BIO-EFFICACY OF POST-EMERGENCE MICRO HERBICIDES IN TRANSPLANTED RICE (*ORYZA SATIVA* L.)

by

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DECLARATION

I hereby declare that this thesis entitled " **Bio-efficacy of post-emergence micro herbicides in transplanted rice (*Oryza sativa* L.)** " is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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My God,

Beloved Parents and my guide Dr. Elizabeth K. Syriac

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Rathod Nilesh Dayaram

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LIST OF ABBREVIATIONS

ai	–	Active ingredient
ALS	–	Aceto lactate synthase
B: C ratio	–	Benefit Cost Ratio
BLW	–	Broad Leaved Weeds
CD (0.05)	–	Critical difference at 5 % level
cm	–	Centimeter
DAS	–	Days after spraying
day^{-1}	–	Per day
et al.	–	And others
Fig.	–	Figure
g	–	Gram
$g\ m^{-2}$	–	Gram per square metre
ha	–	Hectare
HI	–	Harvest index
HWT	–	Hand Weeding Twice
$hill^{-1}$	–	Per hill
i.e.,	–	That is
K	–	Potassium
KAU	–	Kerala AgriculturalUuniversity
kg	–	Kilogram
$kg\ ha^{-1}$	–	Kilogram per hectare
l^{-1}	–	Per litre
LAI	–	Leaf area index
LTR	–	Light transmission ratio
m	–	Metre

LIST OF ABBREVIATIONS CONTINUED

m^{-2}	–	Per square metre
MOP	–	Muriate of Potash
MSL	–	Mean sea level
N	–	Nitrogen
NAR	–	Net assimilation rate
NRCWS	–	National research centre for weed science
NS	–	Non significant
P	–	Phosphorus
Plant $^{-1}$	–	Per plant
Panicle^{-1}	–	per panicle
PAR	–	Photosynthetically active radiation
PDA	–	Potato dextrose
P^H	–	Negative logarithm of hydrogen ion concentration
RH	–	Relative humidity
Rs. ha^{-1}	–	Rupees per hectare
SE	–	Standard error
sp.	–	Species
t ha^{-1}	–	Tonnes per hectare
viz.,	–	Namely
WCE	–	Weed Control Efficiency

List of symbols

%	–	Per cent
°C	–	Degree Celsius
@	–	At the rate of
&	–	And
>	–	More than

INTRODUCTION

1. INTRODUCTION

Meeting food demand for the burgeoning population has become a major challenge now than ever before. Agriculture is in the forefront of national and international agenda to assume food security and sound management of natural resources. Cereal plays major role in our food economy and is the most important part of diet throughout the world. Amongst cereals, rice *(Oryza sativa* L.) is the most important and extensively grown in tropical and subtropical regions of the world. Rice is the staple food for more than half of the world's population (FAO, 2004). Rice plays unique role in providing calories to the majority of Asian and Latin American countries. It is grown in 112 countries in the world, covering every continent, and is consumed by 2500 million people in developing countries (Angiras and Attri, 2003). Among cereals, rice is the major source of calories for about 40 % of the world population and every third person on earth eats rice every day in one form or other (Datta and Khushi, 2002). Rice (*Oryza sativa* L.) is the leading cereal of the world (Ashraf *et al.*, 2006), and more than half of the human race depend on rice for their daily sustenance (Chauhan and Johnson, 2011). It is the primary source of income and employment for more than 100 million households in Asia and Africa (FAO, 2004). World's rice demand is projected to increase by 25% from 2001 to 2025 to keep pace with population growth (Maclean *et al.*, 2002), and therefore, meeting ever increasing rice demand in a sustainable way with shrinking natural resources is a great challenge.

Weed is as old as agriculture, and from the very beginning farmers realized the interference of weed with crop productivity (Ghersa *et al.,* 2000), which led to the co-evolution of agro-ecosystems and weed management (Ghersa *et al.*, 1994). Weeds are the greatest yield-limiting constraint to rice (WARDA, 1996). Weed competition is one of the important biotic constraints in rice production and it can cause a reduction of 28-45% of grain yield in transplanted rice (Singh *et al.*, 2003).

Hand weeding is very easy and environment-friendly but tedious and highly labor intensive. Farmers very often fail to remove weeds due to unavailability of labor at peak periods. Moreover, morphological similarity between grassy weeds and rice seedlings makes hand weeding difficult at early stages of growth. Considering all these situations, herbicide is being considered as the most practical, effective and economical means of weed management in rice (De Datta, 1981). Despite some adverse environmental impacts, no viable alternative is presently available to shift the herbicide dependence for weed management in rice. With the explosive increase in labour cost and difficulty in labour availability, rice farmers in India also have started replacing manual weeding with chemical weeding.

Though herbicides accounts for only 18 per cent of the total pesticides consumed in India, 30 per cent of it is solely used in rice culture (NRCWS, 2007). Despite the obvious advantages of herbicides, their use has raised concerns relating to human health and the environment. Furthermore, through repeated exposure to herbicides, many weeds have become resistant, which reduces the efficacy of previously effective herbicides (Monaco *et al.*, 2002). Considering public apprehensions on pesticide use, Government of Kerala has recently banned the use of some of the pesticides including conventional herbicides.

The use of herbicides offers scope for economical control of weeds right from the beginning, giving rice crop an advantage of good start and competitive superiority. Conventional pre-emergence herbicides such as butachlor, pretilachlor etc. are being frequently used for the management of weeds in transplanted rice. Continuous application of these voluminous herbicides year after year may lead to shift in weed flora from grassy to non-grassy weeds and sedges and development of herbicide resistance in weeds (Rajkhowa *et al.*, 2006).

Recent trend in chemical weed management in rice is the use of low dose high efficiency (LDHE) herbicides, which will not only reduce the total volume of herbicide per unit area, but also make the application easier and economical to the farmer. These new generation herbicides act by inhibiting the action of key plant enzymes *viz.*, aceto lactase synthase (ALS), acetyl co-enzyme-A-carboxylase (ACCase) and protoporhyrinogen oxidase (Protox) depending on their mode of action.

Moreover these new generation herbicides are applied at very low doses and they degrade from the environment in a few weeks. With the recommended use rates, the quantity of herbicides applied to soil at one time is too small to have any detectable influence on soil physical or chemical state (Yaduraju and Mishra, 2002). Ideally a herbicide should remain active in soil for a period sufficient to provide satisfactory weed control and then it must degrade in to innocuous products before it is necessary to apply it again (Yadav *et al.*, 1997).

Of late, an array of promising low dose high efficacy pre- and post-emergence herbicides are available for control of wide spectrum of weed flora in lowland rice (Moorthy, 2002). However, the window of application is very narrow for pre-emergence herbicides usually 1-3 days after transplanting whereas it is spread over the critical period of weed growth for post-emergence herbicides to combat late emerging weeds. The weed-rice ecological relationship is very complex and dynamic and weed spectrum and degree of infestation in rice fields are often determined by rice ecosystems and establishment methods (Juraimi *et al.*, 2013). Hence the new generation herbicides presently available in the market are to be evaluated for their bio-efficacy in different agro-ecological zones.

With this background, the present investigation was undertaken with the following objectives:

- To assess the bio efficacy of two post emergence, micro herbicides (fenoxaprop-p-ethyl and carfentrazone-ethyl) in transplanted rice
- To work out a suitable and economic weed management strategy for transplanted rice

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In India weed problem is one of the most important biotic constraints that limit rice productivity (Saha and Rao, 2007). Effective control of weeds is, therefore, vitally important. Transplanted rice, in particular, is infested by heterogeneous type of weed flora under lowland ecosystems which reduces yield up to 48 per cent and an yearly loss of 15 million tonnes is caused due to weed competition (Saha, 2009). Prevention of weed competition and provision of weed free environment at critical periods of rice growth is necessary for successful rice production. Among the various weed management techniques chemical weed control is a better option compared to cultural and mechanical methods. Recently a number of low dose herbicides have been developed which are characterized by crop selective weed control at use rates of 2-100 g ha^{-1}. These microherbicides are ecofriendly due to their less environmental persistence and low toxicity to non target organisms. The literature pertaining to the above aspects is reviewed in this chapter.

2.1. WEED SPECTRUM IN TRANSPLANTED RICE

Rice fields can be colonized by terrestrial, semi aquatic or aquatic plants and wide variations of weed plants from country to country and with the different types of rice culture have been reported; they range from more than 1800 species in South and South East Asia to about 30 species in Eastern Europe. Weed survey study indicated that in South and South Asia, 65 species are found in deep water rice, 194 species in dry seeded rice, 559 species in transplanted rice, 558 species in upland rice and 180 species in wet seeded rice (Muthukrishnan *et al.*, 2010).

