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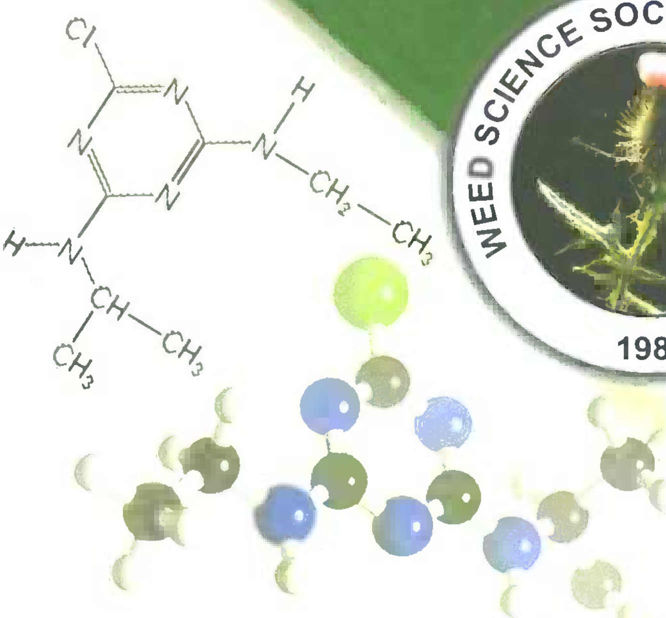

WEED SCIENCE SOCIETY OF PAKISTAN 1987

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1. Contributors do not have to be members, however, copies of journal and reprints will be provided free of cost to the members only.
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3. Common names of herbicides should be used and rates should be given in active ingredients
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   Prasad, K. 1985. Efficacy of post-emergence weedicides applied at different stages in control of annual weeds of irrigated wheat under mid-Himalayan conditions. Pesticides 19(6): 20-22. [Weed Absts., 35(5): 1431;1986].

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ETHICS FOR WEED SCIENCE

Robert L. Zimdahl[1]

ABSTRACT

Those engaged in agriculture including the sub-discipline - weed science possess a definite but unexamined moral confidence or certainty about the correctness of what they do. This paper examines the origins of that confidence and questions its continued validity. The basis of the moral confidence is not obvious to those who have it, or to the public. In fact the moral confidence that pervades agriculture and weed science is potentially harmful because it is unexamined. This paper advocates analysis of what it is about agriculture's moral confidence and its interactions with the greater society that inhibits or limits agriculture's development and contributions. All engaged in agriculture should strive to nourish and strengthen the aspects of agriculture that are beneficial and change those that are not. To do this we must be confident to study ourselves, our institutions, and be dedicated to the task of modifying the goals of both.

Keywords: Weed science, work ethics, agriculture

INTRODUCTION

I begin with a story and a conundrum (a puzzle). In his 1999 book, “The Lexus and the Olive Tree”, Thomas Friedman, the New York Times Chief Foreign Correspondent, tells about the lion and the gazelle. He said, “Every night lions go to sleep knowing that in the morning when the sun comes up, if they can't outrun the slowest gazelle, they will go hungry. Every night gazelles go to sleep knowing that in the morning, when the sun comes up, if they can't outrun the fastest lion, they will be eaten. The one thing lions and the gazelles both know when they go to sleep each night is that in the morning, when the sun comes up, they had better start running”.

My observation is that many colleagues in agriculture are in a hurry; they are running. Everyone seems to be in a hurry to get to work, to lunch, to get home. Life is going too fast. There is not enough time to do all that must be done and very little time left to do what one wants to do. We drive and walk as we speak on our cell phones. We multi-task, work at the office and at home.

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Why are we running? The lion and the gazelle know why they are running. I am not sure we know either why we are running or where we are going. People in developed countries are, on average, 4 $^{1/2}$ times richer than their great-grandparents were at the end of the 19th century. But, they are not $4^{1/2}$ times happier. Greater consumption and more running have not made consumers any happier.

As we run to do so many things, we are trapped by the Conundrum of Consumption. A conundrum is a puzzle that has no satisfactory solution. The conundrum of consumption is an ethical and environmental problem. The conundrum is: limiting the consumer life-style to those in our world who have already attained it is not politically possible, ecologically sufficient, or ethically defensible.

The puzzle (the conundrum) is that if the life-style of developed nations is extended to all who want it, and many do, it will hasten the demise of the ecosystem that all are dependent on *and* it is ethically wrong to harm the system life depends on.

When you get up tomorrow morning, probably sometime after the sun comes up and you begin another busy day, perhaps with a running start, I suggest you think about where you are going and why you are running. We run in our scientific careers to do the experiments, write the papers, or get a grant. We run in our personal life to balance family and work, to care for others, and provide a good life for those we love. We run in our ethical life as we struggle to determine how to know what we ought to do. I ask myself and encourage you to ask if your running, your haste, causes you to miss important things.

Moving to the ethical realm and ethical assumptions, I ask "Does your running lead to greater happiness for you and others? Is achieving happiness for others something we simply assume will follow from our work? Should happiness for others be a goal of our work?"

I think all people may achieve the greatest happiness for themselves and others when their lives and work develop a capacity to feel the pain of other humans. The ethical position of agricultural science and of your research and teaching has a role in creating more or less happiness in the world. It is up to us.

Agricultural scientists have assumed that as long as our research and the resultant technology increased food production and availability, agriculture and its practitioners were somehow exempt from negotiating and re-negotiating the moral bargain that is the foundation of the modern democratic state (Thompson, 1989). It is a moral good to feed people and agriculture does that. Therefore, we assume that anyone who questions the morality of our acts or our technology simply doesn't understand the importance of what we do. We assume that we are technically capable and that the good results of our technology make us morally correct. Berry (1981) questions our assumption and reminds us of our obligation. We have lived by the assumption that what was good for us would be good for the world. We have been wrong. For it is only on the condition of humility and reverence before the world that our species will be able to remain in it.

How Do We Know What To Do?

An important question is - In view of the Conundrum of Consumption: “How do we know what to do?”

During what is called the axial age (900 to 200 BCE) all four of the world’s major religions developed (Islam, Christianity, Hinduism, and Buddhism). Geniuses pioneered entirely new kinds of human experiences. Analysis of the time and what was created shows that what mattered in all religions was not what you believed, not your faith, but how you behaved. Religion was about doing things that changed you. It is one way to determine the right thing to do. By doing, by acting in the world, one can commit to an ethical life. Without self-understanding and self-sacrifice that are part of an ethical life, we will not progress toward the mutual goal of peace.

By the 17th century the scientific revolution marked the beginning of a whole new cosmology and world view that characterizes modern science. Traditional religious beliefs were not rejected but were seen as only indirectly relevant to understanding the natural world. They were no longer the only way to determine the right thing to do.

Comments about how all religions were concerned with doing things that changed you and determining the right thing to do may seem strange inclusions in a talk about ethics for weed science. But they are a useful example of how to determine the right thing to do, how to behave, how to become ethical scientists.

Ethics is also about doing things that change you. Ethical standards lead to the moral life - to live for others. To look beyond self-interest and extend one’s activities to include others are common to all religious traditions[1].

Ethical standards guide people toward abandoning greed, selfishness, violence, and hatred and accepting an obligation to be compassionate toward their fellow humans. If one’s ethical standards compel acting compassionately, to feed the hungry, give drink to the thirsty, welcome the stranger, and visit the imprisoned, regardless of who they are or why they are hungry, thirsty, strange, or imprisoned,

[1]***Islam*** - No one of you is a believer until he loves for his brother what he loves for himself, ***Christianity*** - All things whatsoever ye would that men should do to you, do ye even unto them, ***Confucianism*** - Never do to others what you would not like them to do to you, ***Judaism*** - Thou shalt love thy neighbor as thyself, ***Hinduism*** - Men gifted with intelligence...should always treat others as they themselves wish to be treated, ***Taoism*** - Regard your neighbor’s gain as your own gain, and regard your neighbor’s loss as your own loss.

then such people are good, helpful, and sound. This may be one of the best tests of our ethical behavior in life and in the practice of agriculture.

However, I always ask myself, "How can I determine what to do? How do I know that what I choose to do is the right thing?" My task is to address and perhaps answer those questions. Scientists know what to do through experiments. The scientific **empiricist** goes and looks. We can know **pragmatically**. We test validity by practical results. What works best? Or we can be **skeptical** where the truth must always be in question. Each of these is an acceptable way to determine what is right.

There are other, more common, ways that many people use. We rely on **authority** - the government or a parent (My father says...). We rely on **tradition** - we have always done it this way in my family, church, or community, or in my university or research center. We rely on **legal authority** - it's the law! We can know by **revealed truth** - found in religion. The latter is often done without examination to determine if we think we see the whole world when we tend, often in spite of our best efforts, to see only one aspect and think we have grasped the whole.

Finally, and of greatest importance this morning, we can know what is right by **reason**. Reason is the ability to think, form judgments, and draw conclusions. It requires thought and judgment based on logic and sound reasons. It is not easy.

Many ignore the simple test of their work - their ethical standard. What are the results? If their ethical standard makes them intolerant and unkind, the results are not good, independent of profit, crop yield, or scientific prestige. If, on the other hand one's ethical standards compel acting compassionately toward others (feed the hungry, give drink to the thirsty, welcome the stranger and visit the imprisoned, regardless of who they are or why they are hungry, thirsty, strange, or imprisoned,) then such people are good.

We are all born with a sense of what is right and wrong, but that sense is often unexamined and not supported by careful reasoning. We must strive to be good in our personal lives and in our science.

The truest test of the moral condition of any scientific or other discipline is its willingness to examine its moral condition. As one explores agriculture's dilemmas to determine what ought to be done rather than just what can be done, one finds surprising agreement about the standards used to decide what ought to be done. When we know the right and wrong things to do, there will still be conflicts, and there will still be choices as we seek answers to agriculture's complex problems. There are often no easy choices between what is ethical and clearly not ethical. The choice is between two alternatives, neither of

which is all bad. And the end result of choosing is often not clear when the choice has to be made. Moral dilemmas are common and we need an ethical foundation to guide decisions between two choices where each has strong supporting arguments. For example: 1) Should we increase agricultural production, to feed more people, regardless of the environmental harm the technology that creates the production causes?; (2). Should we raise animals in confinement if it is harmful to the animals but makes meat cheaper for consumers?; (3) Should we mine water from deep aquifers or the Indus river to maintain irrigated farms in dry land areas even though the production system is not sustainable?; (4) Should we change soybean production systems to decrease soil erosion?; (5) Should we decrease nitrogen fertilizer use to reduce effects on fish and ecological stability?; (6) Should family farms be protected or allowed to die because they are economically inefficient, that is, they can't make sufficient profit?; (7) Should the US give more or less food aid to developing countries?;
(8) Should we accept or reject agricultural biotechnology?; and (9) Should we reduce herbicide and other pesticide use?

All the things in this partial list are difficult dilemmas for agriculture and each has a moral dimension. They are not just scientific questions. It is time for all involved in agriculture to think about and address the ethical dimensions of these and similar questions. It is our responsibility to provide the next generation of agriculture's practitioners, scientists and teachers with the intellectual tools required to guide decisions about agriculture's existing and future ethical dilemmas (Chrispeels, 2004).

However, my task today is not to comment on weed management. My task is to provide reasons for moral examination of our science and comment on how it can be done. I begin with three points about science and agriculture*, viz.* (1) Those engaged in agriculture are certain about the moral correctness, the goodness, of their activity; (2) The basis of that moral certainty (the supporting reasons) is not obvious to those who have it, and (3) In fact, agriculture's moral certainty is potentially harmful because it is unexamined by most of its practitioners.

Moral certainty and lack of moral debate inhibit discussion about what agriculture ought to do. Discussions of moral dilemmas will lead to foundational moral theories that provide a guide for change. These theories are guides, not absolute rules. They are the invisible, foundation on which our actions rest. Exploration of the moral certainty posited for agriculture will reveal several principles that can be used to answer important questions about agricultural practices.

The Benefits and Costs of Modern Agriculture

The success of modern agriculture may be the greatest story never told (Sidey, 1998). Few segments of the world's scientifictechnological enterprise have such an impressive record. Developed country agriculture is a productive marvel and is envied by many societies where hunger rather than abundance dominates. Science and technology have created steady yield increases through development of higher yielding cultivars, synthetic fertilizers, better soil management, mechanization, and improved pest control (including weeds). Without yield increases since 1960, 10 to 12 million square miles would be required (roughly the land area of the U.S., the European Union and Brazil) to achieve present food production (Avery, 1997). Modern high yield agriculture may not be one of the world's problems but rather the solution to providing sufficient food for all, sufficient land for wildlife, and protecting the environment.

Agricultural producers are proud of these achievements. In the USA, the food production system is part of a large, vertically integrated commercial system (Blatz, 1995). The family farm as an independent and self-supporting entity is dying. As the number of farmers decreases, land in agriculture remains nearly constant because farm size increases. I suspect a similar, slower process in Pakistan: agriculture accounts for 25% of GDP, supports 3/4 of the people, and employs ½ the labor force.

When small farms and farmers disappear it is usually regarded as progress. There is little concern for the effects of the profit driven system that harms small farmers on the environment on which agriculture and life are dependent. The monetary rewards of the modern agricultural system have been good for the survivors. The social rewards of belonging to a caring community, the spiritual satisfaction of serving a larger public purpose, the communities and the businesses they need and support have been sacrificed to the bottom line (Goldschmidt, 1998). This is neither necessary nor desirable.

Successful agriculture has become a business in which producers seek high production at low cost. Agriculture in developed countries has become industrialized in terms of its size and methods of operation and in its values. The purpose is to produce as much as possible at the lowest cost of capital and labor to generate maximum profit (Blatz, 1995). Production is agriculture's and weed science's single, dominant ethical principle. We have a produce as much as possible ethic

Claims of agricultural abundance are true in many societies. No society should assume its agricultural abundance is assured. The system that produces food should not be treated as one that can manufacture abundance at will (Blatz, 1995). As you know, the weeds will always be with us.

When the foundational values of the any production system ignore protection of the land, maintenance of water quality, and, biodiversity its values are questionable. These are essential parts of production and maintenance of life. When we and the agricultural system regard food as just another industrial commodity that can be purchased by those with money, then the ethics of the system ought to be, and will become, a subject of societal concern.

It is not surprising that the endless pursuit of production and the associated technology conflict with societal values (Thompson, 1989). Agricultural and weed science technology have exposed people to risk. In the past most of the risks of agricultural technology were borne by the user. Now many risks are borne by others. Technology developers, and users, in their moral certainty, have not secured or even considered how to secure the public's consent to use technology that exposes people to involuntary risk (Thompson, 1989). Agricultural producers and the scientific community that supports them by developing technology have been seduced into thinking that, so long as they increased food availability, they were exempt from negotiating the moral bargain that is a foundation of modern democracies. Thoughtful people will not entrust their water, their diets, or their natural resources blindly into the hands of farmers, agribusiness firms, and agricultural scientists. Agricultural people must participate in the dialog that leads to social consensus about risks. They must be willing to understand the positions of their fellow citizens. For most non-agricultural segments of society, these are not new demands. For agriculture and weed science, they are. All who practice agriculture (e.g., farmers, scientists) have been so certain of the moral correctness of their pursuit of increased production that they failed to listen to and understand the positions of other interest groups (e.g., environmental, organic). Agriculturalists have not developed any value position other than the value of production and have not offered reasons why production ought to retain its primacy.

Goals for Agriculture and Weed Science

Production of abundant food and fiber must remain a dominant goal. However, we ought to ask what other goals should be considered and when and why one or more of these may take precedence over production. I do not have time to present all possible goals and will deal only with social and environmental goals.

Social Goals for Weed Science

Aiken (1984) suggested that sustainable, environmentally safe production that meet human needs, and contributes to a just social order may be of greater moral importance than profitable production. This is not the dominant view in agriculture or among weed scientists. Few agricultural voices speak of a just social order. There is no objection to achieving a just social order but it is not my job!

Many in agriculture think sustainability can be achieved by modification of the present, successful system. Achieving sustainability is thought of as a scientific problem. However, because agriculture is the largest and most widespread human interaction with the environment, achieving sustainability will have social and ecological effects.

Agricultural markets are powerful mechanisms, but often they are not just. If they were just, then my country, the world's richest nation, would not have hungry people. Producers need to recognize the connection between what they produce, the market that distributes it, and justice for all. Agricultural and weed scientists speak loudly about production and markets but are usually silent on justice.

As family farms and rural communities disappear, the virtues they instilled in past generations (love thy neighbor, be kind to animals, help those in need, etc.) are still valued by society. One way to encourage these virtues is for them to be prominently displayed in the social purpose of an economically central activity such as agriculture. To accomplish this, all agricultural and weed scientists are going to have to abandon the singular pursuit of production as their only goal and incorporate social goals as part of agriculture. This necessitates developing and then debating the reasons that determine what the right goals are.

Environmental Goals for Agriculture

Environmental goals for agriculture are linked to social goals. Sustainability is regarded by those in agriculture as primarily a production and secondarily an environmental goal, but others see it as a social goal. The view depends on what one wants to sustain. In agriculture, to sustain usually means protecting the productive resource (soil, water, gene pools) and maintaining production. Others argue the productive resource is important, but ranks below sustaining environmental quality, family farms, rural life, small agricultural businesses, and small communities. This debate goes to the heart of what agriculture ought to be. Agriculture has a major responsibility because it is so widespread and has the potential to care for or harm so much land. This is a different view from protecting only the productive ability of land. Land is not simply a productive resource. It is the basis of life. Without the land there will be no agriculture, no life, so land must be regarded as something more than other productive resources (e.g., fertilizer, machines, irrigation water, pesticides, or seed). To harm or destroy the land is to destroy something essential to life, and that certainly raises a moral question.

The challenge of social and environmental goals for agriculture is that they involve values. It is generally not recognized in agricultural science that values are not external to the science and technology but its basis (Capra, 1996). Scientists know they are responsible for the scientific integrity of their work and for its intellectual contribution. They do not as readily assume responsibility for the moral aspects of their work. Science is not value-free, it is value-laden. Moral questions are abundant.

Anyone can dismiss criticism of weed science by saying "Well, it is not true for me." This makes our personal beliefs, our assumptions, absolutely secure, and provides no reason to examine them (Melchert, 1995). How any idea fits our assumptions, especially one that is critical of our profession, is not a reliable guide. It is best to know the arguments, the reasons that support the criticism. In science the data or theory that best explains the observations usually wins. In ethics the best reasons win. It is wise to avoid the temptation to ignore good reasons that disagree with our assumptions. We assume a lot in science, often incorrectly. Here are a few examples of scientific assumptions that were wrong and led to the wrong conclusion, *viz:* (1) Data on historical estimates of the distance from earth to the center of the universe - Copernicus (1473-1543), 0 Kilometers. Distance from the center of the universe - Galileo (1564-1642), 149,000,000 million kilometers. Current estimated distance from earth to the center of the Milky Way Galaxy is 8,000 light years; (2) Data on the estimated number of earth-like planets in the universe in Europe in 1500 = 7. Estimated number of earth-like planets in 2005, 3×10^{21}; and (3) Data on the estimated number of species on earth Linnaeus (1758) = 20,000. Now = 1,500,000 to 1,800,000. Estimated total number of species = 3,600,000 to 112,000,000].

When we think of the future of agriculture, it is important that we see that our scientific and moral assumptions and vision of the future affect (Harman, 1976) how we recommend agriculture be practiced. The research and teaching we do now involves assumptions and a view of a future we expect, desire, or fear (Harman, 1976). Do your running and your scientific assumptions lead to greater success and happiness for others? Does your work yield a moral good?

Most of my colleagues in U.S. Colleges of Agriculture are certain that their research and teaching are morally correct. They defend their objective approach to weed science and their objectivity in defending agriculture against emotional attacks from people who don't understand it. The scientist's frequent appeal to the value of objectivity in science is evidence of a lack of awareness of the inevitable subjectivity of science.

Re-moralizing Agriculture

To suggest re-moralizing is not a claim that agriculture lacks moral standards or that all past achievements must be abandoned. I am not going to suggest a new, correct set of moral standards for agriculture. I recommend examining where moral values come from; and what are or ought to be the source of moral values for agriculture.

The emphasis on increasing production and reducing production costs to increase profit identifies agriculture's utilitarian ethical standard:

to provide the greatest good for the greatest number. This ethical position, accepted and largely unexamined within agriculture, has assumed that increasing production and reducing cost optimizes agriculture's social benefits. There has been almost no debate within agriculture about the standard's correctness. One result has been that many scientists, ignorant of their own social context and all results of their technology, have, without questioning, accepted the loss of small farmers and rural communities as part of the necessary cost of achieving the goal of maintaining a cheap food supply (Stout and Thompson, 1991).

The utilitarian standard is evaluated by results. Agriculturalists measure total production, crop yield and profit to evaluate what they do. They conclude that they are acting morally because all increase. The results are good. The cry for justice by the poor and the pleas of those concerned about loss of environmental quality are overwhelmed by achieving increased production.

None of what I have said should be interpreted as an attack on the moral standards of individual scientists. "Agricultural scientists have been reluctant revolutionaries". They have wanted to change agricultural practice and results but have neglected the revolutionary effects of their efforts. They believed that their work could be reduced to their little piece without considering the whole system. Increasing production was the goal, and, it was believed, it could be accomplished without revolutionary effects (Ruttan, 1991).

Intensive farming systems with chemical and energy intensive technology led to major increases in plant and animal production, increased the size of farms, minimized labor requirements, and maximized use of technology. These things allowed many nations to fulfill more adequately than any societies have the most important task in all human history: finding a way to extract from the ecosystem enough resources to maintain life. To do this, natural ecosystems were changed to make them more productive of the things humans need and want. The associated problem is that human societies have had difficulty balancing their demands against the ability of ecosystems to produce and survive. Intensive agriculture has met people's needs and many wants, a high value. But it is made unsustainable demands on the ecosystem, which was less valued. Agricultural scientists, use their success in meeting human needs to support their belief in the universal relevance and applicability of intensive farming. Western agriculturalists believe that all societies ought to adopt modern chemical, energy, and capital intensive agricultural methods and the associated values, because they embody the best, most rational, and most modern, thinking of humankind. This belief has three problems: it is false, it is immoral, and it is dangerous. Part of re-moralizing agriculture is to give up some of our pride about the moral correctness of all agricultural practices and values.

The goal of modern agriculture has been to produce more without any concern for the welfare of those whose lives were being destroyed. There was little thought about the effects of the system on the environment. Bottom line thinking has become the norm and is one thing we must reconsider if we are serious about our communities, and our agriculture.

As we reconsider the bottom line, there will be conflicting views on the nature of the problem and different views of sustainability (Allen, 1993). It is unusual to find anyone against sustainability. However, there are many views of what ought to be sustained and how to achieve sustainability. Re-moralizing requires that we give up the common agricultural defense against criticism, *viz*: (1) The first defense has been to deny that the suggested problem exists e.g., the loss of small farms is unfortunate but it is an economic not an agricultural matter, and (2) The second defense has been to explain that the reforms advocated (e.g., reductions in pesticide use, humane animal treatment) will make food too expensive and diminish the favorable balance of trade. The argument is that the public will not tolerate higher food costs to save a few small, inefficient farms, or to help citizens of developing countries. Reform may diminish the food surplus, and that is not politically acceptable.

Re-moralizing agriculture asks that we consider challenging views of agricultural practice. For example, in many countries agriculture is heavily subsidized and over harvests the resource. Exploitation of the land is never sustainable. Agricultural sustainability will not be achieved by adjustments to the present system, only by a new system. (Not all agree - See Federoff, *et al.,* 2010). It is a challenge that must be considered by the agricultural community.

CONCLUSION

I conclude that while agricultural scientists are ethical in the conduct of their science (they don't cheat, don't fake the data, give proper credit, etc) and in their personal lives (they earn their wages, take care of family, respect others, are responsible for their actions, etc.), they do not extend ethics into their work. Agricultural scientists are reluctant revolutionaries that Ruttan (1991) identified, but also realists. Realists run agricultural research and the world; idealists do not. Idealists attend academic conferences and write thoughtful articles (Kaplan, 1999). The action is elsewhere. The reality may be publish or perish in academia, but it is produce profitably or perish in the real agricultural world. Realism rules, and philosophical and ethical correctness are not necessary for useful work in science (Rorty, 1999).

I find that true, but I want more. I want us to accept the difficult task of analyzing the results of our science. We must strive for an analysis of what it is about weed science, agriculture and our society that limits our aspirations and needs modification. We must strive to strengthen features that are beneficial and change those that are not. We must be sufficiently confident to study ourselves and our institutions and dedicated to the task of modifying both. People don't want their assumptions about their science, its results, or their lives challenged, they believe their assumptions are correct and they want to use them.

A comment by the Russian author Leo Tolstoy[2] about art is relevant. Tolstoy urged us to question and debate the correctness of our scientific and moral assumptions. We need to examine our ethical foundation and our values. Tolstoy said: "I know that the majority of men who not only are considered to be clever, but who really are so, who are capable of comprehending the most difficult scientific, mathematical, philosophical discussions, are very rarely able to understand the simplest and most obvious truth, if it is such that in consequence of it they will have to admit that the opinion which they have formed of a subject, at times with great effort, - an opinion of which they are proud, which they have taught others, on the basis of which they have arranged their whole life,–that this opinion may be false".

To preserve what is best about modern weed science and to identify the abuses modern technology has wrought on our land, our people and other creatures, and begin to correct them will require many lifetimes of work (Berry, 1999). We ought to see agriculture in its many forms -- productive, scientific, environmental, economic, social, political, and moral. It is not sufficient to justify all activities on the basis of increased production. Other criteria, many with a clear moral foundation, must be included. We live in a post-industrial, information age society, but we do not and no one ever will live in a post-agricultural society. Societies have an agricultural foundation within their borders or elsewhere. Those in agriculture must strive to assure all that the foundation is secure.

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PLASTICITY FACILITATES *Anthemis cotula* TO INVADE DIVERSE HABITATS

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ABSTRACT

In view of the significant contribution of phenotypic plasticity in survival and spread of invasive species in heterogeneous adventive environments, present study was carried out on natural populations of Anthemis cotula L. (Stinking mayweed) growing in habitats that differ in disturbance. The vegetative (stem height, number of lateral branches, root mass, and shoot mass) and reproductive (number of disc florets per plant and per capitulum and number of capitula per plant) traits exhibited significant phenotypic plasticity across such habitats. Number of disc florets per plant (used as the measure of fitness) was highest in riparian populations and lowest in populations growing in habitats with relatively low disturbance. Fitness in populations supported by habitats with high disturbance was 5183.85 disc florets per plant. Although the number of disc florets per capitulum did not vary significantly across populations supported by different habitats, the number of capitula per plant ranged from 148.10 in riparian populations to 20.74 in populations growing in low disturbance habitats. Among the vegetative attributes, stem mass and number of lateral branches per plant varied significantly across populations supported by habitats with different disturbance regimes. Quantification of the phenotypic selection acting on these vegetative and reproductive traits estimated through use of selection differentials and gradients varied in sign and strength across the sites which indicate that different traits are favoured under different habitat conditions. Comparison of the phenotypic plasticity of A. cotula with a con-familial alien but less invasive species-Galinsoga parviflora - allows us to conclude that phenotypic plasticity not only enables the former to maintain fitness across a broad range of environments but also contributes significantly to its invasiveness in the Kashmir Himalaya.

Key words: Invasive, plasticity, fitness, Kashmir Himalaya.

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INTRODUCTION

Phenotypic plasticity, defined as the ability of a genotype to express different phenotypes in different environments (Pigliucci, 2005; Richards *et al*., 2006), has been frequently reported as the primary mechanism enabling aliens to colonize environmentally diverse habitats (Baker, 1965; Callaway *et al*., 2003; Parker *et al*., 2003; Sultan, 2004; Valladares *et al*., 2006).

In fact, plasticity in morphological and physiological traits initially allows introduced species the environmental tolerance to become naturalized across a range of environments (Baker, 1974) following which recombination of genetic variation among introduced individuals results in the evolution and expression of beneficial plastic responses in the colonized habitats (Ellstrand and Schierenbeck, 2000; Donohue *et al*., 2005; Richards *et al*., 2005). Although studies of phenotypic plasticity have a long history in plant ecology (Bradshaw, 1965: Schlichting and Pigliucci, 1998; Pigliucci, 2001), the extent to which patterns of plasticity differ among traits, life histories and habitats, and the adaptive basis of this variation are largely unresolved questions (Dorken and Barrett, 2004).

A suite of methods for estimating the strength of selection on multiple quantitative traits (Lande, 1979; Lande and Arnold, 1983; Arnold and Wade, 1984a, 1984b) are in vogue that allow separation of the direct and indirect components of selection on a set of correlated traits. Selection of phenotypic traits that enhance fitness are, particularly, important in promoting plant invasions and it would become evident only when the plastic response in invaders is measured relative to those of related but non-invasive species (Richards *et al*., 2006).

It is in this context, the present study was carried out to document intra- and inter-populational phenotypic plasticity in several vegetative and reproductive traits of *Anthemis cotula* L. (Stinking mayweed; family Asteraceae) in Kashmir Himalaya and to check whether or not this invasive species exhibits greater plasticity in major ecological traits in its field populations supported by terrestrial open habitats (with low and high levels of disturbance) and riparian habitats. Besides, a comparison of selection on trait complexes in three environments (terrestrial open habitats with low and high disturbance and riparian habitats) was also investigated during the present study. In addition, plasticity in the investigated attributes of *A. cotula*, was compared with that of *Galinsoga parviflora* which was chosen for being a con-familial alien but less invasive species.

MATERIALS AND METHODS

Study species

Anthemis cotula L. (Stinking mayweed, Mayweed chamomile), an annual, ill-scented, self-incompatible herbaceous member of sunflower family (Asteraceae), is native to southern Europe-west Siberia (Erneberg, 1999). It has a woody tap root; glabrous erect stem; alternate, sessile, slightly puberulous, pinnately dissected leaves; solitary terminal capitula; small pubescent imbricate involucral bracts; ray florets white; disc florets fertile and yellow in colour. Fruit is an achene. Because of its prolific growth and allelopathic activity, this species is becoming increasingly problematic in many parts of the world, including Kashmir Himalaya.

Galinsoga parviflora (Gallant soldier) native to tropical America is an annual herb found in most temperate and subtropical regions of the world. It has a shallow fibrous root system and erect branched stem which is slightly hairy. Leaves are opposite, simple, ovate and slightly hairy. Flower heads consist of many yellow tubular florets, and 4-5 white 3-lobed ray florets surrounded by membranous bracts. Fruit is an achene and propagation is by seeds.

Study sites

Twenty natural populations of *A. cotula* in the Kashmir, Himalaya, India, were studied during 2005. The study populations were sustained by habitats varying in the level of disturbance (Fig.1); nine populations were supported by open terrestrial habitats with low disturbance; eight by open terrestrial habitats with high disturbance and three by riparian habitats. These sites represented almost all the habitats invaded by *A. cotula*. In view of limited occurrence and restriction of *G. parviflora* to open terrestrial habitats with low disturbance in the Kashmir Himalaya, only four natural populations were selected and data on the same vegetative and reproductive traits in both the species was obtained during the study period.

Common pot experiment

Achenes from four representative populations of *A. cotula* supported by low, high disturbance sites and riparian habitats were raised in pots of 30 cm diameter, filled with garden soil and sand (3:1). The seedlings after emergence were thinned and 5 seedlings of almost equal size were maintained in each plot. 20 pots of each population were maintained for further studies.

