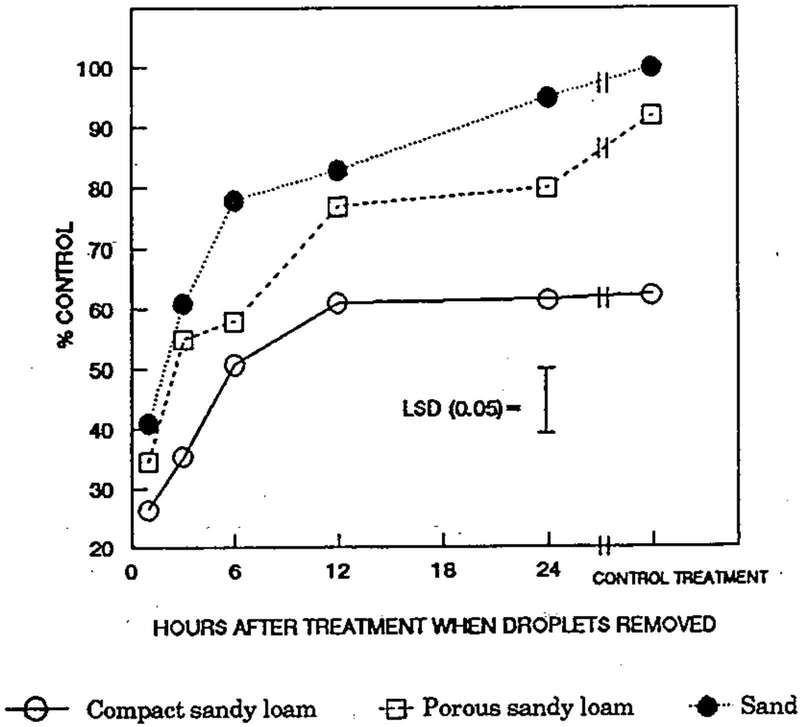

Figure 2. Effect of droplet contact period on phytotoxicity of glyphosate on *I. cylindrica*

Regrowth reduction of plants at different soil characteristic depend on the time intervals between droplet application of glyphosate and stripping of the droplet deposit (Figure 3). At the earliest time interval (one hour after application), least reduction of regrowth was obtained and increased as the time interval was increased. In addition plant in sand were significantly more regrowth reduction than those in compact and porous sandy loam soil. For example, 50% regrowth reduction was recorded at 24 hour interval in sand compared with 85% and 90% regrowth reduction at compact and porous sandy loam soil respectively.

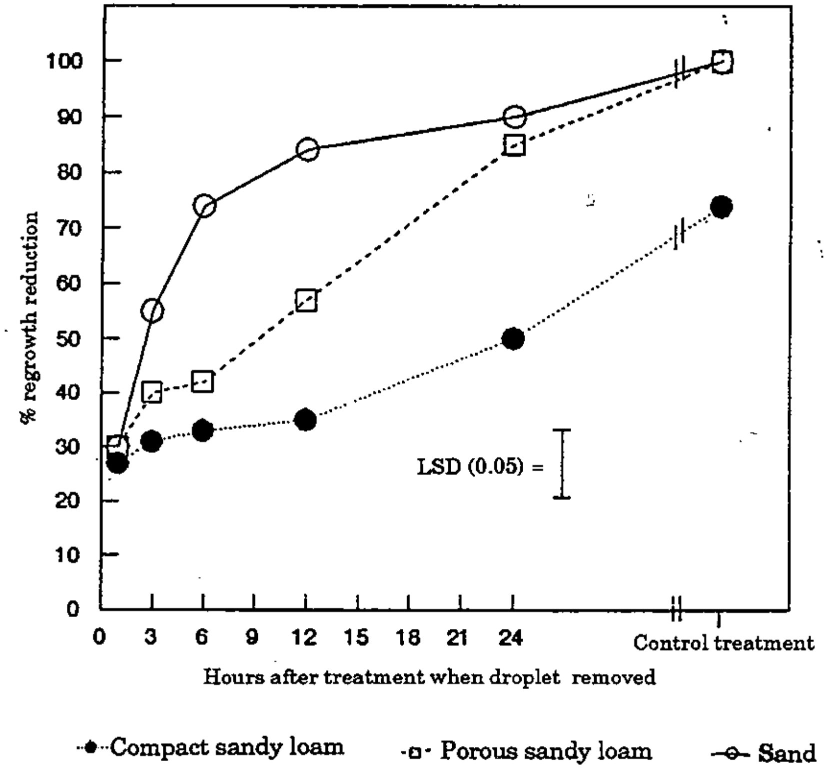

Figure 3. Regrowth reduction of *Imperata cylindrica* grown in three soil types after treated with glyphosate

The germination of rhizome fragment varied between soil types (Figure 4). More germination of rhizome was observed from sand compared with those from sandy loam soil. Rhizome germination was also depend on the age or node position of the rhizome.

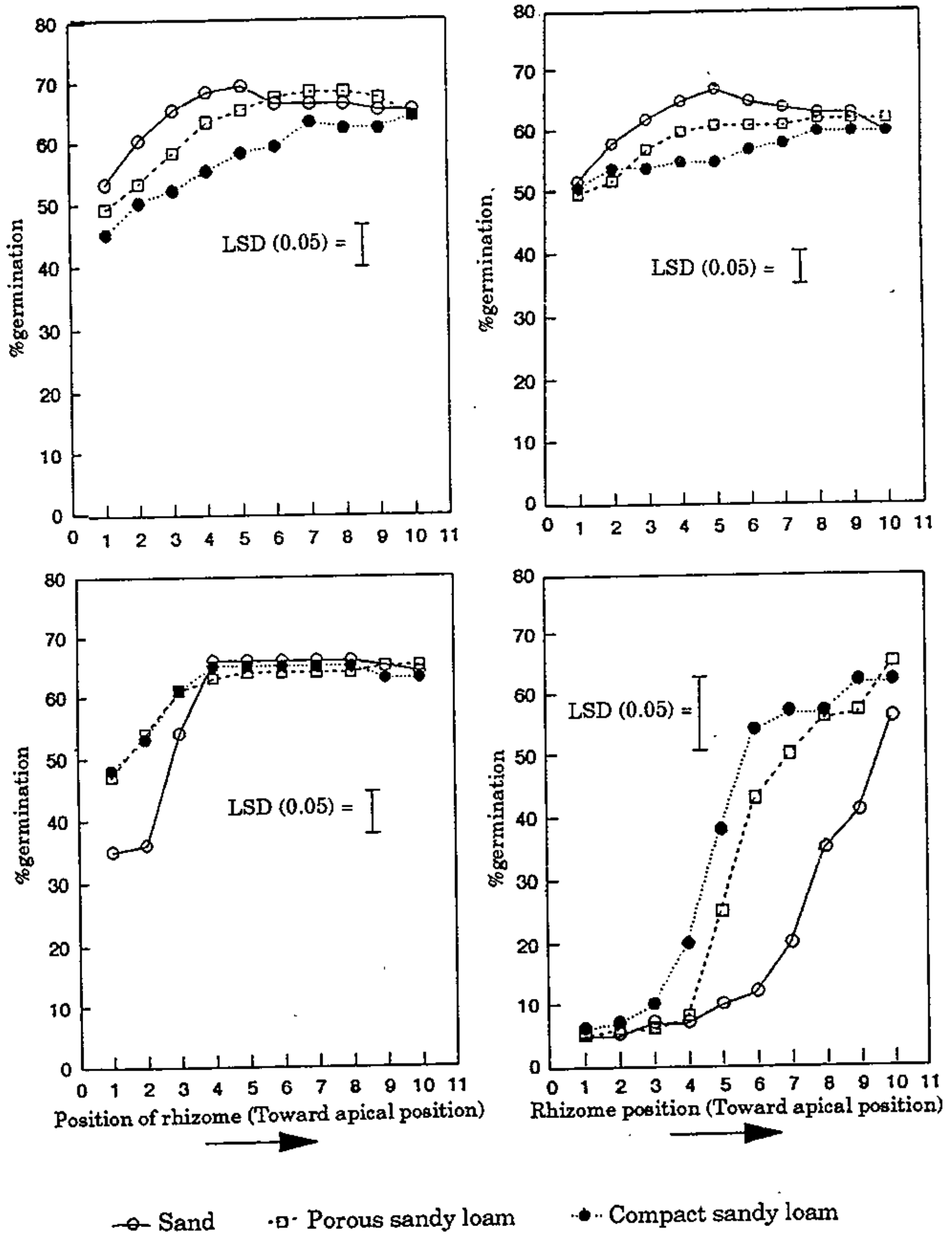

Figure 4. Germination of rhizomes from different soil types and harvesting intervals after glyphosate treatment

The phytotoxic effect of herbicide on rhizome germination depend on the period between harvesting of rhizomes and chemical application. Reduction of rhizome germination started at 3 days after treatment. More rhizomes from sand failed to germinate compared with those from porous and compact sandy loam.

DISCUSSION

Tillers, leaf and rhizome number, rhizome length, leaf area, leaf and rhizome dry weight are the important parameters to differentiate the morphological characters of *I. cylindrica*. Generally, plants at sandy loam soil were grown with higher density, thicker canopies or sheets (Table 1) and more rhizomes (Table 2) compared with those grown in sand. The capacity and efficiency of rhizome, leaf and tiller production was actually the major strategic importance of this weed. It is clearly concluded that control must be taken at the early establishment in order to effectively reduce or stop rhizome production. Delay in employing cultivating activities or chemical treatment, would lead to an increase rhizomes produced and difficulty in eradicating all viable rhizomes or buds.

In addition, variation in the producing capacity of rhizomes may have significance in planning control measures. Selection of suitable herbicides with appropiate concentration, sprayers and volumes of spraying which may resulted in better control could be corectly employed.

Tables 1 and 2 also illustrated that the area at sandy loam soil had higher density of *I. cylindrica* with thicker sheet or canopy than those from sand. The phytotoxic effect was significantly greater in sand than those at sandy loam soil (Table 1). Improved performance of glyphosate depends greatly on maximum coverage of the herbicide on the foliage. In sand,the good coverage of spraying was presumably occured with deep penetration within the canopy to contact the foliage. This better spray coverage may facilitate better herbicide retention, uptake and consequently better control. Reduction of spray volume is probably an essential factor capable of influencing better spray coverage. Low spraying volume usually delivered smaller droplets which does not run off the surface. Large droplets from high volume spraying were more liable to run off from leaf surface.

The persistent control of *I. cylindrica* depend greatly on the amount of chemical distribute and translocated at the rhizome parts. It is common that the amount of herbicide translocated to the rhizome also depend on the morphological and anatomical characteristics of rhizome (Ipor, 1989).

In this study, the percentage of rhizome germination was reasonably high and varied between position of fragments toward apical part. Soerjani and Soemarwoto (1969) found that the germination of single bud rhizome section at 0.5 - 1.0 cm length was ranged between 47 to 86%. Rhizome fragment from sand able to germinate more toward apical parts compare with those from porous and compact sandy loam soil. This indicated that higher movement of herbicide with sufficient amount toward the apical position which probably destroyed the anatomical structure of rhizome. Degree of destruction led to reduction of rhizome germination.