Subramanian *et al.* (2006) reported that weed flora of the experimental field were composite in nature, consisting of grasses such as *Echinocloa colonum* L., *E. crus-galli* L. and *Cynodon dactylon* L.; sedges such as *Cyperus rotundus* L., *C. difformis* L. and *C. iria* L.; broad leaved weeds such as *Eclipta alba* L. *Ammania baccifera* L., *Phyllanthus niruri* L. and *Ludwigia parviflora.*

The major weed reported in Kerala are *Alternanthera* sp., *Aeschynomene* sp., *Cleome* sp., *Cyperus* sp., *Echinochloa* sp., *Eichhornia crassipes, Fimbristylis miliaceae, Grangea maderaspatana, Hydrolea, Monochoria, Lindernia, Ludwigia parviflora, Oldenlandia, Phyllanthus, Salvinia, Sphaeranthus indicus, Sphenoclea zeylanica,* etc. Of these, *Cyperus* sp. is the most abundant weed sp. present in all the rice growing tracts of Kerala and *Grangea maderaspatana* is observed mainly in the Kole lands of Kerala (Leenakumary, 2007).

The major weed flora reported in Vellayani, Thiruvananthapuram are *Echinochloa colona* (L.) Link., *Cyperus difformis, Fimbristylis dichotoma (L.)* Vahl., *Scirpus grossus* L.f., *Limnocharis flava* (L.) Buchenau., *Monochoria vaginalis* (Burm. f.) Presl. Ex Kunth., *Ludwigia parviflora* Roxb., *Ipomoea aquatic* Forsk., *Lindernia rotundifolia* blanc vert., *Salvinia molesta* D.S. Mitch., *Marsilea quadrifolia* Linn. And *Pistia stratiotes* L. Royle (Yadav, 2006).

The results of the field survey conducted by Sajithbabu (2010) revealed that, there were 46 weed specii associated with the cultivated wetland rice ecosystems of Thiruvananthapuram district in Kerala state during the first crop season. The broad leaved weeds and grasses topped the list with 16 specii each. The sedges which found place in the list included 10 from Cyperaceae and one from Eriocaulaceae. The list of weed flora during the second crop season totaled to 49 species which included 16 grass specii, 11 sedges and 19 broad leaved specii. This result highlighted the weed floristic diversity in the wetland ecosystems of Kerala state.

2.2 CROP WEED COMPETITION

Crops as well as weeds have the same requirement for the growth and development, and competition begins when crop and weeds grow in close proximity to each other and supply of a single necessary factor falls below the demand of both. Once this occurs, the other factors necessary for plant growth cannot be used effectively even though they may be present in abundance. The overall effect of competition would be a reduction in the biomass and reproductive potential of the competitors. The outcome of the competition would depend not only on the competing species but also on their density, duration and the level of fertility (Moody, 1991).

Behra and Jena (1997) explained the major reasons for higher rice grain and straw yield under weed control treatments both in upland and transplanted situation as their effectiveness in controlling weeds during critical period of rice crop growth.

Phogat and Pandey (1998) reported that presence of weeds increased the crop-weed competition and lowered effective tillers, thousand grain weight and grain yield. The lowest grain yield in unweeded control is due to increased crop-weed competition and higher dry matter accumulation of weeds.

Weeds are the cause of serious yield reduction in rice production worldwide. Losses caused by weeds vary from one country to another, depending on the predominant weed flora and on the control methods practiced by farmers. Two examples give an idea of the dimensions of the problem. In China, 10 million tonnes (Mt) of rice are lost annually due to weed competition (Ze Pu Zhang, 2001); such a quantity of rice is sufficient to feed at least 56 million people for one year.

Each trait in a plant if able to increase its size and vigor at the early growth stage, increases its ability to compete with weeds (Ni *et al.*, 2000). They have also reported that rice biomass at the tillering stage was the best index to determine competition with weeds.

Study was conducted in lowland fields to determine *Oryza sativa* plant traits that confer competitive ability against weeds. Initial biomass (IB), crop growth rate (CGR), leaf area index (LAI), and biomass at tillering of *O. sativa* plants were associated with their competitiveness against weeds, whereas relative growth rate, net assimilation rate, and tillering capacity of *O. sativa* were not. Biomass at tillering affected weed biomass directly, and IB, CGR and LAI indirectly affected weed biomass through *O. sativa* biomass. Biomass at tillering was the best predictor of modern cultivar competitiveness against weeds (Moody *et al.*, 2000).

Weed competition with crops is a part of weed ecology. The word competition comes from the Latin word 'compete' which means to ask or sue for the same things.

Competition begins when crop and weeds grow in close proximity to one another and the supply of an essential factor falls below their demands. Crop plants vary greatly in their ability to compete with associated weeds. The total effect of interference as reflected in the crop growth and yield results from competition for nutrients, moisture and sunlight (Rao, 2000).

Weed species differ in their ability to compete with rice (Smith 1968). The degree of rice-weed competition depends on rainfall, rice variety, soil factors, weed density, duration of rice, weed growth and crop age when weeds started to compete, and nutrient resources, among other variables (Ampong Nyarko and De Datta, 1991).

2.2.1 Critical Period of Crop Weed Competition

Critical period of weed competition is the period before and after which weed growth does not affect crop yield (Zimdahl, 2004). Ghosh (2010) observed that 3-4 weeks after transplanting was the critical crop weed competition. The most critical period for competition between rice and weeds is when the rice is in the vegetative phase and the yield components of rice are being differentiated (Mukherjee and Singh, 2003).

The critical period of crop-weed competition varies considerably with the crop cultivar, weed flora, weed incidence, climatic and edaphic condition (Alstorm, 1990). During early establishment, the weeds make 20-30 per cent of their growth while the crop makes 2-3 per cent of its growth (Moody, 1990). There is evidence that the critical period exists during which weeds should be controlled to prevent losses (Radosevich *et al.*, 1997).

Singh *et al.* (1999) reported that mean grain yield was the highest in the plot kept weed free up to 60 days after transplanting. According to Dhammu and Sandhu (2002), weedy condition upto first 40 days or more had significantly less rice yield than weed free. They also reported that infestation of *Cyperus iria* throughout the crop growth period caused 64 per cent reduction in rice yield.

A weedy situation for the first 15 days only or weed free situation for the first 60 or 75 days produced grain yields comparable with weed free conditions (Muthukrishnan *et al.*, 2010).

2.2.3 Competition for light

Competition for light can occur throughout rice growth whenever plants are growing closely together. Weeds compete with rice by growing faster and by shading rice with large, horizontal leaves. Shading occurs with a high leaf area index (LAI) reducing the light available to the vegetation below the canopy as expressed in a low light transmission ratio (LTR) below the canopy (Mercado, 1979).

Most weeds and rice have maximum photosynthesis and growth in full sunlight (Ampong-Nyarko and De Detta, 1991). The ability to compete for light depends largely on the comparative growth stature of the competitors. Thus plants which are tall or have an erect habit will have a competitive advantage over short or prostrate plants. Rice suffers little competition for light from *Monochoria vaginalis* (Burm.F.) Presl., a short-statured plant whereas competition from *Echinochloa cruss-galli* (L.) Beauv., a tall weed which eventually overtops the rice plant can be quite severe particularly in the later stages of growth (Moody, 1995).

Srinivasan and Palaniappan (1994) indicated that number of filled grains panicle^{-1} was lowest with competition of *Echinochola* sp. ultimately resulting in the lowest percentage of filled grains. This might be due to the interception of light by tall growing *Echinochola* sp., resulting in poor photosynthesis and photo-chemical energy supply, which ultimately affected the translocation of photosynthates to the developing grains.

The light transmission ratio was lower in *Echinochloa crus-galli* L. and *Ammania spp.* as compared to rice which decreased shoot and grain production and increased tiller mortality (Caton *et al.*, 1997). According to Gibson and Fischer (2001) and Gibson *et al.* (2001) competition for light is a critical factor in the process of interference between rice and weeds. Leaf area and number of tillers are directly correlated with the capacity of the crop to intercept light and suppress weed growth.

This suggests the importance of combining phenological characteristics to maximize the level of competitiveness of rice with weeds.

Saha *et al.* (2003) reported that weeds competing with rice included *Leptochloa,* nutgrass and especially barnyard grass, which overshadowed and eliminated light to dwarf rice.

2.2.3 Competition for Water

Water is one of the critical factors in crop production. The amount and distribution of rainfall determines the kind of crops grown throughout the year in an area, particularly under unirrigated condition. In tropical areas where there is a distinct dry season, crop-weed competition for water becomes a serious problem (Mercado, 1979).