Data collection

In each field population 50 individuals of *A. cotula* were randomly selected and permanently tagged for recording data on different attributes. A sub-sample of 10 mature individuals was used to record data on plant height, root, shoot and floret mass, number of lateral branches, number of capitula per plant, number of disc florets per capitulum and number of disc florets per plant. These data were also raised from pot grown individuals of *A. cotula* and four populations of *G. parviflora*.

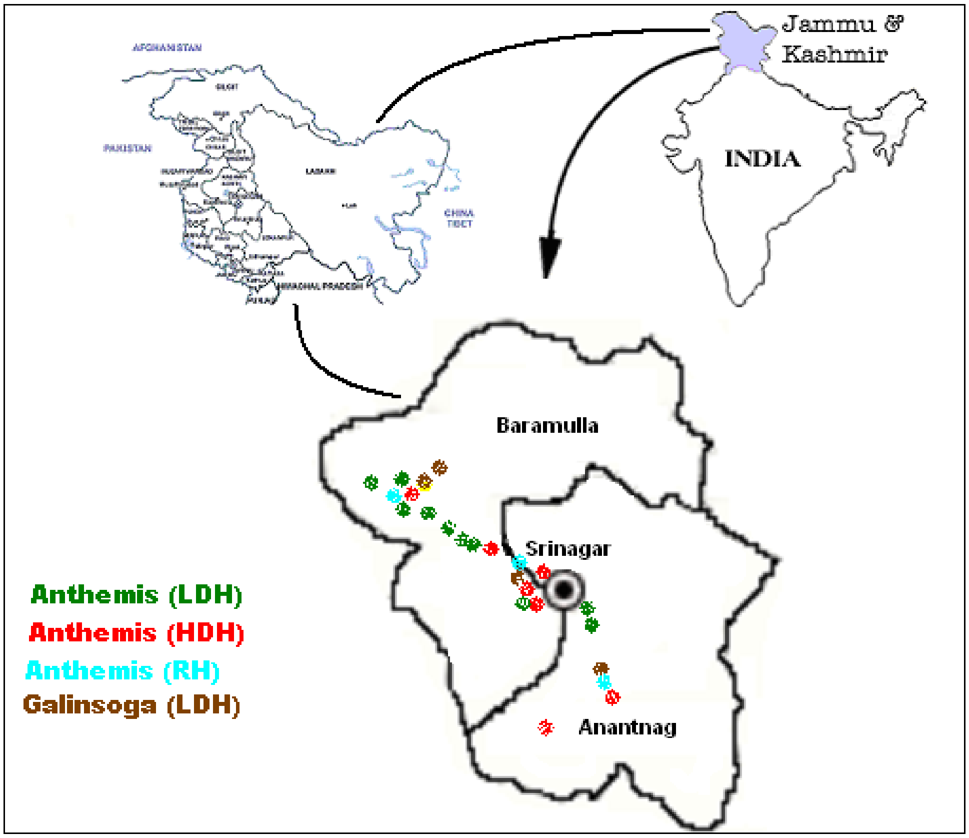

Fig. 1. Map showing study sites with low disturbance (LDH), high disturbance (HDH) and Riparian (RH) habitats.

Data analysis

Basic statistics, such as trait means and variances were calculated using SPSS 10. An ANOVA was carried out for all vegetative and reproductive traits between populations supported by different habitat types. Plasticity index ((maximum mean-minimum mean)/maximum mean) was calculated following Valladares *et al*. (2000).

Selection differentials and gradients

Phenotypic selection analyses were conducted on traits of individuals of *A. cotula* so as to analyze the possible difference(s) in selective forces in different habitat types. All phenotypic traits were standardized to a mean of 0 (SD = 1). No other transformations were applied because data did not violate the distributional assumptions of multiple regressions. Absolute fitness measures, in the form of number of fertile disc florets per plant, were converted to relative fitness measures. Subsequently, the standardized selection differentials were estimated, a technique that indicates the total selection for each phenotypic trait, includes selection acting directly on the trait and selection acting on correlated traits (Lande and Arnold, 1983; Arnold and Wade, 1984). It also estimates the magnitude and direction of selection by determining the covariance between that trait and the values of some estimates of fitness (Schluter, 1988; Galen, 1989). Also the selection gradients were estimated, a multivariate technique that reveals the direction and magnitude of selection for each quantitative trait, independent of the other traits (Lande and Arnold, 1983; Arnold and Wade, 1984a). The directional selection gradient, β, was obtained from the partial-regression coefficients of a linear regression of relative fitness on all the traits.

RESULTS AND DISCUSSION

Values of the phenotypic traits of *A. cotula* considered in the present study are summarized in Table-1. Vegetative and reproductive characters, except floret mass per plant, varied significantly between populations and habitats ($P<0.001$). It was in contrast to *G. parviflora*, where such traits (Table-2) did not differ significantly across populations ($P>0.05$). In riparian populations of *A. cotula* all traits, except height, exhibited higher values (Table-2). Riparian habitats with frequent soil disturbance, offer opportunities for recruitment mostly after floods in the form of smaller gaps (Richardson *et al*., 2007) and, therefore, competition for pollinators and light is reduced; but in terrestrial habitats with more inter-specific competition the plants have to be taller so as to compete successfully with other plants for light (Falster and Westoby, 2003). Thus, a trade-off between height and number of laterals per plant is seen in *A. cotula* (Table-3), with former contributing to success in mixed cultures and latter in more disturbed conditions.

Fitness (measured as number of disc florets per plant) was highest in riparian habitats and lowest in terrestrial habitats with low disturbance (Table-3). A common prerequisite for successful colonization is that disturbance removes limiting factors or barriers to invasion (Johnstone, 1986; Hobbs, 1989) and the extent to which these are removed are related to the type of disturbance and disturbance intensity (Myers, 1983; Armesto and Pickett, 1985; Hobbs, 1989) and their ability to increase resource availability.

Table-1. Vegetative and reproductive characters of *Anthemis cotula* (Mean±S.E.) from different populations.

Habitat type	Site	Height Plant^{-1} (cm)	Number of lateral branches plant^{-1}	Root mass plant^{-1} (g)	Shoot mass plant^{-1}(g)	No. of capitula Plant^{-1}	No. of disc florets Capitulum^{-1}	No. of disc florets plant^{-1}	Floret mass plant^{-1}(g)
Terrestrial open habitats with low disturbance	LD1	35.80±1.28	1.50±0.22	0.84±0.12	5.55±0.20	21.20±1.07	109.50±1.45	2311.30±96.85	1.30±0.20
	LD2	50.80±1.38	1.10±0.10	0.35±0.09	1.97±0.30	12.10±1.02	96.00±1.01	1156.10±90.69	0.52±0.16
	LD3	19.80±2.93	1.20±0.13	0.41±0.04	1.69±0.19	12.70±1.27	94.90±1.68	1196.50±113.21	0.58±0.08
	LD4	52.80±1.71	1.00±0.00	0.92±0.07	4.49±0.22	15.20±0.92	113.80±0.71	1730.40±105.85	0.54±0.08
	LD5	49.20±2.03	1.40±0.22	1.10±0.14	9.42±0.42	23.30±2.58	115.60±1.07	2698.90±306.54	1.57±0.12
	LD6	76.60±4.21	1.20±0.13	1.51±0.12	7.35±0.15	19.20±1.86	126.30±1.14	2415.30±225.94	1.30±0.12
	LD7	26.30±1.37	2.00±0.30	1.09±0.10	8.77±0.24	29.00±2.13	120.70±1.14	3501.10±258.66	1.07±0.08
	LD8	27.70±1.20	1.50±0.17	1.07±0.08	8.86±0.22	27.30±2.17	125.20±2.02	3389.90±237.88	1.17±0.06
	LD9	36.10±3.43	1.50±0.22	0.37±0.04	3.10±0.31	26.70±1.99	129.90±1.86	3462.30±249.02	1.23±0.13
Terrestrial open habitats with high disturbance	HD1	93.50±4.90	1.30±0.15	1.18±0.18	9.16±1.04	41.60±3.60	120.10±1.68	4971.10±408.74	1.97±0.47
	HD2	72.20±2.76	1.60±0.22	0.88±0.03	15.17±0.33	38.10±2.41	130.00±1.21	4932.60±281.29	2.77±0.13
	HD3	43.00±2.44	1.30±0.15	1.29±0.05	8.29±0.12	35.30±2.01	122.60±1.09	4323.50±242.37	2.00±0.03
	HD4	62.60±2.85	1.30±0.15	0.99±0.10	14.29±0.51	43.90±1.68	114.30±0.72	5013.90±181.85	2.33±0.13
	HD5	53.50±2.66	2.00±0.30	1.09±0.08	27.80±1.59	52.10±3.09	132.20±1.28	6871.30±381.59	3.23±0.26
	HD6	50.90±2.00	1.70±0.21	1.23±0.19	14.00±0.43	34.60±2.42	129.00±1.23	4449.70±291.05	2.62±0.20
	HD7	85.50±4.23	1.30±0.15	2.00±0.20	21.91±2.10	53.00±2.36	128.70±1.10	6807.20±274.95	3.81±0.38
	HD8	35.00±1.53	2.10±0.35	1.66±0.17	11.63±0.26	30.50±2.25	134.80±1.31	4101.50±289.66	1.54±0.15
Riparian habitats	RH1	74.20±3.53	10.50±0.56	4.62±0.19	46.09±0.70	138.10±2.81	136.20±1.09	18801.00±369.36	11.78±0.34
	RH2	24.40±1.12	10.00±0.65	2.00±0.07	16.68±1.04	158.90±3.94	138.50±1.35	22021.10±648.36	10.69±0.58
	RH3	30.20±1.00	10.40±0.45	1.61±0.18	17.07±1.46	147.30±4.81	114.80±1.29	16884.00±492.62	9.39±0.99

Table-2. Vegetative and reproductive characters of *Galinsoga parviflora* (Mean±S.E.) from different populations.

Site	Stem height (cm)	No. of lateral branches plant^{-1}	Root mass (g)	Shoot mass (g)	No. of capitula plant^{-1}	No. of disc florets capitulum^{-1}	No. of disc florets plant^{-1}	Floret mass (g)
S1	31.30 ±1.10	1.00 ±0.00	0.31 ±0.04	1.18 ±0.20	71.30 ±14.97	39.10 ±1.07	2803.20 ±579.58	0.24 ±0.05
S2	30.50 ±2.03	1.00 ±0.00	0.21 ±0.03	1.22 ±0.26	47.20 ±9.21	38.50 ±0.82	1836.10 ±357.58	0.21 ±0.09
S3	34.10 ±3.49	1.00 ±0.00	0.32 ±0.07	1.29 ±0.24	65.60 ±12.04	39.20 ±1.13	2548.00 ±447.25	0.16 ±0.04
S4	31.50 ±2.07	1.00 ±0.00	0.32 ±0.10	1.52 ±0.43	73.30 ±22.15	39.20 ±1.13	3009.60 ±1018.47	0.27 ±0.10

Table-3. Vegetative and reproductive characters of *Anthemis cotula* (Mean±S.E.) from different habitats.

Trait	Habitat types		
	Terrestrial open habitats with low disturbance	**Terrestrial open habitats with high disturbance**	**Riparian habitats**
Stem height (cm)	41.68 ±1.91	62.03 ± 2.40	42.93 ± 4.31
No. of lateral branches/plant	1.38 ± 0.07	1.58 ± 0.08	10.30 ± 0.32
Root mass/plant (g)	0.85 ± 0.05	1.29 ± 0.06	2.74 ± 0.26
Shoot mass/plant (g)	5.69 ± 0.32	15.28 ± 0.78	26.62 ± 2.63
No. of capitula/plant	20.74 ± 0.85	41.14 ± 1.22	148.10 ± 2.70
No. of disc florets/ capitulum	114.66 ± 1.34	126.46 ± 0.83	129.83 ± 2.10
No. of disc florets /plant	2429.09 ±112.87	5183.85 ± 152.10	19235.37 ± 487.47
Floret mass/plant (g)	1.03 ±0.05	2.53 ± 0.12	10.62 ± 0.43

Table-4 summarizes the values of the phenotypic traits obtained from individuals of pot grown populations. Analysis of variance did not reveal significant differences between any of the traits considered in the present study across different populations (P>0.05). The results indicate that the variations of each variable observed in fields are plastic response to environments, not genetically determined. Plasticity rather than genetic differentiation help the invader acclimate to different habitats, supporting general purpose hypothesis.

Comparison of the fitness plasticity of *A. cotula* with *G. parviflora* (Fig. 2) reveals that the former is able to maintain relatively high fitness across a range of habitats being highest in riparian habitats, but the latter is confined only to terrestrial open habitats with low disturbance. There is abundant evidence that plant species and populations may differ remarkably in the extent of their plastic responses to comparable environmental challenges (Schlichting and Levin, 1984; Valladares *et al.*, 2000; Sultan, 2001). Plasticity index of various vegetative and reproductive traits in the habitats of occurrence of the two species is presented in Fig. 3. All the traits invariably showed higher plasticity in *A. cotula* than *G. parviflora*. Besides, the traits in populations of *A. cotula* sustained by terrestrial open habitats with low disturbance revealed higher plasticity while as the same was least in the riparian populations.

Phenotypic selection analyses (Table-5) demonstrated that measures of covariance between standardized traits and relative fitness (selection differential) in *A. cotula* yielded statistically significant selection differentials in terrestrial habitats for almost all traits, except number of disc florets per capitulum in both high and low disturbance habitats and shoot mass per plant only, in terrestrial habitats with high disturbance. Significantly positive relationship between number of lateral branches per plant and relative fitness was noticed across all the three habitats. Selection gradients for stem height, root and shoot mass, number of capitula per plant and number of disc florets per capitulum were statistically significant in low disturbance terrestrial habitat with stem height, root mass and number of capitula per plant showing positive sign. In high disturbance terrestrial habitats number of lateral branches, shoot mass, and number of capitula per plant were significant with stem mass showing negative sign. Selection gradient in respect of number of capitula per plant was the only statistically significant trait in riparian populations of the species.

Table-4. Vegetative and reproductive characters of *Anthemis cotula* (Mean±S.E.) from different populations grown in pots.

Population	Stem height (cm)	No. of lateral branches Plant^{-1}	Root mass (g)	Shoot mass (g)	No of capitula plant^{-1}	No. of disc florets capitulum^{-1}	No. of disc Florets plant^{-1}	Floret mass (g)
P1	41.20±6.29	1.20 ±0.20	0.44 ±0.15	2.86 ±0.87	47.20 ±18.58	163.04 ±11.77	8210.60 ±3304.96	0.68±0.18
P2	48.20±9.16	1.20 ±0.20	0.41 ±0.11	4.06 ±1.59	60.40 ±19.86	171.56 ±17.16	11428.96 ±4136.54	1.12±0.43
P3	35.90±7.61	1.40 ±0.24	0.62 ±0.17	3.35 ±1.12	39.00 ±15.61	156.00 ±16.42	6710.12 ±2734.44	0.76±0.31
P4	25.40±5.16	1.40 ±0.24	0.45 ±0.08	2.24 ±0.58	35.60 ±4.49	179.88 ±12.67	6196.76 ±545.81	0.53±0.20

Table-5. Standardized selection differentials (α) and linear selection gradients (β) for several traits in populations of *A. cotula* from three different habitats.

Trait	Open terrestrial habitats with low disturbance		Open terrestrial habitats with high disturbance		Riparian habitats	
	α	**β**	**α**	**β**	**α**	**β**
Stem height (cm)	0.073**	0.338***	0.043*	-0.090	0.007	0.256
No. of lateral branches/plant	0.140***	-0.018	0.119***	0.404***	0.054***	0.123
Root mass/plant (g)	0.112***	0.281*	0.084***	0.026	0.019	-0.151
Shoot mass/plant (g)	0.054*	-0.449***	0.037	-0.611***	0.007	0.188
No. of capitula/plant	0.152***	1.033***	0.124***	0.904***	0.061***	0.721*
No. of disc florets/capitulum	0.014	-0.490***	0.031	0.105	0.005	-0.098
Floret mass/plant (g)	0.118***	-0.012	0.086***	0.114	0.061***	0.232

* $P < 0.05$; ** $P < 0.01$; ***$P < 0.001$

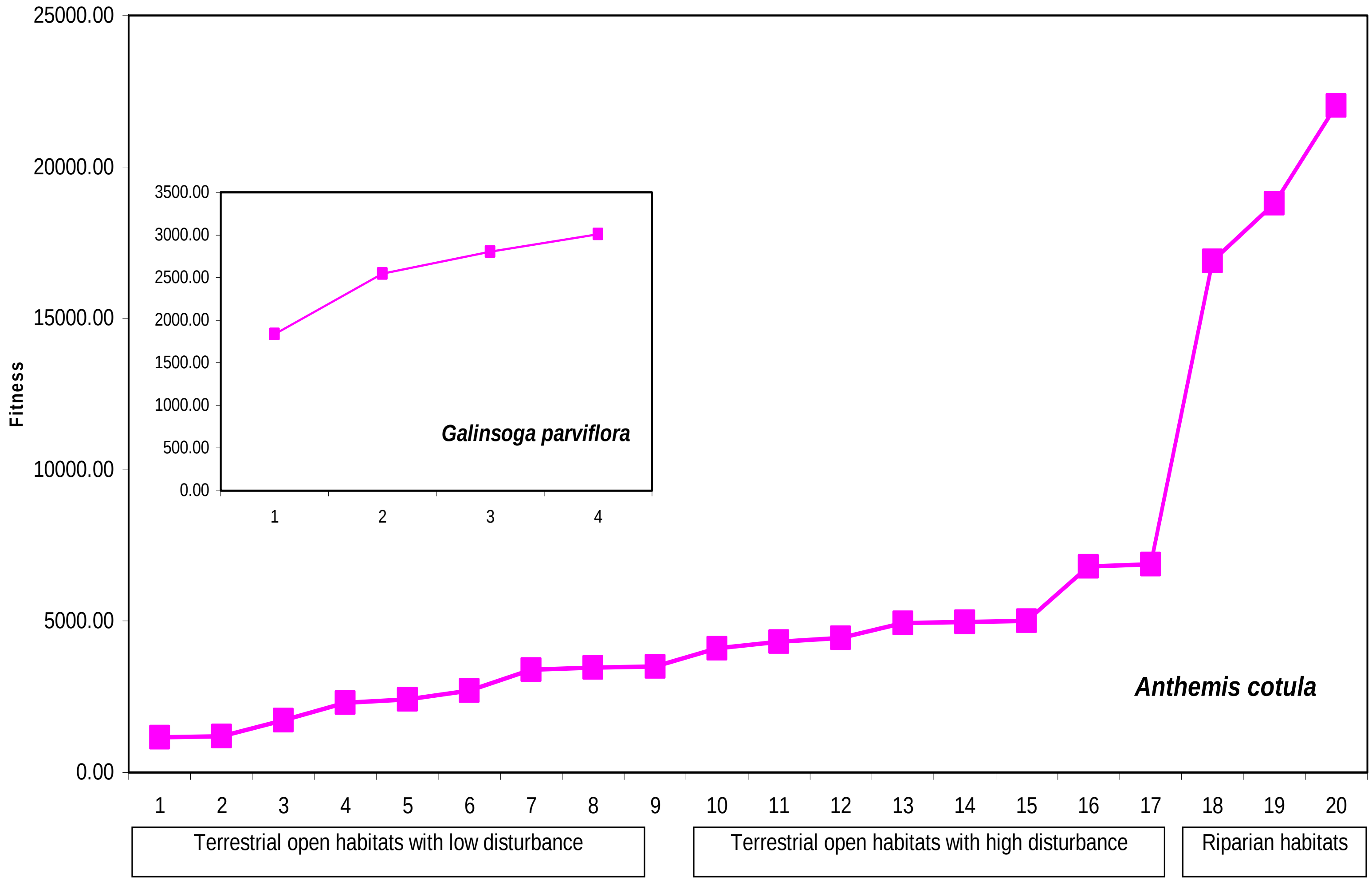

Fig. 2. Comparison of fitness (number of achenes plant^{-1}) of *Anthemis cotula* in different habitats with that of *Galinsoga parviflora*.

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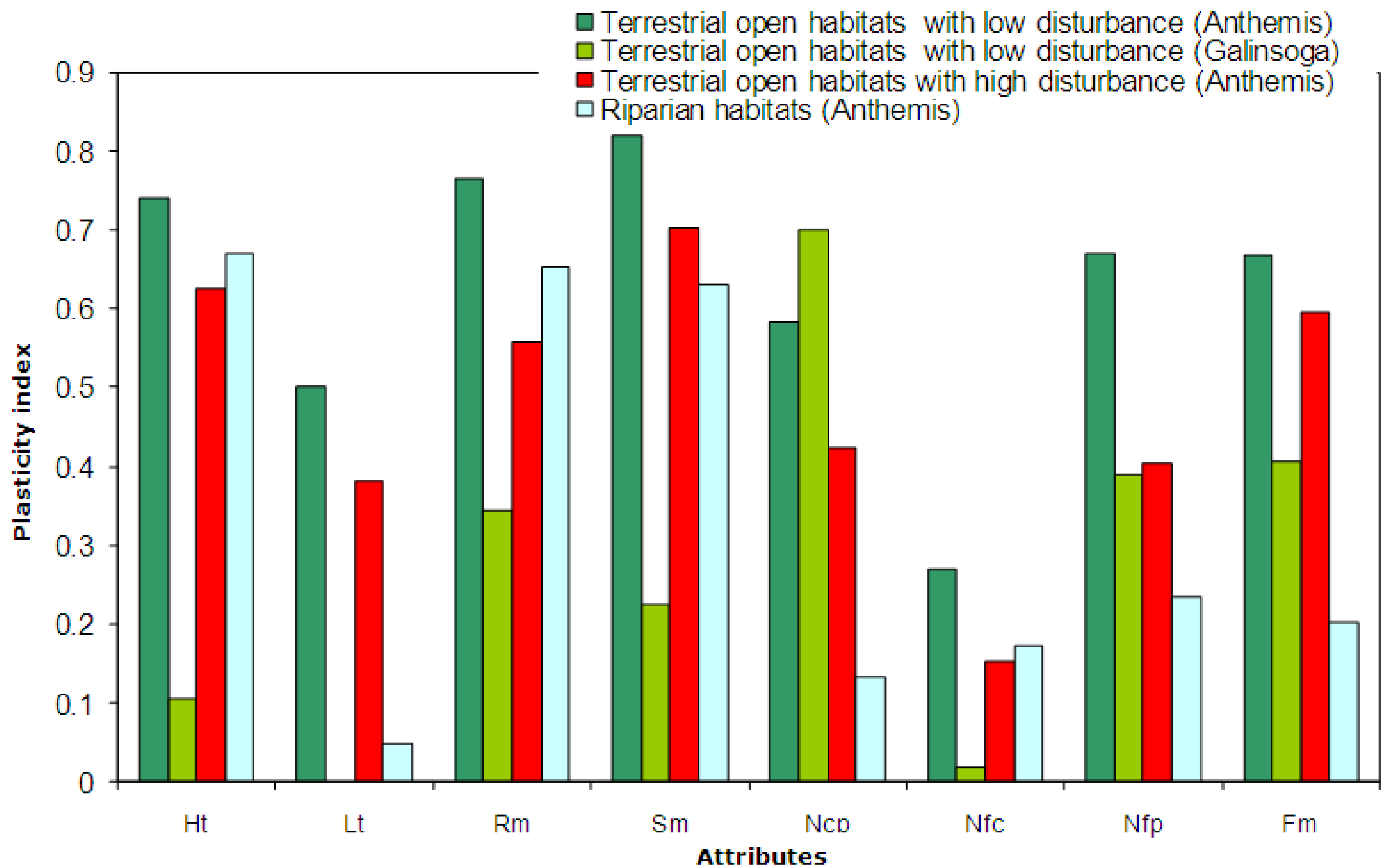

Fig. 3. Comparison of the Plasticity Index of various traits of *Anthemis cotula* and *Galinsoga parviflora* (Ht = Stem height; Lt = Number of lateral branches; Rm = Root mass; Sm = Stem mass; Nfc = Number of disc florets per capitulum; Nfp = Number of flowers per plant; Fm = Floret mass.

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EFFECTS OF HERBICIDES ON WEED SUPPRESSION AND RICE YIELD IN TRANSPLANTED WETLAND RICE

Md. Nasimul Bari[1]

ABSTRACT

Eight herbicides, i.e. oxadiazone, butachlor, pretilachlor and anilphos from pre-, and MCPA, ethoxysulfuran, pyrazosulfuran Ethyl and oxadiarzil from post-emergence category were applied at recommended rates in transplanted wetland rice during aman (autumn), aus (summer) and boro (winter) growing seasons at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh (BSMRAU) during 2007-08 to study their effects on weed control and rice yield. Results revealed variations in the performance of herbicides in different seasons. Pre-emergence herbicides performed better regarding weed control efficiency and rice yield. Based on the initial performance, butachlor and MCPA were further applied at concentrations ranging from 50% to 150% of the recommended rates in transplanted aus rice in 2009. Data indicated that butachlor provided better weed control efficiency and contributed to better crop growth and grain yield compared to MCPA irrespective of concentration. It might be due to that pre-emergence application of Butachlor provided effective early season weed control, which MCPA could not since apply as post-emergence. The highest grain yield of 4.18 t ha^{-1} was contributed by weed free treatment, while the least (2.44 t ha^{-1}) was by weedy check. Among the herbicide treatments, the highest grain yield of 4.08 t ha^{-1} was obtained from butachlor, while the lowest (2.83 t ha^{-1}) grain production was harvested in the plots receiving MCPA @ 125% of the recommended rate. Results further revealed a positive relationship between butachlor rate and grain yield, although a declining trend was apparent at higher than the recommended rates, while a negative relationship was found in MCPA treatments.

Key words: Pre-emergence herbicides, post-emergence herbicides, *Oryza sativa*, chemical control.

INTRODUCTION

In rice cultivation a considerable portion of production cost is involved in weed control. Hand weeding and other traditional control

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methods are time consuming and involve high labour cost. In Bangladesh, severe weed infestation reduces the grain yield by 70-80% in Aus rice (early summer), 30-40% for transplanted Aman rice (Late summer) and 22-36% for modern boro rice (winter rice) cultivation (Mamun, 1990). According to Willocquet *et al*., (1998), the losses due to infestation of weeds are greater than the combined losses caused by insect, pest and diseases in rice. Mamun, *et al.* (1993) reported that weed growth reduced the grain yield by 68-100% for direct seeded *aus* rice, 22-36% for modern *boro* rice and 16-48% for transplanted *aman* rice. This loss is, therefore, a serious threat for the food deficit countries like Bangladesh and necessitates proper weed management for rice production. Herbicidal weed control methods offer an advantage to save labour and money, as a result, regarded as cost effective (Ahmed *et al.*, 2000). Chemical weed control has become popular in Bangladesh mainly due to scarcity of labour during peak growing season, and lower weeding cost. In Bangladesh the annual consumption of herbicides grew over 4000 metric tons in 2008 (BCPA, 2010) compared to only 108 tons during 1986-87 (BBS, 1991), and the growth is almost exponential. Although, herbicide use was confined in tea cultivation at early stages, it is now being overwhelmingly used in rice cultivation as well. Oxadiazone, pretilachlor, butachlor, ethoxysulfuran, pyrazosulfuran ethyl, oxadiarzil, anilphos, 2,4-D, etc. are the commonly used herbicides in rice cultivation in Bangladesh.

In modern, intensive and complex crop production practices application of fertilizers, insecticides, herbicides and fungicides are common. The so-called “Green Revolution” during the 1960s facilitated the use of agro-chemicals, particularly chemical fertilizers and insecticides in the country. Indiscriminate use of Herbicide has resulted in the devopment of weed resistance and environmental degradation. So, herbicides may also become a burden if appropriate measures are not taken at early stages regarding safe use of safe herbicides for sustaining farm productivity as well as protecting environment (Singh *et al.,* 2005). Therefore, the present study was undertaken to fulfill the following objectives:

(a) to see the performance of selected herbicides used at recommended rates on weed suppression and yield performance of transplanted wetland rice

(b) to see the effects of herbicides at variable rates on weed suppression as well as growth and yield of transplanted wetland rice, and

(c) to determine the effects of herbicides on soil organic matter content and soil biomass carbon content.

MATERIALS AND METHODS

Experiment-1. Comparative performance of herbicides on weed suppression and yield of transplanted wetland rice.

Eight commonly available herbicides, of which four were from pre-emergence and the rest from the post-emergence category were collected from the local markets. All herbicides were applied at recommended rates in transplanted wetland rice during three consecutive growing seasons under wetland condition. Besides, one control (weedy check) treatment, one weed free treatment and one manual weeding at 25, 35 and 45 days after transplanting (DAT) were also included. The experiment was conducted in the experimental farm of the BSMRAU during 2007 and 2008 in RCB design with 3 replications. Transplanted *Aman* (cv. BR39), *Boro* (cv. BR28) and *Aus* (cv. BR26) rice were used as test crop. The treatments were applied as follows:

Treatments:

T1: Oxadiazone @ 2000 ml ha^{-1} (pre-emergence at 7 DAT).
T2: Butachlor @ 1875 ml ha^{-1} (pre-emergence at 7 DAT).
T3: Pretilachlor @ 1000 ml/ha (applied pre-emergence at 7 DAT).
T4: Anilphos @ 1300 ml ha^{-1} (pre-emergence at 7 DAT).
T5: MCPA @ 1000 ml ha^{-1} (post-emergence at 25 DAT).
T6: Ethoxysulfuran @ 100 g ha^{-1} (post-emergence at 20 DAT).
T7: Pyrazosulfuran Ethyl @ 150 g ha^{-1} (post-emergence at 20 DAT).
T8: Oxadiarzil @ 1875 ml ha^{-1} (post-emergence at 20 DAT).
T9: Manual weeding at 20, 35 and 50 DAT (standard for MV rice).
T10: Weed free (weeded at 7 days interval after transplanting upto flowering).
T11: Unweeded (control)

Parameters studied:

Weed biomass, weed control efficiency (WCE); grain yield and straw yield.

Experiment-2. Effects of herbicides application rates on the performance of transplanted *aus* rice.

Based on performance of the herbicides in terms of weed control efficiency as well as rice grain yield under experiment-1 two better performing herbicides were further tested at variable rates in *aus* rice (cv. BR26) in 2009 at the same location in the split-plot design in RCBD with 3 replications. The herbicides butachlor and MCPA were in the mainplots while the herbicide rates *viz.* 50, 75, 100, 125 and 150% of the recommended rates, were assigned to the sub-plots. Weed free and weedy check were also included in the trial.

Parameters studied:

Weed control efficiency (WCE); plant height, tiller dynamics, phenology, yield components, soil organic matter content, soil biomass carbon content.

Crop Management Practices:

Standard management practices for MV rice were followed in both the experiments.

Weed control efficiency (WCE):

WCE was calculated by using the following formula:

$$WCE = \frac{DMC - DMT}{DMC} \times 100$$

Where, DMC = Weed dry matter in unweeded treatment and DMT = Weed dry matter in weed control treatment. The data recoded for the individual traits was subjected to the ANOVA technique and the significant means were separated by LSD test (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

Experiment-1. Comparative performance of herbicides on weed suppression and yield of transplanted wetland rice.