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RAINFAST GLYPHOSATE PLUS L-77 FOR *IMPERATA CYLINDRICA* AND GENERAL WEED CONTROL

K. TANPHIPHAT, S. CAMPIRANON, D.L. SUTTNER, P.M. HALOS, T.K. HOCK, W. GUNAWAN AND C.S. PERERA

ABSTRACT

Series of experiments were conducted between 1988 to 1990 to evaluate the rainfastness of glyphosate plus L-77 surfactant (360 g ae/L + 34 g ai/L) on *Imperata cylindrica* and general weeds. Rainfastness was a function of formulation, rate and spray volume. Glyphosate plus L-77 at the rates of 2.16 + 0.2 kg ae (ai)/ha) and 0.81 + 0.08 kg ae (ai)/ha applied with mistblower at the spray volume of 30 L/ha provided a 1 h rainfastness on *I. cylindrica* and general weed, respectively, while glyphosate (Roundup, 360 g ae/L) at the corresponding rate did not. Glyphosate plus L-77 applied with mistblower at the spray volume of 30 L/ha was more rainfast than that applied with CDA at 50 L/ha or CKS at 450 L/ha. In addition to a rainfast property, the formulation also provided a fastburn symptom and a broader spectrum of control of some broadleaf weeds like *Borreria latifolia* compared to glyphosate applied at the same rate.

INTRODUCTION

Glyphosate, discovered in 1971 and sold commercially as Roundup (360 g ae/L), is a postemergence nonselective herbicide. It is very effective in controlling perennial and annual weeds because of its rapid translocation and high phytotoxicity. Glyphosate enters plants through the aerial, usually chlorophyll-containing parts. Under favorable conditions, glyphosate rapidly penetrates leaves. Sprankle, Meggitt and Penner (1975) found that 34% of the applied ^{14}C-glyphosate was absorbed into treated leaf of *Agropyron repens* within 4 h. Diffusion is regarded as the most likely process for glyphosate absorption.

Effect of environmental conditions on the spray solution at the time and immediately following application can effect herbicide performance. Unfavorable environmental conditions after application may preclude the absorption of a substantial amount of glyphosate into plants and cause treatment failure. Rainfall is one of the most critical factors that may have a significant effect on glyphosate efficacy, especially in the tropical zone. Due to its higher water solubility, glyphosate is relatively easily washed by rain from leaf surfaces. Caseley (1972) demonstrated that rainfall at 12.5 mm at 2 h after herbicide application resulted in complete loss of activity in *Agropyron repens*. In general, a 6-8 h rain-free period is required for penetration of sufficient active ingredient to give acceptable performance of glyphosate (Behrens and

Elakkad 1972; Baird and Upchruch 1972; Coupland and Caseley 1981). Such period might not easily be found under the tropical conditions as rainfall is often unpredictable. As a consequence, a rainfast glyphosate formulation has been developed. Series of experiments were conducted in SEA to evaluate the rainfastness of glyphosate formulation. The effects of rates, equipment and spray volumes on rainfastness were determined *I. cylindrica* and general weeds.

MATERIALS AND METHODS

General Materials and Methods

Field experiments were conducted in South East Asia during 1988-1990. Efficacy of several glyphosate formulations, rates and spray volumes were evaluated on *I. cylindrica* and general weeds. The herbicide were applied at different rates and different equipments. Simulated rainfall was applied at 1 or 2 h after application by slowly pouring 10 L of water onto a 1 m^2 of treated area using showering can. Experimental design was a split block and replicated by locations. Weed control spectrum, rainfastness and burndown improvements were evaluated at 7, 15, 30 days and after monthly application.

Effect of L-77 Concentrations on Weed Control Spectrum and Rainfastness of Glyphosate

Efficacy of glyphosate at 0.81 kg ae/ha in combination with L-77 concentrations ranged from 0.05% to 0.02% v/v were evaluated on general weeds. Treatments were applied using mistblower at spray volume of 50 L/ha. Weed control spectrum and rainfastness were evaluated after application.

Effect of Equipment and Spray Volume on Rainfastness

Experiments were conducted to determine the rainfastness of glyphosate plus L-77 applied with different equipments and spray volumes. GLyphosate + L-77 applied with different equipments and spray volumes. Glyphosate + L-77 at 0.81 + 0.08 kg ai (ae)/ha were sprayed using spinning disc (CDA) at the spray volume of 50 L/ha or mistblower at 30 L/ha. Rainfastness was monitored after application.

Rainfastness of Glyphosate plus L-77 in *I. cylindrica*

Efficacy of glyphosate plus L-77 at different rates and spray volumes were determined in *I. cylindrica*. Rainfast and fastburn enhancement were evaluated. Experimental details were similar to those described above.

RESULTS

Effect of L-77 Concentrations on Weed Control Spectrum and Rainfastness of Glyphosate

Glyphosate at 0.81 kg/ha plus L-77 concentration from 0.1 - 0.2% v/v applied with mistblower at 50 L/ha provided a broader spectrum of weed control than glyphosate (Roundup, 360 g ae/L) at 1.08 kg/ha sprayed with knapsack sprayer at 450 L/ha (Figure 1). Differences were most obvious in a difficult to control species like *Borreria* where glyphosate at 1.08 kg/ha provided only 55% control. The addition of L-77 increased *Borreria* control up to 90%. Weed control provided by glyphosate/L-77 treatments was comparable to that provided by glyphosate/ metsulfuron-methyl at 0.54/0.015 kg/ha, a broad spectrum standard treatment. Simulated rainfall occurred at 1 h afterapplication reduced the efficacy of most herbicides (Figure 2). Efficacy of glyphosate at 1.08 kg/ha was significantly reduced when rainfall occurred at 1 h after application. The addition of L-77 improved rainfastness of glyphosate. Glyphosate at 0.81 kg/ha in the presence of L-77 at 0.05% v/v became equally rainfast as glyphosate alone at 1.08 kg/ha. Higher concentration of L-77 further improved rainfastness.

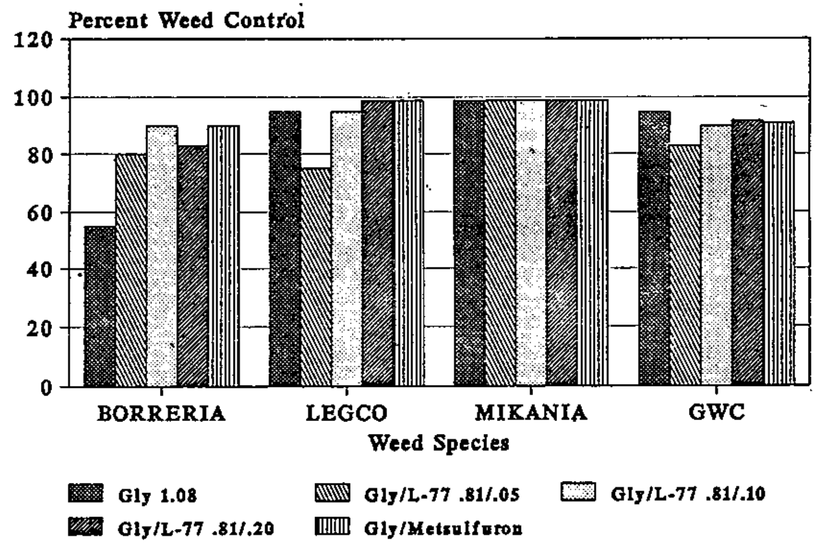

Figure 1. Weed control by glyphosate at different concentration of L-77 at 30 days after treatment. Glyphosate at 1.08 kg ae/ha and glyphosate plus metsulfuron-methyl at 0.54 + 0.015 kg ae (ai)/ha were applied with conventional knapsack sprayer (CKS) at the spray volume of 450 L/ha. The rest of the treatments were applied with mistblower (MB) at 50 L/ha.

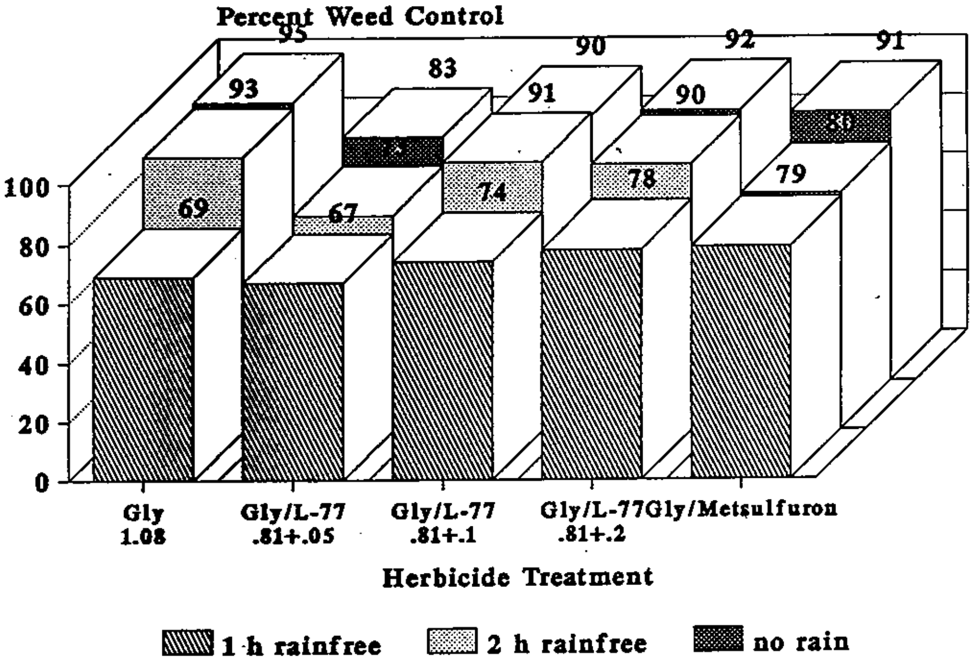

Figure 2. Rainfastness of glyphosate plus L-77 at different concentrations on general weeds (*Borreria latifolia, Digitaria adscendens, Pueraria phaseoloides, Mikania micrantha, Paspalum conjugatum* and *Ottochloa nodosa*. Glyphosate at 1.08 kg ae/ha and glyphosate plus metsulfuron-methyl at 0.54 + 0.015 kg ae (ai)/ha were applied with conventional knapsack sprayer (CKS) at the spray volume of 450 L/ha. The rest of the treatments were applied with mistblower (MB) at 50 L/ha.

Effect of Equipment and Spray Volume on Rainfastness

In most cases, performance of both glyphosate and glyphosate plus L-77 was enhanced by mistblower spraying at 30 L/ha regardless of rainfall (Table 1, 2). Performance of both herbicides under rainfall conditions was significantly increased by the mistblower application compared to the CDA. With the same equipment, glyphosate plus L-77 was more rainfast that glyphosate alone. In the mistblower application, glyphosate plus L-77 was 2 h rainfast on *B. latifolia* dan *O. nodosa* while glyphosate alone was not. Control of both species by glyphosate plus L-77 was slightly superior to glyphosate when rainfall occurred 1 h after treatment.

Table 1. Effect of equipment/spray volume on rainfastness of glyphosate/L-77 *Borreria latifolia* control at 30 DAT.

Herbicides	Rate kg ae (ai)/ha	Rain-free period (h)	Percent control CDA (50 L/ha)	Percent control MB (30 L/ha)
Glyphosate	0.81	1	48	80
GLyphosate	0.81	2	65	90
Glyphosate	0.81	no rain	80	100
Glyphosate/L-77	0.81 + 0.08	1	45	90
Glyphosate/L-77	0.81 + 0.08	2	50	98
Glyphosate/L-77	0.81 + 0.08	no rain	63	98

Table 2. Effect of equipment/spray volume on rainfastness of glyphosate/L- 77 *Ottochloa nodosa* control at 15 DAT.