Competition for water and nutrients usually begins before competition for light and is thought to be more important. Competition is greatest when plant roots are closely intermingled, and crops and weeds are obtaining their water from the same volume of soil. Less competition occurs if the roots and weeds are concentrated in different areas of the soil profile. The more competitive plant has a faster growing and larger root system so that it is able to exploit a larger volume of soil quickly (Moody, 1995). If plants have similar root length, those with more widely spreading and less branched root systems will have a comparative advantage in competition for water (Zimdahl, 1999).

2.2.4 Competition for Space

Competition between crop and weeds can be modified by manipulating crop geometry, as increase in crop density can enhance the crop's share of the total resources. Plant population affected the weed biomass production and it was highest with lower plant population (Ghuman *et al.,* 2008).

Crop row spacing did not influence plant height of *Echinochloa colonum* and *Echinochloa crus-galli,* but the height of both species was influenced by their emergence time in the field. *Echinochloa colonum* emerging with rice sown in 30 cm rows produced 3000 seeds plant^{-1}, whereas narrowing rice rows to 20 cm reduced seed production to 2200 seeds $plant^{-1}$, 29 per cent reduction. Similarly *Echinochloa crus-galli* produced 2100 and 2900 seeds $plant^{-1}$ when emerged with rice in 20 and 30 cm rows, respectively (Chauhan and Johnson, 2010).

2.2.5 Competition for Nutrients

Weeds usually grow faster than the crop plants and then they absorb the available nutrients earlier, resulting in reduced availability to crop plants. Grassy weeds compete for mineral nutrients and soil water apart from light, CO_2 etc. as they have an extensive and fibrous root system. Similarly, sedges pose serious competition for nutrients. The roots of sedge dominate the surface feeding zone and obstruct nutrient flow to crop root. Non grassy weed being deep rooted, explores the subsurface zone for mineral and exert less competition for nutrients with rice (Raju and Reddy, 1986).

The three most common yield limiting nutrients are N, P and K. Competition, however, may occur for any nutrient required for plant growth. Weeds also have a large requirement for nutrients (Ampong-Nyarko and De Detta, 1991).

Nitrogen responsive crop species are more competitive under high N fertilization, but if the associated weed is also responsive to N, it utilizes more of the applied N and no advantage in crop yield may be obtained (Ehsanullah *et al.* 2001).

Kolhe *et al.* (1987) observed a greater uptake of N, P and K by the crop and a reduced removal of these nutrients by weeds occur in herbicide treated and hand weeded plots as compared with unweeded control. The loss of 11.49 kg N, 1.71 kg P and 12.40 kg K ha^{-1} was prevented by weed control in transplanted rice.

Singh *et al.* (1999) reported that initial weed free treatment for 45 days or longer resulted in significantly higher rice grain and straw yields and lower dry weight and nutrient uptake by weeds. Competition between crop and weeds is primarily for nitrogen with most intense competition occurring in the early stage. The uptake of nutrients (N, P and K) by rice was significantly higher in weed free treatment. The season long weedy treatment depleted 35 kg N, 15 kg P_2O_5 and 45 kg

K_2O ha^{-1} by weeds, while rice crop under weed free up to maturity removed 60, 26 and 80 Kg ha^{-1} of N, P_2O_5 and K_2O respectively.

Weeds remove a large amount of plant nutrients from the soil. An estimate showed that weeds could deprive the crops of 47 per cent N, 42 per cent P, 50 per cent K, 39 per cent Ca and 24 per cent Mg of their nutrient uptake (Balasubramaniyam and Palaniappan, 2001). Uninterrupted weed growth in rice depleted 59.3 kg N, 10.5 kg P_2O_5 and 35.0 kg K_2O on per hectare basis (Raju and Gangwar, 2004).

2.2.6 Effect of Weed Competition on Crop Growth Characters and Yield Attributes

Under a given set of environmental condition, a hectare of land can produce a certain amount of total vegetative dry matter. In order to maximize crop yield, all of this growth should be in the form of crop. Any weed growing in association with the crop will reduce vegetative potential of the crop and ultimately result in loss of yield (Moody, 1978).

Weed free conditions produced more productive tillers and fertile grains per panicle, compared to weed density 500 m^{-2} to 2000 m^{-2} (Begum *et al.,* 2009). Among the weed control treatments, weed free treatment recorded significantly higher effective tillers and grain yield as compared to partial weedy treatment (Walia *et al.*, 2009).

Mahapatra *et al.* (2002) and Saini and Angiras (2002) reported a decrease in thousand-grain weight due to weed competition. The control of weeds promoted the yield and yield attributes including productive tillers m^{-2}, number of filled grains per panicle and thousand grain weight in rice (Raju *et al.,* 2002, Yadav, 2006, Yadav *et al.*, 2009).

Weed competition is one of the prime yield limiting biotic constraints resulting in yield reduction of 28 to 45 per cent (Singh *et al.*, 2003). Weed management is one of the major factors, which affect rice yield. Uncontrolled weeds cause grain yield reduction up to 76 per cent under transplanted conditions (Singh *et al.*, 2004).

Estimation of yield losses caused by competition from weeds ranges from 30 to 100 per cent (Dobermann and Fairhurst, 2000). Weed free condition at early stage of growth was found more important than at later stages for getting higher yield of rice (Thapa and Jha, 2002). Rice yield losses due to uncontrolled weed growth and weed competition were least (12%) in transplanted rice (Singh *et al.*, 2011).

Weed infestations can also interfere with combine operation at harvest, significantly increase harvesting and drying costs. Weeds seed contamination of rice grain lowers grain quality and may lower the cash value of the crop (Muthukrishnan *et al.*, 2010).

2.3 WEED MANAGEMENT TECHNIQUES

Weed management is essentially a skillful combination of prevention, control and eradication measures to manage weeds in a crop or environment. The various methods of weed management are grouped under three broad categories: traditional, chemical and biological. Reliance on a single method of weed control such as continuous use of the same or similar herbicides could create serious problems by perennial weeds and may also result in weed shift. So the recent approach in weed management is the development of integrated weed management techniques using a combination of effective herbicides along with other methods without affecting the soil flora and fauna and without any residue problem.

2.3.1 Hand Weeding

Hand weeding is done by physical pulling out or removal of weeds by hand or removal by hand operated implements like khurpi which resembles the sickle. It is probably the oldest method of controlling weeds and is still a practical method for eliminating weeds from cropped and non cropped lands (Rao, 2000). Hand weeding continues to be the most common method of weed management in any system of rice culture.

The manual method of weed control is laborious, back breaking and time consuming (Mani and Gautam, 1973). According to Gogoi *et al.* (2001), manual weeding is difficult, many a time due to continuous rains prevailing during rainy seasons and also due to scanty labour. Ravindran (1976) pointed out that hand weeding on the 20^{th} and 40^{th} day after transplanting although gave higher yield, the net profit was lower due to increased labour charge.

Prasad *et al.* (1992) opined that use of herbicide could save upto 75 per cent energy input than hand weeding. He also reported that energy use efficiency was higher with herbicide than with hand weeding. Balasubramanian (1996) pointed out that number of productive tillers in rice was enhanced by hand weeding twice. Pandey *et al.* (1997) reported that maximum grain yield and net profit were obtained from hand weeded plots. Maximum grain yield was recorded with hand weeding treatment but it was comparable to anilofos @ 0.3 kg ha^{-1} + one hand weeding. Higher weed control efficiency was also recorded with hand weeding twice (AICRPWC, 1997). Hand weeding was more effective and the most common tool to control weeds in transplanted rice (Muthukrishnan *et al.*, 1997). According to Rao (2000) manual weeding is effective against annuals and biennials but do not control perennials and is expensive in areas where labour is scarce.

Laxminarayan and Mishra (2001) observed that hand weeding at 15, 30 and 40 DAT resulted in higher crop dry matter compared to anilofos @ 0.04 kg ai ha^{-1}. Two hand weedings at 20 and 40 DAT could control almost all categories of weeds (Bhowmick, 2002). Hand weeding twice recorded the least weed count and highest weed control efficiency (69.9 and 70.1%) during first and second season respectively (Gnanavel and Kathiresan, 2002). Rekha *et al.* (2002) reported that hand weeding twice at 20 and 40 DAT resulted in very low weed dry weight compared to herbicide treatment and unweeded control. Pal *et al.* (2002) observed that hand weeding twice and ethoxysulfuron + anilofos resulted in higher grain yield and less weed growth. According to Singh *et al.* (2003) hand weeding at 30 and 50 DAT recorded significantly lower weed population and dry matter accumulation of weeds over weedy check. Kathirvelan and Vaiyapuri (2003) pointed out that hand weeding (20 and 40 DAT) recorded higher grain yield and straw yield (5.81 and 7.26 t ha^{-1}).