Weed Control Efficiency

In general, pre-emergence herbicides performed better than the post-emergence herbicides which were exhibited by lower weed biomass as well as higher weed control efficiency in all the growing seasons (Table-1). However, variations existed within treatments. Among the pre-emergence herbicides, the highest WCE was observed in pretilachlor treatments in both *aman* and *aus* season being followed by butachlor. Butachlor, however, showed the highest WCE among the herbicide treatments in *boro* rice. On the other hand, anilphos could not show its worth in WCE except in Aus 2008 season. Manual weeding was found comparable to herbicide treatments, in all the growing seasons. Among the post-emergence herbicides, only MCPA contributed to higher WCE, particularly during *boro* and *aus* season. Data indicated seasonal variations in the efficacy levels of applied herbicides. One of the causes behind lower weed control efficiency during *aman* growing season might be due to interruption by heavy rainfall which might cause dilution as well as leaching and/or seepage loss of herbicides from the treated plots. These inferences are supported with the work of Panwar *et al.* (1992) who obtained varying level of weed control with the use of different herbcides.

Table-1. Weed control efficiency by selected herbicides in transplanted rice at harvest.

Treatment	Aman 2007		Boro 2007		Aus 2008	
	Weed biomass (g m^{-2})	WCE (%)	Weed biomass (g m^{-2})	WCE (%)	Weed biomass (g m^{-2})	WCE (%)
Oxadiazone @2000 ml ha^{-1}	88.44	67.72	177.20	30.49	27.07	84.19
Butachlor @1875 ml ha^{-1}	31.80	88.39	25.73	89.91	21.47	87.46
Pretilachlor @ 1000 ml/ha	20.08	92.67	35.07	86.24	10.40	93.93
Anilphos 1300 ml ha^{-1}	169.40	38.18	210.67	17.37	37.73	77.96
MCPA @ 1000 ml ha^{-1}	135.52	50.54	82.13	67.78	20.53	88.01
Ethoxysulfuran 100 g ha^{-1}	172.00	37.22	259.60	-1.83	22.80	86.68
Pyrazosulfuran Ethyl @ 150 g ha^{-1}	264.68	3.40	224.27	12.02	44.13	74.22
Oxadiarzil @1875 ml ha^{-1}	203.40	25.77	229.33	10.04	189.87	-10.91
Manual weeding	35.12	87.18	17.33	93.20	21.07	87.69
Weed- free	4.05	98.52	3.61	98.58	0.00	100.00
Weedy check	274.00	-	254.93	-	171.20	-

T7: Pyrazosulfuran Ethyl @ 150 g ha^{-1} (post-emergence at 20 DAT).
T8: Oxadiarzil @ 1875 ml ha^{-1}

Rice yield

Herbicide treatments contributed to higher yield performance compared to control in all the growing seasons except Oxadiarzil, which could not show considerable yield increase over control during the growing seasons (Table-2). Even though it was found inferior to unweeded treatment during *aus* 2008 season. Among the herbicide categories, pre-emergence herbicides performed better than post-emergence ones, particularly during *boro* and *aus* growing seasons. Among the pre-emergence herbicides, the highest yield was contributed by butachlor treated plots in *aman* and *aus* growing seasons, although oxadiazone superseded butachlor in *boro* growing season. Among the post-emergence types, the highest yield was obtained from MCPA treated plots in all of the three growing seasons (Table-2). The previous work of Ali *et al.* (2010) also agrees with our findings who also obtained increased yield with the use of different hebicides.

Table-2. Performance of herbicides in terms of rice grain yield in three growing seasons.

Treatment	Aman 2007		Boro 2007		Aus 2008	
	Yield (t ha^{-1})	Yield increase over control (%)	Yield (t ha^{-1})	Yield increase over control (%)	Yield (t ha^{-1})	Yield increase over control (%)
Oxadiazone	3.68	30.96	4.01	157.05	4.43	71.04
Butachlor	3.94	40.21	3.68	135.90	4.68	80.69
Pretilachlor	3.76	33.81	3.52	125.64	4.07	57.14
Anilphos	3.93	39.86	2.35	50.64	4.37	68.73
MCPA	4.05	44.13	2.92	87.18	4.13	59.45
Ethoxysulfuran	3.86	37.37	2.23	42.95	3.70	42.86
Pyrazosulfuran Ethyl	3.72	32.38	2.34	50.00	3.89	50.19
Oxadiarzil	3.80	35.23	1.79	14.74	1.73	-33.20
Manual weeding	3.75	33.45	3.54	126.92	3.99	54.05
Weed free	3.47	23.49	3.57	128.85	4.02	55.21
Control	2.81		1.56		2.59	
$LSD_{0.05}$	NS*		0.8133		1.293	
CV (%)	9.82		16.51		19.64	

* N.S= Non-significant (p>0.05 in F-test)

Experiment-2. Effects of herbicides rates of application on the performance of transplanted *aus* rice.

Weed control efficiency

On the basis of WCE as well as grain yield performance in the first experiment butachlor (pre-emergence) and MCPA (post-emergence) were further tested at variable rates in the next aus growing season. Data on weed biomass counted at different time intervals showed that weed infestation was comparatively lower in butachlor treated plots (T1-T5) compared to MCPA treated plots (T6-T10). MCPA being weaker; its treated plots possessed higher weed biomass even higher than the weedy check treatment (Fig. 1). The highest weed biomass was recorded at 75 DAT where MCPA was applied @ 50% of the recommended dose whereas the least was noticed in butachlor treated plot at recommended dose. Consequently, WCE was lower in the MCPA treated plots as compared to butachlor treatments (Fig. 2). The lower weed count in butachlor is due to its higher efficacy to control weeds in rice. Whereas MCPA is a broadleaf killer and it only picked broadleaf weeds, while the grasses escaped its control, hence its overall effect was lesser as compared to butachlor.

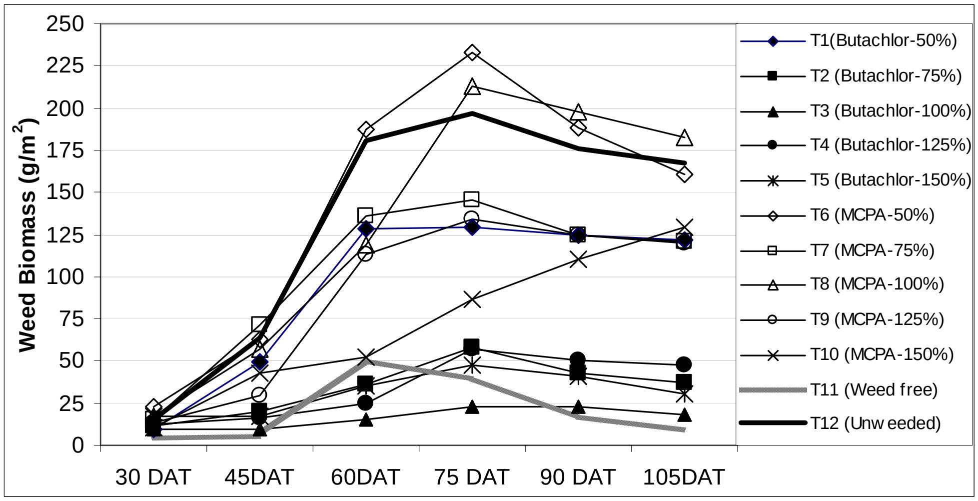

Fig. 1. Weed biomass in transplanted aus rice as affected by concentration of herbicides.

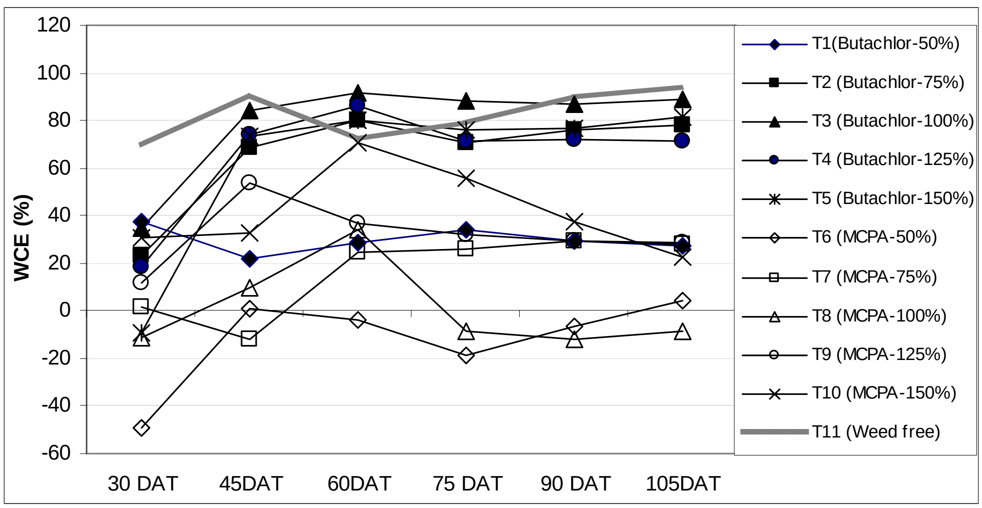

Fig. 2. Weed control efficiency (WCE) of herbicides as affected by concentration.

Performance of rice

Plant Height

Results on plant height as affected by herbicide rates has been shown in Fig. 3. Data indicated that butachlor (T1-T5) application irrespective of rates contributed to taller plants as compared to MCPA treated plots (T6-T10). Plant height increased in butachlor treated plots even better than in weed free plots. It might be due to the fact that butachlor treatment at early crop growth stages suppressed weed population effectively which resulted in higher vigour and growth of rice plants.

Tillers Dynamics

Data on tiller production over time indicated that tiller number increased up to 75 DAT in herbicide treated plots compared to weed free plots where tiller increase continued up to 90 DAT (Fig. 4). Among the tested herbicides butachlor application contributed to higher number of tillers per unit area compared to MCPA treatment as a whole. Among the butachlor treatments, its application @ 125% of the recommended rate contributed to the highest number of tillers at 75 DAT, however, next to weed free treatment.

Phenology

First flowering was noticed to be induced slightly earlier in MCPA treated plots (T6-T10) as compared to butachlor treated plots (T1-T5) as evident in Table-3. Similar trend was noticed in case of days to 50% flowering. However, the difference was not considerable with weed free as well as unweeded treatments. Maturity, however, came slightly earlier in butachlor treated plots compared to MCPA treated ones. However, the differences among the treatments were non-significant.

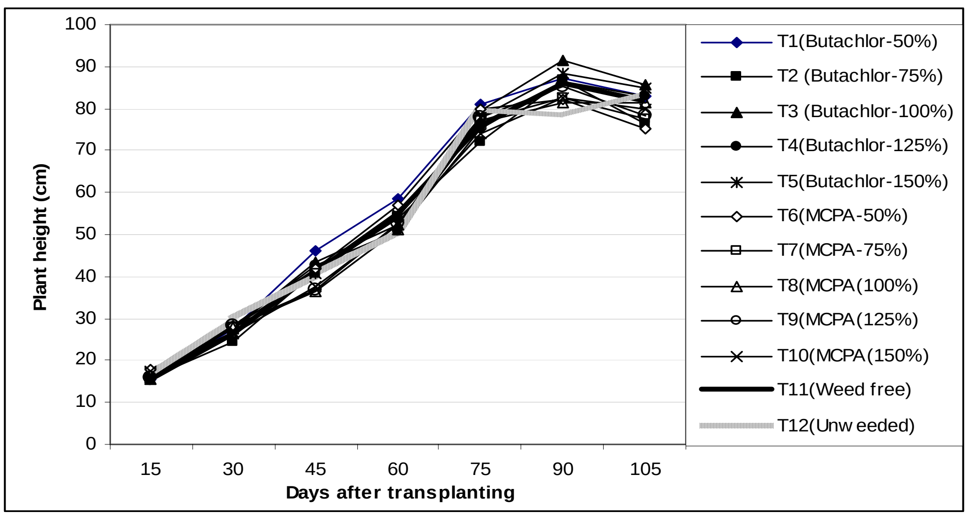

Fig. 3. Plant height as affected by concentrations of butachlor and MCPA.

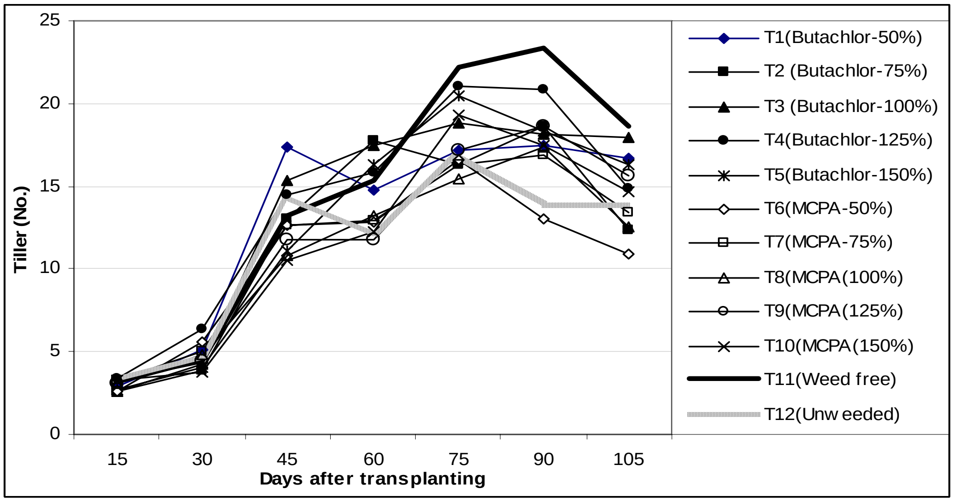

Fig. 4. Tiller development as affected by different concentrations of butachlor and MCPA.

Table-3. Phenological events in transplanted *aus* rice as affected by different concentrations of butachlor and MCPA.

Treatment	Days				
	1st flowering	50% flowering	Difference between 1st & 50% flowering	Maturity	Difference between 1st flowering & maturity
Butachlor (50%)	69.33	74.33	5.00	108.00	38.67
Butachlor (75%)	70.33	75.67	5.33	109.67	39.33
Butachlor (100%)	69.33	74.00	4.67	108.33	39.00
Butachlor (125%)	70.33	75.67	5.33	109.33	39.00
Butachlor (150%)	70.67	75.33	4.67	109.33	38.67
MCPA (50%)	68.00	72.33	4.33	107.67	39.67
MCPA (75%)	68.00	73.00	5.00	108.33	40.33
MCPA (100%)	68.67	73.33	4.67	108.67	40.00
MCPA (125%)	68.33	73.00	4.67	108.33	40.00
MCPA (150%)	69.00	75.00	6.00	110.00	41.00
Weed free	69.33	74.33	5.00	109.00	39.67
Control	68.00	73.00	5.00	109.00	41.00

Rice Yield

Data on grain yield revealed that butachlor application contributed better than MCPA (Table-4). The highest grain yield of 4.18 t ha^{-1} was harvested in the weed free treatment, being followed by 4.08 t ha^{-1} in T2 treatment where butachlor was applied at recommended rate. Among the MCPA treatments, the highest grain yield of 3.76 t ha^{-1} was contributed by MCPA @ 75% of the recommended rate. MCPA treatments contributed to higher grain yields over control plots, however, much lower than the weed free plots. The present findings are corroborated with the previous work of Tapader (2003), Panwar *et al.* (1992), Mondol *et al.* (1995) and *Singh et al.* (2005).

Data indicated that butachlor treated plots contributed to yield increase ranging from 16.39% to 67.21% with an average value of 50.40% over the weedy check, while the respective increase in yield for MCPA was only 31.56% (Table-4). Data further revealed inclining trends in yield increase with the increase in butachlor rate, although yield was in declining trend when concentration crossed the recommended dose (Fig. 5). In case of treatments receiving MCPA a declining trend was also noticed. Pacanoski and Glatkova (2009) found significant increase in rice grain yield with the use of Mefenacet+ bensulfuron methyl in comparison with untreated control. These findings are further supported with the work of Bhuiyan and Ahmad (2010), who also realized better yields in rice with the mixture of Mefanacet and bensulfuron.

From data presented it might reasonably be argued that pre-emergence herbicides offered early season weed control up to the period of full canopy cover by rice plants, which might also contributed to higher grain yield. Application of MCPA at 25 DAT (as recommended) could not bring the desired benefits as weeds grew luxuriantly and. competed with the crop for resources like nutrients, solar radiation, water and space.

Results so far indicated that herbicide application offered higher weed control efficiency as well as higher rice yield as observed in different growing seasons as well as different situations. However, since herbicide application has been increasing rapidly in the country, impacts of repeated as well as longer term application of herbicides in wetland rice on soil health parameters raise concern as well as deserve attention for further research before reaching any precise conclusion.

Table-4. Yield and yield contributing characters as affected by varying rates of butachlor and MCPA .

Treatment	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	Grain yield (t ha^{-1})	Yield increase over control (%)	Average yield under herbicide treatments	Yield increase over control (%)
Butachlor (50%)	59.73	7.70	2.84	16.39	3.67	50.40
Butachlor (75%)	61.43	13.90	3.79	55.33		
Butachlor (100%)	72.21	7.30	4.08	67.21		
Butachlor (125%)	62.00	10.93	3.79	55.33		
Butachlor (150%)	61.30	5.83	3.83	56.97		
MCPA (50%)	61.13	5.57	3.60	47.54	3.21	31.56
MCPA (75%)	69.53	5.84	3.76	54.09		
MCPA (100%)	63.83	10.57	2.96	21.31		
MCPA (125%)	55.73	15.40	2.83	15.98		
MCPA (150%)	58.43	20.44	2.91	19.26		
Weed free	72.17	6.43	4.18	71.31		
Weedy check Control	59.07	23.50	2.44	-		
$LSD_{0.05}$	13.32	NS	0.8295			
CV (%)	11.7		14.9			

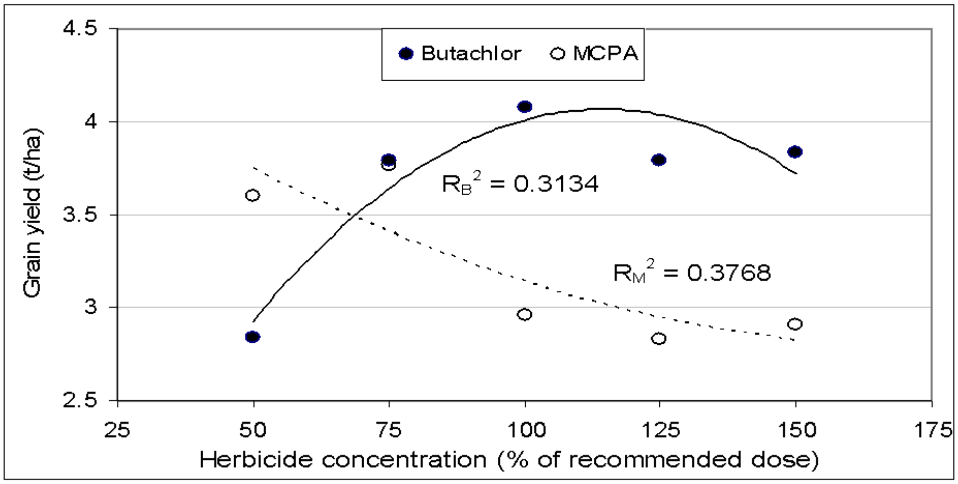

Fig. 5. Relationship between butachlor and MCPA concentrations and rice grain yield.

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EFFECT OF WEEDING REGIME AND PLANTING DENSITY ON MORPHOLOGY AND YIELD ATTRIBUTES OF TRANSPLANT AMAN RICE CV. BRRIDHAN41

Md. Nizamul Hassan[1], Sultan Ahmed[1], Md. Jasim Uddin[1] and Md. Mahmudul Hasan[2]

ABSTRACT

A field experiment was carried out to investigate the effects of weeding regime and planting density on morphology and yield attributes of transplant aman rice cv. BRRI dhan41. Four weeding regimes viz., three hand weeding, two hand weeding, herbicidal control and no weeding were considered as factor A, while four different planting densities viz. two, three, four and five seedlings hill^{-1} were considered as factor B in split plot design in RCBD. Data were recorded on plant height, number of effective tillers hill^{-1}, weight of 1000 grains, grain yield plot^{-1} and straw yield plot^{-1} and some other vital yield attributing characters. Highest value was recorded from the treatment combination of three hand weeding regimes with two seedlings hill^{-1} in most of the evaluated traits. The weakest treatment combination was the no weeding with five seedlings hill^{-1}. So, three hand weeding and two seedlings hill^{-1} are recommended to be practiced for transplant aman rice cv. BRRIdhan41 at farmers' fields in Bangladesh.

Keywords: Weeding regime, planting density, transplant aman rice cv. brridhan41.

INTRODUCTION

Rice (*Oryza sativa* L.) is the dominant staple food for many countries in Asia and Pacific, South and North America as well as Africa (Mobasser *et al.*, 2007). In Asia more than 2 billion people obtain 60 to 70% of their calories from rice (Dowling *et al.*, 1998). In Bangladesh rice occupies 10.37 million hectares land (about two third of the total cultivated land) and it stands first among the cereals (BBS, 2008). Transplant aman rice covers the largest area of 5.7 million hectares (48.67%) with a production of 9.3 million tons rice grain (42.78%) and the average yield is about 1.63 t ha^{-1} in Bangladesh

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(BBS, 1994). The average yield of rice is much lower as compared to other leading rice growing countries. The crop plant growing depends largely on temperature, solar radiation, moisture and soil fertility for their growth and nutritional requirements. An unsuitable population of crop may have limitation in the maximum availability of these factors. Significant effect of planting density on the yield and yield components of rice was also found by Baloch *et al.*, (2002). Weeds compete with rice plant severely for space, nutrients, air, water and light by adversely affecting plant height, leaf architecture, tillering habit, shading ability, growth pattern and crop duration (Miah *et al.*, 1990). Weed depresses the normal yield of grains per panicle and grain weight (Bari *et al.*, 1995). Subsistence farmers of the tropics spend more time, energy and money for weed control than any other aspect of crop production (Kasasian, 1971). Poor weed control is one of the major factors for yield reduction in rice (Amarjit *et al*, 1994). Weed can be controlled by mechanical means or chemical means. Mechanical weed control is expensive and chemical method leads to environmental pollution and in many weed species have developed resistance against the herbicides. Increasing the frequency of hand weeding one or two times at 21 and 40 days after transplanting (DAT) was found to reduce the weed density and weed dry matter resulting in two fold increase in grain yield (Anonymous, 1976). Thus, the best weeding regimes need to be found out with a view to reduce yield losses due to weed infestation and getting maximum yield of transplant aman rice. Keeping the above facts in view, the present study was conducted to determine the optimum planting density for getting the maximum yield best combination of planting density and weeding regime for obtaining yield of transplant aman rice cv. BRRIdhan41.

MATERIALS AND METHODS

An experiment was carried out under field conditions to study the effects of weeding regimes and planting density on yield of Transplant aman cv. BRRIdhan41 at Patuakhali Science and Technology University, Bangladesh. The experiment was laid out in a split-plot under Randomized Complete Block Design (RCBD) with three replications. The size of each sub plot was 4.0 m x 2.5 m. There were four weeding regimes viz., W_1 = three hand weeding, at 15, 30 and 45 days after transplanting (DAT), W_2 = two hand weeding, at 15 and 30 days after transplanting, W_3 = herbicidal control and W_4 = no weeding were considered as factor A, while four different planting densities viz. D_1 = two, D_2 = three, D_3 = four and D_4 = five seedlings hill^{-1}, were considered as factor B. Previously water soaked seeds for 24 hours were sown in the nursery bed on 15 July, 2007. All recommended intercultural operations were adopted to raise a good crop.

Data collection of weeds

The species of weeds found growing in the experimental area were identified. To determine the relative weed density, weeds growing in the unit plots were counted by each kind. Weeds were sampled with the help of quadrat method and recorded. The relative weed density m^{-2} was recorded as under:

$$\text{Relative weed density (\%)} = \frac{\text{Density of the given species m}^{-2}}{\text{Total density of all weed species m}^{-2}} \text{ X } 100$$

Three weed samples per m^2 were collected at the time of weeding. The quadrat was placed at random in the unit plot and all the weeds within each 1 m^2 were uprooted, dried first in the sun and thereafter, for 24 hours in an electric oven maintaining a constant temperature of 70 ^{0}C. After drying weight of each sample were taken. The average weed dry weight was expressed in g m^{-2}.

Data collection of crop characters

Plant height was measured from the ground level to the tip of longest panicle. Data were collected from five hills per plot and then averaged. The panicles which had at least one grain were considered as effective tillers. Panicle length was recorded from the basal node of the rachis to the apex of each panicle. Grains lacking any food material inside were considered as unfilled grains and such grains present on the each tiller were counted. Presence of any food material in the grains was considered as filled grains and such grains presence on the each tiller was counted. Total number of grains from randomly selected five hills were counted and then averaged. One thousand clean dried grains were counted form the seed lot obtained from each plot and weighed by using an electric balance. Grains obtained from randomly selected five hills were sun dried and weighed carefully. Then it was averaged to get grain weight hill^{-1}. Straw obtained from randomly selected five sample hills of respective plot was dried in sun and weighed and then averaged. Grains obtained from each unit plot were sun dried and weighed carefully. The dry weights of grains from the panicle of the sample hills were added to the respective plot yield to record the grain yield plot^{-1}. Straw obtained from each unit plot including the straw of five sample hills of respective plot was dried in sun and weighed to record the straw yield plot^{-1}. The grain and straw yields per plot were subsequently converted to ha^{-1} and recorded. Data recorded for different crop parameters were compiled and tabulated in proper form for statistical analysis. Analysis of variance was done with the help of computer package MSTATC. The mean differences among the treatments were tested with Duncan's New Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Weed components

The data presented in Table-1 exhibit six species of weeds with their families which were identified in the experimental plot. Among the weed species *Eclipta alba* was dominant with its maximum density m^{-2} (121.00) followed by *Marsila quardifolia* (52.33), while *Monochoria hastata* was the minimum in number m^{-2} (2.67). The relative density of weed species showed that *Eclipta alba* possessed 62.72% infestation among the identified weed species, while 27.13% infestation was caused by *Marsila quardifolia* (Table-1). From the data in Table-1, it was further found that dry weight of weed m^{-2} was the highest in *Marsila quardifolia* (23.16 g), while *Eclipta olba* was the second highest (2.89 g). The minimum dry weight of only 0.1g was recorded for *Paspalum distichum* (Table-1).

Table-1. Mean number of species of weeds infesting transplant aman rice cv. BRRIdhan41 with their density, relative density and dry weight m^{-2}.

Scientific Name	Local Name	Family	Weed density m^{-2}	Relative density %	Dry weight (g m^{-2})
Marsila quardifolia	Shusni	Marseliaceae	52.33	27.13	23.16
Echinochloa colonum	Khude Shyama	Poaceae	4.33	2.25	1.33
Scirpus macronatus	Chechra	Cyperaceae	7.33	3.8	0.13
Eclipta olba	Kesoti	Compositae	121	62.72	2.89
Paspalum distichum	Gitla	Poaceae	5.25	2.72	0.10
Monochoria hastata	Nukha	Pontederiaceae	2.67	1.38	0.60

Crop parameters

Plant height

Effect of weeding regime

Plant height was significantly affected by different weeding regimes (Table-2). It was found that the tallest plants (125.37 cm) were found in three hand weeding treatment (at 15, 30 and 45 DAT) which was statistically similar (124.13 cm) to two hand weeding treatment. Whereas, shortest plant height was produced where no weeding was done (Table-2). The results revealed that more hand weeding produced highest plant height. This might be due to the availability of more nutrients from a weed free environment.

Effect of planting density

Plant height was statistically significant for the planting density (Table-2). It was found that planting two seedlings $hill^{-1}$ at a spacing of

20 cm × 15 cm produced tallest plant height (126.89 cm), while lowest (116.51 cm) plant height was from five seedlings hill^{-1} when planted at similar spacing (Table-2). Mobasser *et al.* (2007) showed that plant height was decreased significantly with increase of planting density, which supports the present results.

Interaction effect of weeding regime and planting density

Plant height was significantly influenced by the interaction effect between weeding regime and planting density (Table-3). The tallest plants (128.80 cm) were obtained in the interaction between three hand weeding (at 15, 30 and 45 DAT) and two seedlings hill^{-1} which was statistically similar (128.27 cm) to the interaction between two hand weeding and two seedlings hill^{-1}. The shortest plants (110.63 cm) were observed in the interaction between no weeding and five seedlings hill^{-1}. This result was similar to the findings of Mobasser *et al.* (2007) who found that plant height was decreased significantly with increase of planting density.

Number of effective tillers hill^{-1}

Effect of weeding regime

Statistical results showed that the number of effective tillers hill^{-1} were significant due to different weeding regimes (Table-2). The highest number of effective tillers hill^{-1} (9.25) were found in three hand weeding (at 15, 30 and 45 DAT), whereas lowest one (5.04) were observed in no weeding treatment. The results revealed that more hand weeding produced highest effective tillers hill^{-1}. This might be due to more light and nutrient reception of crop from a weed free environment.

Effect of planting density

There was significant variation on the number of effective tillers hill^{-1} due to various plant populations (Table-2). The highest number of effective tillers hill^{-1} (10.39) was obtained in two seedlings hill^{-1} when planted at a spacing of 20 cm × 15 cm. However, the lowest effective tillers hill^{-1} (5.86) was found from five seedlings hill^{-1} (Table-2). The higher number of effective tillers hill^{-1} from lower seedlings hill^{-1} might be due to lesser nutrient competition among the lower number of plants per unit area and the availability of more space to rice plants.

Interaction effect of weeding regime and planting density

The interaction effect of weeding regime and planting density showed significant variation in respect of number of effective tillers hill^{-1} (Fig. 1). A decreasing trend was found with the increase of number of seedlings hill^{-1} from the two seedlings hill^{-1} (Fig. 1). However, the maximum number of effective tillers hill^{-1} (12.33) were obtained from the treatment combination of W_1D_1 (three hand weeding and two seedlings hill^{-1}), while the minimum number (3.30) was found from no weeding with five seedlings hill^{-1} treatment combination (Fig. 1). Mobasser *et al.* (2007)

found that effective tillers were decreased significantly with increase of planting density which was similar with the present study.

Panicle length

Effect of weeding regime

The results on main effects of weeding regime showed that different weeding regime had significant effect on panicle length (Table-2). The three hand weeding at 15, 30 and 45 DAT gave the maximum panicle length (22.44 cm) and no weeding or control condition gave the minimum (18.95 cm). The maximum panicle length from higher hand weeding might be due to reception of more light and better supply of nutrient crop from a weed free environment.

Effect of planting density

The length of panicle was also significantly influenced by different planting density (Table-2). The D_1 treatment (two seedlings hill^{-1} planted at 20 cm × 15 cm spacing) gave the largest panicle length (24.06 cm). On the other hand five seedlings hill^{-1} gave the shortest (18.10 cm) panicle length.

Interaction effect of weeding regime and planting density

The interaction effect of weeding regime and planting density had significant influence on the panicle length (Fig. 2). The highest length of panicle (25.23 cm) was obtained from the treatment combination of W_1D_1 (three hand weeding with two seedlings hill^{-1}), though it was similar (24.93 cm) to the treatment W_3D_1 (herbicidal control with two seedlings hill^{-1}) and the lowest (17.00 cm) panicle length was obtained from the treatment W_4D_4 (no weeding with five seedlings hill^{-1}). There was a decreasing trend of panicle length with the increasing plant population (Fig. 2). Almost similar results were also represented by Hasan and Sarker (2002).