Herbicides	Rate kg ae (ai)/ha	Rain-free period (h)	Percent control CDA (50 L/ha)	Percent control MB (30 L/ha)
Glyphosate	0.81	1	15	28
Glyphosate	0.81	2	30	30
Glyphosate	0.81	no rain	80	90
Glyphosate/L-77	0.81 + 0.08	1	38	60
Glyphosate/L-77	0.81 + 0.08	2	43	68
Glyphosate/L-77	0.81 + 0.08	no rain	63	90

Table 3. Rainfastness of glyphosate plus L-77 in *Imperata cylindrica* at 30 and 150 DAT

Herbicide	Spray Volume (L/ha)	Rate (kg ae (ai)/ha)	Percent control, 30 DAT			Percent control, 150 DAT		
			1h	2h	NR*	1h	2h	NR*
Glyphosate	50	1.08	15	21	33	0	5	40
Glyphosate	50	2.16	22	31	58	5	60	97
Glyphosate	800	1.08	19	29	36	0	0	0
Glyphosate	800	2.16	24	36	56	0	40	98
Glyphosate + L-77	50	1.08 + 0.1	21	25	35	15	15	99
Glyphosate + L-77	50	2.16 + 0.2	43	56	65	80	95	99

* 1 h = 1 h rainfree period
2 h = 2 h rainfree period
NR = No rainfall

Rainfastness of Glyphosate Plus L-77 in *I. cylindrica*

Glyphosate plus L-77 at 2.16 + 0.2 kg ae (ai)/ha applied with mistblower with the spray volume of 50 L/ha was rainfast on *I. cylindrica* (Table 3). GLyphosate alone applied at the corresponding rate and equipment was not. Rate reduction of both herbicides could not be achieved without sacrificing rainfastness. Simulated rainfall occurred at 1 h after application only slightly decreased the efficacy of glyphosate plus L-77 as *Imperata* control at 150 DAT was still maintained at 80%. In addition to an increased rainfastness, L-77 also enhanced a fastburn property of glyphosate when rainfall occurred after application. This was observed at 30 days after treatment.

DISCUSSION

Glyphosate is a very effective herbicide, however, it requires a rain-free perriod of 6-8 h for optimum performance. This period id too long to maintain under the tropical conditions where rainfall is often unexpected. The effect of L-77 in enhancing rainfastness of glyphosate has been known for sometimes. Results from our studies indicated that glyphosate plus L-77 (360 + 34 g ae (ai)/L is a promising candidate for rainfast glyphosate formulation. Rainfastness, however, is a complex interactions between herbicides/surfactant concentrations, spray volumes and equipments. Glyphosate plus L-77 at 0.81 + 0.08 kg ae (ai)/ha and at 2.16 + 0.2 kg ae (ai)/ha applied with mistblower at spray volume of 30-50 L/ha are required to be rainfast in general weed and *I. cylindrica*, respectively. Increasing spray volume or reducing rate can adversely affect rainfastness. Beside a rainfast property, the new formulation also provided a fastburn symptom and better control of some broadleaf, like *B. latifolia* compared to glyphosate alone applied at the same rate.

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METSULFURON EFFICACY ON *LANTANA CAMARA* WITH DIFFERENT SURFACTANTS

P. MOTOOKA[1], L. CHING[2] AND G. NAGAI[3]

ABSTRACT

Metsulfuron (Ally®, 60% a.i.) was evaluated with different surfactants for the control of lantana (*Lantana camara* L.) in a dry pasture and in a humid pasture in Hawaii. Metsulfuron in two applications caused severe injury to lantana at both sites but there was no difference between rates of metsulfuron applied between 17.5 g a.i./ha and 70 g a.i./ha and little difference between surfactants used.

INTRODUCTION

Lantana, a woody shrub commonly used as an ornamental, is a pest in plantation crops, pastures, and natural ecosystems in many parts of the world. Holm *et al.* (1977) reported that lantana was a problem in southern Africa, Madagascar, the Americas, southern Asia, Australia, and the Pacific islands. It is also a threat to native flora in the Galapagos Islands of Ecuador (Lawesson and Ortiz, 1990). At the first meeting of the Asian-Pacific Weed Science Society, Motooka *et al.* (1967) reported that lantana was the second most serious weed of pastures in Hawaii. This has not changed in the 24 years since.

Lantana was an early target for biocontrol by the predecessor agency of the state of Hawaii Department of Agriculture. Over a span of 50 years beginning in 1902, 27 species of phytophagous insects were released in Hawaii for lantana control and 15 became established (Funasaki *et al.*, 1988). Although biocontrol was highly successful in places, the noxious weed specialists of the department still consider lantana their most troublesome weed (M. Isherwood, Hawaii Dept. Agric., Memorandum dated Aug. 7, 1990). This perception is perhaps influenced by the tolerance of lantana to many herbicides. Research in Hawaii indicates that 2,4-D, dicamba and triclopyr were ineffective on lantana (HITAHR, 1981, 1983, 1989, 1991). Picloram was efficacious (HITAHR, 1982, 1989) but restrictions on its use limit its usefulness. Hexazinone was effective (unpublished) but rate limitations constrains its usefulness also. Control of lantana with tebuthiuron was erratic, excellent in low rainfall areas, (HITAHR, 1988, 1991; Motooka *et al.*, 1989), poor in high rainfall areas

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(unpublished). Although lantana was very tolerant of foliar applications of triclopyr (HITAHR, 1989), it was very susceptible to basal bark applications of triclopyr ester in diesel oil (unpublished) which demonstrated that lantana was sensitive to triclopyr and which suggested some impediment to triclopyr uptake in foliar treatments. The surfactant Silwet L-77®, (polyalkyleneoxide modified polydimethylsiloxane) (hereafter L-77) greatly increased the efficacy of metsulfuron on gorse (*Ulex europaeus* L.) in New Zealand (Balneaves 1985) and of metsulfuron and triclopyr on gorse in Hawaii (Motooka *et al.*, 1989). However, surfactants did not improve the efficacy of foliar-applied triclopyr on lantana (HITAHR, 1989).

Metsulfuron and different surfactants were evaluated for the control of lantana.

MATERIALS AND METHODS

Field trials to evaluate metsulfuron with different surfactants for lantana control were conducted at sites in Kohala, island of Hawaii and at Kapahi, island of Kauai. The Kohala site, on Hawi stony silty clay soil (Typic Ustropepts) under 760 mm annual rainfall represented a dry ecosystem. The Kapahi site was in a high rainfall (1900 mm/y) area on Pooku silty clay soil (Typic Acrohumox).

Plots 2 by 5 m in randomized complete blocks in four replicates were treated with different rates of metsulfuron (Ally 60%) and with different surfactants. At both sites the lantana were less than 1.25 m tall. Treatments were applied twice, the second when the treated plants began to recover at 4 months after initial treatment.

The surfactants used were a commonly available non-ionic Ultramar NI® (nonylphenoxypolyethoxyethanol) (hereafter NI), L-77, and Activate 3® (dimethylpolysiloxane 1%, Alkyl oxy polyethoxy ethanol 9%, and propylene glycol 2%) (hereafter A-3).

The treatments were applied with a CO_2 sprayer, with a four-nozzle boom with 110015 nozzle tips (Spraying Systems) at 138 kPa pressure.

Evaluation of the treatment effects were subjective scoring of plant injury on a 0-10 scale and weed supression based on visually estimated changes in lantana cover:

$$\left(1 - \frac{\text{final cover}}{\text{initial cover}}\right) \times 100\% = \text{percentage weed control}$$

For analysis, the data were transformed to the arcsin of its square root and retransformed for presentation.

RESULTS AND DISCUSSION

At both sites, the first application produced moderate injury symptoms. The second application induced very severe injury symptoms 2.5 months later (Tables 1, 2). There was no difference in rates of metsulfuron or types of surfactant applied. By 6 months after the second application symptomless foliage was beginning to flush and estimates of percentage of control indicated that all treatments except the no-treatment check were equally effective.

Table 1. Lantana control with metsulfuron and different surfactants at Kohala

Rate (g a.i./ha)	Surfactant[1]	Control[2] 11/14/90 (%)	Control[2] 4/5/91 (%)
Check	0	12	8
17.5	NI	93	56
	L-77	89	60
35	NI	93	62
	L-77	96	74
70	NI	98	60
	L-77	99	81

1 NI = Utramar NI® (Brewer Environmental) at 0.5%.
L-77 = Silwet L-77® (Union Carbide) at 0.2%.
2 Check vs. chemical, significant, p = 0.005.

Table 2. Lantana injury rating and control with metsulfuron with different surfactants at Kapahi

Rate (g a.i./ha)	Surfactant[1]	Injury Rating[2] 11/27/90	Control[3] 04/19/91 (%)
0	0	0.1 a	45
30	NI	5.2 b	50
	L-77	7.3 bc	77
	A3	5.8 bc	68
60	NI	6.4 bc	61
	L-77	8.4 c	61
	A3	5.9 bc	39

1 NI = Ultramar NI® (Brewer Environmental) at 0.5%
L-77 = Silwet L-77® (Union Carbide) at 0.2%
A-3 = Activate 3® (Leffingwell) at 0.5%
2 Injury rating 0 - 10 scale, 0 = no effect, 10 = complete kill.
Means denoted by different letters are significantly different by Duncan's new multiple range test at p = 0.05.
3 Nonsignificant.

At Kapahi, the high rainfall site, early injury ratings indicated little difference between surfactants but did demonstrate a clear response of all chemical treatments over the non-treatment check (Table 2). However, by 6 months after the second application, estimates of percentage of control indicated no difference between chemical treatments and the check. Although early symptoms were not obvious, drift or root uptake by check plants from adjacent plots may have occurred. Lantana plants outside the trial plots were larger and more vigorous than those in the check plots.

CONCLUSION

Even after two applications lantana plants began to recover from severe suppression from metsulfuron 6 months after treatment regardless of surfactants used. However the lowest metsulfuron rate used was either sufficient or greater than necessary to severely suppress lantana. The severe injuries induced by metsulfuron indicated that metsulfuron has potential for lantana control perhaps with the exploitation of annual droughts in dry areas and mechanical control in wet areas to extend the period of stress on lantana.

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HERBICIDES AND WATER QUALITY

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ABSTRACT

Increased public concern about agricultural chemicals in ground water has resulted in increased research and extension funding in the USA. Some states are developing Geographic Information Systems (GIS), such as the Hawaii Natural Resource Information System (HNRIS), as decision-making aids. HNRIS consists of geographical databases, computer hardware and software to permit data collection, storage and retrieval, and utilized appropriate models. The Attenuation Factor (AF) model is being used in HNRIS to evaluate herbicide contamination potential in Hawaii. The advantages and disadvantages in the use of simple models may not be valid, interpretation of the output from systems that use such models must be limited. However, even with its limitations, GIS systems such as HNRIS are becoming important decision aids and their usefulness will improve as better databases and pesticide assessment models are developed.

INTRODUCTION

There have been several recent reviews on herbicides and the environment, therefore this presentation attempts to increase an awareness of policy changes that have resulted in shifts in herbicide research and extension programs in the United States.

There are increasing concerns about the safety of pesticides in the food supply and in the environment. We will not debate whether these concerns are justified, but few would question that public concern on this topic has heightened. There are differences in opinion on this topic. For example, the National Research Council (NRC) in the USA published a document entitled "Alternative Agriculture" (Pesek, 1989), which had strong message for agricultural production with less use of pesticides and inorganic fertilizers. The Council for Agricultural Science and Technology (CAST) was requested to review the NRC report. CAST's review was published in July 1990 as Special Publication No. 16 entitled "Alternative Agriculture Scientists' Review (Jordan, 1990). The review noted the differences in opinion among the scientists who reviewed the NRC report. It appears that most scientists were critical of the report. In contrast to the general public, most scientists appeared to be

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satisfied that the pesticide use regulations in place are providing sufficient safeguards for limiting pesticides in the food supply and environment.