Manual weeding, although efficient in controlling weeds, has been restricted due to several economical and technological factors (Khaliq *et al.*, 2011). The lowest total weed density (1.40 m^{-2}), dry matter production (1.37 g m^{-2}) and weed control efficiency irrespective of weed species was recorded under two hand weedings at 20 and 40 DAT (Singh *et al* ., 2012).

Among weed management practices the maximum yield was recorded with two hand weeding (20 and 45 DAS/DAT) which was statistically at par with herbicide (bispyribac sodium 25 g ai ha^{-1} + one hand weeding and significantly superior over herbicide alone and weedy check (Singh and Singh, 2012).

2.3.2 Chemical Weed Control

Chemical weed control is indispensable in rice culture due to severity of weed problem, hike in labour wages and non-availability of labour during peak periods of cultivation. Chemical weed control can be considered as a better alternative to traditional hand weeding. Today the sales of herbicides have outstripped those of all other classes of pesticides. Currently herbicides constitute 45 per cent of the world pesticide market (Rao, 2000).

The weed control efficiency of various chemicals has been studied extensively and many herbicides are now available for rice growers. Several workers have evaluated the bio-efficacy of herbicides for weed control in rice and it seems that herbicides will play a major role in controlling weeds in rice culture.

Economic benefits of herbicide application over manual weed control were reported earlier (Rangiah *et al.*, 1975; Versteeg and Maldonado, 1978; Lakshmi, 1983). Jacob (2002) opined that application of herbicides resulted in high net income and BCR.

Rajkhowa *et al.* (2001) pointed out that application of herbicides increased available N and K due to reduction in nutrient removal by weeds. Corroboratory results were reported by Jacob (2002) and Seema (2004). Narwal *et al.* (2002) explained that all herbicidal treatments gave significantly higher yield and better yield attributes than weedy check. Sharma *et al.* (2003) observed that all herbicidal treatments significantly reduced the density and dry weight of weeds over weedy check.

2.3.3 New Generation Herbicides

Today's high technology modern agriculture heavily depends on herbicides, as they constitute a vital and integral component of weed management practices. Many of the herbicides widely used in the 1960's and 1970's have been phased out and replaced by the newer and more potent herbicides discovered later. Use of some older herbicides have been considerably restricted, reduced and eliminated in view of environmental and toxicological problems and the availability of more effective and safer herbicides (Rao, 2000).

A new generation of low-application rate herbicides that function by inhibiting the action of key plant enzymes are gaining popularity among farmers. As these herbicides are highly effective at very low rates; they are known as low dose high efficacy (LDHE) herbicides or micro herbicides. With these herbicides there is a possibility of reducing the dose of the chemical by 100 to 1000 times over traditional herbicides (Brown, 1990). These herbicides show high herbicidal potency at very low rates making them environmentally safe.

2.3.3.1 Fenoxaprop-p-ethyl

The mode of action of this new generation herbicide is by inhibiting Acetyl Co-enzyme-A Carboxylase (ACCase). ACCase inhibitors cause injury on grass plants. Cyhalofop-butyl and metamifop are the other herbicides in this group. All the herbicides in this group are systemic but cyhalofop-butyl and fenoxaprop-p-ethyl are less mobile and do not control perennial grasses. Consequent to the application of fenoxaprop-p-ethyl newer leaf tissue will be yellow (chlorotic) or brown (necrotic) and the leaves in the whorl can be easily pulled out. Symptoms develop slowly. This herbicide is reported to be very effective for controlling grass weeds.

Dixit and Varshney (2008) observed that application of fenoxaprop-p-ethyl @ 60 g ai ha^{-1} applied at 20 DAS was highly effective for reducing the density of *Echinochloa colona* in transplanted rice due to higher efficacy for controlling grasses and performance of butanil on weed management ranked next to fenoxaprop-p-ethyl. Similar observation were made by (Subramanian *et al.*, 2006).

Saini and Angiras (2002) reported that fenoxaprop-p-ethyl @ 90 g ai ha^{-1} (20 and 25 DAS) was at par with fenoxaprop-p-ethyl @ 75 g ai ha^{-1} (20 and 25 DAS) and significantly superior to butachlor, anilofos, cyhalofop-butyl and pretilachlor with respect to weed dry weight and grain yield in direct seeded puddled rice.

Better efficacy was observed for fenoxaprop-p-ethyl @ 75 and 90 g ai ha^{-1} applied at 15 DAT as compared to 25 DAT and also compared to its lower doses, *viz.*, 45 and 60 g ai ha^{-1} at both application time (15 and 25 DAT) in respect of weed dry matter production and rice grain yield in transplanted rice (Singh *et al.*, 2003a). Fenoxaprop-p-ethyl + ethoxysulfuron at 45 g ai ha^{-1} provided excellent control of crowfoot grass when applied at the four (99%) and six-leaf (86%) stage (Bhagirath, 2011).

According to Kumar *et al.* (2010) fenoxaprop-p-ethyl @ 60 g ha^{-1} (20 DAT) followed by one hand weeding (30 DAT) significantly reduced the total weed population and weed dry weight, at all crop growth stages than weedy check. Singh *et al.* (2004) reported that application of fenoxaprop-p-ethyl @ 56.25 g ha^{-1} 10 DAT effectively controlled *Echinochloa colona, Echinochloa crusgalli, Leptochloa chinensis* and *Ischaemum rugosum.*

Weed dry weight was reduced to 42.5 g m^{-2} with application of fenoxaprop-p-ethyl @ 90 g ha^{-1} (15 DAT) compared to 224.2 g m^{-2} in weedy check. Also there was no phytotoxicity of fenoxaprop-p-ethyl at any of the doses and stages of application (Singh *et al.*, 2003a). Snipes and Street (1987) evaluated ethyl ester of fenoxaprop-p-ethyl and reported that it is an effective herbicide against barnyard grass at 0.17

and 0.2 kg/ha when applied up to 5-6 leaf stage of weed and fenoxaprop-p-ethyl did not adversely affect the grain yield of rice. Khodayari *et al.* (1989) also reported fenoxaprop-p-ethyl as an effective alternative for control of graminaceous weeds in rice. Corroboratory results are reported by Smith (1988).

Application of fenoxaprop-p-ethyl and 2,4-D mixture at 6+ 200 g ai ha^{-1} and 9+ 300 g ai ha^{-1} were more effective than the rate at 3+ 100 g ai ha^{-1} in cotrolling weeds in rice. Also phytotoxicity was noticed for the herbicide mixture; the lower rates registered slight phytotoxicity whereas the highest dose (9 + 300 g ai ha^{-1} resulted in moderate phytotoxicity (Chamkrachang *et al.*, 2006).

2.3.3.2 Carfentrazone-ethyl

Carfentrazone-ethyl is a broad spectrum post-emergence herbicide. It belongs to the triazolinone family and is a protoporhyrinogen oxidase (Protox) inhibitor with contact action. It is selective in cereals, maize, rice and fodder grasses. The key sensitive weeds in cereals are *Galium aparine, Veronica hederifolia* and *Lamium* sp., but it also provides outstanding efficacy on a wider range of weeds such as *Solanum nigrum*, *Chenopodium album* and *Amaranthus retroflexus*. Carfentrazone-ethyl is active at low dose rates (20 g ai ha^{-1}). It gives optimum results against young weeds, which are controlled within 1 to 2 weeks. These characteristics make carfentrazone-ethyl an ideal partner for other commonly used cereal herbicides such as sulfonylureas, diflufenican and phenoxy herbicides. In addition, carfentrazone-ethyl also has a very good toxicological and environmental profile, including a very short half-life in soil and water (Cauchy, 2000).

Application of commercial formulation of carfentrazone-ethyl in rice fields produced pseudo first order half lives (t 1/2) of 6.5 to 11.1 hours in water and 37.9 to 174 hours in sediment. The rapid dissipation from water was due to its hydrolysis to the chloropropionic acid which further degraded to propionic, cinnamic and benzoic acid (Nigim and Crosby, 2001).

Application of carfentrazone-ethyl @ 57 ml/ acre at 3-4 leaf stage of weeds (mid post emergence) provided greater control than at 1-2 leaf stage (early post emergence) because it controlled weeds that emerged later in rice fields (Meir *et al.*, 2011).

Carfentrazone-ethyl is a reduced risk herbicide that is currently being evaluated for aquatic weeds and it effectively controlled waterhyacinth, water lettuce (pistia), salvinia and landoltia (*Landoltia puctata*) (Koschnick *et al.*, 2004).