Number of grains tiller^{-1}

Effect of weeding regime

Present study showed that the number of grains tiller^{-1} significantly differed among the different weeding regimes (Table-2). The highest number of grains tiller^{-1} (105.95) were found in three hand weeding (at 15, 30 and 45 DAT) which was followed by herbicidal control weeding regime (98.92), while the minimum number of grains (79.70) were recorded from no weeding treatment.

Effect of planting density

Planting density significantly contributed to the number of grains tiller^{-1} (Table-2). The highest number of total grains tiller^{-1} (108.75) were obtained from two seedlings hill^{-1} and the lowest grain numbers tiller^{-1} (80.80) were from five seedlings hill^{-1} (Table-2). Sarker *et al.* (2002) also endorsed similar results.

Interaction effect of weeding regime and planting density

Effect of interaction between weeding regime and planting density was found significant in respect of number of grains tiller^{-1} (Table-3). The maximum number of grains tiller^{-1} (124.00) were obtained from the treatment combination of W_1D_1 (three hand weeding with two seedlings hill^{-1}). The minimum number of grains tiller^{-1} (70.20) were found with no weeding and five seedlings hill^{-1}, which was statistically similar to no weeding (71.92) with four seedlings hill^{-1} (W_4D_4) treatment combination (Table-4). Sarker *et al.* (2002) reported from a field trial that 15 day old single seedling hill^{-1} with 30 cm × 30 cm spacing the highest number of seeds panicle^{-1} (131.4) were obtained out of 178.45 spikelets panicle^{-1} as compared to the conventional practices at 40 day old 4 seedlings with spacing of 20 cm × 15 cm.

Weight of 1000 grains (g)

Effect of weeding regime

The effects of weeding regimes were found statistically significant in respect of 1000 grains weight (Table-2). The highest (22.90 g) and lowest (21.09 g) weight of 1000 grains were found from the weeding regime of three hand weeding and no weeding, respectively. The highest 1000 grains weight from highest hand weeding might be due to less nutrient competition between crop and weed.

Effect of planting density

Different number of seedlings hill^{-1} had also significant effect on 1000 grains weight (Table-2). The maximum 1000 grain weight (23.56 g) was obtained from the treatment D_1 (two seedlings hill^{-1}) and the lowest weight (20.61 g) was found from maximum number of seedlings hill^{-1} when planted at a spacing of 20 cm × 15 cm. Baloch *et al.* (2002) found maximum 1000 grain weight from comparatively lower population and higher planting density.

Interaction effect of weeding regime and planting density

The interaction effect was also significant in case of 1000 grain weight (Table-3). The highest (24.01 g) and lowest (19.88 g) weight of 1000 grain were recorded from the treatment combination of W_1D_1 (three hand weeding regime with two seedlings hill^{-1}) and W_4D_4 (no weeding regime with five seedlings hill^{-1}), respectively. Muhammad *et al.* (1997) reported that 1000 grain weight decreased with increasing plant density.

Grain yield plot^{-1} (kg)

Effect of weeding regime

Weeding regime markedly influenced the grain yield plot^{-1} (Fig. 3). The maximum (3.40 kg) and minimum (2.12 kg) grain yield plot^{-1} were recorded from three hand weeding and no weeding regime, respectively. Haque *et al.* (2003) reported that the highest grain yield (3.95 t ha^{-1}) was from three hand weeding regime, which was almost similar to the finding of this study.

Effect of planting density

The results on different planting densities revealed that grain yield was significantly influenced by planting density (Fig. 4). A gradual decrease of grain yield was recorded with the increase of seedling population $hill^{-1}$. However, two seedlings $hill^{-1}$ produced the maximum grain yield $plot^{-1}$ (4.02 kg), while five seedlings produced the minimum grain yield $plot^{-1}$ (1.83 kg). Mobasser *et al.* (2007) also found increased grain yield with the decreasing plant population.

Interaction effect of weeding regime and planting density

The analysis of variance indicated that interaction between weeding regime and planting density was significant for grain yield $plot^{-1}$ (Table-3). Three hand weeding regime with two seedlings $hill^{-1}$ gave maximum grain yield $plot^{-1}$, while no weeding regime with four seedlings $hill^{-1}$ gave minimum yield $plot^{-1}$. Findings of Mobasser *et al.* (2007) agreed with the result of this study.

Straw yield $plot^{-1}$ (kg)

Effect of weeding regime

Data showed that there was a significant effect on the straw yield $plot^{-1}$ for weeding regimes (Table-2). The highest straw yield $plot^{-1}$ (5.46 kg) was found in three hand weeding regime (at 15, 30 and 45 DAT), but the lowest (3.65 kg) was observed in control treatment.

Effect of planting density

Significant variation on the straw yield $plot^{-1}$ was observed due to various planting densities (Table-2). The highest straw yield $plot^{-1}$ (6.22 kg) was obtained in two seedlings $hill^{-1}$ when planted at a spacing of 20 cm × 15 cm (D_1). However, the lowest straw yield $plot^{-1}$ (3.33 kg) was from five seedlings $hill^{-1}$ treatment.

Interaction effect of weeding regime and planting density

The interaction effect of weeding regime and planting density showed significant variation in respect of straw yield $plot^{-1}$ (Table-3). However, the maximum straw yield $plot^{-1}$ (7.00 kg) was obtained from the treatment combination W_1D_1 (three hand weeding and two seedlings $hill^{-1}$), while the minimum grain weight $hill^{-1}$ (2.67 kg) was found from no weeding with four seedlings $hill^{-1}$ treatment combination which was statistically identical (2.99 kg) to the treatment combination of no weeding regime with five seedlings $hill^{-1}$.

Based on the above results, it can be summarized that almost all of the yield and yield contributing characters of transplant aman rice cv. BRRIdhan 41 were performed best under three hand weeding regime (at 15, 30 and 45 DAT) and two seedlings $hill^{-1}$ when transplanted at a spacing of 20 cm × 15 cm. So, from the maximum yield point of view the above treatment combination would be the best under the Ganges Tidal Flood Plain (AEZ 13) in Bangladesh.

Table-2. Effects of weeding regime and planting density on yield and yield components of BRRIdhan41.

Treatments		Plant height (cm)	Number of effective tillers $hill^{-1}$	Panicle length (cm)	Number of grains $tiller^{-1}$	Weight of 1000 grains (g)	Straw yield $plot^{-1}$
Weeding regime	W_1 3 hand weedings	125.37a	9.25a	22.44a	105.95a	22.90a	5.46a
	W_2 2 hand weedings	124.13ab	8.38b	21.42b	95.18c	22.35b	5.05b
	W_3 herbicide control	123.20b	8.41b	21.72b	98.92b	22.45b	5.05b
	W_4 weedy check	117.42c	5.04c	18.95c	79.70d	21.09c	3.65c
	Level of significance	*	*	*	**	*	*
	% CV	1.66	11.90	2.93	4.27	1.81	9.24
	LSD value at 0.05	1.70	0.77	0.52	3.38	0.34	0.37
Planting density	D_1 2 seedlings $hill^{-1}$	126.89a	10.39a	24.06a	108.75a	23.56a	6.22a
	D_2 3 seedlings $hill^{-1}$	124.85b	8.14b	22.35b	99.04b	22.88b	5.37b
	D_3 4 seedlings $hill^{-1}$	121.87c	6.69c	20.04c	91.15c	21.80c	4.29c
	D_4 5 seedlings $hill^{-1}$	116.51d	5.86d	18.10d	80.80d	20.61d	3.33d
	Level of significance	*	*	*	**	*	*
	% CV	1.66	11.90	2.93	4.27	1.81	9.24
	LSD value at 0.05	1.70	0.27	0.54	3.38	0.34	0.37

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly by per DMRT at 5% level of probability.
*Significant at 5% level of probability, **Significant at 1% level of probability

Table-3. Interaction effects of weeding regime and planting density on the growth and yield of BRRIdhan41.

Weeding regime × Planting density	Plant height (cm)	Number of grains tiller^{-1}	Weight of 1000 grains (g)	Grain yield t ha^{-1}	Straw yield t ha^{-1}
W_1D_1	128.80a	124.00a	24.01a	4.66a	7.00a
W_1D_2	126.27bc	108.77c	23.41cd	3.74c	6.05cd
W_1D_3	124.80cd	102.67d	23.02ef	3.08e	5.12f
W_1D_4	121.60e	88.35gh	21.15i	2.10h	3.67h
W_2D_1	128.27a	106.00cd	23.58bc	4.19b	6.65ab
W_2D_2	126.13bc	98.05e	23.12def	3.37d	5.76de
W_2D_3	124.07d	98.33e	21.85g	2.73f	4.40g
W_2D_4	118.05f	78.34j	20.85ij	1.77ij	3.41hi
W_3D_1	127.17ab	112.33b	23.86ab	4.24b	6.40bc
W_3D_2	125.20cd	105.34cd	23.23cde	3.55cd	5.56e
W_3D_3	124.67cd	91.67fg	22.17g	2.87ef	4.98f
W_3D_4	115.76g	86.33hi	20.55j	1.91hi	3.25ij
W_4D_1	123.33de	92.66f	22.79f	3.00e	4.84f
W_4D_2	121.80e	84.00i	21.51h	2.37g	4.11g
W_4D_3	113.92h	71.92k	20.17k	1.60jk	2.67k
W_4D_4	110.63i	70.20k	19.88k	1.52k	2.99jk
Level of significance	*	**	*	**	*
% CV	1.66	4.27	1.81	9.24	9.24
LSD value at 0.05	1.70	3.38	0.34	0.22	0.37

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT) at 5% level.

W_1 = Three hand weeding at 15, 30, 45 (DAT)	D_1 = Two seedlings hill^{-1}	* Significant at 5% level of probability
W_2 = Two hand weeding at 15, 30 (DAT)	D_2 = Three seedlings hill^{-1}	** Significant at 1% level of probability
W_3 = Herbicidal control	D_3 = Four seedlings hill^{-1}	
W_4 = No weeding	D_4 = Five seedlings hill^{-1}	

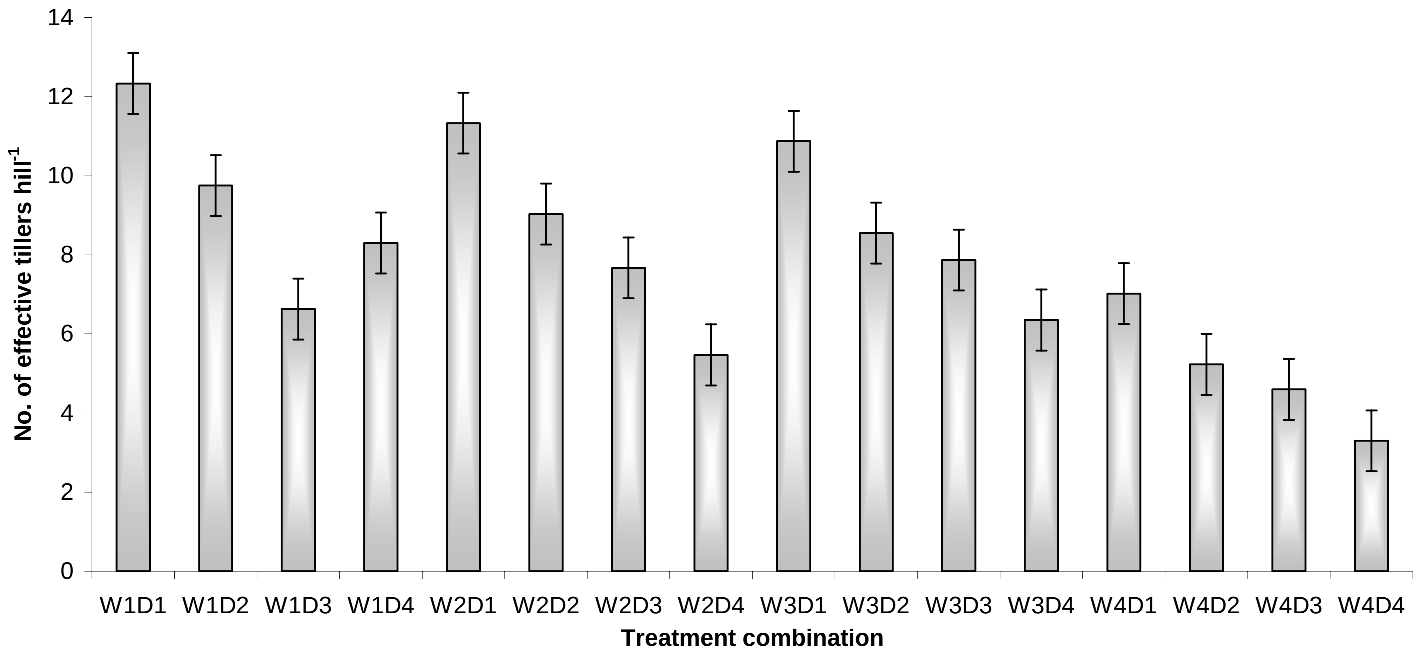

Fig. 1. Interaction effect of weeding regime and planting density on number of effective tillers hill^{-1} of transplant aman rice cv. BRRIdhan41. The vertical bar represents LSD at 0.05 probability level.

W_1 = Three hand weeding at 15, 30, 45 (DAT)	D_1 = Two seedlings per hill
W_2 = Two hand weeding at 15, 30 (DAT)	D_2 = Three seedlings per hill
W_3 = Herbicidal control	D_3 = Four seedlings per hill
W_4 = No weeding	D_4 = Five seedlings per hill

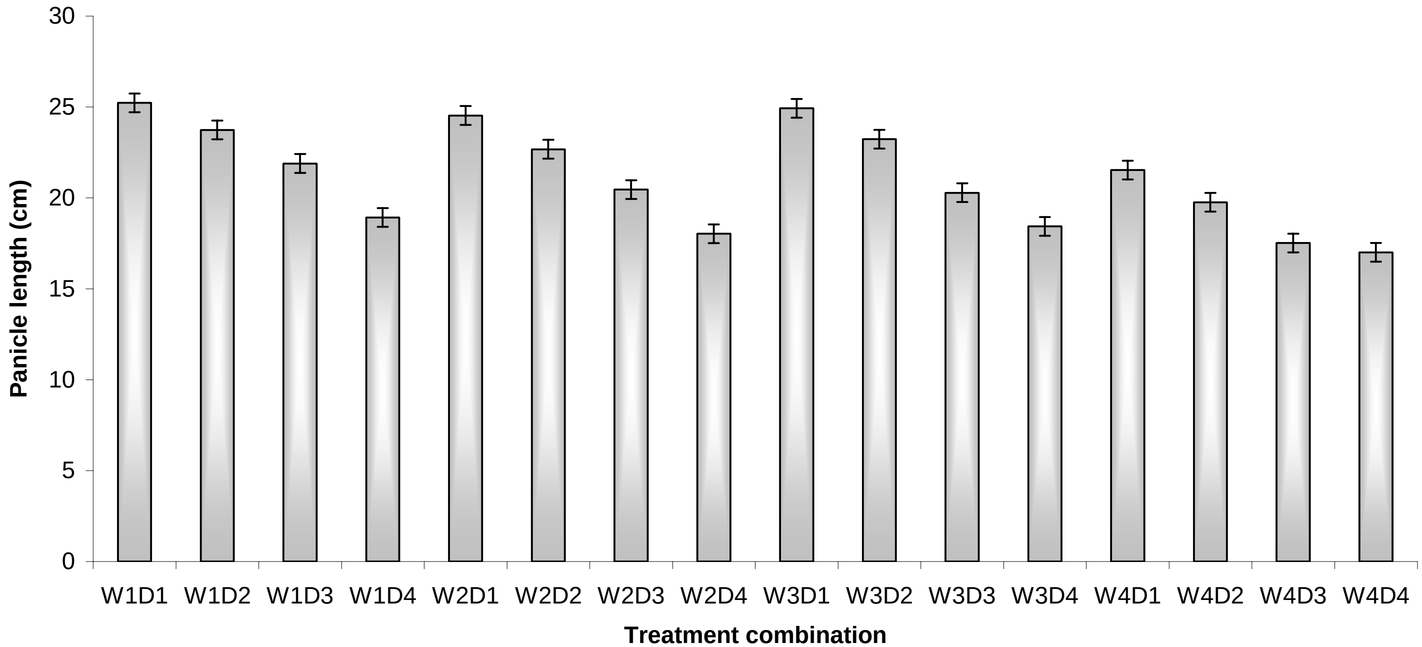

Fig. 2. Interaction effect of weeding regime and planting density on panicle length (cm) of transplant aman rice cv. BRRIdhan41. The vertical bar represents LSD at 0.05 probability level.

W_1 = Three hand weeding at 15, 30, 45 (DAT)
W_2 = Two hand weeding at 15, 30 (DAT)
W_3 = Herbicidal control
W_4 = No weeding

D_1 = Two seedlings per hill
D_2 = Three seedlings per hill
D_3 = Four seedlings per hill
D_4 = Five seedlings per hill

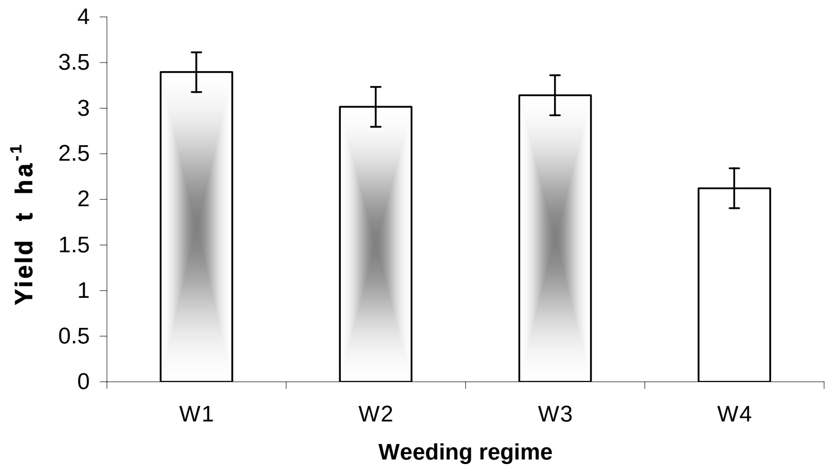

Fig. 3. Effect of weeding regime on grain yield (t ha^{-1}) of transplant aman rice cv. BRRIdhan41. The vertical bars represent LSD at 0.05 probability level.

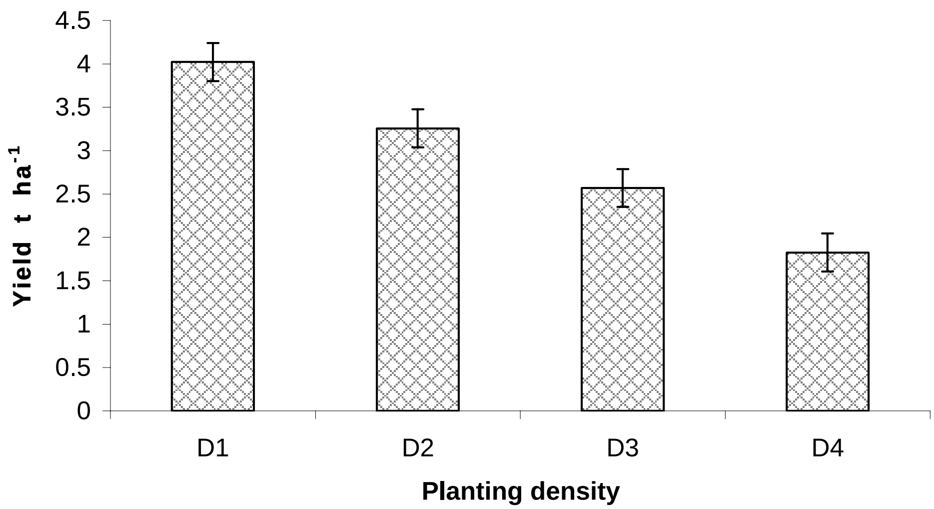

Fig. 4. Effect of planting density on grain yield (t ha^{-1}) of transplant aman rice cv. BRRIdhan41. The vertical bars represent LSD at 0.05 probability level.

W_1 = Three hand weeding at 15, 30, 45 (DAT)
W_2 = Two hand weeding at 15, 30 (DAT)
W_3 = Herbicidal control
W_4 = No weeding

D_1 = Two seedlings per hill
D_2 = Three seedlings per hill
D_3 = Four seedlings per hill
D_4 = Five seedlings per hill

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EFFECT OF CROP ESTABLISHMENT METHODS AND WEED MANAGEMENT PRACTICES ON PROTEIN CONTENT, NUTRIENT UPTAKE AND YIELD OF RICE (*Oryza sativa* L.)

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ABSTARCT

A field experiment was conducted during two consecutive Kharif seasons of 2003 & 2004, to find out most suitable weed management practices for different crop establishment methods. Maximum loss of nutrients by weeds was recorded under zero tillage followed by dry seeding under moist condition while highest content of protein in grain and straw was recorded under transplanting. Highest grain yield (54.72q ha^{-1}) was also recorded under transplanting which was at par with drum seeding (54.53 q ha^{-1}) during first year and significantly superior over other methods during second year. Chemical + 2 hand weeding produced significantly higher grain yield (61.04 q ha^{-1} & 60.88 q ha^{-1}) over other weed management practices during first and second year, respectively.

Key words: Crop establishment methods, Rice, Nutrient uptake, Protein content, Weed management practices.

INTRODUCTION

Rice is one of the most important cereal crops, as it is staple food of more than 70% population of the world. The slogan "Rice is life" is most appropriate for India as this crop plays a vital role in national food security. It is well documented that initial plant stand contributes substantially in our productivity as a low cost technology. Although, transplanting has been reported to be the best establishment method (Jana *et al.* 1981; Singh *et al.* 1997) but due to high labour charges and unavailability of field workers during peak period some alternative like drum seeding, zero tillage, direct seeding under moist condition, must be explored, to ensure optimum population at a lower cost. Weeds compete with plants for all critical growth factors viz. space, sunlight, water and nutrient thus cause considerable yield loss. Manna (1991) reported yield reduction due to weeds to the extent of 25% in transplanted rice, 32% in puddled broadcast rice and 52% in direct sown rice. Keeping in view these

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facts, an attempt has been made to find out the best weed management practice for different establishment methods.

MATERIALS AND METHODS

The present experiment was conducted at Agronomy Research farm of Narendra Dev University of Agriculture and Technology, Kumarganj, Faizabad, India during Kharif 2003 & 2004. The soil of the experimental field was silty loam in texture with low organic carbon (0.36-0.39%) and nitrogen (180.12-193.70 kg ha^{-1}) and medium in phosphorus (14.20-15.11 kg ha^{-1}) and potassium (246.4-268.08 kg ha^{-1}). The experiment was laid down in split plot design, main plot treatments comprise 4 crop establishment methods viz. M_1-dry seeding under moist condition, M_2-drum seeding, M_3- zero tillage and M_4- transplanting while sub plot treatments consisted of 4 weed management practices i.e. W_0- control, W_1- chemical + one hand weeding (20 DAS/DAT), W_2-two hand weeding (20 & 40 DAS/DAT) and W_3- chemical + two hand weeding (20 & 40 DAS/DAT). Different herbicides were used for different establishment method as glyphosate @ 1.0 kg a.i. ha^{-1} for zero tillage, butachlor @ 1.5 kg a.i. ha^{-1} for transplanting, anilofos @ 0.4 kg a.i. ha^{-1} for drum seeding and pendimathalin @ 1.0 kg a.i. ha^{-1} for dry seeding under moist condition and zero tillage plots. The rice variety Sarju-52 was used for sowing and fertilized with NPK @ 120:60:40 kg ha^{-1}. Irrigation and other agricultural operations were conducted as per recommendation.

RESULTS AND DISCUSSION

Nutrient uptake by crop

N, P and K uptake by rice was significantly influenced by different crop establishment methods and weed management practices during both the years (Table-1). Transplanting and drum seeding (96.22 & 96.42 kg ha^{-1}) being at par, significantly increased the uptake of N, P and K over dry seeding and zero tillage during 2003 while transplanting (96.53 kg ha^{-1}) was found significantly superior over all other methods in 2004. This might be due to the fact that puddling reduced the weed population as well as infiltration rate which led to higher grain and straw yield under transplanting and when multiplied by corresponding nutrient content resulted in significant increase in N, P and K uptake in both grain and straw. Significantly higher values of N, P and K uptake were recorded with chemical + 2 hand weeding. These results are in conformity with Singh *et al.* (1998) and Jaiswal and Singh (2001).

Nutrient uptake by weed

The loss of nutrients through weeds was minimum with transplanting followed by drum seeding (Table-1). Highest nitrogen uptake of 8.82 & 3.81 kg/ha was recorded under zero tillage during first and second year, respectively. Similarly during first and second year P & K uptake was also higher with zero tillage which was 1.82 & 0.78 kg $ha^{-1}$for P and 11.10 & 4.28 kg $ha^{-1}$for K. occurrence of more number of weeds per unit area and favorable growing condition, turning crop weed competition in favour of weed, resulted significant increase in dry weight of weed under zero tillage. These finding are also in agreement with number of researchers like Nandal & Singh (1994) and Sinha *et al.* (2005). NPK uptake by weeds was also significantly influenced by different weed management practices during both the years. Highest value of nitrogen loss 12.21 and 4.77 kg ha^{-1} was recorded with control plots during both the years. Weed management practices chemical + 1 hand weeding (W_1), two hand weeding (W_2) and chemical + 2 hand weeding (W_3) reduced the loss of nitrogen to the extent of 46.84, 67.48 &70.59 kg ha^{-1} in first year and 44.86, 66.45 and 72.32 kg ha^{-1} during second year. During first and second year, highest removal of P & K (2.46 and 0.96 kg ha^{-1} and 13.35 & 5.41 kg ha^{-1} respectively) was found under control plots. All the weed management practices significantly reduced the loss of nutrients over control. Lowest removal of nutrients was found with chemical + two hand weedings during both the years. The results are similar to those reported by Raghupati *et al*. (1992).

Protein content in grain and Straw

Protein content in grain and straw was significantly influenced by different crop establishment methods and weed management practices in 2003 while non significant differences were observed during 2004 (Table-2). Highest protein content (7.53%) in grain was recorded with transplanting during first year. Regarding weed management practices, highest protein content (7.57%) was recorded with chemical + 2 hand weeding which was significantly superior over control only. In straw highest protein content of 3.38% was recorded with zero tillage which was 4.20, 3.43 and 2.65 per cent higher dry seeding under moist condition (M_1), drum seeding and transplanting, respectively during first year. Different weed management practices failed to bring any significant variation during both the years. Rana *et al.* (2000) and Singh, (2002) have also reported similar findings in their studies.

Yield

Grain and straw yields were significantly influenced by different crop establishment methods and weed management practices during both the years (Table-2). Highest grain yield was recorded under transplanting (54.72q ha^{-1}) which was at par with drum seeding (54.53 q ha^{-1}) during first year, while during second year transplanting (55.29 q ha^{-1}) significantly increased the grain yield over all other methods.

Table-1. Nutrient uptake by crop & weed as influenced by crop establishment methods & weed management practices.

Treatments	N uptake by crop (kg ha^{-1})		P_2O_5 uptake by crop (kg ha^{-1})		K_2O uptake by crop (kg ha^{-1})		N uptake by weed (kg ha^{-1})		P_2O_5 uptake by weed (kg ha^{-1})		K_2O uptake by weed (kg ha^{-1})	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Method of crop establishment												
Dry seeding (M_1)	66.58	67.10	13.50	14.02	23.06	23.17	8.59	3.16	1.75	0.64	9.14	3.55
Drum seeding (M_2)	96.42	88.40	19.68	18.00	33.18	30.37	5.40	1.85	1.10	0.39	6.06	2.13
Zero tillage (M_3)	77.98	73.13	15.93	14.66	26.51	24.87	8.82	3.81	1.82	0.78	11.10	4.28
Transplanting (M_4)	96.22	96.53	19.68	19.68	33.18	33.18	3.45	1.50	0.70	0.31	3.85	1.68
C .D at 5%	2.12	6.96	0.38	1.56	1.16	2.33	2.21	0.71	0.21	0.15	1.07	0.80
Weed management practices												
Control (W_0)	51.00	47.30	10.28	9.56	18.16	16.31	12.21	4.77	2.46	0.98	13.35	5.41
Chemical+1 hand weeding (W_1)	79.26	76.96	16.06	15.47	27.80	26.61	6.49	2.63	1.07	0.54	7.48	2.95
Two hand weeding (W_2)	99.96	95.73	20.55	19.38	35.06	32.72	3.97	1.60	0.96	0.33	4.72	1.80
Chemical +2hand weeding (W_3)	107.20	105.76	21.93	21.37	36.00	36.00	3.59	1.32	0.89	0.27	4.59	1.48
C .D at 5%	5.40	4.45	1.13	0.97	1.50	1.5	1.55	0.55	0.65	0.12	1.10	0.65

Table-2. Yield and protein content in grain and straw as influenced by crop establishment methods & weed management practices.

Treatments	Yield (q ha^{-1}) 2003		Yield (q ha^{-1}) 2004		Protein content in grain (%)		Protein content in straw (%)	
	Grain	Straw	Grain	Straw	2003	2004	2003	2004
Method of crop establishment								
Dry seeding (M_1)	37.26	47.15	38.41	42.53	7.36	7.07	3.25	3.33
Drum seeding (M_2)	54.53	65.61	50.62	58.57	7.26	7.05	3.27	3.35
Zero tillage (M_3)	44.53	53.23	42.27	48.27	7.45	7.03	3.38	3.40
Transplanting (M_4)	54.72	66.02	55.29	63.94	7.53	7.13	3.30	3.38
C.D. at 5%	1.31	1.56	4.12	4.43	0.26	NS	0.07	NS
Weed management practices								
Control (W_0)	28.12	34.89	26.47	33.52	7.11	7.03	3.27	3.35
Chemical +1 hand weeding (W_1)	44.52	55.58	43.77	49.32	7.37	7.10	3.32	3.36
Two hand weeding (W_2)	57.28	69.27	55.46	61.53	7.51	7.03	3.26	3.38
Chemical +2hand weeding (W_3)	61.04	72.27	60.88	68.95	7.57	7.13	3.35	3.37
C.D. at 5%	3.01	3.74	2.66	2.74	0.30	NS	NS	NS

The increase in grain yield due to transplanting, drum seeding and zero tillage was 46.85, 46.43 and 19.51 per cent higher during first year and 43.94, 31.45 and 10.05 per cent higher during second year over dry seeding. Higher grain yield under transplanting was due to better crop growth and development resulting higher values of yield attributes which increased the grain yield. These findings are also in agreement with those of Goel and Verma (2000) and Yadav *et al*. (2005). The highest yield during both the years was recorded under chemical + 2 hand weeding. The increase in yield due to chemical + 1 hand weeding (W_1), two hand weeding (W_2) and chemical + two hand weedings (W_3) was to the extend of 58.32, 103.69 and 117.06% in 2003 and 65.35, 1089.52 and 130.00% in 2004 over control. Similar trend was found regarding straw yield also. Highest straw yield during both the years was recorded with transplanting (66.02 & 63.94 q ha^{-1}) followed by drum seeding. In weed management practices highest straw yield during both the years was recorded under chemical + 2 hand weeding while lowest yield was found under control plots. Similar results have also been reported by Bhan *et al.* (1980) and Kumar and Gautam (1986).