However, the increasing public concerns have clearly driven action by policy makers (such as the US Congress) and funding agencies. We will outline these changes, particularly with the United States Department of Agriculture (USDA) and describe examples of the kind of research programs that are being conducted in land grant institutions in the USA. In response to the need for sound, orderly information on this topic, many states are developing Geographic Information Systems (GIS). We would like to illustrate the development of a GIS, and the necessity for pesticide models used in conjuction with the GIS technology to be tested thoroughly before these systems can be implemented effectively.

ENVIRONTMENTAL ISSUES RECEIVE INCREASED RESEARCH SUPPORT

The National Research Council in the USA published in 1989, a document entitled "Investing in Research A Proposal to Strengthen the Agricultural, Food and Environtmental System" (Hullar, 1990). That report states that a major reason for the increasing emphasis on natural resources and the environtment is the growing number of contaminants from agricultural production, found in underground water supplies. They propose that support for agricultural research be increased by $500 million annually, with one major initiative being a focus on natural resources and the environtment.

"Research Agenda for the 1990s" (Clark, 1990) is a strategic plan for the State Agricultural Experiment Stations. This document notes that production agricultures issues have been the principal focus, while minimal efforts have been placed on the environtment, food processing, marketing and safety. The new agenda emphasizes the quality of life for American citizens at the forefront of agricultural research. In the area focussing on the environtment and natural resources, protectingg water quality is an important issue.

The Joint Council on Food and Agricultural Sciences is another very important policy-making body. It is interesting to note the change in priorities established for the years 1985 to 1990 (Hullar, 1989). In 1985, "Maintaining water quality" ranked seven out of seven priority issues. In 1989, and again in 1990, "Maintaining water quality" ranked first of the same seven priority issues.

Clearly several different bodies are emphasizing the need for more research on issues related to herbicides and water quality, and reprioritizing funding accordingly.

The U.S. Department of Agriculture and Its Role in the Water Quality Crisis

There is active interest in the effects of agricultural practices on the quality of subsurface waters (groundwater). While there are localized instances of groundwater contamination from agricultural chemicals, the situation is not catastrophic; but prevention would be the best cure. The USDA respons to public concerns, especially when they are reflected through the Congress.

The USDA has had a long-standing effort to address the matter of "non-point" pollution of surface waters from agricultural operations; and has recently re-directed attention toward the impacts of agricultural chemical on groundwater. The justification to this re-direction rests upon the level of public concern, and on the fact that over one-half of our population depends upon groundwater for drinking water. Technology exists to remove contaminants from drinking water, but the cost is not trivial or transient, and the disposal of the contaminant-removal media is also problematic.

The Extension Service (ES), USDA in cunjunction with Cooperative Extension in the various states, announced its "National Initiative in Water Quality", in January 1988. In response to the announcement of a "Presidential Initiative on Water Quality" in February 1988, the USDA developed and implemented a number of specific programs to address agricultural impacts on groundwater quality. This Departmental program has resulted in the establishment of additional programs to meet the goals of the USDA water quality initiative. These programs are based upon the premise that educational and technical assistance programs are efficient and cost-effective ways to change peoples practices from water-quality threatening ones to water-quality sensitive ones, and to reduce agricultural impacts on water quality.

The Cooperative Extension System (CES) is a three-way partnership among the governments of the federal, state and local levels. It was originally instituted to provide educational programs for farmers who were physically isolated from the State Experiment Stations and the Land Grant Colleges, where almost of the agricultural research was done. The System has persisted because it is a proven mechanism for the rapid transfer of information and technology from those sources to the agricultural community.

The Sustem identified four major issues affecting water quality and the rationales for each:

Issue 1 : What is the nature of our water resources? Rationale: If people understand the nature of the resource, they will be able to envision how their actions might impact the resource.

Issue 2 : What are the impacts of agricultural, industrial and household chemicals on the water resource, water users, and water uses? Rationale: If the impacts are identified and understood, it will be possible to design or adopt practices to minimize such impacts. The matter of relative contributions must be understood to develop rational priorities.

Issue 3 : What can domestic, agricultural and municipal water users do to conserve their water resources, and to protect or enhance its quality? Rationale: Water quantity is becoming a major issue in many areas, and it must be addressed. Quality and quantity issues are linked, since a shortage of water precludes definitive concern about its quality.

Issue 4 : What can private citizens and or local governments do to address the public concern about the interactions of land use, chemical use, and water quality? Rationale: Unless solutions can be suggested, identified, or developed, the matter of water quality becomes moot. Moreover, many of the decisions that will impact upon water quality are policy decisions, at the personal or local government level.

In addition to these national issues, the System has been involved in defining other areas of concern, identifying more specific approaches to dealing with these general issues. We have identified a number of important internal foci for specific state programs. These are: 1. Pesticide management 2. Plant nutrient management 3. Animal waste management 4. Wellhead protection 5. Public policy 6. Staff development

In addition to these internal programs, the ES is also involved in a massive USDA effort to demonstrate the responsiveness of American agriculture; these include demonstration projects, hydrologic unit area projects, and the Midwest Systems Evaluation Areas.

The ultimate test of the sincerity of governments and agencies to deal with identified problems is the reallocation of resources or the provision of new ones. The USDA's budget for water quality programming has been increased from $110 million in 1989 to $202 million in 1991. During the same period, the CES has increased its resources devoted to water quality from $18 million to about $40 million. Both the increased allocations from the US Congress, and the reallocation of resources from within federal and stage agencies, indicate the importance of the water quality issues within the USA.

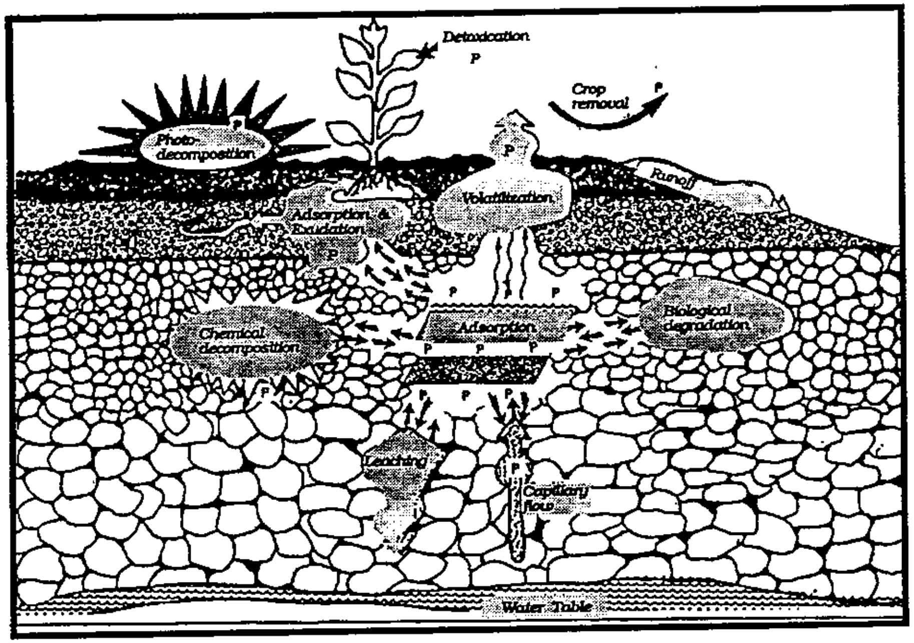
HNRIS Applications for Herbicides and the Environment

An example of the increased sensitivity to agricultural chemicals in the groundwater, and the increased state and federal resources being directed toward this issue is the Hawaii Natural Resource Information System (HNRIS) (Liang and Khan, 1986) as a decision-making aid.

The Environmental Protection Agency (EPA) has proposed two criteria for classifying pesticides as candidates for restricted use (EPA, 1991). These criteria based on various combinations of the measured persistence and mobility of a pesticide ingredient and its detection in groundwater in a specified number of counties/states at levels greater than 10% of Maximum Contaminant Level (MCL). While these criteria are simple to understand and easy to implement, their two important disadvantages are the need for extensive well monitoring and the inability to account for variations in hydrogeologic factors important in pesticide leaching. To monitor or predict chemical pollution by measurement is not feasible. Generally studies are done with one set of pesticides in one set of hydrogeologic environment. Funds will not be able to conduct research on every pesticide usage pattern over a wide variety of geological formations. Predictive models may hold the key to determining where pesticides can be used safely (Kearney, 1987). Numerous methods for single site evaluations, ranging from simple indices to complex simulation models, that account for soil and climatic factors, have been proposed to overcome these shortcomings. The hydrogeologic factors vary spatially, hence to apply these schemes to assess large areas, hydrogeologic properties of all sites in an area are needed. Thus, the application of GIS technology is very useful for this type of analysis.

Pesticide screening criteria The problem of predicting the contamination potential of a pesticide is complex, as illustrated by the intricate pathways and processes involved in pesticide loss (Figure 1). Besides the chemical properties of a pesticide, there are many soil and climatic factors affecting pesticide fate such as, soil bulk density, particle density, organic matter content, permeability, rainfall, temperature, crop type and depth to groundwater table. Numerous procedures for the assessment of pesticide contamination potential have been proposed which take into account the important soil and climatic factors seen as shortcomings of the EPA pesticide screening criteria.

One simple but widely used scheme, from which the EPA criteria are derived, is to classify pesticides in terms of their persistence and mobility in soils. Basically, pesticides are grouped by their partition coefficient and half-life and those very mobile and very persistent have a high probability of leaching in vulnerable environtments (Cohen, 1984; Gustafsan, 1989). This scheme, for example, designates atrazine as moderately persistent and highly mobile, with medium surface loss potential and large leaching potential. Other site assessment methods include tabulation of chemical and hydrogeologic factors believed to affect pesticides movement (Jones, 1987), weighted indices such as DRASTIC (Aller *et al.*, 1985), physically based simple models (Rao, *et al.*, 1985; Mahmood and Sims, 1986), simple simulation models such as CMIS (Nofziger and Honrsby, 1985) and complex simulation models (Davidson, *et al.*, 1968; Rao and Jessup, 1982; Carsel *et al.*, 1984). Some of these models are quite complex even for a single site evaluation. What makes it even more difficult is that the problem of herbicides in the environtment is spatial in nature. The



P = pesticide

Adapted from Herbicide Injury, Symptoms and Diagnosis, Skroch, W.A. and Sheets, T.J. (eds.), North Carolina Agricultural Extension Service, AG-85, Dec. 1981

Figure 1. Simplified representation of major pesticide loss pathways in the environment.

complex simulation models, require a large number of soil, crop, climate and pesticide parameters. The cost of obtaining these data can be prohibitive. Therefore, simpler, preferably physically based, models are needed (Kearney, 1987).

Rao *et al.* (1985) proposed a relatively simple physically based model for estimating pesticide attenuation factor. Attenuation Factor (AF) is an index of relative likelihood of groundwater contamination computed on the basis of the percent of applied chemical leaching beyond the surface soil, and is computed from the equation below.

AF = $\exp[-(0.693\ L_{gw}.RF.FC)/(q.t_{1/2})]$ where,
$t_{1/2}$ = half life of pesticide, yr
L_{gw} = distance to groundwater, m
BD = bulk density, Kg/m^3
K_{oc} = sorption coefficient, m^3/Kg

AC = air-filled porosity, (P-FC)
PD = particle density 2,650 Kg/m^3 (2,800 for Hawaii soils)
q = net groundwater recharge, meter/year
RF = $[1+(BD.OC.K_{oc})/FC + (AC.K_h)/FC]$
OC = organic carbon, fraction by weight
FC = field capacity, fraction by volume
P = (1-BD/PD), dimensionless
K_h = Henry's constant, dimensionless

AF values range from zero to 1; a value of zero implies that none of the applied chemical is likely to contaminate the aquifer, whereas a value of 1 indicates that all of the chemical may leach into an aquifer. Therefore, the chemicals can be arranged in the order of their AF values to evaluate their contamination potential at a site, or for a given chemical the parcels of land in an area can be evaluated for their relative susceptibility to contamination.