Richardson *et al.* (2008) pointed out that carfentrazone-ethyl applied @ 56, 112 and 224 g ai ha^{-1} produced 72, 84 and 92 per cent control respectively of the aquatic weed, alligator weed (*Alternanthera philoxeroides*) at 4 weeks after the herbicide treatment.

Non Sulfonyl Urea herbicides, butachlor, carfentrazone-ethyl mefenacet, pretilachlor, pyrazolate, several Sulfonyl Urea herbicide-based mixtures, ethoxysulfuron plus fentrazamide, pyrazosulfuron-ethyl plus pyrazolate plus simetryn, and non-SU herbicide-based mixtures, pyrazolate plus butachlor, pyrazolate plus pretilachlor, simetryn plus molinate, carfentrazone-ethyl plus butachlor and carfentrazone-ethyl plus thiobencarb can be used to control both the resistant and susceptible biotypes of *Monochoria vaginalis* when applied before the second leaf stage (Yongin and OhDo., 2003).

Wersal and Madsen (2012) reported that water hyacinth treated with the combination of diquat and carfentrazone-ethyl at 280 and 152 g ai ha^{-1} resulted in 99 per cent reduction in biomass 4 weeks after treatment (WAT); although control was similar to diquat applied at 560 g ai ha^{-1}, carfentrazone-ethyl applied at 76 and 152 g ai ha^{-1}, diquat + carfentrazone- ethyl at 140 + 76 g ai ha^{-1} and all other combinations containing 280 g ai ha^{-1} of diquat. Carfentrazone-ethyl applied at 152 g ai ha^{-1} resulted in 89 per cent biomass reduction 4 WAT.

Ellis *et al.*, (2003) opined that carfentrazone-ethyl is a fast acting herbicide which is relatively cheap and tank mixes well with other herbicides *viz.*, bentazon, acifluorfen+ bentazon, triclopyr, bispyribac sodium, bensulfuron, propanil and halosulfuron. The herbicides could effectively control joint vetch (*Aeschynomene virginica*), pitted morning glory (*Ipomoea lacunosa*) and hemp sesbania (*Sesbania *exaltata*), but barnyard grass control ranged from excellent to moderate in drilled rice.

According to Glomski and Getsinger (2006), carfentrazon-ethyl @ 0.112, 0.168 to 0.224 kg ai ha^{-1} is effective in controlling the aquatic weed giant salvania, however, retreatment may be necessary to control any remaining viable plant tissue leading to regrowth of treated plants.

2.3.3.4 Fenoxaprop-p-ethyl + Carfentrazone-ethyl

Herbicide combinations have been well documented in agricultural settings to improve efficacy, reduce the costs associated with weed control, and identify antagonistic combinations (Green, 1989). Kiran *et al.,* (2010) opined that application of herbicide mixtures may be useful for broad spectrum control of weeds in rice.

Aurora and De Datta (1992) while reviewing weed management in rice, opined that herbicide combinations usually provided wider control spectrum and/or better or more lasting control than when components of the combination are applied alone.

Carfentrazone-ethyl was compatible with fenoxaprop-p-ethyl as tank mixture without any adverse effect on efficacy of both herbicides against complex weed flora in wheat. Fenoxaprop-p-ethyl+ carfentrazone-ethyl in 5:1 ratio appeared as the best combination for achieving maximum WCE (Yadav *et al.*, 2009a).

Compatability of fenoxaprop-p-ethyl and carfentrazone-ethyl as tank mixture in controlling complex weed flora in wheat has been reported by earlier workers (Singh and Singh, 2005; Chopra *et al.*, 2008) as well.

2.3.3.5 Bispyribac Sodium

Bispyribac sodium, a pyramidinyl carboxy herbicide @ 25 g ai ha^{-1} at 15 or 25 DAT is effective to control many annual and perennial grasses, sedges and broad leaved weeds in rice field (Yadav *et al.*, 2009). Walia *et al.* (2008) reported that in direct seeded rice pre-emergence application of pendimethalin @ 0.75 kg ai ha^{-1} fb one hand weeding produced highest seed yield (4049 kg ha^{-1}) which was at par with post-emergence application of bispyribac sodium@ 30 g ai ha^{-1} applied at 30 DAS (3554 kg ha^{-1}).

Pre-emergence application of oxyfluorfen @ 0.25 kg ha^{-1} followed by post-emergence application of bispyribac sodium 0.05 kg + metsulfuron methyl @ 0.01 kg ha^{-1} recorded the least weed count (11.00 m^{-2}) and weed dry matter production (114.65 kg ha^{-1}) and highest WCE (90.12%) favoring higher grain yield of aromatic rice (5.32 t ha^{-1}). This was *at par* with the pre-emergence application of butachlor @ 1.25 kg ha^{-1} followed by post emergence application bispyribac sodium 0.05 kg + metsulfuron 0.01 kg ha^{-1} and the pre-emergence application of pendimethalin @ 1.0 kg ha^{-1} followed by post-emergence application bispyribac sodium 0.05 kg + metsulfuron 0.01 kg ha^{-1} (Gnanavel and Anbhazhagan, 2010).

Yadav *et al.* (2007) reported that bispyribac sodium was very effective against mixed flora of weeds in wet seeded rice. Pre-emergence application of pendimethalin (0.75 kg ha^{-1}) followed by bispyribac sodium (20 g ha^{-1}) recorded less weed dry weight (0.17 t/ha) (Walia *et al.*, 2008). According to Kiran *et al.* (2010) sequential application of oxadiargyl @ 75g/ha and bispyribac sodium @ 30g/ha recorded lowest weed density and dry weight with maximum WCE (88%) which was on par with hand weeding twice (89%). These results are also confirmed by Kiran and Subramanyan (2010).

Veeraputhiran and Balasubramanian (2010) recorded significant reduction in total weed dry weight and highest WCE of 98 percent with application of bispyribac sodium. Bispyribac sodium applied @ 15 or 25 DAT was found effective against grass weeds but control of broad leaved weeds and sedges was more when applied at 15 DAT (Yadav *et al.*, 2010). Mehta *et al.* (2010) got maximum weed control efficiency of bispyribac sodium when applied @ 30g ai ha^{-1} particularly against *Echinochloa crusgalli.*

2.4 EFFECT OF HERBICIDES ON SOIL MICROBIAL ACTIVITY

Herbicides being biologically active compounds, an unintended consequence of the application of herbicides is that it may lead to significant changes in the population of microorganisms and their activities thereby influencing the microbial ecological balance in the soil affecting the productivity of soil. The increasing reliance of rice cultivation on herbicides has led to concern about their toxicological behavior in the rice field environment (Latha and Gopal, 2010).

Like the higher plants, microorganisms also respond to herbicides in very different ways. Soil microorganisms have the capacity to detoxify and inactivate the herbicides present in the soil. The microorganisms involved in herbicide detoxification include bacteria, fungi, actinomycetes and algae. Among these, bacteria predominate (Rao, 2000). Changes in micro flora may be from direct or indirect action of the herbicides but there is eventually a return to normal. It has been suggested that normal rates of application of most herbicides have no pronounced or adverse effect on the total microbial population (Bollen, 1961; Audus,1964). Lekshmi (1984) reported that fungal and bacterial colonies were maximum in bentazone treated soil; butachlor, propanil, fluchloralin, 2,4-D sodium salt and benthiocarb did not influence the fungal population. But there was an increase in bacterial population due to these herbicides except fluchloralin and there was not much variation in actinomycetes population.

Devi (2002) found that population of microflora in rice soil varied with time, after application of 2,4-D. Though a negative influence of 2,4-D on soil bacteria was observed in the early period, their population was restored within 30 DAS and this period coincided with the persistence of 2,4-D in wet land paddy. According to Zanardini *et al.,* (2002) the soil bacteria *Pseudomanas fluorescence* strain B_2 was able to degrade the microbial metabolites of metsulfuron and chlorsulfuron.

The herbicides *viz.*, 2,4-D EE, butachlor, pretilachlor and pyrazosulfuron ethyl were evaluated at different doses (1 FR, 2 FR, 5 FR, 10 FR, 100 FR) for their effect on total heterotrophic bacteria, fungi and actinomycetes. Butachlor showed highest reduction in microbial populations, (7.85 to 34.20 % reduction over control) and soil enzyme activities (5.03 to 19.11 % reduction over control), Populations at 1 FR and 2 FR pyrazosulfuron ethyl concentrations recovered within

30 days to reach populations not significantly different from the control treatments (Latha and Gopal 2010).

Short duration static tests were carried out (30 minutes) based on the inhibition of luminescence of the bacteria *Vibrio fischeri* after exposure to the herbicides 2,4-D, metsulfuron-methyl (Ally), bentazone (Basagran), quinclorac (Facet), oxyfluorfen (Goal), and pyrazosulfuron-ethyl (Sirius) at maximum concentrations of 100 mg/litre (ai). Ally and Sirius did not present toxicity for *V. fischeri*, as they resulted in an inhibitory effect of < 20%. (Poleza *et al.*, 2008).