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EVALUATION OF POST EMERGENCE HERBICIDES ON WEED CONTROL IN RICE NURSERY

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ABSTRACT

A field experiment was conducted during rainy seasons of 2007-08 and 2008-09 to evaluate different post emergence herbicides like cyhalofop butyl 100 g ha^{-1}, bis-pyribac-sodium 20 to 50 g ha^{-1}, propaquizafop 50 g ha^{-1}, ethoxy sulfuron 15 g ha^{-1}, 2,4-D Na salt 800 g ha^{-1}, alone and tank mixture of cyhalofopbutyl 100 g ha^{-1} + ethoxy sulfuron 15 g ha^{-1} 2,4-D Na salt 800g ha^{-1} for broad spectrum weed control in rice nursery. Results revealed that all the herbicidal treatments significantly reduced total weed density and dry weight over unweeded check. Among the treatments, post emergence application of bis-pyribac-sodium 30 g ha^{-1} applied 15 at DAS (days after sowing) significantly reduced total weed density, dry weight and was on par with its higher doses of 40 and 50 g ha^{-1} with weed control efficiency of 74 to 79 percent. Among the treatments, post emergence application of propquizafop 50 g ha^{-1} caused severe stand loss of rice (90 percent) by 14 days after application. Whereas, bis-pyribac-sodium at higher dose of 50 g ha^{-1} also caused slight injury, but crop recovered with in 14 days after application. Tank mixing of cyhalofop butyl 100 g ha^{-1} with 2, 4-D Na salt 800 g ha^{-1} or ethoxy sulfuron 15 g ha^{-1} did not offer any additional advantage compared to bis-pyribac-sodium 30 g ha^{-1}.

Key words: Post emergence herbicides, rice nursery.

INTRODUCTION

In transplanted rice cultivation, maintenance of weed free nursery is a pre requisite, in order to ensure good seedling vigour and ultimate optimum stand in rice and also to reduce early weed competition in main field. In rice nurseries, continuous use of grassy herbicides for the control of problematic weed like *Echinochloa* spp. resulted in weed shift towards broad leaf weeds (BLW) and sedges which became problematic and significantly reduce the crop growth. Though, 2,4,-D is used for control of BLW but it is causing slight injury

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besides poor or no control of grassy weeds. In past, several workers reported about the possible use of pre- and post-emergence grassy herbicides in rice nurseries (Rao and Moody, 1988; Hariom *et al.*, 1993; Narasimha-Reddy *et al.*, 1999; Venkata-raman, 2000; Rao, 2005). But, there is a dire need to evaluate new selective post emergence herbicides for broad spectrum weed control in rice nursery as the information available on this aspect is scanty. Keeping this in view the present investigation was conducted to find out a selective broad spectrum herbicide for control of grasses, sedges and BLW in a single spray in rice nursery as an alternative to the existing recommendation.

MATERIALS AND METHODS

A field experiment was conducted consisting of 12 treatments with three replications using randomized complete block design during rainy season of 2008 and 2009 at Regional Agricultural Research Station, Lam, Guntur, A.P, India. The soil of the experimental plot was clay loam with a pH of 8 and medium in available N and P and high in available potassium. Rice seeds of cultivar 'Samba Mashuri' ('BPT' 5204) at 50 kg ha^{-1} and common weed seeds (grasses and BLW) at 10 kg ha^{-1} were mixed thoroughly and broadcasted uniformly in 2x2 m^2 plots.

The crop and weed seeds were inter mixed with soil in the upper 2 to 3 cm layer. All the recommended cultural practices except weed control were followed for raising the nursery. Post-emergence herbicides were applied on 15 DAS using spray volume of 500 L ha^{-1}. Phytotoxicity rating was made on 7 and 14 days after treatment (DAT). Observations on seedling density, weed density, dry weight of crop and weed were recorded from one quadrate at 30 days after sowing (DAS). The data on weed population was transformed to $\sqrt{x+0.5}$ transformations before statistical analysis and then subjected to ANOVA followed by LSD test for mean separation (Steel *et al.*, 1997).

RESULTS AND DISCUSSIONS

Effect on weeds

The dominant weed flora of the experimental field consisted of grassy weeds such as *Echinochloa colona* and *Dinebra retroflexa*; sedges like *Cyperus rotundus* and broad leaf weeds *Commelina benghalensis*, *Phyllanthus niruri*, *Cynotis cucullata*, *Eclipta alba*, *Digeria arvensis*, and *Trianthema portulacastrum.* All the weed control treatments significantly reduced the density of grasses, BLW, total weed density and dry weight over unweeded check (Table-1). Among the treatments, post emergence application of bis-pyribac-sodium 30 g ha^{-1} reduced weed growth with higher weed control efficiency (WCE) of 74 % and was at par with its higher doses of 40 and 50 g ha^{-1} and also with hand weeding at 15 DAS and significantly superior to post emergence application of cyhalofopbutyl 100 g ha^{-1}, propaquizafop 50 g ha^{-1} and 2,4-D Na salt 800 g ha^{-1}.

It was further observed that tank mixing of cyhalofopbutyl with 2,4–D Na salt/ethoxy sulfuron did not offer any additional advantage when compared to alone application of bis-pyribac-sodium. This clearly indicates broad spectrum control by bis-pyribac-sodium. These observations are supported by the previous work of Rao and Moody (1988) who recommended the use of herbicides over the mechanical control of weeds in rice nurseries.

Effect on crop

The visual rating on phytotoxicity of herbicides recorded at 7 and 14 days after application indicated that post emergence application of propaquizafop 50 g ha^{-1} caused severe stand loss of rice at 60 and 90 %, respectively. Whereas bis-pyribac-sodium at higher dose of 50 g ha^{-1} also caused slight injury of pale yellow /topburn etc. But crop recovered by 10 days after application (Table-2). All the herbicide treatments except propaquizafop significantly influenced crop dry weight over unweeded check.

Among the treatments, post emergence application of bis-pyribac-sodium 30 g ha^{-1} recorded higher crop dry weight but was on par with the other doses (20,40, and 50 g ha^{-1}) and also with alone application of cyhalofop butyl, ethoxy sulfuron and their combination. However, none of the herbicides could reach the level of hand weeding, which recorded the highest dry weight of rice seedling at 30 DAS.

These results are corroborated with those reported by Rao (2005) and further supported by the work of Patel *et al.* (1985) and Rao and Moody (1988), who obtained a variable control in rice nurseries with the use of different herbicides.

From this study, it can be concluded that post emergence application of bis-pyribac-sodium 30 g ha^{-1} applied 15 DAS was found to be the most effective due to its effective broad spectrum control, high selectiveness to rice with out any phytotoxicity and higher dry matter accumulation in rice seedlings and lower cost of application compared with hand weeding. The next best treatment is the lower dose of bis-pyribac-sodium 30g ha^{-1} applied 15 DAS.

Table-1. Effect of different treatments on weed density and dry weight in rice nursery (Pooled data).

Treatments	Dose (g ha^{-1})	Time of application (DAS)	Weed density (plants m^{-2}) at 30 DAS				Total weed dry weight (g m^{-2}) at 30 DAS	WCE (%)
			Grasses	Sedges	BLW	Total weeds		
T1- Unweeded check	-	-	9.9 (108.7)	5.6 (30.1)	10.6 (112.0)	15.8 (251.3)	11.7 (140.0)	-
T2- Hand Weeding	-	15	4.4 (20.0)	4.1 (18.0)	4.4 (20.0)	7.6 (58.0)	3.8 (14.5)	68
T3- Cyhalofop butyl	100	15	3.0 (10.0)	5.3 (25.3)	7.3 (54.0)	9.4 (90.0)	5.1 (26.4)	56
T4- Bis-pyribac-sodium	20	15	3.7 (18.0)	4.8 (24.0)	5.4 (30.7)	8.3 (70.7)	3.8 (14.8)	68
T5- Bis-pyribac-sodium	30	15	2.1 (6.00)	4.2 (18.0)	3.2 (12.0)	6.0 (39.3)	3.1 (9.5)	74
T6- Bis-pyribac-sodium	40	15	1.5 (2.7)	3.4 (11.3)	2.9 (8.0)	4.7 (22.0)	2.9 (8.1)	75
T7- Bis-pyribac-sodium	50	15	1.2 (2.0)	3.8 (16.0)	1.8 (4.0)	4.7 (26.0)	2.5 (6.3)	79
T8- Propaquizafop	50	15	4.1 (22.7)	5.4 (31.3)	7.6 (59.7)	10.5 (114.0)	4.6 (16.0)	61
T9- Ethoxysulfuron	15	15	5.8 (33.3)	3.6 (14.0)	3.8 (14.0)	7.8 (61.3)	4.0 (15.5)	66
T10-2,4–D Na salt	800	15	5.4 (30.7)	3.7 (17.3)	0.9 (0.7)	6.7 (46.7)	4.7 (22.6)	60
T11-Cyhalofop butyl + ethoxysulfuron	100+15	15	3.2 (12.0)	3.7 (13.3)	2.5 (3.3)	5.6 (34.0)	4.0 (16.0)	66
T12-Cyhalofop butyl + 2,4–D Na salt	100+800	15	4.1 (17.3)	3.4 (12.0)	2.6 (7.3)	5.8 (34.7)	4.0 (16.0)	66
$CD_{0.05}$			1.68	1.36	1.24	1.35	1.19	

*DAS Days after sowing. **Data transformed to $\sqrt{x+0.5}$ transformation. ***Figures in parentheses are original values

Table-2. Effect of different treatments on crop injury, density, plant height and dry weight in rice nursery.

Treatments	Dose (g ha^{-1})	Time of application (DAS*)	Crop injury (%) Days after application		Plant density (plants m^{-2})	Plant Height (cm)	Crop dry weight (g m^{-2})	Cost of Treatment (Rs. ha^{-1})
			7	14				
T1-Unweeded check	-	-			726	20.3	50.0	-
T2-Hand Weeding	-	15			920	26.7	105.7	2,500
T3-Cyhalofopbutyl	100	15			803	25.4	70.3	1,600
T4-Bis-pyribac-sodium	20	15			1028	24.7	75.0	1,200
T5-Bis-pyribac-sodium	30	15			830	23.0	80.0	1,800
T6-Bis-pyribac-sodium	40	15			1011	22.7	72.5	2,400
T7-Bis-pyribac-sodium	50	15	10	0	992	21.1	69.3	3,000
T8-Propaquizafop	50	15	60	90	240	16.3	19.5	1,600
T9-Ethoxysulfuron	15	15			888	25.4	70.2	500
T10-2,4–D Na salt	800	15			861	21.0	65.0	220
T11-Cyhalofop butyl + Ethoxysulfuron	100+15	15			863	24.0	68.0	2,100
T12-Cyhalofop butyl + 2,4-D Na salt	100+800	15	10	0	834	22.2	65.3	1,820
$CD_{0.05}$					144.5	2.98	13.51	

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PERFORMANCE OF WEED MANAGEMENT PRACTICES FOR DIFFERENT ESTABLISHMENT METHODS OF RICE (*Oryza sativa* L.) IN DRY SEASON

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Abstract

Effect of rice establishment methods and weed management practices on associated weeds and grain yield of rice was studied at BRRI farm Gazipur and BRRI farm Bhanga, Faridpur District during dry seasons of 2006 and 2007. Seven weed control treatments were imposed inside three planting methods in Split Plot under RCBD. Herbicide MCPA 500 @ 500g a.i. ha^{-1} showed some phytotoxicity in broadcasting and drum seeded system where other treatment combinations did not show any significant phytitoxicity on crops. Grass type weed were dominant in direct wet seeded rice whereas sedges and broad leafs were dominant in transplanting method of rice. Weed control efficiency varied from 80 to 85% during 2006 and 88-91% in 2007 against different weed control treatments. Weed number and weight was significantly higher in broadcast and drum seeded method resulting lower weed control efficiency than transplanting method. Different groups of herbicide + one hand weeding gave statistically similar yield compared with weed free treatments except MCPA500 @ 500g a.i. ha^{-1} + one hand weeded treatments. Higher panicles m^{-2} in broadcasting and drum seeded method led to higher grain yield than transplanting method. Interaction effect of ethoxysulfuron 150WG @ 15g a.i. ha^{-1} + one hand weeding in broadcasted method and pretilachlor 500EC @ 500g a.i. ha^{-1} + one hand weeding under drum seeding produced higher grain yield, whereas other combinations of treatments produced intermediate grain yield. Broadcasting and drum seeding method produced lower grain yield in unweeded condition as compared with transplanting method under the with same condition. It is thus, concluded that for realizing higher yields of rice drum and broadcast methods should be integrated with ethoxysulfuron and pretilachlor @150 and 500 g a.i. ha^{-1}, respectively in combination with one hand weeding.

Key Words: Rice, establishment method, weed management, herbicide.

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INTRODUCTION

In Bangladesh, transplanting is the most popular planting method for rice establishment. There is an increasing trend to replace transplanting of rice by wet seeding. Effective weed control is one of the major requirements to ensure a successful wet seeded rice crop. The transformation in crop-establishment technique from transplanted to wet seeded rice cultivation has resulted in dramatic change in the type and degree of weed infestation (Subramaninan *et al.,* 2006). Weed Management is very critical factor for successful production of wet seeded rice, because the soil conditions favor simultaneous germination of weed seeds along with rice seeds. So it is difficult to control weeds by hand weeding in the early stage of crop growth in wet seeded rice (James, 1998). Uncontrolled weed growth causes nine percent greater reduction in grain in wet seeded rice than in transplanted rice (Moody, 1993). Herbicide is more efficient in timely control of weeds in wet seeded rice. Chemical weeding preferably the use of pre-emergence herbicide is vital for effective and cost-efficient weed control in such situation where weeds complete with the main crop right since the date of germination (Subramaninan *et al.,* 2006). Again herbicide alone does not solve the purpose of weed control satisfactorily in wet seeded rice unless it is supplemented with manual weeding. Continuous use of same herbicide having the same mode of action may lead to the development of resistance in weeds (Malik and Singh, 1993). Pre emergence herbicides mainly control weeds in the earlier stages and weeds emerging at later stages of rice growth are not controlled efficiently. So combination of chemical and manual weeding becomes essential for effective management of weeds to get good yield. Therefore the experiment were conducted with a number of pre and post emergence herbicides alone and its combination with hand weeding to develop an effective and viable weed management practice for wet seeded rice compare with transplanting method.

MATERIALS AND METHODS

The Experiment was conducted at BRRI farm, Gazipur and Faridpur, Bangladesh, during the season of *Boro* 2006 and 2007, to scrutinize the effectiveness of herbicide along and its combination with one hand weeding to develop a useful weed management practices in broadcasting, drum seeding and transplanting method of rice. Seven weed control treatments were imposed inside three planting method system. Weed control treatments were oxadiazone 25EC @ 0.5kg a.i. ha^{-1} + one hand weeding, pretilachlor 500EC @ 0.5kg a.i. ha^{-1} + one hand weeding, ethoxysulfuran 150 WG @ 100g a.i. ha^{-1}+ one hand weeding,. MCPA 500 @ 0.5kg a.i. ha^{-1} + one hand weeding, butachlor 5G @ 1.25 kg a.i. ha^{-1} + one hand weeding, weed free and the weedy check (control). Rice establishment methods were broadcasting, drum seeding and transplanting. 'BRRI dhan29' was used as a variety. Rice establishment methods were placed in main plots and weeding methods in the subplots. Seeds were broadcasted @ 40kg ha^{-1} on 5^{th} December, 2006 and 7^{th} December, 2007 at Gazipur and Faridpur, respectively and at the same time sprouted seeds were seeded by drum seeder used by single row thin layer. In the same day seeds were seeded in the seedbed for transplanting. Forty two days old seedlings were transplanted at 15 January, 2006 and 17 January, 2007 at Gazipur and Faridpur. Oxadiazone 25 EC, pretilachlor 500EC and butachlor 5G were applied in broadcasted and drum seeded plot at 6 DAS with a thin layer of water in the plot. In transplanted plot same herbicide was applied at 6 DAT. Post emergence herbicide ethoxysulfuron 150 WG was sprayed at 2 leaf stage of weeds (at 15 DAP) and MCPA 500 was applied at 3-4 leaf stage of weeds (20 DAP) in broadcasted, drum seeded plot and at the same approach was adopted in transplanted plot. Water was available in the plot during herbicide application. Fertilizer was applied as per BRRI recommended doses. Weeds were counted at 45 days after planting before one hand weeding. Weed control efficiency was calculated using weed dry weight data following the formula of Rao (1985). Phytotoxicity of the herbicide to rice plants was determined by visual observations (Yellowing of leaves, burring leaf tips, stunting growth etc). The degree of toxicity on rice plant was measured by the phytotoxicity rating as used by IRRI (1965) like 1. No toxicity 2. Slightly toxicity 3. Moderate toxicity 4. Severe toxicity and 5. Plant kill Phytoxicity rating was done within a week after application of herbicides. Phytotoxicity was observed three times at 3, 5 and 7 days after application of herbicide and the mean rate was calculated from 10 sample plants of a until plot. Yields and yield contributing characters of rice were recorded after harvest. The data were analyzed following analysis of variance(ANOVA) technique and mean separation was done by multiple comparison test (Gomez and Gomez, 1984) using the statistical program MSTAT-C (Russell, 1986).

RESULTS AND DISCUSSION

Phytotoxicity of herbicides on rice plants

The degree of toxicity of different pre and post emergence herbicide to rice plants and the symptoms produced on plant are presented in Table-1. It is observed that butachlor 5G @ 1.25kg a.i. ha^{-1} showed insignificant phytotoxicity in both broadcasting and drum seeded rice and in case of transplanting it showed no toxicity during 2006 and 2007. MCPA 500 @ 0.5 kg a.i. ha^{-1} showed some toxicity in

Table-1. Rating of herbicide toxicity under different rice establishment methods.

Treatment	Rating		Broadcasted and drum seeded rice	
	2006	2007	Symptom observed on rice crop, 2006	Symptom observed on rice crop,2007
T1	1.58	1.64	Temporary slight yellowing of leaves which required 9-11 days to recover	Temporary slight yellowing of leaves which required 10-12 days to recover
T2	1.45	1.62	Some times slightly yellowing of leaves.	Slight yellowing of leaves which required 7-10 days to recover
T3	1.40	1.45	Some times slightly yellowing of leaves.	Some times slightly yellowing of leaves.
T4	2.25	2.23	Slightly to moderate toxic. Yellowing of leaves, temporary stunting of growth. Plants required 10-17 days to regain their normal growth and leaf color after application of herbicide. Sometimes plant killed.	Slightly to moderate toxic. Yellowing of leaves, temporary stunting of growth. Plants required 10-15 days to regain their normal growth and leaf color after application of herbicide. Sometimes plant killed.
T5	1.30	1.32	Some times slightly yellowing of leaves.	Some times slightly yellowing of leaves.
			Transplanting	
T1	1.35	1.45	Some times slightly yellowing of leaves.	Some times slightly yellowing of leaves.
T2	1.18	1.20	Some times very slightly yellowing of leaves.	Some times very slightly yellowing of leaves.
T3	1.13	1.12	No toxicity	No toxicity
T4	1.60	1.48	Temporary yellowing of leaves which required 10-16 days to recover	Temporary slightly yellowing of leaves which required 8-11 days to recover
T5	1.0	1.0	No toxicity	No toxicity

T1=Oxadiazone 25EC @ 0.5kg a.i. ha^{-1} + 1HW, T2=Pretilachlor 500EC@ 0.5kg a.i. ha^{-1} + 1HW, T3=Ethoxysulfuron 1500WG @ 15g a.i. ha^{-1} + 1HW, T4=MCPA500 @ 0.5kg a.i. ha^{-1} + 1HW, T5=Butachlor 5G @ 1.25 kg a.i. ha^{-1} + 1HW.

broadcasting and drum seeded plot which cause temporary yellowing, stunted plants, leaf tips turned brown, a few number of injured leaves and some plants killed in both years of study. Others herbicides showed minor phototoxicity in both transplanted and direct seeded rice. It is also observed that phytotonicity symptoms were more prominent in direct seeded wet rice than transplanting in both the years and locations.

Effect on weeds

Weed number, weed weight and weed control efficiency varied due to different weed management practices during 2006 and 2007 (Table-2). Weed number and weight was highest in weedy check plot followed by other weed management treatments in both the years. Weed control efficiency varied from 80% to 85% in 2006 and 88% to 91% in 2007 in different weed management treatments. Weed dynamics also varied in rice establishment method (Table-3). Weed number and weight was significantly higher in broadcast and drum seeded method, consequently these resulted in lower weed control efficiency than transplanted method. During 2006 among different groups of weeds, grasses constitute 63%, sedges 32% and broadleaf constituted only 5% of total population in broadcasting method. Drum seeded method attained 58%, 27% and 15% of grasses, sedges and broadleaves weeds, respectively. In case of transplanting, grasses constituted 29%, sedges 40% and broadleaves were 31%. Similar trend of data were observed in the year of 2007. So it is evident that grassy weeds were dominant in direct wet seeded rice whereas, sedges and broadleaf weeds were dominant in transplanting method (Table-3).

Table-2. Weed density and weed control efficiency as affected by weed management practices.

Treatment	Weed number (m^{-2})		Weed weight ($g\ m^{-2}$)		*WCE (%)	
	2006	***2007***	***2006***	***2007***	***2006***	***2007***
T1	2.56b	2.70b	2.31c	1.35b	85	88
T2	2.64b	2.54b	2.62b	1.28b	81	89
T3	2.79b	2.65b	2.65b	1.29b	81	90
T4	2.93b	2.47b	2.71b	1.19b	80	91
T5	2.85b	2.45b	2.55bc	1.15b	82	91
T6	8.91a	6.74a	6.04a	3.92a	-	-
CV(%)	29.81	17.86	7.81	17.79	-	-
$LSD_{0.05}$	**1.36**	**0.58**	**0.29**	**0.43**	**-**	**-**

Weed data were transforming by square root transformation.

* % Weed Control Efficiency was calculated regarding the treatment over no weeding.

T1 = Oxadiazone 25EC @ 0.5kg a.i. ha^{-1} + 1HW, T2 = Pretilachlor 500EC@ 0.5kg a.i. ha^{-1} + 1HW, T3 = Ethoxysulfuron 1500WG @ 15g a.i. ha^{-1} + 1HW, T4 = MCPA500 @ 0.5kg a.i. ha^{-1} + 1HW, T5=Butachlor 5G @ 1.25 kg a.i. ha^{-1} + 1HW, T6 = Control (Unweeded).

Table-3. Weed prevalence and weed control efficiency as affected by rice establishment methods.

Treatment	Weed number (m^{-2})		Weed weight (g m^{-2})		WCE (%)		Weed species as group (%)			Weed species as group (%)		
							2006			2007		
	2006	2007	2006	2007	2006	2007	G	S	B	G	S	B
Broadcasting	4.04a	3.42a	3.31	1.96a	81.5	87.6	63	32	05	60	30	10
Drum seeding	3.82ab	3.72a	3.27	1.98a	82.0	88.8	58	27	15	56	32	12
Transplanting	3.45b	2.64b	2.86	1.15b	84.65	93.4	29	40	31	30	45	25
CV (%)	29.81	17.86	7.81	0.22	-	-	-	-	-	-	-	-
$LSD_{.0.05}$	0.48	0.43	ns	17.79	-	-	-	-	-	-	-	-

Weed data were transformed by square root transformation. G = Grass, S = Sedge, B = Broadleaf.

Yield and yield components

Yield and yield contributing characters were significantly affected due to different weed management options (Table-4). Number of panicles was higher in weed free plot which is statistically alike with other weed management treatment except weedy check (control) plot during *boro* 2006 and 2007. Lowest number of panicle was found in the weedy check plot. Similar trend of results was found in case of filled grains $panicle^{-1}$ and 1000 grain weight although in *boro* 2006 there is no significant difference for panicle length. Among different weed management treatments weed free plot produced significantly higher grain yield (5.24 tha^{-1}) which is statistically at par with other weed management treatments followed by MCPA 500 + one hand weeded plot which produced 4.66 t ha^{-1} of grain yield, while the weedy check plot gave the lowest (1.61 tha^{-1}) grain yield. Grain yield is higher during 2007 compared with 2006 due to single cropped area where yield potential is high.

Yield and yield components were also affected by rice establishment methods (Table-5). During 2006 yield and yield components did not vary significantly but in 2007 highest panicles m^{-2} were found in drum seeded method that is statistically alike with broadcasting method. Lowest panicle m^{-2} were found in transplanting

Table-4. Yield and yield components of rice as affected by weed management practices.

Treatment	Panicles m^{-2}		Grains $panicle^{-1}$		Panicle length (cm)		1000 grain weight (g)		Grain yield ($t\ ha^{-1}$)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
T1	285a	465a	85a	113a	20.0	20.24bc	20.97a	22.40a	5.19a	7.97ab
T2	276a	466a	81a	114a	20.14	18.02bc	21.5a	21.46a	4.99ab	7.97ab
T3	260a	463a	79a	115a	20.05	21.55ab	21.34a	21.99a	4.81ab	7.94ab
T4	255a	458a	78a	113a	20.80	21.95ab	21.44a	21.89a	4.66b	7.93b
T5	270a	468a	82a	115a	20.25	19.64bc	21.09a	21.62a	4.98ab	7.97ab
T6	278a	484a	83a	124a	20.15	16.68c	20.92a	21.37a	5.24a	8.24a
T7	119b	264b	52b	91b	21.44	25.89a	20.18b	20.41b	1.61c	3.44c
CV(%)	11.16	5.23	7.45	5.99	6.33	22.17	2.90	5.28	8.57	5.17
$LSD_{0.05}$	32.08	26.16	6.62	11.72	ns	4.17	0.70	0.95	0.44	0.27

T1=Oxadiazone 25EC @ 0.5kg a.i. ha^{-1} + 1HW, T2=Pretilachlor 500EC@ 0.5kg a.i. ha^{-1} + 1HW, T3=Ethoxysulfuron 1500WG @ 15g a.i. ha^{-1} + 1HW, T4=MCPA500 @ 0.5kg a.i. ha^{-1} + 1HW, T5=Butachlor 5G @ 1.25 kg a.i. ha^{-1} + 1HW, T6=Weed free,T7=Control(Unweeded).

Table-5. Yield and yield components as affected by rice establishment methods.

Rice establishment method	Panicles m^{-2}		Grains $Panicle^{-1}$		Panicle length (cm)		1000 Grain Weight (g)		Grain Yield ($t\ ha^{-1}$)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Broadcasting	253	464a	79.38	106b	20.06	23.17b	20.97	21.03b	4.78	7.44a
Drum Seeding	252	471a	79.14	109b	20.69	23.70b	21.24	21.5b	4.51	7.49a
Transplanting	242	380b	72.57	118a	20.50	25.01a	20.98	22.38a	4.50	7.12b
CV(%)	11.16	5.23	7.45	5.99	6.33	4.64	2.90	5.16	8.57	5.17
$LSD_{(0.05}$	ns	14.52	ns	4.20	Ns	0.75	ns	0.75	ns	0.24

method but highest grains panicle^{-1} were found in transplanted rice followed by drum seeded and broadcasting method of rice. Similar results were found for 1000 grain weight. Highest grain yield (7.49 t ha^{-1}) was found from drum seeded method that is statistically alike with broadcasting method, but higher than the transplanted rice.

Interaction effect of weed management and rice establishment method significantly varied in weed number, panicles m^{-2} and grain yield of rice during 2007 (Table-6). Among the interactions highest weed number was found in weedy check x drum seeded combination which is statistically alike with weedy check x broadcasting combination, followed by weedy check x transplanted rice.

Table-6. Interaction effect of weed management and rice establishment method on weed, panicles m^{-2} and grain yield of rice.

Interaction effect (WxPM)	Weed number (m^{-2})		Panicles m^{-2}		Grain yield (t ha^{-1})	
	2006	2007	2006	2007	2006	2007
T1P1	2.88	2.76c	274	489ab	4.98	8.17abc
T1P2	2.98	3.05c	268	504ab	5.08	8.16abc
T1P3	3.10	2.29c	263	404c	4.96	7.58bc
T2P1	3.15	2.44c	275	501ab	4.58	8.20abc
T2P2	2.92	2.87c	287	506ab	4.88	8.22ab
T2P3	9.23	2.32c	283	392c	5.33	7.48bc
T3P1	2.51	2.82c	122	508ab	1.54	8.23ab
T3P2	2.38	2.64c	288	497ab	5.29	8.13abc
T3P3	2.74	2.49c	287	385c	4.97	7.46c
T4P1	2.99	2.44c	280	473b	4.9	8.14abc
T4P2	2.88	2.92c	241	493ab	4.60	8.04abc
T4P3	9.53	2.06c	273	408c	5.0	7.6bc
T5P1	2.31	2.27c	275	499ab	5.18	8.21abc
T5P2	2.56	2.79c	121	502ab	1.68	8.13abc
T5P3	2.51	2.29c	294	405c	5.29	7.58bc
T6P1	-	-	272	520a	4.91	8.23ab
T6P2	-	-	238	517ab	4.58	8.51a
T6P3	-	-	250	417c	4.81	7.96abc
T7P1	2.64	7.81a	252	263d	5.10	2.92e
T7P2	2.73	8.02a	276	277d	5.22	3.24e
T7P3	7.97	4.39b	115	254d	1.62	4.16d
CV (%)	29.81	17.86	11.16	5.23	8.57	5.17
Lsd(.05)	ns	0.98	Ns	38.42	ns	0.63

Weed management:
T1 = Oxadiazone 25EC @ 0.5kg a.i. ha^{-1} + 1HW, T2 = Pretilachlor 500EC @ 0.5kg a.i. ha^{-1} + 1HW, T3 = Ethoxysulfuron 1500WG @ 15g a.i. ha^{-1} + 1HW, T4 = MCPA500 @ 0.5kg a.i. ha^{-1} + 1HW, T5 = Butachlor 5G @ 1.25 kg a.i. ha^{-1} + 1HW, T6 = Weed free, T7 = Control (Unweeded)
Rice establishment method:
P1= Broadcasting; P2= Drum seeding; P3= Transplanting

Highest number of panicles m^{-2} were found in weed free x broadcast method which is statistically similar with weed free x drum seeded plot. The lowest panicles m^{-2} was recorded in weedy check x broadcasting plots which is statistically alike with weedy check x drum seeded plot and weedy check x transplanted plots. Highest grain yield (8.51 t ha^{-1}) was produced from weed free x drum seeded plot and lowest (2.92 tha^{-1}) grain yield was harvested in weedy check x broadcasting plot which is statistically similar with weedy check x drum seeded plot followed by weedy check x transplanted plot. Other combinations of treatments produced intermediate grain yield. The above results support with the findings of James, (1998).

It is observed from the data in Table-7 that broadcasting and drum seeded methods produced lower yield in unweeded conditions compared with transplanting involving the some condition in both the years. Weed is the main cause to reduce grain yield in direct wet seeded rice. Subsequently direct seeding produced more weed prevalence than transplanting. These results suggest that for realizing higher yields of rice, drum and broadcast methods should be integrated with ethoxysulfuron and pretilachlor @150 and 500 g a.i. ha^{-1}, respectively in combination with one hand weeding under dry season rice cultivation of Bangladesh.

Table-7. Effect of method of crop establishment on rice yield (t ha^{-1}) under weed free and weedy conditions.