Spatial analysis system for pesticide screening To apply the site evaluation procedures to large areas, the hydrogeologic properties of all sites in an area are needed. Even for a simple model, such as AF, the values of BD, PD, OC, FC, Lgw, etc. are needed for all sites. The task of compiling, inventorying and managing these data can be enormous. Furthermore, since the data are spatial in nature, these must be georeferenced for input to spatial analysis procedures. This task is well accomplished by the application of the GIS technology.

GIS technology A GIS consists of geographical databases, computer hardware, software and overall organization. The GIS software includes components for data collection, storage and retrieval, and spatial modelling. In its simplest form a GIS may be described as an internally referenced, automated spatial information system designed for data management, mapping and analysis (Berry, 1987). The most common notion among all GIS is spatial data processing. Spatial data occurs in three forms, points, lines and polygons or areas. A vegetation stand or soil type appears on land as a polygon. Streams and roads are lines and road intersections, or insect trap locations are points. In a similar fashion, all features of the landscape can be reduced to one of these three spatial cate categories. Before any GIS techniques can be used, information from maps, reports and field observations must be made compatible with the GIS. This process is facilitated by such tools as digitizers. Most GIS packages provide facilities for managing this information and studying the interrelationships of the data layers residing within the system. The most useful component of a GIS is the mapping capability. This allows generation of graphic products which convey information from the database as well as the information layers resulting from the analysis of the original data layers. HNRIS (Liang and Khan, 1986) is a state-wide GIS especially developed for studying problems relating to agricultural, environmental and land use planning issues. Figure 2 provides an overview of the system.

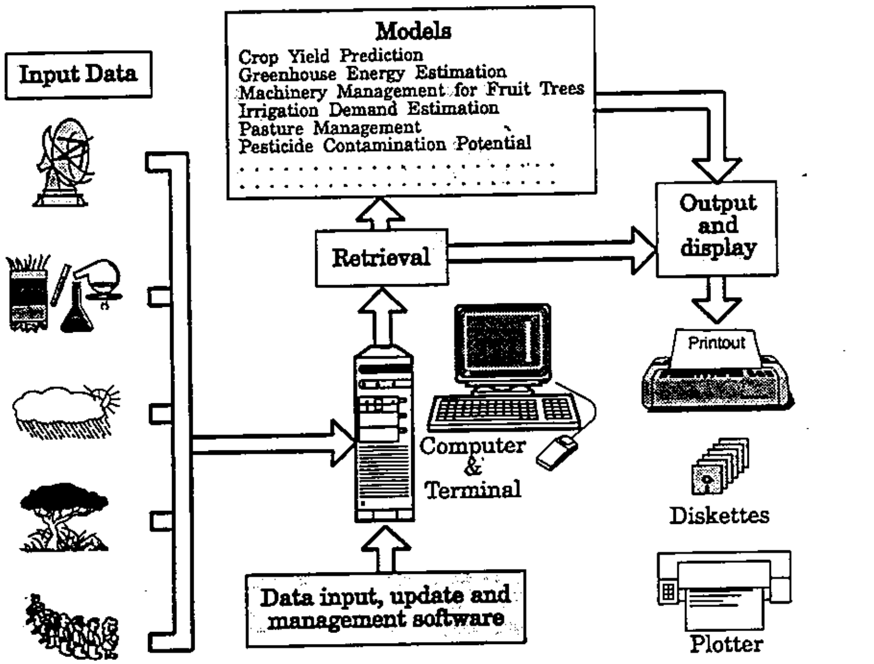


Figure 2. An overview on Hawaii Natural Resource Information System (HNRIS) showing databases, models, and input/output components.

Site assessment models can be linked with a GIS for spatial assessment of pesticide contamination (Khan and Liang, 1989). Because the AF model is simple and its ability to screen pesticides has been tested against other indices (Rao, *et al.*, 1985) and more sophisticated PRZM (Kleveno *et al.*, 1991), it was employed to evaluate atrazine contamination potential on the island of Maui, Hawaii (Figure 3). The relative likelihoood of land parcels to atrazine contamination is shown in various shades of gray. The darker the shade the more likely is the susceptibility to atrazine leaching compared to the less dark parcels. The likelihood of atrazine contamination at a single site is not to be taken as absolute. Thus linking a site model with a GIS for spatial assessment provides a convenient means of quickly assessing a large number of pesticides for a large number of sites.

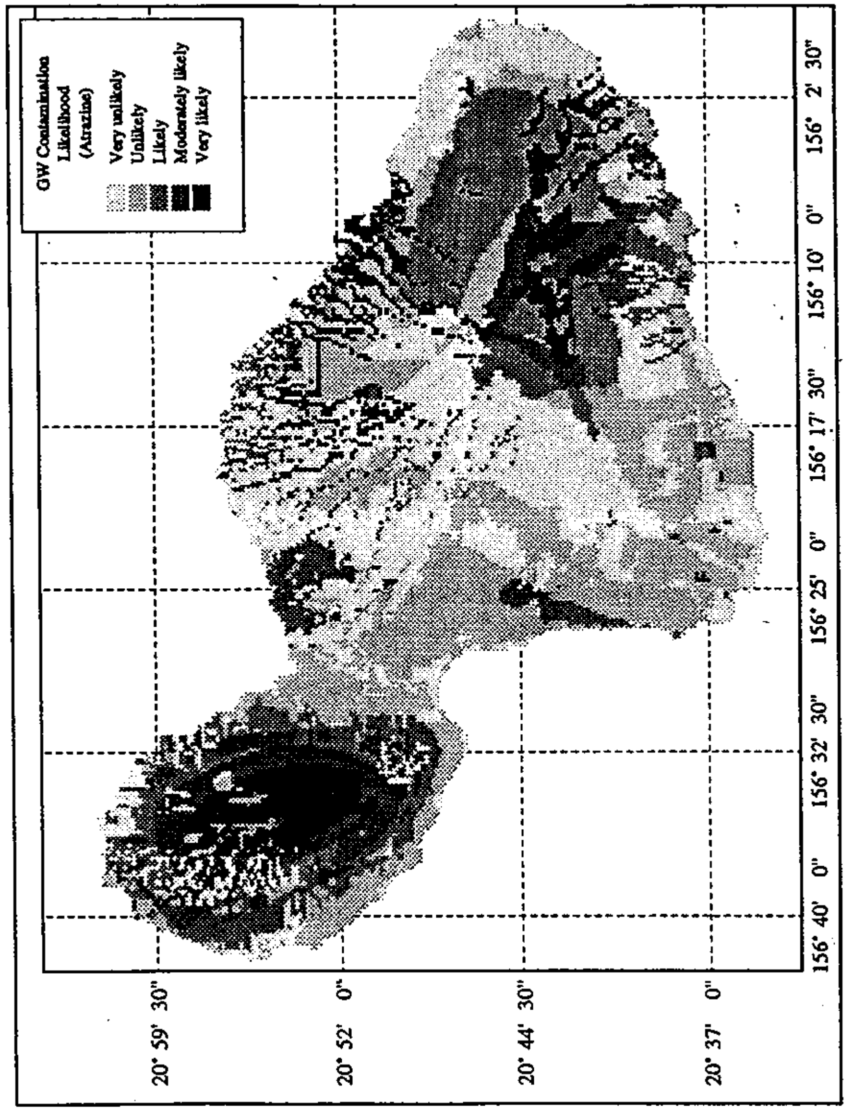


Figure 3. Relative atrazine contamination likelihood based on the AF model for the island of Maui, State of Hawaii.

Need for systems analysis approach A site assessment model such as AF, by itself, does not provide sufficient information for pesticide use regulation. There are concerns about the accuracy of the model input data (Loague *et al.*, 1989), and the model is not designed to make precise predictions even if the input data were absolutely accurate. More importantly, the scale used in Figure 3 for classifying a value of AF as likely or unlikely is somewhat arbitrary.

As yet there is no concise method for deciding when and where a given pesticide should be restricted. Assessment by a computer model is only one piece of helpful information. For the decision-making process, one must understand the entire system: the problem, its extent, circumstances surrounding it, and its seriousness. Only then can corrective/preventive measures be taken to protect the environtment and public safety. Regulators must use scientific judgement based on the circumstances in conjunction with mathematical analysis. Any methodology that can provide them with additional relevant information is helpful. To that effect, the GIS technology is being explored. Its usefulness is demonstrated here by employing HNRIS to analyze the atrazine groundwater contamination problem on the island of Maui, Hawaii.

The Department of Health (DOH), State of Hawaii, monitors the presence of pesticides in groundwater wells. The usual methodology of the herbicide monitoring program is to collect and tabulate data to develop strategies for water pollution control. Numbers in tables are not easily translated into useful information displays, particularly on spatial basis. For this purpose, maps are the ideal tools. Table 1 is an example of the summary of these records for the island of Maui. The results show that atrazine was found in a number of wells in concentrations equal to or greater than the detection limit.

Such a finding generally prompts an assessment of the pesticide use and its contamination potential. The common procedure is to tabulate values of variables considered important in pesticide movement, such as soil organic matter, bulk density, field capacity, pH, rainfall, crop grown, etc. (e.g., Jones, 1987). An attempt is then made to correlate the presence of pesticide in groundwater with these variables. This information is then used to make predictions about other sites. A discussion something like this can follow such a table. Conditions at site A are similar/different to those at site B with respect to rainfall, soil properties, etc., hence the pesticide leaching potential should be more/less at one site versus another. The procedure is very cumbersome, if not impossible to conduct over a large area. It would be very difficult to do this for our example case of atrazine on the Island of Maui. A properly designed GIS, however, allows many ways to look at the overall extent of this problem as illustrated below:

Table 1. Partial summary of well monitoring data on the island of Maui from the State of Hawaii, Department of Health, Groundwater Protection Program

Well Type[a]	Well Number	Well Description	Sample Date	Lab.[b]	Contaminant	Conc. (ppb)	Detec. Limit
D	6-5616-?	Feehan's Well	10-??-84	MLP	DiBrClpropane	0.040	0.010
Z	6-5519-01	Haiku Elem.	08-10-81	UH	DiBrClpropane	0.010	0.010
I	6-5423-02	Paia HC&S	07-30-85	USGS	Atrazine	0.600	0.100
D	6-5739-02	Kaanapali P-6	07-31-84	UH	TriClpropane	0.370	N.Q.[c]
I	6-5321-01	Kaheka Pump 18	03-12-85	DOH	DiBrClpropane	0.048	0.020
I,D	6-5522-01	Kuau Pump 12	03-04-85	DOH	TriClpropane	0.430	N.Q
					Ethylene DiBr	N.Q	0.020
I	6-5420-01	Maui High Sch	03-04-85	DOH	Ethylene Di Br	0.067	N.Q
D	6-5838-01	Napili Well	03-16-85	DOH	TriClpropane	N.Q	0.200
I	6-5224-02	Puunene HC&S#9	08-21-86	HSPA	Atrazine	0.050	0.050
D	6-5128-02	Puunene S 16	08-21-84	USGS	Atrazine	0.100	0.100
D	6-5430-01	Waiehu	12-01-87	MULTI	Bromacil	1.300	1.000
D	Ditch	Waihee Ditch	10-25-85	HSPA	Atrazine	0.060	0.050
I	6-5340-1	Waihikuli	07-29-85	USGS	Atrazine	0.400	0.050

[a]Key to well types
D = Potable water; water used for drinking purposes
I = Irrigation well
Z = Not used or closed

[b]Key to laboratory names
HSPA Hawaiian Sugar Planters Association
DOH Department of Health
USGS United States Geological Survey
MLP Maui Land and Pineapple Company
UH University of Hawaii Agric Biochem Laboratory
MULTI Multi-Tech Laboratories, Inc.