Ethoxysulfuron, oxadiargyl, thiobencarb, cinosulfuron and butachlor were used in rice fields and microbial biomass and microbial catabolic (richness and evenness) were determined at three intervals (15, 30 and 60 days after herbicide application). Ethoxysulfuron and cinosulfuron herbicides at field rate have little or no effect on soil microbial communities in rice fields as compared with oxadiargyl, thiobencarb and butachlor. (Lakzian *et al.*, 2011).

Microorganisms also play important role in the degradation of sulfonylureas in soil. Compared with sterilized soil, faster and more effective degradation of some sulfonylureas in non sterilized soil revealed that the degradation mainly depended on the soil microbial communities. (Brown, 1990).

The application of the post emergence herbicides fenoxaprop-p-ethyl and ethoxysulforon, which were sprayed at 20 days after crop emergence suppressed the fungal population from 46.3×10^3 (20 DAE) to 34.7×10^3 which again increased to 53.8×10^3 at 50 DAE. (Choudhary *et al.,* 2008). Samanata *et al.,* (2005) reported that application of post emergence herbicides carfentrazone-ethyl, 2-4-D and pyrazusulfuron-ethyl inhibited the microbial growth in soil up to 10 days of its application and in later stage significantly augmented the population of total bacteria, actinomycetes and fungi over that of control in the rhizosphere soil of rainy season rice.

2.5 HERBICIDE RESIDUES IN THE ECOSYSTEM AND IN PLANT PARTS

Herbicides that persist much longer than desired, pose several potential environmental problems. They may also cause injury to succeeding crop in a multiple cropping system. In intensive cropping system, repeated application of herbicides for each crop and in the case of gross misapplication and over use, there is a potential danger of persistence in soil and residual accumulation on the crop produce (Sankaran *et al.*, 1993). Ideally, a herbicide should remain active in soil for a period sufficient to provide satisfactory weed control and then it must degrade in to innocuous products before it is necessary to apply it again (Yadav *et al.,* 1997). Most of the new generation micro herbicides are less persistent in addition to their low application rates and hence residue related problems are also less compared to traditional herbicides which are applied at higher doses.

According to Vega *et al.* (2000), the degradation pathway of triasulfuron was due to the cleavage of sulfonyl urea bridge to two transformation products and chemical and microbial processes were the important soil degradation processes.

Application of commercial formulation of carfentrazone-ethyl in rice fields produced pseudo first order half lives (t1/2) of 6.5 to 11.1 hours in water and 37.9 to 174 hours in sediment. The rapid dissipation from water was due to its hydrolysis to chloropropionic acid which further degraded to propionic, cinnamic and benzoic acid (Nigim and Crosby, 2001).

Residual studies of penoxsulam applied @ 22.5 g ha^{-1} in transplanted rice , indicated that there were no residues of the herbicide in soil, straw and grains (Mehta *et al.,* 2011).

The problem of herbicide residue in plants is not as serious as that of residues of other pesticides. Several workers have detected residues of applied herbicides in rice plant parts, but they were below maximum residue limit (Jayakumar *et al.*, 1994; Mani *et al.*, 1994; Padmavatidevi *et al.*, 1994).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was programmed as field experiment and laboratory studies. The field experiment was conducted during the third crop/ summer season of 2011-'12. Chemical analysis was carried out at the Department of Agronomy and microbial studies were conducted at the Department of Agricultural Microbiology, College of Agriculture, Vellayani. The objective was to assess the bio-efficacy of post-emergence micro herbicides in transplanted rice (*Oryza sativa* L.) and to work out a suitable and economic weed management strategy. The materials used and the methods adopted for the investigation are presented in this chapter.

3.1. SITE DESCRIPTION

The field investigation was conducted in a farmer's field in Kanjirathady padasekharam, in Kalliyoor Panchayath of Nemom Block, Thiruvananthapuram, Kerala , located at 8.5° N latitude and 76.9°E longitude at an altitude of 29 m above mean sea level (MSL).

3.1.1. Climate

The experimental site experiences warm humid tropical climate. The data on various weather parameters, *viz.*, weekly rainfall, maximum and minimum temperature and relative humidity during the period are presented in Appendix-I and graphically represented in Fig. 1.

3.1.2 Cropping Season

The experiment was conducted during the puncha (third crop/ summer) season of 2011-12 *viz.*, from December 2011 to April 2012.

3.1.3 Soil

Soil samples were collected prior to experimentation from 30 cm depth and a composite sample was used for the determination of physico-chemical properties. The important physico-chemical properties studied are given in Table 1. The soil of the experimental site belonged to the textural class of Sandy clay loam and of the

Plate 1. General view of the experimental field

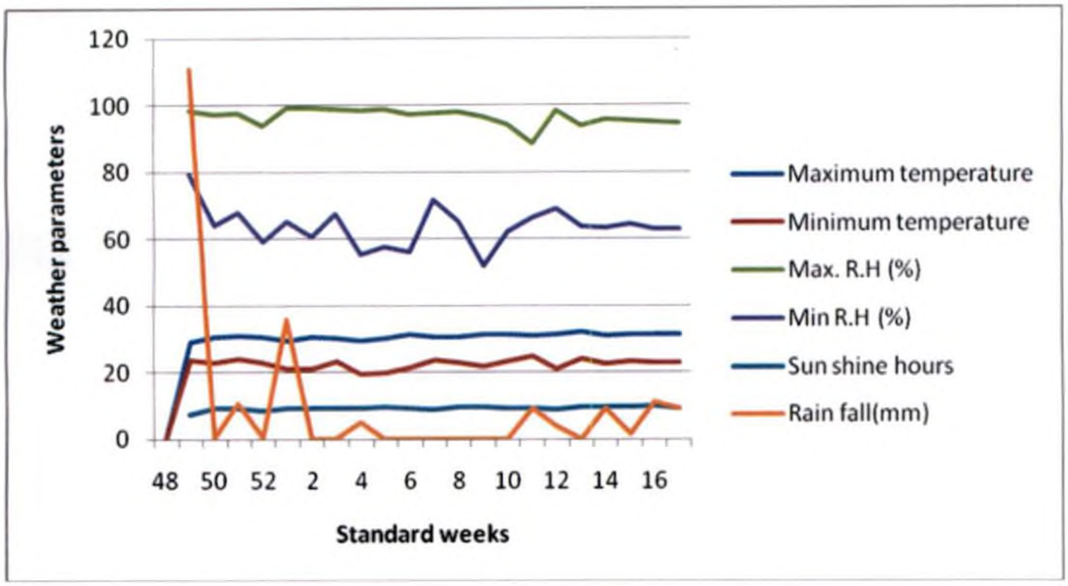
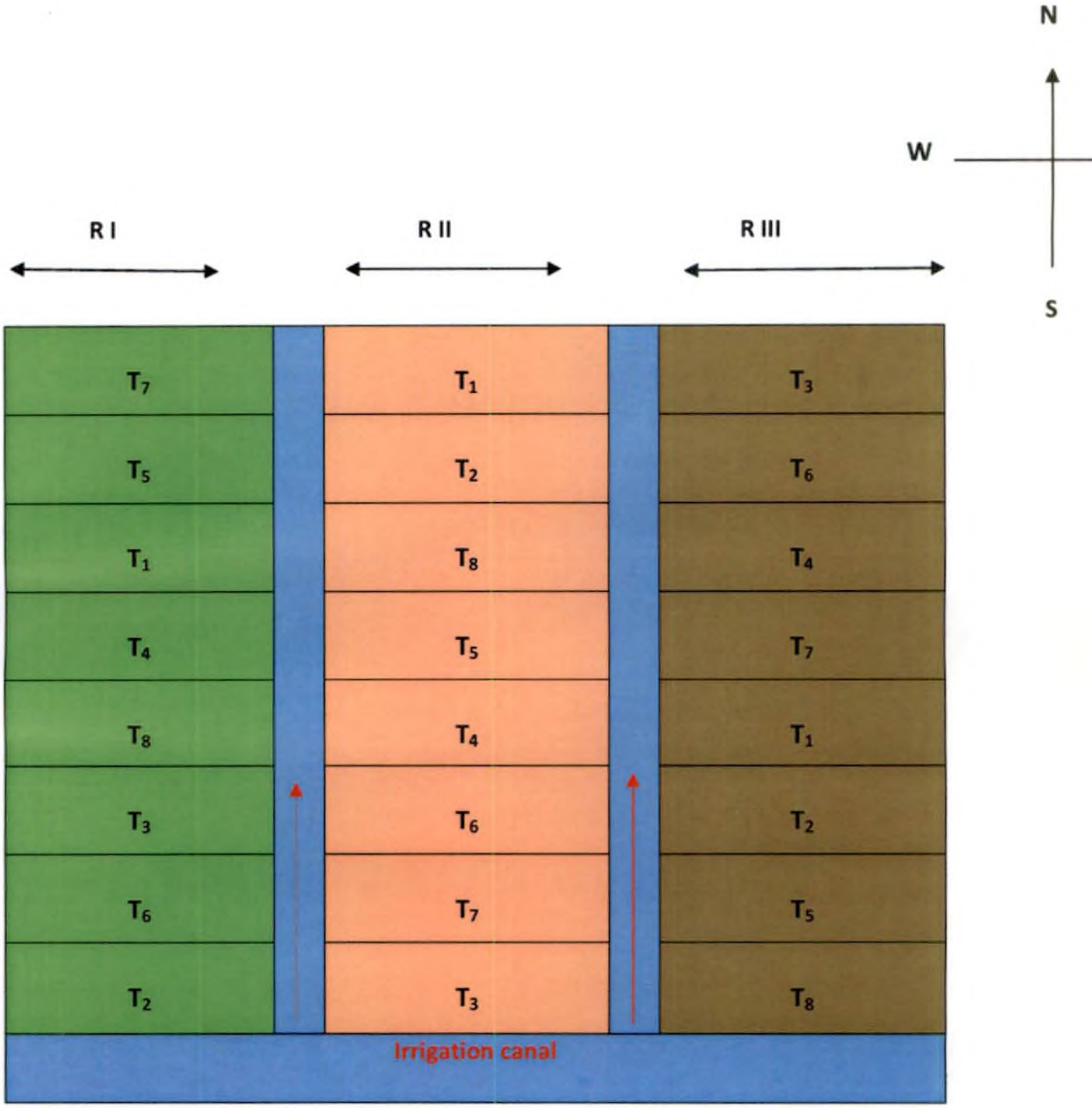