Rice Establishment Method	Grain yield (t ha^{-1})			
	2006		2007	
	Weed Free	Weedy condition	Weed Free	Weedy condition
Broadcasting	5.33	1.53	8.23	2.92
Drum Seeding	5.17	1.67	8.51	3.24
Transplanting	5.22	1.62	7.96	4.16

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RESPONSE OF *Emex australis* TO DIFFERENT POST-EMERGENCE HERBICIDES IN WHEAT (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted to study the effectiveness of different post-emergence herbicides against spiny emex, Emex australis at the University of Agriculture Faisalabad, Pakistan. Fluroxypur + MCPA at 750 mL ha^{-1}, carfentrazone-ethyl at 50 g ha^{-1}, amidosulfuron at 60 g ha^{-1},bromoxynil + MCPA at 1250 mL ha^{-1}, triasulfuron at 40 g ha^{-1}, thiofensulfuron-methyl at 100 g ha^{-1}, tribenuron-methyl at 100 g ha^{-1} and control (no spray) were tested. Carfentrazone-ethyl, fluroxypur + MCPA and bromoxynil + MCPA provided better control (86%, 85% and 76%, respectively) of E. australis over weedy check. Carfentrazone gave the maximum reduction in weed biomass (77%). While bromoxynil + MCPA gave maximum number of fertile tillers (427 m^{-2}), number of grains spike^{-1} (47), 1000 grain weight (33 g) and grain yield (3.39 t ha^{-1}). Thus, for the management of spiny emex, E. australis, the post emergence application of bromoxynil + MCPA and carfentrazone ethyl at 1250 ml and 50 g ha^{-1}, respectively is recommended.

Key words: *Emex australis,* spiny emex, post-emergence herbicides, wheat.

INTRODUCTION

Weed infestation is one of the major causes of low wheat yield in Pakistan that reduces its yield by 17-50% (Anonymous, 1998). The magnitude of the yield losses depends on weed species, weed infestation duration and weed density. A member of family Polygoneceae spiny emex, *Emex australis*, is an erect or diffuse, much branched and throughout glabrous green weed, which has become an important agricultural problem (Shivas and Sivasithamparam, 1994). Due to its high competitive ability and reproductive potential, it has become a serious threat in Pakistan. It is hard and deep root system broadleaf weed, difficult to control due to its re-sprouting ability. Chemical weed control is considered the most effective, time saving and economical way of controlling weeds. However, herbicide response

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differs form species to species. Herbicides commonly used to control broadleaf weeds in wheat in Pakistan are fluroxypur+MCPA, carfentrazone-ethyl, amidosulfuron, bromoxynil + MCPA, triasulfuron, thiofensulfuron-methyl, and tribenuron-methyl. These herbicides have varying potential against different weed species (Tora *et al,* 2010), so the characterization of the sensitivity of *E. australis* against these herbicides is essential. No research has been undertaken to evaluate these herbicides against *E. australis* in Pakistan. Therefore, the objective of this research was to study the response of *E. australis* to different post-emergence herbicides in wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

The study on post emergence herbicides in controlling *E. australis* and their effect on yield and yield components of wheat was carried out at the Agronomic Research Area, Department of Agronomy, University of Agriculture, Faisalabad, Pakistan. Seed bed was prepared by cultivating the soil 2-3 times with a tractor mounted cultivator each followed by planking. Wheat variety 'Sahar 2006' was sown in 2nd week of November, 2008 in 25 cm apart rows with a single row hand drill using a seed rate of 100 kg ha^{-1}. Nitrogen at the rate of 120 kg ha^{-1} and P_2O_5 at 85 kg ha^{-1} was applied in the form of urea and diammonium phosphate (DAP), respectively. Half of the N and whole of P_2O_5 was applied at sowing time and the remaining half of the N was applied at 1st irrigation by broadcast method. The crop was planted in the field having heavy infestation of *E. australis* during the previous years. The experiment comprised of 8 treatments *viz.* fluroxypur + MCPA at 750 mL ha^{-1}, carfentrazone-ethyl at 50 g ha^{-1}, amidosulfuron at 60 g ha^{-1}, bromoxynil + MCPA 1250 mL ha^{-1}, triasulfuron at 40 g ha^{-1}, thiofensulfuron-methyl at 100 g ha^{-1}, tribenuron-methyl at 100 g ha^{-1} and control (no spray) Hand operated knapsack sprayer was used to spray the herbicides. Treatments were applied after 1st irrigation in optimum moisture condition at almost 3-4 leaf growth stage of weed. The experiment replicated 3 times was laid out in a randomized complete block design. The data were recorded on the mortality of *E. australis* at 21 and 42 days after treatment application (DAT) and at harvest time. The crop data were recorded on No. of fertile tillers m^{-1}, No. of grains spike^{-1}, 1000 grain weight (g) and grain yield (t ha^{-1}).

Statistical analysis

The data collected were analyzed by using the Fisher's analysis of variance function of MSTAT statistical computer package and LSD at 5% probability was used to compare the significance of treatment means (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

Density of *E. australis*

The data on weed densities were recorded 21 and 42 days after treatment (DAT) and at harvest time (Table-1). Carfentrazone at 50 g ha^{-1} gave minimum number of weeds (23 and 16 weeds m^{-2}) at 21 and 42 DAT, respectively. Minimum number of weeds (49, 28 and 12 weeds m^{-2}) at the time of 21 and 42 DAT and at harvest respectively were recorded in fluroxypur + MCPA at 750 mL ha^{-1}. Maximum weed control (85%) was observed with fluroxypur+MCPA at 750 mL ha^{-1} whereas amidasulfuron at 60 g ha^{-1} showed minimum (63%) weed infestation over the weedy check (Fig. 1). Carfentrazone-ethyl at 750 mL ha^{-1} was the most phytotoxic to *E. australis* causing 77% reduction in dry weight over weedy check whereas triasulfuron at 40 g ha^{-1} caused minimum reduction in dry biomass (55%) (Fig. 2). There was a great variability among herbicides in their control against *E. australis. E. australis* density decreased as the season progressed compared with 21 DAT (Table-1). This is due to the senescence of *E. australis* caused by inter- and intra-specific competition with wheat and *E. australis*. These results are also supported by Wolf *et al.* (2000). The visual *E. australis* control at harvest was 63.5, 64.7 and 67.7% over weedy check for amidosulfuron, thiosulfuron and tribenuron, respectively, showed less phytotoxic effect on *E. australis* as compared to carfentrazone-ethyl and fluroxypur+MCPA which had maximum weed control over weedy check. These results are supported by Wilson *et al.* (2007). Due to more phytotoxic effect of carfentrazone ethyl on *E. australis* maximum, dry weight per plant reduction was recorded. These results are also in line with Lyon *et al.* (2007).

Yield components and grain yield

Effect of herbicides and *E.australis* on fertile tillers m^{-1}, number of grains per spilke, 1000-grain weight and grain yield was observed (Table-2). Maximum fertile tillers (427 m^{-1}) were recorded in the plots treated with broxoxinal + MCPA at 1250 mL ha^{-1} followed by fluroxypur + MCPA at 750 mL ha^{-1} (403 m^{-1}). The tillers produced by fluroxypur + MCPA were in turn statistically at par with amidosulfuron ans tribenuron. The least fertile tillers (224 m^{-1}) were counted I the weedy check. Maximum number of grains per spike were the same in plots treated with bromoxynil + MCPA at 1250 mL ha^{-1} (47) carfentrazone ethyl (44), tribenuron (43) and triasulferon at 40 g ha^{-1} (45). Whereas thiofensulferon-methyl at 100 g ha^{-1} gave minimum number of grains per spike (40), which could not surpass the weedy check even. Likewise, bromoxinal+MCPA at 1250 mL ha^{-1} (31.95g) and flourxypur+MCPA at 750 mL ha^{-1} (31.98g) gave maximum 1000-grain weight, while all other herbicidal treatments failed to produce higher grain weight as compared to the weedy check (Table-2). All the

Table-1. Effect of different herbicides on density m^{-2} of *E-australis* over time.

Herbicide	No. of weeds m^{-2}		
	21 DAT	**42 DAT**	**At Harvest**
Weedy check	134 a	190 a	85 a
Fluroxypur+MCPA at 750 ml ha^{-1}	49 cd	28 cd	12 d
Carfentrazone-ethy at 50 g ha^{-1}	23 e	16 d	13 d
Amidosulfuron at 60 g ha^{-1}	65 b	45 b	31 c
Triasulfuron at 40 g ha^{-1}	57 bc	45 b	25 cd
Bromoxynil+MCPA at 1250 ml ha^{-1}	37 de	31 c	20 cd
Thiofensulfuron-methyl at 100 g ha^{-1}	68 b	52 b	30 c
Tribenuran at 100 g ha^{-1}	56 bc	40 bc	28 cd
$LSD_{0.05}$	**15.95**	**13.39**	**15.49**

Means sharing the same letter in a column did not differ significantly at 5% probability level.

herbicides produced higher yield as compared to the weedy check. Significant grain yield (3.39 t ha^{-1}) was observed with bromoxynil+MCPA at 1250 mL ha^{-1}, which was statically similar with flourxypur+MCPA at 750 mL ha^{-1} (3.32 t ha^{-1}). Minimum grain yield (2.77 t ha^{-1}) was recorded in plots treated with amidoslfuron at 60 g ha^{-1}, whcich was still higher than the weedy check (Table-2). The effect of bromoxynil+MCPA at 1250 mL ha^{-1} was maximum on yield components and grain yield of wheat. This was due to less competition of weed with wheat. However, minimum number of weeds at 21 and 42 and at harvest were recorded in carfentrazone-ethyl at 50 g ha^{-1} but it perhaps had some suppressing effect on wheat, leading to less grain yield because of physiological response. These findings are further in line with Tora *et al.* (2010) who reported a variable behaviour of different herbicides on different biotypes of corn poppy.

Table-2. Effect of different herbicides on yield components and grain yield of wheat.

Herbicides	No of fertile tillers m^{-1}	No. of grains $spike^{-1}$	100 grain weight (g)	Grain yield (t h^{-1})
Weedy check	224 e	38 d	28.02 b	2.11 d
Fluroxypur+MCPA at 750 ml ha^{-1}	403 ab	46 d	31.98 a	3.32 ab
Carfentrazone ethy at 50 g ha^{-1}	363 cd	44 ab	30.33 ab	3.00 abc
Amidosulfuron at 60 g ha^{-1}	368 bc	42 bcd	31.13 ab	2.77 c
Triasulfuron at 40 g ha^{-1}	330 d	45 ab	31.42 ab	3.16 bc
Bromoxynil+MCPA at 1250 ml ha^{-1}	427 a	47 a	31.95 a	3.39 a
Thiofensulfuron-methyl at 100g ha^{-1}	326 d	40 cd	30.60 ab	2.99 bc
Tribenuran at 100 g ha^{-1}	379 bc	43 abc	31.05 ab	3.03 abc
$LSD_{0.05}$	**38.01**	**3.69**	**3.67**	

Means sharing the same letter in a column did not differ significantly at 5% probability level.

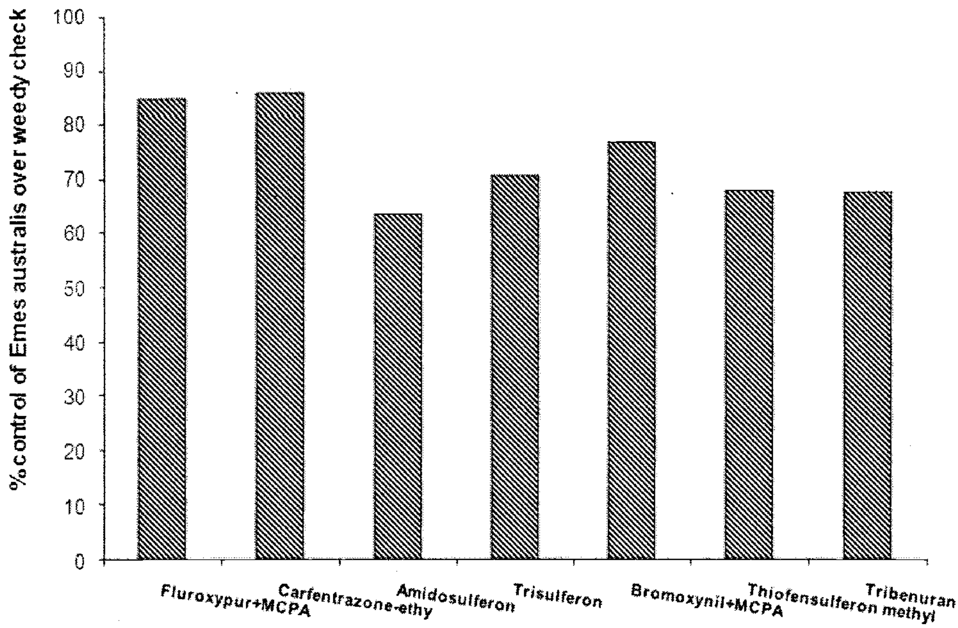

Fig. 1. Effect of herbicides on % control of *Emex australis* over weedy check.

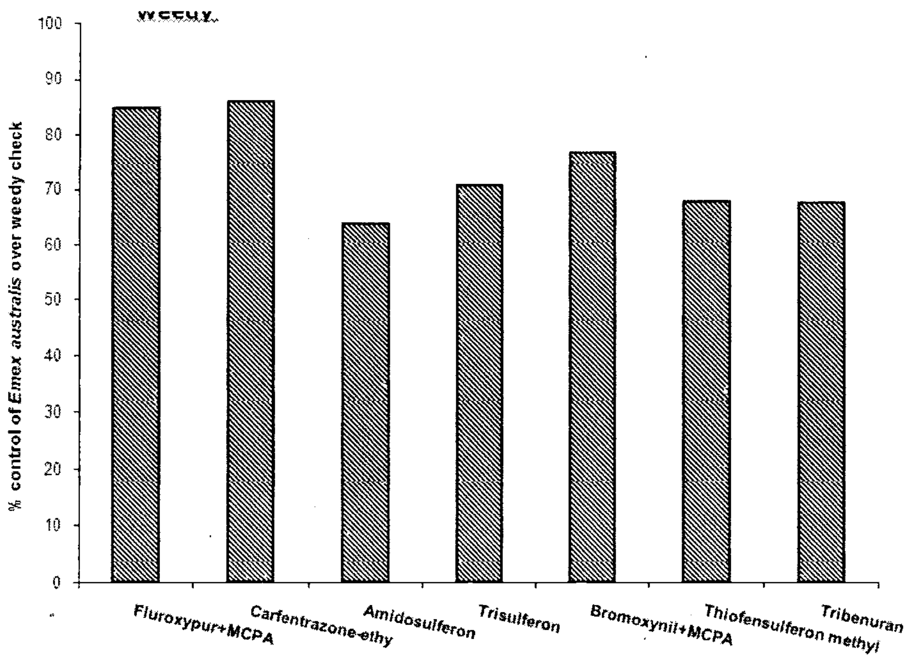

Fig. 2. Effect of herbicides on % reduction in dry weight biomass of *Emex australis* over weedy check.

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ORGANIC WEED MANAGEMENT IN MAIZE (*Zea mays* L.) THROUGH INTEGRATION OF ALLELOPATHIC CROP RESIDUES

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ABSTRACT

Weed suppression is one of the several benefits associated with application of crop residues as mulch in field crops. Nonetheless, the crop residues on the soil surface contribute physically towards weed suppressive effect, yet the chemical effect of phytotoxins released from decomposing residues also imparts significantly for weed control. A field experiment aimed at establishing the weed suppression potential of mixture of crop residues and their effects on maize yield was conducted. Residues of sorghum (Sorghum bicolor L.), sunflower (Helianthus annuus L.), rice (Oryza sativa L.) and brassica (Brassica campestris L.) in various combinations were soil incorporated at 4.5 and 6 t ha^{-1}. Results revealed that a combination of sorghum + sunflower + brassica residues at 6 t ha^{-1} provided > 90% suppression in density and dry weight of horse purslane (Trianthema potrtulacastrum L.) and purple nutsedge (Cyperus rotundus L.) as compared with control (no residue). This treatment also accounted for maximum maize grain yield and net benefits. For better management of natural resources and to decrease environmental pollution, soil incorporation of crop residues may serve as an important weed management tool in maize fields.

Key words: Weeds, crop residues, phytotoxins, *Trianthema potrtulacastrum, Cyperus rotundus.*

INTRODUCTION

Maize is an important crop serving the purpose of food, feed and fodder in Pakistan. Despite availability of superior genetic material to farmer, full yield potential of the hybrids has not been exploited. A national average grain yield of 3 t ha^{-1} indicates that a huge yield gap exists. Practice of using heavy inputs and intensive cultivation has led to heavy weed infestation and remains to be the most devastating reason for lowering grain yield by 83% (Usman *et al.*, 2001). Weed problem is getting from bad to worse day by day. The cropping

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intensity is rapidly increasing and traditional methods as suicidal germination and hand weeding have become impossible. According to Khan *et al.* (2000) traditional hand weeding is slow, tedious and labor intensive. Labor input is not only getting expensive but is also becoming scanty. Very few farmers practice crop rotation for weed control (Narwal, 2000). Chemical weed control is effective but realization of hazards associated with indiscriminate use of farm chemicals during recent years has necessitated looking for ways that reduce dependence upon such chemicals. In fact, weed management in field crops without use of herbicides remains a challenging task for crop managers (Jodaugiene *et al.*, 2006).

Strong need is felt to discover alternative weed management options in organic agriculture (Economou *et al.*, 2002). Mulching of crop residues as a weed control tactic is widely practiced across the globe (Gupta, 1991). A suppressive action on weeds possibly mediated by the release of allelochemicals has been reported for a number of crop residues. Residues of certain crops can pose a chemical (allelopathic) as well as a physical effect on the growth and development of subsequent crops and weeds (Reddy, 2001). The main concern regarding the crop residues is their allelopathic effect on the other or same crop plant (Thorne *et al.*, 1990). Soil incorporation or surface application as mulch of allelopathic crop residues affects weed dynamics by reducing/delaying seed germination and establishment, and suppressing individual plant growth resultantly contributing to overall decline in the density and vigor of the weed community (Gallandt *et al.*, 1999). Decomposing crop residues release a variety of allelochemicals, particularly the phenolics, in the soil causing adverse effects on the other plants (Nelson, 1996). The exploitation of crop residues as surface mulch can suppress weeds and thus can help in reducing reliance on herbicides (Weston, 1996). Phytotoxicity of dried sunflower residues and leaf powder has been reported (Narwal, 1999; Batish *et al.*, 2002). Incorporation of sunflower residues in the soil reduced the growth of sorghum, soybean and canary grass. Cheema *et al.* (2004) stated that sorghum mulch (10-15 t ha^{-1}) decreased the dry weight of purple nutsedge by 38-41% compared to control. Boydston and Hang (1995) found that incorporation of *Brassica napus* residue reduced weed count and biomass by 73-85% and 50-96% in potato field. Evidence of rice phytotoxicity against barnyard grass germination and seedling development are also reported (Chung *et al.*, 2006).

Several studies reported the use of different crop residues separately for weed suppression (Cheema and Khaliq, 2000; Norsworthy *et al.*, 2005; Uremis *et al.*, 2009; Pheng *et al.*, 2010). Previous work of Cheema *et al.* (2004) showed fair degree of success with sorghum mulch yet suppression magnitude attained under field conditions was far below the desired level. Type and concentration of phytotoxins vary in different allelopathic crop/plant species (Rice, 1984). Allelochemicals may work in synergism so that the impact of combined application is often higher than their individual application. Combined aqueous extracts controlled canary grass significantly in wheat (Jamil *et al.*, 2009). In our preliminary studies, residue mixture of sorghum, sunflower and brassica controlled sedges better than when either of these was used alone in pot experiments (Matloob *et al.*, 2010). We hypothesize that the same can be true for the residues of these crops under field conditions too. A little information is available on possible integration of allelopathic crop residues for weed suppression in maize under field conditions. Present work describes the influence of sorghum, sunflower, brassica and rice residues when incorporated in to the soil in different combinations at variable rates against horse purslane (*Trianthema portulacastrum* L.) and purple nut sedge (*Cyperus rotundus* L.), two pernicious weeds of maize filed in the country.

MATERIALS AND METHODS

Site and crop husbandry

Efficacy of mixture of allelopathic crop residues was evaluated as an organic weed management approach in maize fields. Experiment was laid out in randomized complete block design (RCBD) with three replications at Agronomic Research Farm, University of Agriculture Faisalabad (31.5° N, 73.09° S) during spring 2008 and 2009. Soil of experimental site belongs to Lyallpur soil series (Aridisol-fine-silty, mixed, hyperthermic Ustalfic, Haplargid in USDA classification and Haplic Yermosols in FAO classification). The pH of saturated soil paste was 7.6 and total soluble salts were 1.2 dSm^{-1}. Organic matter, total nitrogen, available phosphorus and potassium were 0.71%, 0.062%, 13.1 ppm, and 179 ppm, respectively. The net plot size was 6 x 2.80 m^2. Maize hybrid NT 6621 was dibbled during the first fortnight of March, 2008 and 2009 in 70 cm spaced rows with 20 cm distance between plants. A basal fertilizer dose of 150 kg N, 100 kg P_2O_5 and 100 kg K_2O ha^{-1} was applied. Fertilizers used were urea (46 % N), diammonium phosphate (18 % N and 46 % P_20_5), and sulphate of potash (50 % K_2O). Whole of phosphorus and potassium, and half of nitrogen were applied at the time of sowing. The remaining nitrogen was top dressed at knee height.

Preparation of plant residues and treatment application

Field grown mature plants of sorghum, sunflower, brassica and rice were harvested from the Agronomic Research Area, University of Agriculture, Faisalabad. These plants were chopped into 3-5 cm pieces with a fodder cutter. These residues were mixed in four combinations as sorghum + sunflower + rice, sorghum + rice + brassica, sunflower + rice + brassica and sorghum + sunflower + brassica and each combination was soil incorporated with last cultivation at two rates of 4.5 and 6 t ha^{-1}. Control treatment received no residues.

Harvesting and collection of data

Data on purple nutsedge and horse purslane density and dry weight were recorded at 30 DAS from two randomly selected quadrats (50 x 50 cm^2) from each experimental unit. Weeds were clipped from ground surface and were dried in an oven at 70 °C for 72 h, and the dry weights recorded.

Grains per cob were recorded from 15 randomly selected plants taken from each plot at physiological maturity and average computed. Plots were harvested and grain yield of individual plots was recorded after manual shelling of cobs after sun drying; the same is presented as t ha^{-1}. A random sample of grains was taken from the produce of each plot to record 1000-grain weight by manual counting and weighing on an electric balance. Harvest index was calculated as the ratio of grain yield to biological yield and was expressed as %.

Statistical and economic analyses

The data collected were subjected to Fisher's analysis of variance (Steel *et al.*, 1997) using MSTATC statistical package, and least significance difference test at 0.05 probability was used to compare the differences among treatments' means. Statistical analysis revealed that year *x* treatment effects was non-significant so the mean of two year data are presented and discussed in the results section. Economic and marginal analyses were carried out to look into comparative benefits of different treatments (CIMMYT, 1988).

RESULTS AND DISUSION

Effect of various treatments on weed growth

Weed flora of the experimental comprised of two worst summer weeds, i.e., purple nutsedge and horse purslane. All crop residues at both application levels suppressed the density of both weeds significantly as compared with control (Table-1). Nevertheless, the highest suppression was recorded for sorghum+sunflower+brassica at 6 t ha^{-1} which amounted to 87 and 80%, respectively. Same residue combination at 4.5 t ha^{-1} suppressed these weeds by 65 and 73%.

Significant suppression in weed dry weight over control was also recorded (Table-1). Application of sorghum+sunflower+brassica residues each at 6 t ha^{-1} reduced dry weight of purple nutsedge and horse purslane by 97 and 89%, while all other treatments were at par regarding purple nutsedge dry weight suppression. It is believed that residues of certain crops can exert a physical as well a chemical (allelopathic) influence on weeds (Reddy, 2001). Present studies

Table-1. Influence of combined incorporation of allelopathic crop residues on weed density and weed dry weight.

Treatments (t ha^{-1})		Purple nutsedge		Horse purslane	
		Density	Dry weight (g)	Density	Dry weight (g)
T_1	Control (weedy check)	7.67 a	1.02 a	54.77 a	58.52 a
T_2	Sorghum + sunflower + rice each at 4.5	4.00 b (-47.78)	0.21 b (-61.89)	14.05 cd (-76.47)	18.80 de (-67.86)
T_3	Sorghum + sunflower + rice each at 6	4.33 b (-43.47)	0.34 b (-79.66)	17.43 bc (-68.17)	20.22 cd (-65.45)
T_4	Sorghum +rice + brassica each at 4.5	2.67 bc (65.27)	0.21 b (66.83)	21.00 b (61.65)	21.84 bc (62.67)
T_5	Sorghum + rice + brassica each at 6	1.00 c (-86.94)	0.03 b (-97.03)	16.67 c (-69.57)	18.41 de (-68.53)
T_6	Sunflower + rice + brassica each at 4.5	1.67 bc (-78.32)	0.08 b (-91.80)	17.94 bc (-60.53)	23.33 b (-60.14)
T_7	Sunflower + rice + brassica each at 6	3.00 bc (-60.83)	0.24 b (-76.70)	15.17 c (-72.31)	17.52 e (-70.05)
T_8	Sorghum + sunflower + brassica each at 4.5	2.66 bc (-65.27)	0.12 b (-88.15)	14.89 cd (-72.82)	9.853 f (-83.16)
T_9	Sorghum + sunflower + brassica each at 6	1.00 c (-86.94)	0.01 b (-97.21)	11.00 d (-79.91)	6.525 g (-88.83)
	LSD $P \leq 0.05$	**2.792**	**0.379**	**4.029**	**1.832**

Figures given in parenthesis show percent decrease over control, Means with different letters differ significantly at 5% level of probability.

suggested that suppressive effects on density and dry weights of weeds were imposed by the release of phytotoxic allelochemicals from the crop residues in their immediate vicinity. Allelochemicals in crop residues when applied as surface mulch, probably were solubilized rapidly and when taken up by the germinating seeds proved fatal to a number of vital physiological processes (Bogatek *et al.*, 2005), thus impairing germination and hampering subsequent seedling growth of weeds. It is worthwhile to mention that maize germination and growth was not affected by residue application. Liebman and Sundberg (2006) proposed that species with large food reserve are better able to tolerate and detoxify allelopathic agents. Reduced weed biomass was also reflective of the suppressive effects of sorghum, sunflower, brassica and rice residues application. Inhibition in growth of weeds may be attributed to the presence of several phytotoxins in sorghum such as gallic acid, protocatechuic acid, syringic acid, vanillic acid, p-hydroxybenzoic acid, p-coumaric acid, benzoic acid, ferulic acid, m-coumaric acid, caffeic acids, p-hydroxybenzaldehyde and sorgoleone

(Netzly and Butler, 1986; Cheema *et al.*, 2009). Sunflower contains several allelochemicals viz. chlorogenic acid, isochlorogenic acid, α-naphthol, scopolin, and annuionones (Macias *et al.*, 2002; Anjum and Bajwa, 2005). The members of Brassicaceae family exerted allelopathic effects on germination and growth of other species (Norsworthy *et al.*, 2005) through glucosinolates (Al-Khatib and Boydston, 1999). Several putative allelochemicals including simple phenolics acids such as p-hydroxybenzoic (Chou and Lin, 1976), ferulic (Chung *et al.*, 2001), syringic, caffeic, sinapic, and o-coumaric acids (Olofsdotter *et al.*, 1995) have also been identified in rice. Recent studies have indicated that momilactone A and B may play an important role in rice allelopathy (Kato-Noguchi 2003; Chung *et al.*, 2006). Residue combinations varied in their severity against weeds with species involved and application rates. The variable influence of sorghum, sunflower, brassica and rice residue mixtures on weeds may be due to the type and concentration of allelochemicals present in these species mixture. Allelopathic interactions being concentration dependent are characterized by species specificity of both donor and receiver (Rice, 1984), and manifested due to concerted action of numerous allelochemicals in the substratum (Einhellig, 1996). Khanh *et al.* (2005) reported that magnitude of suppression is directly proportional to the applied dose.

Effect of various treatments on maize yield and yield components

Combinations of crop residues had a significant bearing on number of grains per cob (Table-2) and the maximum number of grains (612.8) were recorded where sorghum+sunflower+brassica residues were applied at 6 t ha^{-1}. Sorghum+rice+brassica (6 t ha^{-1}), sunflower+rice+brassica (6 t ha^{-1}) and sorghum+sunflower+brassica (4.5 t ha^{-1}) recorded the maximum and similar 1000-grain weight. Highest grain yield (5.53 t ha^{-1}) was recorded with application of sorghum+sunflower+brassica residues, each at 6 t ha^{-1}. This treatment also exhibited the highest (36%) harvest index over all other treatments.

Economic and marginal analysis

The effectiveness of any production system is evaluated on the basis of economic returns. Economic analysis revealed that sorghum+sunflower+brassica at 6 t ha^{-1} was the most economical treatments with highest net benefit of PKR 60351 ha^{-1} (Table-3). Marginal and dominance analysis gives a deeper insight into the relative outcome of per unit additional investment on any weed control treatment. Highest marginal rate of return (61%) was also obtained with surface application of sorghum + sunflower + rice residues at 4.5 t ha^{-1} (Table-4).

Present studies conclude that combination of crop residues was more suppressive owing to variety of allelochemicals present in different residues (Jamil *et al.*, 2009), as well as higher concentration of these in the rhizosphere. Moreover, compounds in an allelopathic mixture can replace each other on the basis of their biological exchange rate and can add to each other herbicidal potential (Gerig and Blum, 1991). Integration of crop residues has potential to suppress weeds as an eco-friendly approach in maize fields, and can be successfully employed in organic weed management programs, provided the maximum levels of phytotoxins entering into the soil encounter the early growth and development of weeds.

Table-2. Influence of combined incorporation of allelopathic crop residues on yield and yield components of maize

	Grains cob^{-1}	Grain weight cob^{-1} (g)	1000 grain weight (g)	Grain yield (t ha^{-1})	Harvest index (%)
T_1	530.5g	120.8e	272.5d	3.60g	27.81g
T_2	577.2d(9)	183.6b(52)	318.1a(17)	5.31b(47)	33.38c(20)
T_3	603.2b(14)	180.3b(49)	298.9c(10)	5.21c(45)	31.78de(14)
T_4	570.2e(7)	168.4d(39)	295.3c(8)	4.87f(35)	30.86f(11)
T_5	591.3c(11)	191.4a(58)	316.1a(16)	5.30b(47)	34.44b(24)
T_6	566.5e(7)	175.8c(45)	310.4b(14)	5.08d(41)	31.05ef(12)
T_7	549.1f(4)	172.9c(43)	315.0a(16)	4.96e(38)	32.01d(15)
T_8	549.6f(4)	172.9c(43)	314.5a(16)	4.99e(39)	31.57def(13)
T_9	612.8a(16)	183.4b(52)	307.3b(13)	5.53a(54)	35.79a(29)
LSD $_{0.05}$	4.400	3.393	3.858	0.077	0.806

Figures given in parenthesis show percent increase over control, Means with different letters differ significantly at 5% level of probability

Table-3. Economic analysis of use of allelopathic crop residues for weed management in maize.