[c]NQ. = Not quantifiable

Where is the contamination First we can simply plot all the observation wells on the island of Maui, and look at the location of those wells contaminated with atrazine (Figure 4). This provides considerably more information than Table 1. We see that the distribution of observation wells is not uniform on the entire island. If a pesticide is not detected in the observation wells, it does not mean that all wells on the island are free from pesticide. There may be other sites with characteristics that make them more vulnerable to contamination than represented by the observation sites. This points out the need for carefully planning monitoring schemes.

The contaminated well map can be used in conjuction with simple pesticide mobility and persistence classification (Cohen, 1984; Gustafsan, 1989). If atrazine is found in some wells, then other less persistent and more mobile herbicides are also likely to leach at those sites.

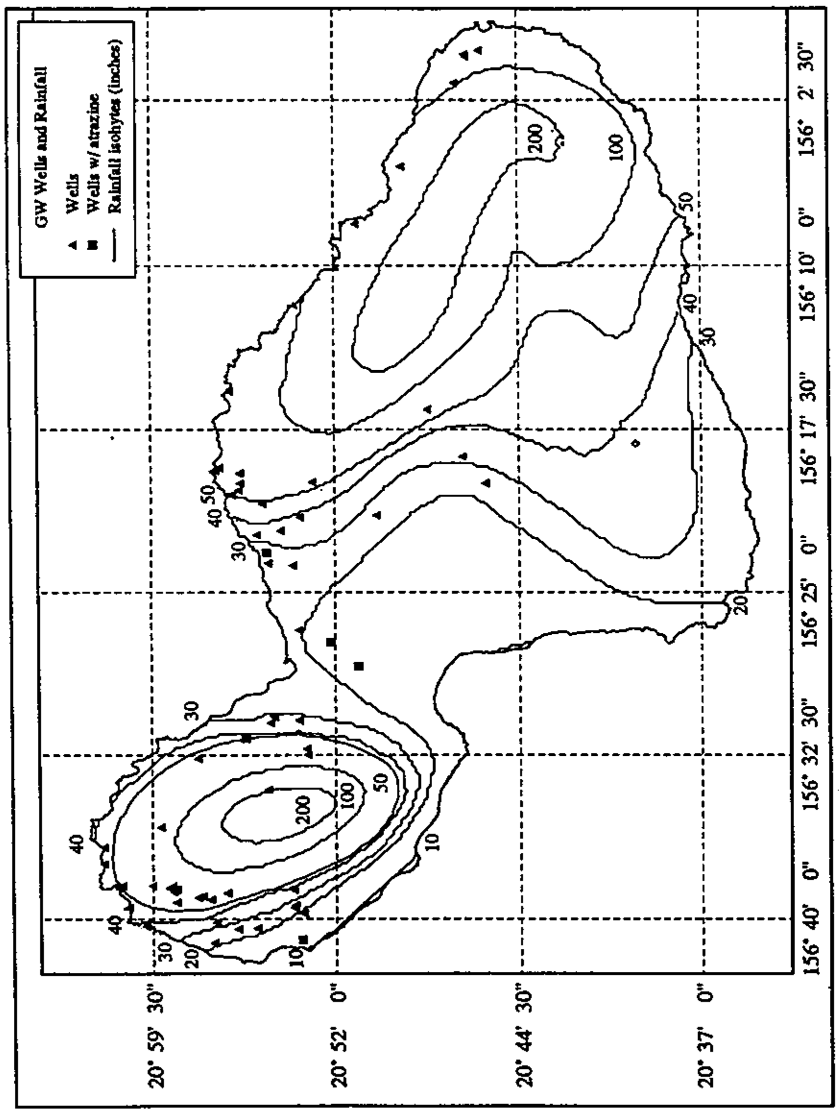


Figure 4. Ground water wells monitored by the State of Hawaii, Department of Health, Ground Water Protection Program. Five sites are contaminated with atrazine.

Are hydrogeological factors responsible Since organic matter content of asoil determines K_{oc} and therefore, the mobility of a pesticide, a map showing distribution of organic matters content (Figure 5) provides information on relative mobility of a pesticide over an area, everything else being constant. This, of course, is very unlikely over a large area. For example, there are many sites with equal organic matter content but distinctly different rainfall, a predominant driving force in pesticide mobility. The map shows that for the sites with the same amount of organic matter, both contaminated and uncontaminated wells occur. This reinforces the point that pesticide mobility assessment should not be based on a single influencing factor.

Are management factors (crops. application methods/timing factors) responsible A common application of a GIS is creating overlays of various information. To illustrate the usefulness of such a simple application of GIS for studying the problem of atrazine on Maui, a number of maps were created using HNRIS. Figure 6 shows an overlay of wells contaminated with atrazine on a layer of present land use. It is evident that the contaminated wells are in or near sugarcane fields. The most obvious reason for this is that atrazine was applied to sugarcane, thus it is likely to leach to underground water. However, there are some wells in sugarcane fields where atrazine has not been detected. This could have been due to the differences in soil and climatic differences.

What is the seriousness of the problem: what actions should be taken Figure 7 shows an overlay of atrazine contaminated wells over groundwater-aquifer type layer. While this information does not help in establishing the cause of atrazine contamination, it is useful in health related actions. The figure shows that two of the contaminated wells are in brackish basal water. Since these waters are not used for drinking, there is no risk to the human population and, hence, there is no reason to take any restrictive action. The other three wells are in diked and basal waters which are used for human consumption. There would be a need for corrective action if the concentration of atrazine exceeded minimum acceptable levels (MCLs). This analysis and observations illustrate how a GIS like HNRIS can be useful for evaluating pesticide related problems.

At present there is no one method which can accurately predict the fate of pesticides in the environtment, and thus can be used for pesticide use regulation. Mathematical models have potential for contamination assessment and possess the advantage of being less expensive than monitoring and experimental measurements. However, models alone are not sufficient for pesticide regulation. There is a need for a systems analysis approach which considers all relevant issues in the area under consideration. The ability of the GIS technology in integrating a large amount of spatial information makes it a useful tool for the pesticide use regulator. It's usefulness will improve as more

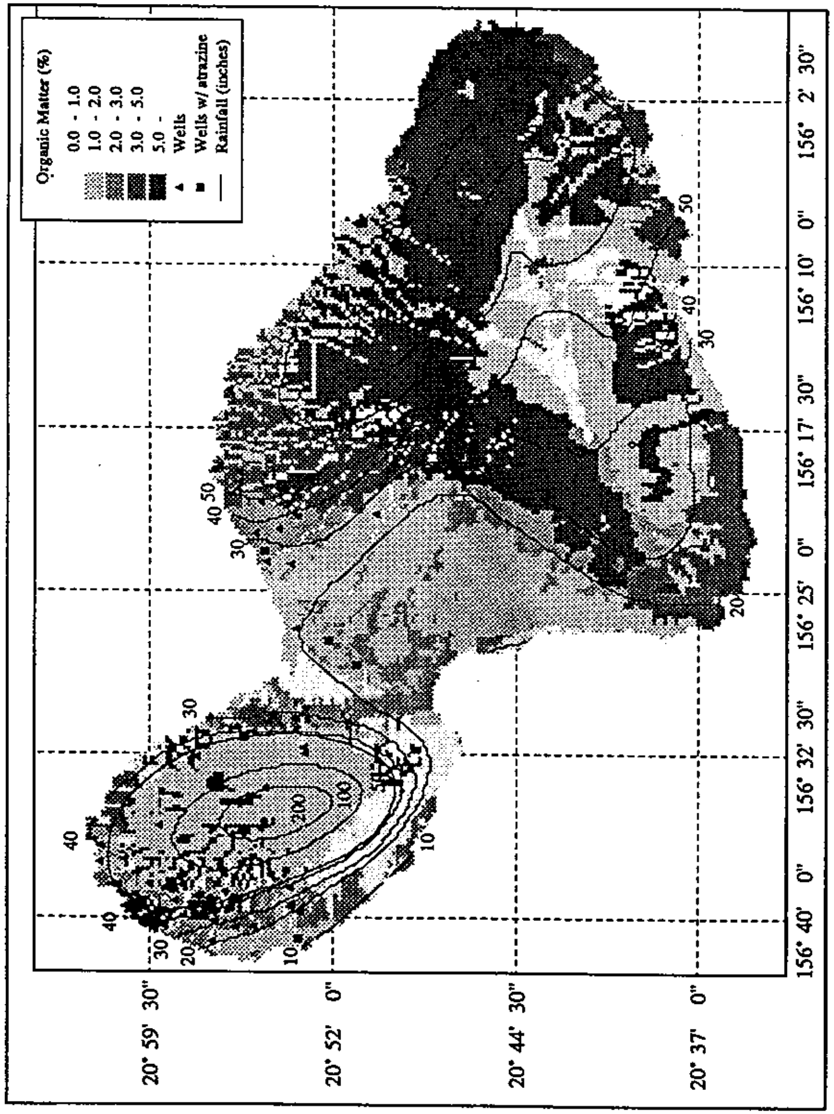


Figure 5. A map showing the distribution of organic matter content of soils.

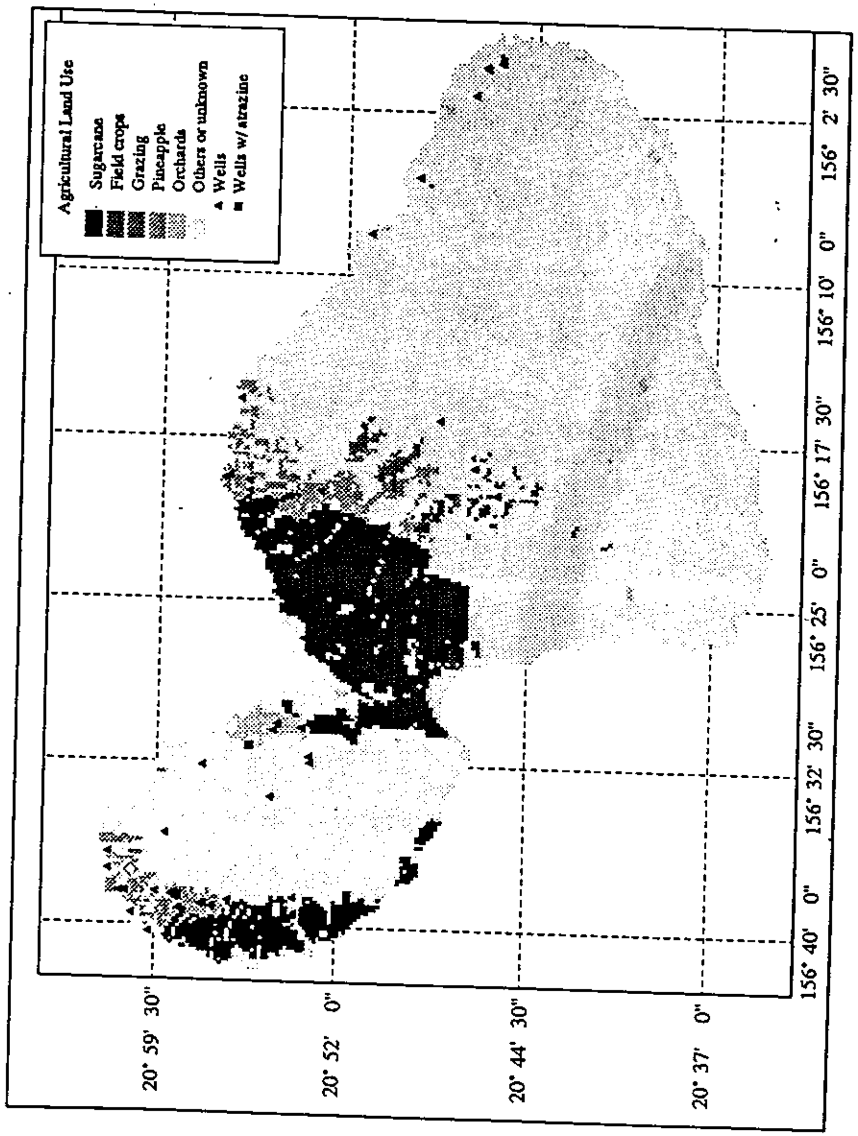


Figure 6. Location of atrazine contaminated wells in relation to present land use. Contaminated wells are mostly in areas producing sugarcane.