Fig. 1. Weather parameters during the cropping period (December 2011- April 2012)



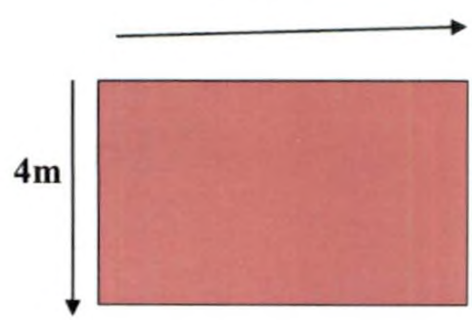


Fig. 2. Lay out of the experimental field

area for destructive sampling

Table 1

Soil characters of the experimental field

A. Physical composition

Sl. No.	Fraction	Content in soil (%)	Method
1.	Coarse sand	47.65	Bouyoucos Hydrometer method (Bouyoucos , 1962)
2.	Fine sand	10.90	
3.	Silt	9.05	
4.	Clay	32.40	

B. Chemical composition

Sl. No.	Parameter	Content	Rating	Method
1.	Available nitrogen (kg ha $^{-1}$)	536.5	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
2.	Available phosphorus (kg ha $^{-1}$)	27.4	High	Bray colorimetric method (Jackson ,1973)
3.	Available potassium (kg ha $^{-1}$)	180.1	Medium	Ammonium acetate method (Jackson, 1973)
4.	P^H	6.2	Slightly acidic	P^H meter with glass electrode (Jackson,1973)
5.	Organic carbon (%)	1.16	High	Walkley and Black's rapid titration (Jackson, 1973)

taxonomical order Oxisol. The soil pH was 6.2 and it was high in organic carbon, medium in available N, high in available P and medium in available K content.

3.1.4 Cropping History of the Experimental Site

The experimental site was lying fallow during the previous season and was heavily infested with mixed weed flora.

3.2 MATERIALS

3.2.1 Crop Variety

The rice variety selected for the experiment was Uma released from Rice Research Station, Moncompu of Kerala Agricultural University. It is a red-kernelled variety, having a duration of 120-125 days. It is reported to be resistant to blast and blight diseases and brown plant hopper and gall midge.

3.2.2 Source of Seed Material

The seeds were obtained from National Seeds Corporation, Regional Office, Karamana, Thiruvananthapuram- 695002.

3.2.3 Manures and Fertilizers

Farmyard manure with an analytical value of 0.4, 0.3, 0.2 per cent N, P, K respectively was used for the experiment. Urea (46 % N), factom phos (20 % N and 20 % P_2O_5) and muriate of potash (60 % K_2O) were used as source of nitrogen (N), phosphorus (P) and potassium (K) respectively.

3.2.4 Herbicides

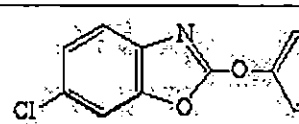
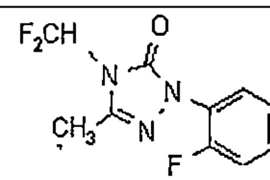
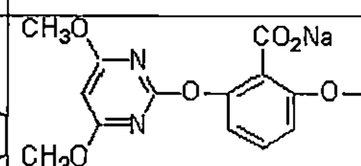
The technical information, toxicity data and other available information of the herbicides fenoxaprop-p-ethyl, carfentrazone-ethyl and bispyribac sodium are given in Table 2.

3.3 METHODS

3.3.1 Design and Layout

The study was conducted during the puncha/ summer season of 2011-2012. The detailed layout plan of the experiment is given in fig. 2.

Table 2. Technical information and toxicity data of the tested herbicides used in the study.

Common name	**Fenoxaprop-p-ethyl**	**Carfentrazone-ethyl**	**Bispyribac-sodium**
Trade name	Whip super, puma super	Affinity	Nominee gold, Tharak
Chemical name	ethyl (*R*)-2-[4-[(6-chloro-2-benzoxazolyl)oxy]phenoxy]propanoate	(*R*)-2-[4-(6-chlorobenzoxazol-2-yloxy)phenoxy]propionic acid ethyl ester	sodium 2,6-bis[(4,6-dimethoxy-2-pyrimidinyl)oxy]benzoate
Chemical structure			
Formulation	WG, EC, EW	EC, SG, WG. DF	SC, water-soluble liquid.
Molecular weight	410.4	384.14	452.35
Physical state, color, odour	White, odourless solid	Viscous yellow liquid.	Odourless, white powder.
Acute oral toxicity LD50 (rats)	>11 000	5,143 mg/kg (rat)	male rats 4111, female rats 2635,
Acute dermal toxicity LD50	>2000	> 4,000 mg/kg (rat)	>2000 mg/kg.
Colour code	Blue	Green	Blue
Price	Rs 378/- for 250 ml	Rs 195/- for 20 gm	Rs 354 /- for 40 ml
Manufacturer	Bayer Crop Science Ltd., Maharastra	FMC India Pvt. Ltd., Tamilnadu	P I Industries, Gujarat

Design	:	Randomized Block Design (RBD)
No. of treatments	:	8
Replication	:	3
Gross plot size	:	6 m x 4 m
Net plot size	:	4.2 m × 3.6 m
Total number of plots	:	24

Two rows of plants were left as border on all the sides and the observations were taken from the net plot area. An area of 1 x 4 m^2 was set apart in all plots for destructive sampling.

3.3.2 Treatment Details

T1 – Fenoxaprop-p-ethyl @ 60 g ai ha^{-1} at 20 DAT

T2 – Fenoxaprop-p-ethyl @ 90 g ai ha^{-1} at 20 DAT

T3 – Carfentrazone-ethyl @ 20 g ai ha^{-1} at 20 DAT

T4 – Carfentrazone-ethyl @ 25 g ai ha^{-1} at 20 DAT

T5 – Fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1} at 20 DAT

T6 – Bispyribac sodium @ 30 g ai ha^{-1} at 20 DAT

T7 – Hand weeding twice (HWT) at 20 and 40 DAT

T8 – Weedy check

The required quantity of herbicide was weighed / measured, dissolved / mixed in required quantity of water and sprayed in the field using a knapsack sprayer fitted with flood jet nozzle.

3.3.3 Field Culture

All cultural practices except weed management were carried out as per Package of Practices Recommendations: Crops (KAU, 2011)

3.3.3.1 Nursery

The field was repeatedly ploughed, puddled and leveled and beds of size 6m ×1m were prepared. FYM @ 1 kg per m^{-2} was applied to the nursery bed. Pre-germinated seeds of paddy variety Uma were sown @ 80 kg ha^{-1}. Recommended water management practices were adopted to produce healthy seedlings. Seedlings were maintained in the nursery till 4-5 leaf stage.