Treatments	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	Remarks
Maize grain yield	3603	5307	5210	4867	5300	5080	4963	4997	5533	kg ha^{-1}
Adjusted yield	3242.7	4776.3	4689	4380.3	4770	4572	4466.7	4497.3	4979.7	kg ha^{-1} [To bring at farmer's level (10%)]
Maize grain value	38912	57316	56268	52564	57240	54864	53600	53967	59800	Rs. 480/40 kg
Maize stalk yield	9357	10600	11190	10900	10100	11290	10620	10830	9927	kg ha^{-1}
Adjusted stalk yield	8421.3	9540	10071	9810	9090	10161	9558	9747	8934.3	kg ha^{-1} [To bring at farmer's level (10%)]
Maize stalk value	2947	3339	3525	3434	3533	3182	3345	3411	3127	Rs. 350/t
Gross income	41859	60655	59793	55998	60773	58046	56945	57378	62927	Rs. ha^{-1}
Cost of sorghum mulch	-	937	1276	937	937	-	-	937	1276	Rs. 25/40 kg
Cost of sunflower mulch	-	375	500	-	-	375	500	375	500	Rs. 10/40 kg
Cost of brassica mulch	-	-	-	300	400	300	400	300	400	Rs. 8/40 kg
Cost of rice mulch	-	300	400	300	400	300	400	-	-	Rs. 8/40 kg
Cost of mulch application	-	400	400	400	400	400	400	400	400	Rs. 200/man 2 men day^{-1} ha^{-1}
Cost that vary	-	2012	2576	1937	2137	1375	1700	2012	2576	
Net benefit	41859	58643	57217	54061	58636	56671	55245	55366	60351	Rs. ha^{-1}

$\mathbf{T_1}$=Control, $\mathbf{T_2}$= Sorghum + sunflower + rice at 4.5 t ha^{-1}, $\mathbf{T_3}$= Sorghum + sunflower + rice at 6 t ha^{-1}, $\mathbf{T_4}$= Sorghum + rice + brassica at 4.5 t ha^{-1}, $\mathbf{T_5}$= Sorghum + rice + brassica at 6 t ha^{-1}, $\mathbf{T_6}$= Sunflower + rice + brassica at 4.5 t ha^{-1}, $\mathbf{T_7}$= Sunflower + rice + brassica at 6 t ha^{-1} , $\mathbf{T_8}$= Sorghum + sunflower + brassica at 4.5 t ha^{-1} , $\mathbf{T_9}$= Sorghum + sunflower + brassica at 6 t ha^{-1}

Table-4. Marginal analysis of use of allelopathic crop residues for weed management in maize

Treatments (t ha^{-1})	Cost that vary (Rs. ha^{-1})	Net benefit (Rs. ha^{-1})	Change in cost (Rs. ha^{-1})	Change in net benefit (Rs. ha^{-1})	Marginal rate of return (%)
T_1=Control	0	41859	-	-	-
T_6= Sunflower+rice+brassica at 4.5	1375	56671	1375	14812	11
T_7= Sunflower+rice+brassica at 6	1700	55245	-	-	D*
T_4= Sorghum+rice+brassica at 4.5	1937	54061	-	-	D
T_2= Sorghum+sunflower+rice at 4.5	2012	58643	75	4582	61
T_8= Sorghum+sunflower+brassica at 4.5	2012	55366	-	-	D
T_5= Sorghum+rice+brassica at 6	2137	58636	125	3270	26
T_9= Sorghum+sunflower+brassica at 6	2576	60351	439	1715	4
T_3= Sorghum+sunflower+rice at 6	2576	57217	-	-	D

^{D} Dominated due to less benefit than preceding treatments (higher costs but low net benefits); Variable cost is the cost of purchase of inputs, labor and machinery ha^{-1} that vary between the experimental treatments; Net benefit is gross income less variable cost; Marginal rate of return is the ratio of change in net benefit to change in cost expressed in percentage.

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SCREENING OF PRE AND POST EMERGENCE HERBICIDES AGAINST CHICKPEA (*Cicer arietinum* L.) WEEDS UNDER SEMI RAINFED CONDITIONS OF POTHOHAR, PAKISTAN

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ABSTRACT

A field study was carried out to evaluate the performance of pre and post emergence herbicides on weeds and yield and yield components of chickpea variety PJ-91 during the year 2008-09 at Koont Research Farm, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi under semi rainfed conditions of Pothohar, Pakistan using RCB design having three replications. Two pre-emergence herbicides (Stomp 330 EC, Dual gold 960 EC) and two post-emergence herbicides (Puma super 75 EW, Topik 15 WP) were applied including control treatments (weed free and weedy check). The results of this study showed that maximum seed yield of 401.0 kg ha^{-1} was obtained from hand hoeing treatment followed by post emergence herbicide Puma super 75 EW applied @ 1.2 lit ha^{-1} with 353.2 kg ha^{-1} seed yield against 212.2 kg ha^{-1} from weedy check treatment. The highest yield in top scoring treatment is due to higher number of branches plant^{-1}, number of pods plant^{-1}, number of grains pod^{-1} and individual grain weight. So from the results of this study it is concluded that hand hoeing can be recommended only for small land holders with sufficient available family labour while, Puma super 75 EW @ 1.2 lit ha^{-1} is recommended for control of chickpea weeds under semi arid rainfed conditions.

Key words: Chemical control, gram, mechanical control, post and pre-emergence herbicides.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an ancient crop that has been grown in India, the Middle East and parts of Africa for many years and is an important edible legume pulse of the family Fabaceae, subfamily Faboideae. In Pakistan, chickpea is cultivated on an area of 1094 thousands hectares with production of 760 thousand tons (Anonymous, 2009).

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Sexena (1980) reported that potential yield losses in chickpea due to weeds ranged between 22 to 100% whereas, Vaishya *et al.* (1996) reported 41.7% losses in chickpea due to weed competition. Ahmad *et al.* (1982) carried out a weedicide (dicuran, banvel, mataven and afalon) trial and reported that dicuran was the most effective and killed 78% of broad leaved and 51% of narrow leaved weeds. Ozair (1987) stated that fluazifop-butyl @ 0.75 + fomesafem @0.25 kg ha^{-1} gave 100% weed control except *Cyperus rotundus*, and gave 67% more yield over weedy check. Reddy *et al.* (1998) reported that the application of pendimethalin, metolachlor, alachlor, fluchloralin and butachlor gave an effective level of control of *Cyperus rotundus*. However, hand weeding at 20 DAS resulted in the highest yield compared with any herbicide treatment. Similarly, Bhalla *et al.* (1998) reported that herbicide treatment gave 50 to 64% weed control with an increase in yield. Stork (1998) reported that weed growth was significantly reduced by the use of herbicide and resulted in increased yield of 50% against the control.

In Pakistan, among many reasons of low productivity of chickpea yield, heavy infestation of weeds is considered serious one as they compete with the crop for light, space, nutrient and moisture. In rainfed areas the control measures for weeds become even more intricate problem in comparison with irrigated areas due to low moisture availability as most of the herbicides work under the availability of sufficient soil moisture. In view of the above facts, a study was carried out to evaluate the performance of most suitable herbicide along with optimum dose under rainfed conditions of Pothohar, Pakistan.

MATERIALS AND METHODS

An experiment was carried out at the Research Farm Koont, Arid Agriculture University Rawalpindi during the winter 2008-2009. The experiment consisting of eight treatments (Table-1) was laid out in a Randomized Complete Block Design with three replications having plot size of 7x3 m^2. The chickpea crop variety 'PJ-91' was sown on 25 October 2008 in rows with hand drill. The common weed species which were observed in the experimental area included lambsquarters (*Chenopodium album* L.), field bindweed (*Convolvulus arvensis* L.), bur clover (*Medicago polymorpha* L.), Indian sweetclover (*Melilotus indica* L.), scarlet pimpernel (*Anagallis arvensis* L.), wild oats (*Avena fatua* L.), little seed canary grassy (*Phalaris minor* L.) and onion weed (*Asphodelus tenuifolius* Cav.).

Nitrogen @ 23 and phosphorous @ 58 kg ha^{-1} was applied at seed bed preparation. All recommended agronomic practices except treatments were followed for raising the crop. The soil analysis of experimental site showed slight alkalinity having *p*H 7.9 and medium in P (10.49 mg kg^{-1}) and K_2O (70.17 mg kg^{-1}), while low in organic matter (0.73 %) with loamy characteristics. The rainfall received during the growing period was 283.5 mm (Table-2). Pre-emergence herbicides were applied just after sowing on same day while post emergence herbicides were applied 30 days after sowing. Two hand hoeing were done 30 and 60 DAS in the hand weeding treatment. After maturity crop was harvested in the first week of April, 2009.

Germination count m^{-2} was measured from each plot after complete emergence of crop. Ten plants were randomly selected from each plot to record the data about different agronomic parameters like plant height at maturity, number of fruit bearing branches $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, 1000-grain weight, total biological yield, total seed yield and harvest index.

Total weed biomass from each plot was measured by uprooting of weeds from the selected area and drying the sample in an oven at 70^0 C for 48 hours to determine the herbicidal efficiency. The data for the individual parameter were subjected to analysis of variance using MSTAT-C software (MSTATC, 1988). To test the significance of treatments, significant means were subjected to the least significance difference test at 5% probability level (Steel *et al.*, 1997).

Table-1. Treatments used in the experiment.

Treatments	Common name	Dose ha^{-1}	Time of application
1- Stomp330 EC	pendimathalin	3.00 lit	Pre-emergence
2- Stomp330 EC	pendimathalin	3.75 lit	Pre-emergence
3- Dual gold960 EC	S-metolachlor	2.00 lit	Pre-emergence
4- Dual gold960 EC	S-metolachlor	2.50 lit	Pre-emergence
5- Puma super 75 EW	fenoxaprop-p-ethyl	1.20 lit	Post-emergence
6- Topik 15 WP	fenoxaprop-p-ethyl	250 g	Post-emergence
7- Hand hoeing	-	-	Post-emergence
8- Weedy Check	-	-	Post-emergence

Table-2. Rainfall and the prevailing temperature during crop growth period.

Month	Rainfall (mm)	Mean Min. Temp. (°C)	Mean Max. Temp. (°C)	Mean Temp. (°C)
October	23.0	16.3	30.8	23.55
November	1.0	8.8	26.5	17.65
December	57.0	6.8	21	13.9
January	68.0	6.0	18.6	12.3
February	34.0	7.6	20.4	14
March	28.0	11.8	26.2	19
April	72.5	12.3	31.3	21.8
Mean	40.50	9.94	24.97	17.46

Total Rainfall during growth period 2008-2009= 283.5 (mm).

RESULTS AND DISCUSSION

Germination count (%)

There was no significant effect of herbicides on the germination of chickpea crop (Table-3). However, highest numerical germination count (14.53) was recorded where Puma super 75EW was applied @1.20 lit ha^{-1} while, minimum crop germination (13%) count was recorded where Stomp 330 EC was applied @ 3.00 lit ha^{-1} which could be the result of herbicide effect that might have suppressed the germinating plants. These results are in agreement with Khan *et al.* (1999) has recorded no negative effect of herbicides on germination of plants.

Weed biomass (kg ha^{-1})

Data regarding weed biomass (Table-3) showed significant effect of different treatments applied. Statistically significant total weed biomass of 6851 kg ha^{-1} was produced from weedy check while, lowest weed biomass was produced by hand hoeing treatment. The presence of higher biomass of weeds in control treatment clearly indicates the heavy weed infestation of weeds in rainfed areas. In chemical control measures Puma super 75 EW applied @ 1.20 lit ha^{-1} showed better performance with lowest weed biomass of 4792 kg ha^{-1}, which however, was statistically at with Topik 15 WP (4997 kg ha^{-1}).

Plant height (cm)

It is evident from the data presented in Table-3 that plant height was significantly affected by various treatments. Maximum plant height of 17.58 cm was recorded in hand weeding treatment which is statistically at par with the treatment where Stomp 330 EC @ 3.75 lit ha^{-1} was applied while, minimum plant height of 14.12 cm was recorded in weedy check. The decrease in plant height in weedy check plots clearly showed the weed competition effect on plant growth and development. This was due to the fact that weeds utilized the resources more efficiently than crop plants and suppressed the crop growth and thus resulted in decrease in their height. The results are contrary to those reported by Khan *et al.* (2000) who stated that soybean plant height was not significantly affected by pre-emergence herbicides.

Table-3. Efficacy of different herbicides on Germination count m^{-2}, weed biomass and plant height of chickpea.

Treatments	Dose ha^{-1}	Time of application	Germin. count m^{-1}	Total weed biomass (kg ha^{-1})	Plant height (cm)
1-Stomp330 EC	3.00 lit	Pre	13.32	5509 b	15.20 bcd
2-Stomp330 EC	3.75 lit	Pre	14.05	5497 b	17.28 a
3-Dual gold960 EC	2.00 lit	Pre	14.15	5489 bc	14.96 cde
4-Dual gold960 EC	2.50 lit	Pre	14.33	5159 cd	15.95 bc
5-Puma super 75 EW	1.20 lit	Post	14.53	4792 e	15.96 bc
6-Topik 15 WP	250 g	Post	13.67	4997 de	14.59 de
7-Hand hoeing	-	Post	14	125 f	17.58 a
8-Weedy Check	-	Post	13	6851 a	14.12 e
Cd1			N.S*	337.2	1.035

Any two means not sharing a letter common in a row or column differ significantly at 5% probability level.
Cd1 = Critical difference at 5%level of probability
N.S. = Non significant, Pre = Pre-emergence, Post = Post-emergence

Number of fruit bearing branches per plant

Number of fruit bearing branches $plant^{-1}$ were significantly affected by various treatments (Table-4). Significantly higher number of fruit bearing branches of 13.73 were recorded in hand hoeing treatment which is almost similar to chemical control measures against the minimum of 10.62 branches $plant^{-1}$ recorded in weedy check. More number of fruit bearing branches $plant^{-1}$ in hand hoeing treatment was the result of absence of weeds and better utilization of resources i.e. moisture, light, nutrients, space etc by the crop plants and thus produced more number of fruit bearing branches $plant^{-1}$. While, it is true for weedy check treatment due to the result of more weed infestation. These findings are in line with the results of Althahi *et al.* (1994).

Number of pods per plant

As the fruit bearing branches increase, number of pods plant^{-1} also increase. The data presented in Table-4 clearly indicated that number of pods plant^{-1} was significantly affected by various herbicides treatments. Significantly, maximum number of pods plant^{-1} (32.64) were recorded from hand hoeing treatment against the minimum number of pods plant^{-1} of 13.61 in weedy check control treatment. Hand weeding was followed by Puma super 75EW applied @ 1.20 lit ha^{-1}, which showed statistically similar results (29.07) with Stomp 330 EC applied @ of 3.00 lit ha^{-1}. The herbicides such as Stomp 330 EC applied @ 3.75 lit ha^{-1}, Dual gold 960 EC applied @ 2.50 lit ha^{-1} and Topik 15 WP applied @ 250 g ha^{-1} are statistically similar with each other. Fazal *et al.* (1987) also found that herbicide Orifan applied @ 3.0 lit ha^{-1} proved much better than 1.5 lit ha^{-1} of same herbicide in reducing weeds population, weed biomass and increasing number of pods as compared to control treatment and consequently Orifan brought about an increase of 58% in grain yield over control.

Number of grains per pod

The effect of different treatments on number of grains pod^{-1} remained non significant (Table-4), however it varied from 1.20 to 1.40 grains pod^{-1}. These non-significant results can be attributed to the genetic make up of the variety. These results are in conformity with those reported by Khan *et al.* (2000) who stated that number of seeds pod^{-1} were not affected significantly by pre-emergence herbicides.

1000-Grain weight (g)

1000 grain weight was significantly affected by different treatments (Table-4). Among the treatments significantly higher 1000 grain weight of 316 g was obtained from Puma super 75 EW applied @ 1.20 lit ha^{-1} against the lowest individual grain weight of 250.3 g recorded from weedy check treatment. All the chemical treatments statistically remain at par with each other but significantly higher 1000 grain weight than the weedy check treatment.

Seed Yield (kg ha^{-1})

Data presented in Table-5 showed statistically significant effect of different treatments on seed yield. The highest grain yield of 401 kg ha^{-1} was recorded from hand hoeing treatment followed by Puma super 75 EW @ 1.20 lit ha^{-1} (353.2 kg ha^{-1}) against the minimum yield of 212.2 kg ha^{-1} obtained from the weedy check treatment. The chemical control with Stomp 330 EC either applied @ of 3 lit ha^{-1} or 3.75 lit ha^{-1} and Topik 15 WP applied @ 250 g ha^{-1} produced similar results while the performance of Dual gold remain very poor in our study. The higher yield in hand hoeing treatment and in Puma super 75 EW @ 1.20 lit ha^{-1} is the result of greater number of fruit bearing branches plant^{-1}, number of pods plant^{-1} and increased individual grain weight than the control treatment where the weeds competed with the crop plants for growth and development and thus resulted in poor yield. These results are in line with Shah *et al.* (2000) and Malik *et al.* (2001) who concluded that weedy check plots had lesser yield than the weed free treatments.

Table-4. Efficacy of different herbicides on yield components of chickpea crop.

Treatments	Dose ha^{-1}	Time of application	Fruit bearing branches plant^{-1}	No. of pods plant^{-1}	No. of grains pod^{-1}	1000 grain wt (g)
1-Stomp 330 EC	3.0 lit	Pre	12.97abc	27.63bc	1.25	310.0 a
2-Stomp 330 EC	3.75 lit	Pre	13.07ab	26.13cd	1.33	300.0 a
3-Dual gold960 EC	2.0 lit	Pre	12.17bc	23.47e	1.26	303.3 a
4-Dual gold960 EC	2.5 lit	Pre	12.20bc	25.60d	1.33	302.3 a
5-Puma super 75 EW	1.2 lit	Post	13.27ab	29.07b	1.4	316.0 a
6-Topik 15 WP	250g	Post	12.63bc	26.17cd	1.13	303.3 a
7-Hand hoeing	-	Post	13.73a	32.64a	1.35	308.0 a
8-Weedy Check	-	Post	10.62d	13.61f	1.13	250.3 b
Cd1			**1.20**	**1.981**	**N.S**	**43.1**

Cd1 = Critical difference at 5%level of probability
N.S. = Non significant, Post = Post-emergence, Pre = Pre emergence

Biological yield (kg ha^{-1})

Biological yield was significantly affected by different treatments tested in the experiment (Table-5). Again hand hoeing treatment significantly produced higher biological yield (1026 kg ha^{-1}) than the chemical treatments. Among the herbicide treatments, Puma super 75 EW applied @ 1.20 lit ha^{-1} produced the highest biomass of 945.2 kg ha^{-1} compared to the lowest in control plot (688.2 kg ha^{-1}). Puma super 75 EW @ 1.20 lit ha^{-1} produced statistically similar results with Stomp 330 EC applied @ of 3.75 lit ha^{-1} and Topik 15 WP which was applied @ 250 g ha^{-1}. Higher biological yield in these treatments was the result of higher photosynthate available in hand weeding and the herbicidal treatments which subsequently produced higher number of pods $plant^{-1}$ and thus led to higher final grain yield as well.

Harvest index (HI)

Data pertaining to harvest index is presented in Table-5 revealed that there was a non-significant effect of different treatments on harvest index and HI ranged between 39.12 to 30.76. These results are against the finding of Jabbar (1995) who reported that hand hoeing and application of Stomp 330 E @ 3.75 lit ha^{-1} resulted in significant increase in harvest index of wheat crop against weedy check treatments.

CONCLUSION

It can be concluded from the results that hand hoeing is the most effective method for weed management if the crop is grown on small area but on large scale, whereas application of Puma super 75EW @ 1.20 liter ha^{-1} as post-emergence can be used to minimize the weed infestation. In case of pre-emergence herbicides Stomp 330 EC @ 3.75 lit ha^{-1} can be used in with the availability of sufficient soil moisture.

Table-5. Grain and Biological Yield and Harvest Index of chickpea as affected by different treatments.

Treatments	Dose ha^{-1}	Time of application	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	H.I. %
1-Stomp330 EC	3.00lit	Pre	320.2bcd	894.2cd	36.15
2-Stomp330 EC	3.75lit	Pre	332.5bc	922.6bc	35.85
3-Dual gold960 EC	2.00lit	Pre	284.1d	818.2e	34.84
4-Dual gold960 EC	2.50lit	Pre	300.6cd	844.7de	35.49
5-Puma super 75 EW	1.20lit	Post	353.2b	945.2b	37.35
6-Topik 15 WP	250 g	Post	319.8bcd	900bc	35.51
7-Hand hoeing	-	Post	401.0a	1026a	38.12
8-Weedy Check	-	Post	212.2e	688.2f	30.77
Cd1			**41.9**	**44.11**	**N.S**

Cd1 = Critical difference at 5%level of probability
N.S. = Non significant, Post = Post-emergence, Pre = Pre emergence

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THE EFFECT AND COST BENEFIT RATIO OF DIFFERENT WEEDING METHODS ON THE YIELD OF CHICKPEA UNDER AGROCLIMATIC CONDITIONS OF DISTRICT KARAK

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ABSTRACT

An experiment was conducted at Agricultural Research Station Ahmad Wala, Karak, Khyber Pakhtunkhawa-Pakistan, during rabi season 2006-07 for elaborating the effect of weeding methods on the yield and yield components of chickpea. The experimental design was Randomized Complete Block (RCB) with split plot arrangement. The experiment was replicated four times with the main plots including three varieties of chickpea whereas the subplots comprised of four treatments viz. hand weeding one time, hand weeding twice, Isoproturon 500 EW and a weedy check. The weedicide Isoproturon was applied @ 0.741 kg a.i. ha^{-1} as a post emergence. The data were recorded on number of weeds m^{-2}, number of productive branches plant^{-1}, number of pods plant^{-1}, number of grains pod^{-1}, 1000 grain weight (g), grain yield kg ha^{-1} and cost benefit ratio, Number of weeds m^{-2}, number of productive branches plant^{-1}, number of pods plant^{-1}, number of grains pod^{-1}, 1000 grains weight (g) and grains yield (kg ha^{-1}) were significantly affected by different treatments. Maximum grain yield was produced by normal hand weeding twice treatment (1429.90 kg ha^{-1}) and proved to be the best one, while lowest grain yield (777.95 kg ha^{-1}) was recorded in weedicide application. Similarly maximum number of pods plant^{-1} (52.50), number of grains pod^{-1} (2.42), number of productive branches plant^{-1} (6.42), 1000 grain weight (235.58 g) and highest grain yield (1429.90 kg ha^{-1}) were recorded in normal hand weeding twice treatment. The Cost: benefit analysis revealed the highest cost: benefit ratio of 1:1:9 in the hand weeding twice. Thus, hand weeding of chickpea twice is recommended for the chickpea growers of Karak, Khyber Pakhtunkhawa-Pakistan.

Key words: Chickpea, weeds control, cost benefit ratio.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) belongs to family Fabaceae. The name chickpea is derived from the Latin name *Cicer* (Muehlbauer,

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1996). Chickpea seed has 38-59% carbohydrates, 3% fiber, 4.8-5.5% oil, 3% ash, 0.2% calcium and 0.3% phosphorus. Digestibility of protein varies from 76-78% and its carbohydrates from 57-60% (Hulse 1991, Huisman and Vander poel, 1994). Sprouting is said to increase the proportionate amounts of ascorbic acid, choline, panthenic acid, biotin, inositol and Vitamin K. The limiting amino acid concentrations are 0.52% for methionine, 1.45% for lysine and cystine, 0.71% for threonine, 0.16% for tryptophan (William *et al.*, 1994). Glandular secretion of the leaves and pods consists of malic acid and oxalic acids, giving a sour taste and damage trousers and shoes. Medicinal applications include use for aphorodisiac, bronchitis, catarrh, cutamenia, cholera, constipation, diarrhea, dyspepsia, flatulence, snakebite and warts. Acids are supposed to lower the blood cholesterol levels (Geervani, 1991). Chickpea green fleshy leaves and stem at pre-flowering stage is one of the most popular winter vegetables amongst people living in southern districts of Khyber Pakhtunkhwa, which also return reasonable amount and provide employment opportunities to the growers.

India is the major chickpea producing country of the world followed by Pakistan, Turkey and Canada etc (FAO, 2002). In Pakistan, during 2006-07, chickpea was grown on an area of 1052.3 thousands ha with a production of 837.8 thousand tons and 796 kg ha^{-1}. During the same year the area, production and yield kg ha^{-1}in Khyber Pakhtunkhwa was 49.0 thousand ha, 21.0 thousand tons and 429, respectively. Punjab with an area of 910.7 thousand ha, production 728.3 thousands ton and yield 800 kg ha^{-1}) is the leaders in chickpea production in Pakistan (MINFAL, 2007). Chickpea is poor competitor with weeds because of slow growth of the crop. *Chenopodium album, Asphodelus tenuifolius, Polygonum plebejum, Poa annua, Vicia sativa, Medicago denticulata, Euphorbia helioscopia, Convolvulus arvensis, Cyperus rotundus, Cynodon dactylon and Cirsium arvense* were common weeds species infesting the experiment. *Cynodon dactylon, Asphodelus tenuifolius and Cirsium arvense* are persistent and serious weeds. In Pakistan, all agricultural crops, both irrigated and rainfed are heavily infested with weeds. The weed problem is getting from bad to worse in irrigated areas where cropping intensity is rapidly increasing as weed control through cultivation practices has become impossible. If weeds are present, there is a severe competition for survival between the weeds and the cultivated crops in which the crops are always the losers. Generally, 20 to 30% losses in grain yield are quite usual and may increase even to 50%. The magnitude of yield losses due to weeds is purely dependent upon environment, location, soil history, type of weed, intensity of weed infestation, duration of weed competition, soil moisture, type of crop cultivated and planting density etc. Traditionally weeds are being controlled through hand weeding or by various cultural practices. However, with the scarcity of annual labour and intensive crop production, introduction of chemical weed control is necessary to replace the congenital control measures. Chemical weed control certainly has its merits over the existing methods. Still it is not as common as it should have been practiced on commercial scale (Shad, 1989). Keeping in view the importance of different herbicides and weeding methods for controlling weeds in chickpea, the present experiment was designed with the aims to select economically suitable method of weeding and to choose the best variety to compete with weed population for chickpea crop.

MATERIALS AND METHODS

A Field experiment was conducted at Agricultural Research Station Ahmad Wàla Karak to evaluate the effect of weeding methods on the yield and yield components of chickpea and respective cost benefit ratio analyses during rabi season 2006-07. The experiment was carried out in Randomized Complete Block Design (RCBD) with split plot arrangement. There were 12 treatments each replicated 4 times. The sub-plot size for each treatment was 9×1.8 m^2. There were 6 rows per treatment. The plant to plant distance was kept 10cm and rows were 30cm apart. Data were recorded on number of weeds m^{-2}, number of productive branches $plant^{-1}$, number of pods $plant^{-1}$, number of grains pod^{-1}, 1000 grains weight (g), grain yield (kg ha^{-1}) followed by cost benefit ratio analyses. The data recorded for each trait was individually subjected to the ANOVA technique by using MSTATC computer software and the means were separated by using Fisher's protected LSD test (Steel and Torrie, 1980).

Main Plots (Varieties)

1. V_1 = Sheenghar
2. V_2 = KK-1 (Karak-1)
3. V_3 = KK-2 (Karak-2)

Sub Plots (Control Methods)

T_1 = Weedy check

T_2 = Hand Weeding one time

T_3 = Normal Hand Weeding two time

T_4 = Isoproturon 500 EW @ 0.741 kg a.i. ha^{-1}

RESULTS AND DISCUSSIONS

Number of Weeds (m^{-2})

Data in Table-1 showed that the main effects for varieties and weed control methods were not statistically significant while the interaction was found statically significant. The perusal of data fro interaction exhibits that the minimum weed densities (310.75) were recorded in the variety of KK-1 under the single hand weeding. It was however statistically comparable with all other herbicidal managements treatments except the weedy check (Table-1). The treatments KK-2 involving the weedy check and the hand weeding once were also at par with the minimum score of KK-1 under hand weeding once. The data exhibits that the morphology of the varieties was different which affect their interaction with the weed management practices. De *et al.* (1995) however recorded different results that all treatments were effective against grassy weeds and herbicides + weeding (integrated) treatments gave greatest reduction in weeds population. Bhalla *et al.* (1998) reported similar results that weeds control efficiency was the greatest under hand weeding (85%) followed by Isoproturon (64%) and Linuron at 0.75 kg ha^{-1} (50%).

Table-1. Effect of weeding methods and varieties on number of weeds m^2 of Chickpea.

Treatments	Sheenghar	KK-1	KK-2	Mean value
Weedy check	410.250ab	375.750abcd	330.000cde	372.000
Hand Weeding Once	416.750a	310.750e	351.500bcde	359.500
Normal Hand Weeding Twice	374.250abcd	353.250bcde	386.500abc	371.333
Isoproturon	318.750de	360.750abcde	387.000abc	355.500
Varieties Mean	380.000	350.000	363.750	
LSD for interaction $_{(0.05)}$				**54.79**

Means in different category showing same letter(s) are not significantly different by LSD at 5% probability level.

Number of Productive Branches $Plant^{-1}$

Data in Table-2 observed that the number of productive branches $plant^{-1}$ were significantly affected by different weed management treatments, while the varieties and the interaction of the varieties with the weed management practices was non-significant statistically. The highest number of productive branches (6.42) were produced by normal hand weeding twice treatment while less number of productive branches (3.83) were recorded in weedicide treatment followed by weedy check treatment (4.16) and hand weeding once treatment (4.33). The number of productive branches were not significantly affected by varieties. The highest number of productive branches (5.00) were observed in Karak-2 variety followed by Karak-1 variety (4.93). These results are also in conformity with those by Marwat *et al.*, 2004.

Table-2. The effect of weeding methods and varieties on number of productive branches plant^{-1} of chickpea.

Treatments	Sheenghar	KK-1	KK-2	Mean value
Weedy check	4.250	4.500	3.750	4.167b
Hand Weeding Once	3.750	5.000	4.250	4.333b
Normal Hand Weeding Twice	5250	6.750	7.250	6.416a
Isoproturon	3.250	3.500	4.750	3.833b
Varieties Mean	4.125	4.938	5.000	
LSD for treatments $_{(0.05)}$				**0.970**

Means in different category showing same letter(s) are not significantly different by LSD at 5% probability level.

Number of Pods Plant^{-1}

Data in Table-3 indicated that the number of pods plant^{-1} were significantly affected by different weed control treatments, while weed management practices x varieties interaction was non-significant statistically. The highest number of pods plant^{-1} (52.50) were recorded in normal hand weeding twice treatment. The lowest number of pods plant^{-1} (26.00) was noted in weedicide treatment. Among the varieties higher number of Pods plant^{-1} were produced by KK-1 (37.62) and KK-2 (36.688), while the least pods were recorded in the variety Sheenghar (Table-3). The interaction although, non-significant statistically showed a numerical spread in the data and highest number of pods plants^{-1} were recorded in KK-1 (56.500) and KK-2 (57.000) involving hand weeding twice (Table-3).

Table-3. The effect of weeding methods and varieties on number of pods plant^{-1} of chickpea.

Treatments	Sheenghar	KK-1	KK-2	Mean value
Weedy check	27.000	31.000	26.750	28.250 bc
Hand Weeding Once	24.250	37.000	35.500	32.250 b
Normal Hand Weeding Twice	44.250	56.500	57.000	52.500 a
Isoproturon 500 EW	24.500	26.000	27.500	26.000 c
Varieties Mean	29.938 b	37.625a	36.688 a	
LSD for varieties $_{(0.05)}$				**4.091**
LSD for treatments $_{(0.05)}$				**4.724**

Means in a different category showing same letter (s) are not significantly different by LSD at 5% probability level.