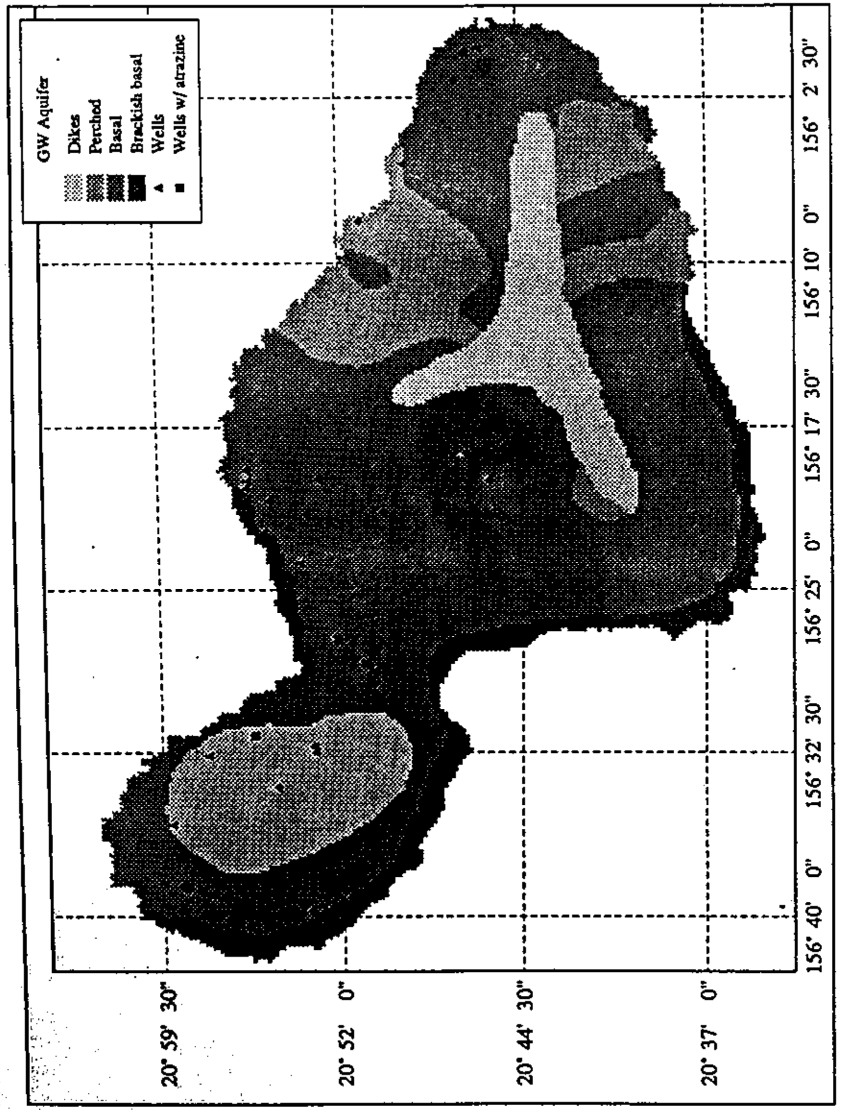


Figure 7. Overlay of atrazine contaminated wells with groundwater aquifer types. Contamination of two of the wells, underlain with brackish aquifer is not critical

spatial data become available in the GIS format and better pesticide assessment models are developed.

EVALUATION OF THE MODEL USED IN HNRIS AND THE INPUT DATABASE

Models must be tested and their limitations understood in order for GIS systems, such as HNRIS to function effectively. The AF model (or index) used in HNRIS is a simplified mathematical representation of chemical movement and dissipation in soils. It is actually more theoretically based than most indices of chemical movement that have been proposed (there have been several). It has its origin in the advection-dispersion equation for solute movement in soils with both sorption and degradation processes represented. However, it does not include some important processes, such as solute dispersion and water flow dynamics. The AF model uses annual water recharge for an area, and thus not take into account the timing of rainfall or irrigation with respect to the time of pesticide application. It also assumes a homogenous profile in the computation, although a layered soil can be accomodated. In defense of the use of AF is some evidence that it compares favorably with more complex and rigorous models in the ranking of pesticides with respect to their likelihood to move to groundwater (Rao *et al.*, 1985; Kleveno *et al.*, 1991). In fact, it is questionable whether the use of a more detailed model would be advisable in view of the high demand of such models for input data and the corresponding paucity of the appropriate data to implement the models. Mathematical models of chemical movement are, therefore, limited in their application by (1) their failure to accurately represent actual physical and chemical processes which control chemical movement and dissipation, and (2) by the uncertainty inherent in the input data required by models. In the application of the AF model in HNRIS for pesticide leaching assessments for Hawaii, it is necessary to use existing data for soil properties, climatic variables, and pesticide properties. Assessment of the reliability of these data has been a high priority for the Hawaii project since its inception about 5 years ago. An inter-disciplinary team of researchers has cooperated to establish the statistical variability (as represented by the standard deviation) of each input variable and evaluate how the uncertainty in each variable impacts upon the reliability of the computed AF index for a given pesticide-soil-climate situation. The characterization of uncertainty in AF computations will be an important consideration in determining the exent to which the model results will contribute to the decision protocol used to regulate pesticide use in the state (Loague *et al.*, 1990). The impact of uncertainty in recharge calculations on AF has been analyzed by Giambelluca (1991). Variability of chemical properties was assessed by Oshiro *et al.* (1991). Soil property uncertainties and their effect on AF reliability have been examined in detail (Loague *et al.*, 1989, 1990); some of the results are presented below to illustrate the nature and impact of soil property variability.

Variability in soil properties The soil properties required for the AF calculation are soil organic carbon, field capacity water content, soil bulk density, and particle density. In general the most variability was contributed by soil organic carbon, a property which is relatively easy to measure but which is not often given much attention in soil survey and characterization. Soil data obtained as part of soil surveys constitute the principal source of soil data in the GIS system used to calculate AF indices for various land areas in Hawaii. Such data were not originally collected with the intention of using them for water quality assessments, thus both the quality and quantity of data are sometimes lacking. All of the necessary soil property data are not often available for each soil series, thus it is necessary to accumulate data for higher soil categories in the soil taxonomy. The HNRIS system presently represents soils at the series level when available. Subgroup of Greatgroup levels are used when data are not available at the series level. Variability in soil properties tends to increase as one moves up toward more inclusive taxonomic categories. The most inclusive category in the U.S. Soil Taxonomy is the Soil Order. Different soil orders tend to vary in the reliability of data which can be used in calculating AF. The following results in Table 2, taken from Loague *et al.* (1990), show the standard deviation for AF (S_{AF}) calculated for diuron with data for five soil orders in the Pearl Harbour Basin in Hawaii. Three conclusions are immediately apparent from the results: 1) The AF values are quite small, suggesting that diuron is not a likely leacher on most soils (for diuron this is principally the result of high sorption on soils with relatively high organic carbon); 2) The AF values for different soil orders are very different, ranging from 6.8E-3 for Ultisols to 1.3E-21 for Inceptisols; 3) The variation (uncertainty) of AF within each soil grouping is very high, such that S_{AF} is about an order of magnitude greater than AF for most orders. The consequence

Table 2. Attenuation Factor (AF) and standard deviation for AF (S_{AF}) for diuron for five soil orders, Pearl Harbour Basin, Hawaii[a]

Soil order	No. soils	AF	S_{AF}
Inceptisols	88	1.3E-21[b]	9.3E-20
Mollisols	42	3.5E-13	1.1E-11
Oxisols	55	1.1E-7	2.7E-6
Ultisols	41	6.8E-3	3.8E-2
Vertisols	14	1.8E-10	4.7E-9

[a]From Loague *et at.* (1990)
[b]E-21 denotes the base 10 exponent, i.e. 10^{-21}

of this last observation is that any ranking of diuron-soil combinations with respect to leaching likelihood based on AF (or a similar pesticide leaching index or model result) must consider the variability of AF.

An effort is currently underway to develop an expert system which will compute both AF and S_{AF} for a given pesticide-soil combination at any soil taxonomic level and incorporate the uncertainty information into the interpretation of the likelihood of pesticide leaching (Yost *et al.*, 1991). In addition, the soil variability information is being used to assess the benefit of additional soil sampling for the purpose of improving the data base (Loague and Green, 1990; Yost *et al.*, 1991).

Model evaluation In utilizing models we know from the outset that many of the required assumptions are not valid. Therefore, it is imperative that we exercise caution in interpreting the model results. Jury and Wagenet (1988) warn that even the best of pesticide leaching models cannot provide reliable estimates of pesticide concentration profiles in the soil or of pesticide concentrations in groundwater for a given situation. They state "The temptation to use models as a basis for making decisions about absolute compliance with regulatory standards must be avoided at all costs". On the other hand, models such as AF can be very useful for ranking pesticide-soil-climate scenarios as to their relative likelihood of contributing to groundwater contamination.

Model evaluation can be accomplished by comparing the results of a simple model like AF with a more complex model like PRZM which simulates dynamic processes not included in the simple model, as has been recently accomplished on the Hawaii project (Kleveno *et al.*, 1991). A more rigorous test is a comparison of model results with field leaching data, an exercise that is currently underway in Hawaii. Field experiments and the associated laboratory analyses are very expensive and time consuming, thus the objectives must be clearly defined and the test locations carefully selected to yield the most useful results for evaluating a variety of models. Data from well executed field experiments can be used repeatedly for testing new models which may be developed in the years to come.

Our experience in Hawaii suggests that the development of a reasonably reliable modelling-GIS approach for advisory application in a regulatory protocol can take a number of years, even when a reasonably good data base exists at the outset. However, the experience in Hawaii and other states in the U.S. that are investigating various modelling options should provide guidance that will shorten the development time in other areas.

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INFLUENCE OF SOIL MOISTURE ON THE POST EMERGENCE ACTIVITY OF NINE SULFONYLUREA HERBICIDES

ANIS RAHMAN[1] AND TREVOR K. JAMES[1]

ABSTRACT

Glasshouse experiments were conducted to investigate the effect of soil moisture levels between 55% and 100% field capacity (FC) on the phytotoxicity of foliar applications of the nine sulfonylurea herbicides, metsulfuron, chlorsulfuron, triasulfuron, sulfometuron, primisulfuron, thifensulfuron, chlorimuron, tribenuron and nicosulfuron. The test species was white mustard (*Sinapis alba* L.) and the soil used was derived from volcanic ash with high field capacity and wilting point values. Results showed a highly significant reduction in damage to plants from all herbicides when the soil moisture was reduced to 55% FC about the time of application compared to the pots watered to 100% FC. Many of the herbicides showed a marked reduction in phytotoxicity also with a drop in soil moisture to 70% FC. The effect of moisture stress was relatively independent of the application rate and could possibly be due to reduced translocation of herbicides within the plant. Adequate soil moisture at the time of treatment appears necessary for optimal effectiveness of the sulfonylurea herbicides.