Ayaz *et al.,* (2001) reported that in desi chickpea there were a number of significant interactions. The pods plant^{-1} was the most variable yield component. It fell rapidly as the population increased. Leport *et al.* (2006) in an experiment showed the variation in pod production and variation among chickpea cultivars under terminal drought at the time of pod set effected the component with the late initiated pods being smaller having fewer seeds pods^{-1} and smaller seeds but no significant differences between pods initiated on the same day on the primary and secondary branches was observed. These results are in line with the findings of Althahabi *et al.* (1994).

Number of Grains Pod^{-1}

Data in Table-4 indicated that weed management treatments significantly affected the number of grains pod^{-1}, whereas the differences among the varieties and interaction of weed management practices x varieties interaction were non-significant statistically. The highest number of grains (2.42) were recorded in normal hand weeding twice treatment while lowest number of grains (1.08) were produced in Isoproturon treatment. It is clear from the data that normal hand weeding twice treatment was the best weeding method to produce maximum number of grains pod^{-1} over normal grains pod. The varieties were not reach to attain the significant effect on the number of grains pod^{-1}. The highest number of grains pod^{-1} were produced by Sheenghar (1.69), Karak-2, (1.69) and followed by Karak-1 (1.5).

Table-4. The effect of weeding methods on number of grains pod^{-1} of chickpea.

Treatments	Sheenghar	KK-1	KK-2	Mean value
Weedy check	1.250	1.250	1.500	1.333 bc
Hand Weeding Once	1.750	1.500	1.750	1.667 b
Normal Hand Weeding twice	2.500	2.250	2.500	2.417 a
Isoproturon	1.250	1.250	1.000	1.083 c
Varieties Mean	1.688	1.500	1.688	
LSD for treatments $_{(0.05)}$				**0.451**

Means in a different category showing same letter (s) are not significantly different by LSD at 5% probability level.

1000 Grains Weight (gm)

Data in Table-5 exhibited that 1000 grain weight was significantly affected by different treatments. The highest 1000 grain yield (235.42 g) was recorded by normal hand weeding twice treatment while lowest 1000 grain yield (192.50 g) was noted in control treatment. The hand weeding once treatment and weedicide treatment did not be at par with each other. The varieties also significantly affected the 1000 grain weight (g). The highest 1000 grain weight (216.56 g) was noted in Sheenghar variety, while lowest 1000grain weight (196.37 g) was recorded in Karak-1 variety. The highest 1000 grain weight (g) in normal hand weeding two time treatment was seem to be the full utilization of nutrients from the soil Quite analogous results were reported by Hosseini (1997) that weeds control favor full utilization of resources

Table-5. Effect of weeding methods and varieties on 1000 grains weight (gm) of chickpea.

Treatments	Sheenghar	KK-1	KK-2	Mean value
Weedy check	206.500	178.500	192.500	192.500 c
Hand Weeding Once	209.500	183.750	205.750	199.667 b
Normal Hand Weeding twice	250.000	228.750	227.500	235.417 a
Isoproturon	200.250	194.500	207.500	200.750 b
Varieties Mean	216.563 a	196.375c	208.313 b	
LSD for varieties $_{(0.05)}$				**3.393**
LSD for treatments $_{(0.05)}$				**3.918**

Means in a different category showing same letter (s) are not significantly different by LSD at 5% probability level.

Grain Yield kg ha^{-1}

Data in Table-6 reveals that the grains yield kg ha^{-1} was significantly affected by different weed management practices, while varieties and the interaction did not show any statistical variation I the grain yield. The highest grain yield of (1429.90 kg ha^{-1}) was obtained from normal hand weeding twice treatment while (777.95 kg ha^{-1}) was recorded in weedicide application treatment. The normal hand weeding twice treatment was the best weeding method for chickpea crop. This seems to be the suitable weeding method for high yield in chickpea. The varieties didn't affect the gram yield positively. This was due to variety characteristics. The highest grain yield (1067.27 kg ha^{-1}) was produced by Sheenghar variety followed by Karak-2 variety (1037.48 kg ha^{-1}), while lowest yield (1018.05 kg ha^{-1}) was noted in Karak-1 variety. Balyan and Malik (1996) reported similar results that the best grain yield of 956-1220 kg ha^{-1} was achieved in weed free treatments. viz the hand weeded treatment and Trifluralin or Pendimethalin in combination with hand weeding. Sesharee *et al.,* (1996) reported similar results that hand weeding twice at 15 and 30 days after sowing gave good weed control and the second highest seed yield of 828 kg ha^{-1}. Bhalla *et al.* (1998) also recorded similar results that the highest seed yield was recorded from the hand weeding treatment (2090 kg ha^{-1}) followed by Linuron at 0.75 kg ha^{-1} (1995 kg ha^{-1}), Isoproturon (1481 kg ha^{-1}) and Linuron at 0.625 kg ha^{-1} (1455 kg ha^{-1}).

Table-6. The effect of weeding methods and varieties on grains yield kg ha^{-1} of chickpea.

Treatments	Sheenghar	KK-1	KK-2	Mean value
Weedy check	808.050	863.875	815.800	829.800 c
Hand Weeding Once	1261.100	1066.675	1052.200	1126.658 b
Normal Hand Weeding Twice	1407.475	1333.350	1548.900	1429.908 a
Isoproturon	792.475	808.325	733.050	777.950 c
Varieties Mean	1067.275	1018.056	1037.487	
LSD for treatments $_{(0.05)}$				**219.8**

Means in a different category showing same letter (s) are not significantly different by LSD at 5% probability level.

Cost benefit ratio $acre^{-1}$ for hand weeding two time treatment:

It was calculated according to the prevailing market rate of the area from sowing to disposal of the produce under barani conditions.

Land preparation	**Expenditure in Rupees**
Ploughing two times Tractor Rs.350 hr^{-1}	350 x 2 = 700
DAP one bag $acre^{-1}$	1100 = 1100
Seed 25 kg $acre^{-1}$ Rs.35.00/kg	25 x 35 = 875
Hoeing and weeding (Two time)	
Three labour for two days	12 x 100 = 1200
Plant protection (Insecticide) Two times 1 litre $acre^{-1}$	2 x 500 = 1000
Harvesting four men for two days	8 x 100 = 800
Transportation tractor	500 = 500
Threshing two hour 500 hr^{-1}	500 x 2 = 1000
Total Expenditure	Rs 7175

Prevailing Market Rate

Total Produce 571.6 kg $acre^{-1}$
Sale of Grain @ Rs.23kg
Rs.13146 + Rs.500 = 13646
Gross Income = 13646
Total Expenditures = 7175

Net Income Rs. 6471
7175 : 13646
Ratio 1 : 1.9

It is indicated from cost benefit ratio that sowing of one acre of gram crop will produce 571.6 kg ha^{-1} under hand weeding twice. It is also revealed that if a farmer when invested one rupee he will get 1.9 rupees. As a whole an expenditure on one acre was Rs.7175 and the income was Rs.13646 and net benefit of Rs.6471.

Cost Benefit Ratio $Acre^{-1}$ for Hand Weeding One Time Treatment

Land Preparation	**Expenditure in Rupees**
Ploughing two time Tractor Rs.350 hr^{-1}	350 x 2 = 700
DAP one bag $acre^{-1}$	1100 = 1100
Seed 25 kg $acre^{-1}$ Rs.35.00 kg^{-1}	25 x 35 = 875
Hoeing and Weeding one time Three labour for two days	6 x 100 = 600
Plant Protection (Insecticide) Two times 1 litre $acre^{-1}$	2 x 500 = 1000
Harvesting four men for two days	8 x 100 = 800
Transportation Tractor	500 = 500
Threshing two hour Rs. 500 hr^{-1}	500 x 2 = 1000
Total Expenditure	6575

Prevailing Market Rate

Total Produce 450.66 kg $acre^{-1}$
Sale of Grain @ Rs. 23 kg = 450.66 x 23 = 10365. 18
=10365.18 +
Sale of Straw = 500.00
10865.18
Gross Income = 10865.18
Total Expenditures 6575 –
Net Income Rs = 4290.18
10865.18: 6575, Ratio = 1 : 1.65

Cost Benefit Ratio for Weedicide

Land Preparation	**Expenditure in Rupees**
Ploughing two time Tractor Rs.350 hr^{-1}	350 x 2 = 700
DAP one bag $acre^{-1}$	1100 = 1100
Seed 25 kg $acre^{-1}$ Rs.35.00 kg^{-1}	25 x 35 = 875
Weedicide 1 kg $acre^{-1}$	500.00 =500
Plant Protection (Insecticide) Two times 1 litre $acre^{-1}$	2 x 500 = 1000
Harvesting four men for two days	8 x 100 = 800
Transportation Tractor	500 = 500
Threshing two hour 500 hr^{-1}	500 x 2 = 1000
Total Expenditure	6475

Prevailing Market Rate
Total Produce 311.18 Kg $acre^{-1}$

Sale of Grain @ Rs .23 / Kg

	311.18x 23 =7157.14
Sale of Straw	= Rs 500.00 +
Gross Income	= Rs 7657.14
Total Expenditure	= Rs 6475.00 -
Net Income Rs	= Rs 1182. 14
	7657.14: 6475.00
Ratio	= 1:1.18

It is clearly evident from the analysis studies that normal hand weeding twice is the best method for controlling weeds in chickpea. Cost benefit ratio showed that normal hand weeding twice increases the farmer income despite the rainfed conditions at the cost benefit ratio of 1:1:9.

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EVALUATION OF DIFFERENT PLANTS BASED PRODUCTS FOR *Striga hermonthica* CONTROL IN SORGHUM (*Sorghum bicolor*) UNDER SUDANESE FIELD CONDITIONS

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ABSTRACT

Sorghum (Sorghum bicolor) is the most important cereal crop in Sudan in terms of both production and consumption. It is worst affected by a noxious parasitic weed Striga hermonthica causing serious crop yield losses. Three successive field experiments were conducted at Dalang, Sudan, from 2008 to 2009, to evaluate the efficiency of four plants (Azadirachta indica, Ocimum basilicum, Lawsonia alba and Cissus quadrangularis) based products on Striga seed germination, seedling mortality, time to 50% Striga seedling emergence and mortality. The treatments were arranged in a randomized complete block design using five replications. All four plants based materials significantly reduced Striga seed germination and causing considerable Striga seedling mortality which was the highest in the treatment with C. quadrangularis plant material. C. quadrangularis plant materials caused 50% of Striga seedling mortality in about 40 days after the first seedling emergence (FSE) while the other plant materials caused 50% seedling mortality in about 60 days of FSE. The effect of the four plant materials under study on the time of 50% Striga seedling emergence was consistent in the three trials. Suppression of S. hermonthica seed germination by allelochemicals released by the plant materials under study is suggested as the mechanism for reduction of S. hermonthica infestation and can act as an effective component of an integrated Striga control program compatible with the limited resources of small-scale subsistence farmers of Sudan.

Key words: Plants based products, *Striga*, *witchweed*, control, integrated weed management.

INTRODUCTION

Striga (witchweed) is a parasitic weed that seriously constrains the productivity of staples such as maize, sorghum, millet and upland rice in Sub-Saharan Africa. The weed survives by siphoning off water

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and nutrients from the crops for its own growth. It causes serious damage to its host crop before emerging from the soil by producing phytotoxins which are harmful to the host crop. Upon attachment to host roots, it withdraws photosynthate, minerals and water, resulting in characteristic "witch" appearance of the host crop manifested by stunting and withering. *Striga* infests as much as 40 million hectares of smallholder farmland in the region and causes yield losses ranging from 20-80% and even total crop failure in severe infestation (African. Agri. Tech. Found., 2010). Among the five major *Striga* species, *Striga hermonthica* (Benth.) is most important and widely distributed in Africa. *S. hermonthica* is an obligate root parasite of the family Orobanchaceae, which causes severe damage to many important agricultural crops such as sorghum, maize and milet in most of sub-Saharan Africa (Sauerborn, 1991). *Striga* removes nutrients and carbohydrates and exerts a phytotoxic effect on the host, resulting in a reduction of photosynthesis, stunted growth, and lower yields (Press *et al.*, 1996; Ransom *et al.*, 1996).

An estimate of 21 million hectares of maize and sorghum are *Striga* infested in Africa with yield loss of 4.1 million tones per year has been reported (Sauerborn, 1991). In Sudan, almost 4.0 million hectares of sorghum are grown, mostly under rainfed conditions. But, sorghum production is increasingly constrained by *S. hermonthica*. Fields which are heavily infested with *Striga* must be abandoned or planted with another non-susceptible crop.

In Sudan, a number of control measures for *Striga* have been adopted by the farmers such as cultural practices, fertilizers, herbicides, germination stimulants, resistant varieties and biological control. Cultural practices include hand pulling, sowing date, planting method, intercropping, catch cropping and crop rotation with emphasis on trap crops. However, it has been proved to be difficult to find selective products to control the parasite and each of them has one or more limitations that have led to low farmer adoption.

The use of plant products for the control of *S. hermonthica* is limited (Marley *et al.*, 2004) so this present study was carried out to evaluate the effect of four different plant materials viz. *Cissus quadrangularis, Lawsonia alba, Azadirachta indica* and *Ocimum basilicum* in controlling the noxious parasitic weed *Striga hermonthica* in Sudan.

MATERIALS AND METHODS

Collection and preparation of plant materials

Neem (*Azadirachta indica*) matured seeds; mature leaves from both Sweet Basil (*Ocimum basilicum*) and henna (*Lawsonia alba*) and mature stem of veldt grape (*Cissus quadrangularis*) were collected from Dalanj locality, South Kordofan State, Sudan. The plant materials were allowed to dry under laboratory conditions for 15 days. After that, all the dried plant parts were separately ground into fine powder and stored dry in a glass container until needed.

Seeds of *S. hermonthica* used for this study were collected from the parasite growing on sorghum (*Sorghum bicolor* L.) in fields around Dalanj (one year prior the experiments were conducted). The seeds were stored at ambient temperature in polyethylene containers in a laboratory till used.

Determination of efficacy of plant materials

Three field experiments were conducted at the farm of the Faculty of Agricultural Sciences, Dalanj University, Dalanj, Sudan during two successive years (2008 and 2009). The first experiment was conducted from mid August to end of December 2008, while the second experiment was conducted from mid April to September 2009 whereas the last one was conducted from mid June to September 2009.

The soil was artificially infested with *Striga* seeds, carried out by mixing l0g of *Striga* seeds with 500g sieved sand. The mixture was shaken thoroughly in air-filled polythene bag for 5 min to ensure a uniform distribution of *Striga* seeds in the inoculum stock.

In all experiments, plots consisted of five rows, 5.0m long with 0.75m spacing. Within rows spacing for sorghum was 0.5m with two sorghum plants per hill. Sorghum seeds were sown at five seeds per hill at planting time and two weeks later they were thinned to two plants per hill. Also at each planting hill, 2 g of plant material in each treatment was applied simultaneously with the sorghum seeds and *Striga* seeds in the planting hill. Four treatments were carried out: Neem seed powder, sweet basil leaf powder, henna leaf powder, veldt grape stem powder and a control (only sorghum infested with *Striga* with no plant material).

The experiment contained five plots (each plot represented one replicate) of each treatment and the control. Each treatment was replicated 5 times in randomized complete block design. Sorghum used in all experiments was a susceptible cultivar called 'Wad Ahmed' which is grown by the farmers in South Kordofan State. Plots were kept weed free by hoe and hand weeding except for *Striga* throughout the growing season. No fertilizer was applied to sorghum at all seasons. Emerged *Striga* plants were counted every other day after emergence until the end of *Striga* emergence. Dead *Striga* plants were also counted every other day till the end of the experiment in order to evaluate the mortality rate caused by each plant material.

Statistical analysis

All the data were subjected to One-way analysis of variance (ANOVA). Arcsine transformations of data presented as frequency were carried out prior to analysis. Duncan's Multiple Range test was used to separate differing means if statistical differences existed between data sets ($P<0.05$ ANOVA). All parametric tests were computed using SAS Statistical Software Package (SAS Institute, 2000. v.8.1).

RSEULTS AND DISCUSSION

The results of the first season in 2008 are represented in Table-1. Number of *Striga* seedling emergence from the different treatments was considerably reduced in treated plots with different plant materials compared to the control.

Our results illustrate that all plant materials significantly ($p=0.05$) reduced *Striga* emergence when compared to the control. The lowest number of emerged *Striga* plants were found in plots treated with veldt grape stem powder (with 3 emerged *Striga* 4.5 m^{-2} compared the control plots which had 33 emerged *Striga* plants 4.5 m^{-2}) followed by henna leaf powder (5.8 plants 4.5 m^{-2}), Neem seed powder (9.4 plants 4.5 m^{-2}) and sweet basil leaf powder (19.6 plants 4.5 m^{-2}), respectively. The effect of plant products in suppressing *Striga* had been reported. Marley *et al.* (2004) found that Neem and parkia significantly reduced *Striga* emergence. Our results indicated that all plant materials showed great effect in managing *Striga* seed banks and it can be used by the farmers as *Striga* seed-bank management technique as part of integrated weed management program.

Table-1. Effect of different plant materials on the *Striga hermonthica* emergence (shoot number) seedling mortality %, Days to 50% emergence and Days to first emergence from mid August to end of December 2008.

Treatment	Shoot No. 4.5m^{-2}	Seedling mortality %	Days to 50% emergence	Days to 1^{st} emergence
Veldt Grape	3.00±1.00a≠	64.62±9.56a	43±0.89a	42.20 ±1.53a
Henna	5.8±2.8b	49.11±5.35b	42.4±3.61a	40±2.88b
Neen	9.4±3.19c	31.77±2.6b	43.6±1.69a	39±1.52b
Sweet Basil	19.6±6.81d	22.20±7.21c	46.6±1.63a	38.2±1.24b
Control	33.00±8.02e	0.00±0.00d	46±0.63a	34.00 ±0.00c

≠Means within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's Multiple Range Test.

All plant materials caused significant mortality of *Striga* seedling when compared to the control (0% mortality). Maximum seedling mortality was recorded in plots treated with veldt grape (64.62%) followed by henna (49.11%), Neem seed powder (31.77%) and sweet basil leaf powder (22.20%), respectively. These results revealed that the plant materials can induce seedling mortality as well as reduced seed bank. Our results showed that *C. quadrangularis* plant materials caused 50% of *Striga* seedling mortality at about 40 days after the first seedling emergence (FSE) while the other plants materials caused 50% seedling mortality at about 60 days of FSE (Data not presented). These data show that veldt grape reduced *Striga* infestation earlier than the other studied plant materials.

The effect of all plant materials on the time of 50% *Striga* seedling emergence was inconsistence and following different pattern through out the three trials (Tables 1-3). The four plant materials had significant impact on days to *Striga* emergence. In plots treated with veldt grape, Neem, sweet basil, henna the period to *Striga* emergence was significantly longer than that in the control plots. The longest time for *Striga* to emerge was observed in plots treated with *C. quadrangularis*. These results are in consistence with the work reported by Hess and Dodo (2004) who reported that time to *Striga* emergence was prolonged when sesame grown in rotation with pearl millet. Results from the first season in 2009 are presented in Table-2. The data during the subsequent year showed the similar trend. The four plants materials reduced *Striga* emergence significantly following the same order as that in 2009, veldt grape, henna, Neem and sweet basil, respectively. Also mortality rate was significantly higher in all plots treated with the four plant materials. Again the plant materials used in this study were significantly prolonged the first time for *Striga* to emerge when compared with the control.

Table-2. Effect of different plant materials on the *Striga hermonthica* emergence (shoot number) seedling mortality %, Days to 50% emergency and Days to first emergence from mid April to September 2009.

Treatment	Shoot No. $4.5m^{-2}$	Seedling mortality %	Days to 50% emergency	Days to first emergence
Veldt Grape	6.7±0.89a	49.50±4.38a	59.11±2.01a	43.56±0.75a
Henna	4.6±2.04b	37.12±9.80b	57.66±0.93a	41.78±0.49b
Neen	24.5±3.49c	34.58±7.73b	61±1.22b	41.11±0.35b
Sweet Basil	15.3±0.92d	17.10±5.62c	55.67±1.56c	40.33±0.3b
Control	77.6±5.45e	0.00±0.00d	55.67±1.641c	38.00±0.00c

Means within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's Multiple Range Test.

Table-3 shows the results obtained in second seasons of 2009. Again the results were consistent with those obtained from previous two seasons. All plant materials significantly reduced *Striga* emergence and caused considerable *Striga* seedling mortality. Veldt grape showed the highest reduction of *Striga* emergence and highest *Striga* seedling mortality among the different plant materials used in this study. Moreover, the time to first *Striga* seedling emergence was significantly prolonged by the all tested plant materials.

Table-3. Effect of different plant materials on the *Striga hermonthica* emergence (shoot number) seedling mortality %, Days to 50% emergency and Days to first emergence from mid June to September 2009.

Treatment	Shoot No. $4.5m^{-2}$	Seedling mortality %	Days to 50% emergency	Days to first emergence
Veldt Grape	9±1.82a≠	78.94±5.42003a	57.67±2.37a	50.11±0.79a
Henna	10.8±0.87b	63.48±9.38479b	59.78±3.05b	45.56±0.29b
Neen	20.9±2.71c	69.10±3.08764b	55.67±0.53a	45.33±0.24b
Sweet Basil	24±3.05d	51.86±6.38925c	59.89±1.66b	45.78±0.32b
Control	97.6±2.54e	0.00±0.00d	65.44±0.63c	42±0.00c

≠Means within a column followed by the same letter are not significantly different at the 5% level of probability according to Duncan's Multiple Range Test.

According to our knowledge this is the first report of allelopathic effect of veldt grape, henna and sweet basil to the noxious parasitic weed *Striga hermonthica*. In the meantime Ciotla *et al.* (1995) have already discovered a fungus to control *S. hermonthica* infesting sorghum. Neem tree, veldt grape, henna and sweet basil are very abundant in Sudan and grow without agronomic practices so these caould be easily availed by the farmers and a continuous supply of these materials in managing *Stiga hermonthica* is certain.

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FIRST REPORT ON *Cassytha filiformis* L. (LAURACEAE), A PARASITIC WEED FROM LAHORE, PAKISTAN

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ABSTRACT

The Cassytha filiformis L. "Woevine" is an angiospermic leafless parasitic weed belonging to the family Lauraceae was found colonizing certain plant species in the premises of Lahore, Pakistan. This parasitic weed was found abundantly on five angiospermic host plants belonging to seven genera of 6 families. Plants including trees and shrubs were heavily infested by C. filiformis in Lahore. The attack was severe and pulling down the branches of the host wrapped with haustorial sinkers. Based on the survey, most of the weed affected patches were recorded in Bougainvillea spectabilis followed by Nerium oleander and Ziziphus mauritiana.

Keywords: Parasitic plant, host plant, *Cassytha filiformis*, Woevine.

INTRODUCTION

Parasites are unusual plants, well adapted to their mode of life. More than 2500 species of higher plants are known to live parasitically on other plants. The most common and serious parasites belong to these botanical families and genera: Cuscutaceae; *Cuscuta* (dodders); Scrophulariaceae: *Striga* (witch weed); Orobanchaceae: *Orobanche* (broom rapes); Cassythaceae: *Cassytha* (ambarbeli); Loranthaceae: *Elytranthe, Korthalsella* and *Loranthus*, Viscaceae: *Arceuthobium* (dwarf mistletoes); *Phoradendron* (American true mistletoes) and *Viscum* (European true mistletoes). These parasitic plants produce flowers and seeds and belong to several widely separated botanical families (Dorr, 1987). They vary greatly in their dependence on their host plants. For example, *Viscum* (mistletoes) have chlorophyll but no roots and therefore depend on their hosts only for water and minerals. Similarly, *Cuscuta* (dodders) and *Cassytha* (amarbel) have little chlorophyll and no true roots. Hence they depend on their hosts for water, food and minerals (Abubacker *et al.*, 2005).

The genus *Cassytha* (Lauraceae) contains 20 species and is distributed in Pacific Rim countries, mainly Australia, Africa, America and Japan (Mabberley, 1997). It is a common stem parasite on Lantana Toddalia and certain other plants in South India (Rangaswamy

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and Rangan, 1963). Being a parasite this plant is unique in the family. Because of its particular characteristics and its parasitic habit it is classified in a separate tribe. The *Cassytha filiformis* L. "woevine" is cosmopolitan in the tropics where it sometimes becomes a pest of economic importance. The host range of *C. filiformis* is very wide. Werth *et al.,* (1979) listed 81 species affected in the Bahamas, including grasses, ferns and gymnosperms as well as broad-leaved angiosperms. Cassytheae, within the family Lauraceae is represented by a single genus *Cassytha* (Hutchinson, 1964) in which 18 species have been described (King, 1966).

Angiospermic parasitic plants are considered as influential factor in determining the fate of the quality and quantity of economically valuable plant species. They are the serious pest in natural forests, plantation, orchards and ornamental trees in many parts of the world (Calder and Bernhard, 1983). The *C. filiformis* produces haustorial sinkers, rather than root, which penetrate the branches and stem of the host plants for drawing water and mineral nutrients (Agrios, 2000). At present *C. filiformis* is a problem in Lahore, infecting the vegetation beauty of the city. The host specificity and taxonomy of the parasite have been briefly discussed in this paper. This paper is also a first report on *C. filiformis* and its host in Lahore, Pakistan.

MATERIALS AND METHODS

The diversified host species of *C. filiformis* were studied in Lahore. Extensive survey was undertaken during January 2009-June 2010 in different areas including forest plantations, parks and road sides. Weed frequency percentage on hosts was calculated on visual observation (Younesabadi *et al.*, 2006).

$$\text{Weed frequency (\%)} = \frac{\text{Number of sites in which a species occurred}}{\text{Total number of sites visited}} \times 100$$

The host species were also identified with the help of available literature (Pederick and Zimmer, 1961; Kuijt *et al.*, 1969; Werth *et al.*, 1979; Visser, 1981; Parker and Ritchie, 1993).

RESULTS AND DISCUSSIONS

According to survey (2009-2010), C. *filiformis* was found on five angiospermic host plants belonging to seven genera of 6 families (Table-1). Plants including trees and shrubs were heavily infested by *C. filiformis* in Lahore.

In the present survey *C. filiformis* was mostly observed along the *Bougainvillea* bushes in the areas under study. Predominantly, weed attack was severe on the species *Bougainvillea, Nerium and Ziziphus* and the frequency of observed patches was up to 35%. The attack was severe and pulling down the branches of the host wrapped with haustorial sinkers. According to literature no report has been found on *C. filiformis* distribution and incidence in Pakistan (Kostermans, 1978). During the survey it was also observed that *C. filiformis* was not host specific. It was also observed that attack was more pronounced through out the year especially in October to April.

Table-1. Various host plants attacked by *Cassytha filiformis*.

Host Plant species	Family
Bougainvillea spectabilis willd	Nyctaginaceae
Citrus aurantifolia Swingle	Rutaceae
Thevetia peruviana (Pers.) K. Schum.	Apocynaceae
Nerium oleander L.	Apocynaceae
Ziziphus mauritiana Lamk.	Rhamnaceae
Butea monosperma (Lam.) Taub.	Fabaceae
Morus alba L.	Moraceae

Description and Characteristics of *C. filiformis* L.

A twining parasitic, perennial angiosperm which adheres to the host by suckers (haustoria). Leaves degenerate and almost assimilate into the stem, which has small elliptical haustoria (Weber, 1981). Stems twining, pale green to yellow-green to orange, filiform, glabrous or pubescent. The individual stems with extensive branching may attain a length of 10 to 20 feet. Leaves modified into minute scales. Spikes 1-2 cm long, rarely reduced to single flower. Small bisexual flowers, sessile, spicate, perianth tube short and globose, stamens six, ovary globose, fruit a drupe enclosed in the enlarged inflated perianth tube. Ovary is first exposed and later enveloped by the enlargement and overgrowth of the calyx tube (Nelson, 2008). Fruit is nearly spherical, smooth, fleshy, about 7 mm in diameter. Single seed with membranous testa. The separation between cotyledons is not well defined (Schroeder, 1967).

The haustoria penetrate the stem or leaf and reach into the vascular tissues, from which they absorb food and water. Soon after contact with the host is established, the base of the *Cassytha* parasite shrivels and dries up, so that the parasite loses all connection with the ground and becomes completely dependent on the host for food and water (Abubacker *et al.*, 2005). The parasite continues to grow and expand while the growth of host plants is suppressed, which may even die. In the meantime, the parasite plant has developed flowers and produced seeds (Dorr, 1987).

C. filiformis is a very typical plant that can be confused only with *Cuscuta*, a vining parasite of the Cuscutaceae. As chemical components in Cassytha species, many aporphine alkaloids, e.g., actinodaphnine, cassythine and dicentrine have been reported from *C. filiformis* (Tomita *et al.,* 1965; Chang *et al.,* 1998; Hoet *et al.,* 2004). According to Nickrent (2002) and Werth *et al.,* (1979), *C. filiformis* appears to be totally indiscriminate in host choice, often covering and parasitizing dozens of host species simultaneously. *C. filiformis* parasitizes a wide variety of mainly woody hosts, including plants of agricultural and economic value, and indigenous as well as endemic species. *Cassytha* and *Cuscuta* have also been reported as hyperparasites of mistletoes such as *Phoradendron* and *Struthanthus* (Kuijt *et al.,* 1964). Among the important economic hosts are fruit plants such as citrus, mango (*Mangifera indica*), cloves (*Eugenia aromatica*), nutmeg (*Myristica fragrans*), and avocado (*Persea americana*). Infections may be fatal. Heavy infestations can eventually smother and kill plants and their coppice re-growth in coastal habitats. *C. filiformis* is a threat to lowland reforestation projects. *C. filiformis* is reported to be capable of transmitting phytoplasmas from palms [Coconut (*Cocos nucifera*); areca (areca yellow leaf disease, ALD)] and a virus disease such as citrus mosaic, caused by citrus mosaic badnavirus CiMV (Nelson, 2008).

During winter *Cassytha* seeds germinate and produce a slender yellowish shoot, but no roots. When in contact with a susceptible host, the shoot encircles the host plant, sends haustoria into it and begins to climb up the plant (Abubacker *et al.*, 2005). Moreover, the parasite as often forms attachments to it (autoparasitism) as it does to its host. In present investigation it become also evident *C. filiformis* has no host specify and it may even thrive well by absorbing least amount of water and nutrient from the host. It weakens or hinders the normal growth and development of host and in last stage cause death to its host (Fig.1).

There are about 20 species of *Cassytha* among which *C. melantha* R.Br. causes severe damage to *Eucalyptus* spp. in Australia (Pederick and Zimmer, 1961) and *C. ciliolata* L. can completely overgrow host trees in S. Africa (Visser, 1981). Otherwise *Cassytha filiformis* is by far the most widespread and common species of the genus. In Previous studies, *C. filiformis* is not reported from Pakistan (Kostermans, 1978. Bamber, 1976; Stewart, 1972; Parker, 1956; Kashyap, *et al.,* 1936) may be due to similarities with *Cuscuta reflexa* L. This study is also an addition to floral information of parasitic plant in Lahore and Pakistan.

Figure 1. Effect of *Cassytha filiformis* L. on its host.

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