INTRODUCTION

The sulfonylurea herbicides are being developed for a wide variety of uses. Various members of the group are registered for use in cereals, rice, soybeans, oilseed rape, maize, and for total vegetation control. Others are being developed for use in pastures and for crops such as cotton, potatoes, peanuts and lucerne, as well as for submerged weed control. Safeners are also being experimented with to further extend the crops that these herbicides can be used in (eg Devlin and Zbiec 1990).

Many innovative properties have been attributed to the sulfonylurea herbicides since their development in the 1970s. Their unprecedented levels of activity allow extremely low application rates and they are active against a wide spectrum of broadleaf and grass weeds. The low dose rates and broad weed spectrum, combined with the favourable toxicological profiles of these compounds have allowed them to be promoted as user- and environmentally-friendly products.

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The sulfonylurea herbicides are mainly used as post emergent foliar sprays that rapidly stop plant growth in susceptible species (Beyer *et al.*, 1988). The principal mode of activity is the inhibition of cell division and growth by inhibiting the plant enzyme acetolactate synthase, thereby blocking branched chain amino acid biosynthesis (Ray 1985). Growth inhibition is very rapid, with visual symptoms usually apparent within 1 to 2 days in rapidly growing plants. Tolerance in crops is due to the rapid inactivation or detoxification of sulfonylureas by the plant (Brown, 1990).

The effect of soil moisture on some of the soil related characteristics of the sulfonylurea herbicides has been well characterised by such workers as Beyer *et al.* (1987), Duffy *et al.* (1987). Iwanzik and Amrein (1988) and Amrein and Gerber (1985). They have shown that lowering the moisture content of the soil extends the halflife of the herbicide by slowing both chemical hydrolysis and microbial breakdown, the two principal modes of their degradation. However there is little published work demonstrating the effect of moisture stress due to low soil moisture on postemergence activity of these herbicides, even though some authors (eg Beyer *et al.*, 1988) and most label directions warn of reduced activity on weeds that are under stress, including moisture stress.

The purpose of the present study was to determine and compare the effect of moisture stress in plants on the phytotoxicity of postemergence applications of nine different sulfonylurea herbicides.

MATERIALS AND METHODS

The soil used for these experiments was a Horotiu sandy loam with 61% sand, 19% silt, 12% clay, 9.8% organic carbon, a pH of 5.6, a bulk density of 0.69 kg/l and a field capacity of 42.8%. This soil is derived from volcanic ash and contains 100% allophane as its clay fraction. As it is formed on fine-textured pumice sediments, this soil has a much lower dry bulk density and a much higher field capacity and wilting point than non-volcanic or alluvial soils.

The herbicides used were metsulfuron (Escort 60% a.i.), chlorsulfuron (Glen 75% a.i.), triasulfuron (Logran 15% a.i.), sulfometuron (Oust 75% a.i.), primisulfuron (Beacon 75% a.i.), thifensulfuron (Harmony 75% a.i.), chlorimuron (Classic 25% a.i.), tribenuron (Granstar 75% a.i.) and nicosulfuron (Accent 75% a.i.). All products were formulated as water dispersible granules. Each herbicide was applied at three rates (Table 1) which were expected from initial studies to reduce plant dry matter to 20% to 80% of untreated control.

White mustard (*Sinapis alba* L.) was used as the test species. Twelve seeds were planted in 15 cm diameter pots and seedlings were thinned to eight plants per pot 3 days after emergence. For the first week after planting soil moisture was maintained close to field capacity, after which the pots were allowed to dry out. The soil moisture in the pots was adjusted to 100%, 70% or 55% of field capacity (FC) only two days before treatment, ensuring that all the plants were at the same stage of growth and of similar size at the time of treatment. Thereafter the soil moisture was maintained within 5% of the desired level by weighing and surface watering each day until the plants were harvested 16 to 20 days later.

The herbicide treatments were applied 14 to 16 days after planting when the mustard plants had four true leaves and were 5 to 7 cm tall. Applications were made with a moving belt, single nozzle, CO_2 powered precision sprayer applying 300 litres/ha at 210 kPa. No adjuvants were used with any of the herbicides. The treatments were replicated four times and the pots were arranged in a randomised block design on the glasshouse benches.

The experiment was carried out three times on 2.3.89, 7.5.89 and 3.8.89. For each experiment plants were grown in the glasshouse maintained at temperatures between 20 and 25°C during the day and above 12°C at night. No artificial light was provided. Herbicide response was evaluated by regular visual assessments taking into account the plant height, vigour, colour and other damage symptoms described earlier by Rahman (1989). The top growth of plants was harvested for dry matter determinations 16 to 20 days after application of herbicide treatments.

RESULTS AND DISCUSSION

The most common effect of all sulfonylurea herbicides tested was stunting of the plant growth. The effects were first noticed, however, as a reduction in the number of lobes on the mustard leaves. This effect was in inverse proportion to the rate of herbicide and increased until the leaves were reduced to stunted knobs around the growing point of the plant. Some herbicides such as metsulfuron also caused a reddish colouration to the foliage of damaged plants. Similar primary and secondary growth responses to sulfonylurea herbicides have been described by Beyer *et al.* (1988) and Blair and Martin (1988).

Damage scores in this study based on visual assessments were well supported by the dry shoot weights. All three experiments gave similar results, which were therefore averaged. Dry shoot weight data for the three rates tested are presented in Table 1. With many of the herbicides the highest rate used often killed most of the test plants in the two high soil moisture regimes.

For each of the herbicides there was a highly significant decrease in phytotoxicity when the soil moisture content dropped from 70% FC to 55% FC. Many of the herbicides also showed a highly significant reduction in phytotoxicity with a drop in soil moisture from 100% FC to 70% FC. For the Horotiu sandy loam soil used in these experiments wilting point occurs at about

50% FC so the plants in the 55% FC regime were severely stressed, often showing wilt symptoms during the hottest part of the day. For all herbicides the highest activity was achieved at 100% FC moisture level. Nalewaja and Woznica (1985) have also reported that *Setaria viridis* (L.) Beauv. was best controlled by chlorsulfuron when soil moisture was at field capacity.

Table 1. Effect of different soil moisture levels on the phytotoxicity of nine sulfonylurea herbicides. Dry shoot weight of white mustard as percent of untreated controls means of three experiments.

Herbicide	Rate	Dry matter (% of untreated control)		
	(g ai/ha)	100% FC*	70% FC	55% FC
Untreated	-	100	100	100
Metsulfuron	0.1	76	99	93
Metsulfuron	0.2	31	53	72
Metsulfuron	0.5	1	14	49
Chlorsulfuron	1.0	15	22	42
Chlorsulfuron	2.0	1	1	6
Chlorsulfuron	4.0	0	0	3
Triasulfuron	1.0	14	22	43
Triasulfuron	2.0	1	1	18
Triasulfuron	4.0	0	0	9
Sulfometuron	1.0	27	43	72
Sulfometuron	2.0	4	14	35
Sulfometuron	4.0	0	2	14
Chlorimuron	2.0	5	6	41
Chlorimuron	4.0	1	4	27
Chlorimuron	8.0	0	1	18
Tribenuron	2.0	15	16	51
Tribenuron	5.0	1	2	23
Tribenuron	10.0	0	1	12
Primisulfuron	2.0	25	36	61
Primisulfuron	5.0	2	4	32
Primisulfuron	10.0	1	1	20
Thifensulfuron	5.0	10	19	49
Thifensulfuron	10.0	2	4	29
Thifensulfuron	15.0	0	2	26
Nicosulfuron	2.0	56	76	84
Nicosulfuron	5.0	49	65	70
Nicosulfuron	20.0	27	47	56

LSD ($P<0.01$) between columns (differences due to soil moisture) is 4.6
LSD ($P<0.01$) between rows (differences due to treatment) is 17.8

* FC - Field capacity.

The effect of soil moisture stress was generally not dependent on the rate of herbicide in most cases. This is best demonstrated by the near parallel lines in Figure 1 were the visual damage assessments from the three rates of nicosulfuron are all reduced by similar amounts as the soil moisture level drops from 100% FC to 70% FC to 55% FC.

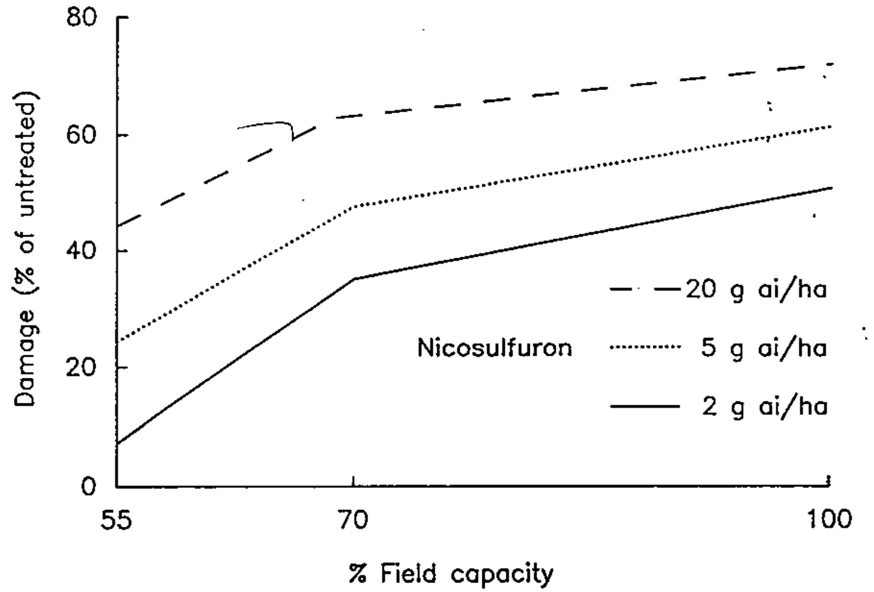

Figure 1. Effect of three rates of nicosulfuron on dry shoot weight of white mustard at three soil moisture levels.

It is not clear from these experiments whether the reduced phytotoxicity of the herbicides was due to reduced penetration of the cuticle or to reduced translocation within the plant. Both of these mechanisms have been reported to reduce the activity of different herbicides in moisture stressed plants. Reynolds *et al.* (1988) demonstrated that absorption of sethoxydim and quizalofop actually increased under conditions of drought stress but that basipetal translocation decreased. Conversely, Blair *et al.* (1983) reported that the reduced activity of glyphosate and ioxynil in stressed plants was partly due to reduced entry into the plant. It is known however that one of the reasons that the sulfonylurea herbicides are so effective at quickly halting plant growth is that being weak acids they are very mobile in the phloem, readily translocating from the point of entry to the meristematic tissues. If this process is affected by the moisture stressed then severely reduced activity is the likely result. This line of reasoning was supported to some extent by the observation that although plants growing at 55% FC showed very little herbicide damage for two weeks after treatment, the phytotoxic symptoms appeared very quickly when the pots were watered in one of the experiments for 5 days before harvesting.

These results show reductions in phytotoxicity either similar to or slightly greater than those reported earlier for many of the grass herbicides and for the two non-selective herbicides glyphosate and glufosinate in experiments conducted under similar conditions (Rahman 1985; James and Rahman 1990).

White mustard is known to be highly sensitive to sulfonylurea herbicides (Rahman *et al*. 1988; Rahman 1989) and the rates used in the glasshouse were therefore lower than the normal field use rates. However, as these experiments were conducted under uniform conditions the results also show the relative activities of the nine sulfonylurea herbicides against a standard test species. Metsulfuron was considerably more active than the other compounds while thifensulfuron and nicosulfuron were the least active. The biological activities of the remaining six chemicals were fairly similar.

The results presented here show that the phytotoxicity of the nine sulfonylurea herbicides included in this study was reduced markedly when the plants were subjected to moisture stress before and after application of the herbicide. Adequate soil moisture is therefore necessary for optimal activity and for ensuring maximum effectiveness under field conditions.

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