3.3.3.2 Main Field Preparation

The experimental area was well ploughed, puddled, leveled and weeds and stubbles were removed. Three blocks with eight plots each were laid out. The plots were separated with bunds of 30 cm thickness and blocks with bunds of 50 cm thickness. Individual plots were perfectly leveled.

3.3.3.3 Application of Manures and Fertilizers

Farmyard manure was applied to all plots @ 5 tons ha^{-1}. Urea, factomphos and muriate of potash were applied to supply N, P_2O_5 and K_2O @ 90, 45 and 45 kg ha^{-1} respectively.

Two- third dose of N, full dose of P_2O_5 and half dose of K_2O were applied as basal dose. The remaining dose of N and K_2O were applied at the panicle initiation stage to all treatments.

3.3.3.4 Transplanting

Twenty four day old, healthy seedlings were gently uprooted from nursery, roots washed and transplanted in the main field at the rate of 2-3 seedlings per hill.

3.3.3.5 Weed Management

Weeding (hand weeding, chemical/ no weeding) as per treatments was done.

3.3.3.6 Water Management

Water management was carried out as per Package of Practices Recommendations: Crops (KAU, 2011).

3.3.3.7 Plant Protection

One spray each of quinalphos and carbaryl was given against stem borer and rice bug. Also cartap hydrochloride 4 G was used against case worm infestation.

3.3.3.8 Harvest

The crop was harvested when the grains turned straw color. The net plot area as harvested separately, threshed, winnowed and weight of grain and straw from individual plots were recorded.

3.4 OBSERVATIONS ON CROP

3.4.1 Growth and Growth Attributes

3.4.1.1 Phytotoxicity Rating

The treated plots were observed closely and the visual symptoms of herbicide toxicity on plants were recorded, 7 days after herbicide application.

3.4.1.2 Plant Height

The plant height was recorded at 20, 40, 60 DAT and at harvest. The height was measured from the base of the plant to the tip of the longest leaf at vegetative stage and to the tip of the longest ear head at harvest stage. The mean of the observations was expressed in cm.

3.4.1.3 Tillers m^{-2}

The number of tillers per square metre was counted and the average was worked out at 20, 40, 60 DAT and at harvest.

3.4.1.4 Dry Matter Production

From each plot, five sample hills were uprooted at 30 DAT, 60 DAT, 90 DAT and at harvest. They were washed and dried in shade and then in hot air oven at 80^0C till constant weight was attained. Dry weight was determined and dry matter production expressed in kg ha^{-1}.

3.4.2 Yield Attributes and Yield

3.4.2.1 Productive Tillers m^{-2}

At harvest, the number of productive tillers was obtained from unit area in the net plot and was expressed as number of productive tillers per m^{-2}.

3.4.2.2 Weight of Panicle

At harvest, ten panicles were selected at random from the sample plants, weighed and mean weight expressed in g.

3.4.2.3 Spikelets per Panicle

The spikelets from ten randomly selected panicles were counted and the mean expressed as the number of spikelets per panicle.

3.4.2.4 Filled Grains per Panicle

Number of filled grains per panicle was obtained by counting the number of filled grains from ten panicles randomly taken from each plot and taking the mean number of filled grains per panicle.

3.4.2.5 Sterility Per cent

The number of filled and unfilled grains per panicle was obtained from ten randomly selected panicles separately and percentage sterility was worked out using the following relationship:

$$\text{Sterility percent (\%)} = \frac{\text{Number of unfilled grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

3.4.2.6 Thousand Grain Weight

One thousand grains were counted from the cleaned and dried produce from the net plot area of each plot and the weight of the grains was recorded in g.

3.4.2.7 Grain Yield

The net plot area was harvested individually, threshed, cleaned, dried and weighed to express the grain yield in kg ha^{-1} at 14 per cent moisture.

3.4.2.8 Straw Yield

The straw obtained from net plot area was dried to constant weight under sun and then weighed to express the straw yield in kg ha^{-1}.

3.4.2.9 Harvest Index

Harvest index was worked out using the formula suggested by Donald and Hamlin (1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.4.2.10 Weed Index

Weed index was calculated using the equation suggested by Gill and Vijayakumar (1969)

$$WI = \frac{X - Y}{X} \times 100$$

where,

X = Yield from weed free plot or treatment which recorded the minimum number of weeds.

Y = Yield from the plot for which weed index is to be computed.

3.5 OBSERVATIONS ON WEEDS

Quadrat of size 50 x 50 cm was placed at random at two sites in the area set apart in each plot for destructive sampling and the weeds falling within the four frames of the quadrat were collected at 20, 40 and 60 DAT and at harvest. The following observations were recorded and average worked out.

3.5.1 Floristic Composition of Weeds

The weeds were identified and categorized into grasses, sedges and broad-leaved weeds.

3.5.2 Dry Matter Production

Weeds were pulled out, washed, dried in shade and later in a hot air oven at 80 °C till a constant weight was attained and the dry matter production was expressed in kg ha^{-1}.

3.5.3 Weed Control Efficiency

Weed control efficiency was calculated using the following formula (Upadhyaya and Sivanand, 1985)

$$WCE = (X - Y) / X \times 100$$

where,

WCE = Weed control efficiency

X = Weed dry weight from treatment which recorded maximum number of weeds (Weedy check)

Y = Weed dry weight from the treatment for which weed control efficiency has to be worked out.

3.5.4 Absolute Density

Absolute weed density was calculated using the formula suggested by Philips (1959).

Absolute density = Total number of weeds of a given species m^{-2}.

3.5.5 Relative Density

Relative density of various weed species was worked out using the formula put forward by Philips (1959).

$$Rd = \frac{\text{Absolute density of a species}}{\text{Total absolute densities of all the species}} \times 100$$

3.5.6 Absolute Frequency

The absolute frequency of each species of weeds was computed according to the equation developed by Philips (1959).

$$Af = \frac{\text{Number of quadrates in which a given species occurred}}{\text{Total number of quadrates used}} \times 100$$

3.5.7 Relative Frequency

Relative frequency of each species of weeds was computed using the relationship developed by Philips (1959).

$$Rf = \frac{\text{Absolute frequency of a species}}{\text{Total of absolute frequencies of all the species}} \times 100$$

3.5.8 Summed Dominance Ratio (SDR)

Mean Summed Dominance Ratio (SDR) for each species was worked out based on the equation developed by Sen (1981)

$$SDR = \frac{\text{Relative density + Relative frequency}}{2}$$

3.5.9 Importance Value (IV)

Importance Value was obtained by adding the relative density (Rd) and relative frequency (Rf) of a given species (Kent and Coker, 1992).

Importance Value (IV) = Relative density (Rd) + Relative frequency (Rf)

3.6 PLANT ANALYSIS

The plant samples were dried in an electric hot air oven at 80 ^{0}C to constant weight, ground and passed through a 0.5 mm sieve. The required quantity of sample was weighed out accurately in an electronic balance, subjected to acid extraction before carrying out the chemical analysis. The weed samples collected at 20, 40, and

60 DAT and at harvest and rice hills uprooted at 20, 40, 60 DAT and at harvest were analyzed for total nitrogen, phosphorus and potassium content.

3.6.1 Total Nitrogen Content

Total nitrogen content was estimated by modified Microkjeldal method (Jackson, 1973).

3.6.2 Total Phosphorus Content

Total phosphorus content was found out using Vanadomolybdo-phosphoric yellow colour method (Jackson, 1973).

3.6.3 Total Potassium Content

Total potassium content in plant was determined using EEL Flame Photometer (Jackson, 1973).

3.6.4 Uptake of Nutrients

The total uptake of nitrogen, phosphorus and potassium by the rice plant and weeds at 20, 40, 60 DAT and at harvest were calculated as the product of nutrient content and the respective plant dry weight and expressed as kg ha^{-1}.

3.7 SOIL ANALYSIS

Soil samples were collected from the experimental area before and after the experiment. The air-dried soil samples were analyzed for both physical and chemical composition.

3.7.1 Physical Composition of Soil

Percentage of coarse sand, fine sand, silt and clay in the composite soil sample were determined by International Pipette Method (Bouyoucos, 1962).

3.7.2 Chemical Analysis

Samples collected before and after the experiment were dried in shade, sieved through 2 mm sieve and analysed to determine the available N content of the soil by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus content by Dickman and Brays molybdenum blue method using Bray No.1 reagent for extraction (Jackson, 1973) and available potassium was determined using neutral normal ammonium acetate extract and estimated using EEL Flame Photometer (Jackson, 1973).

3.7.3 Soil Reaction

pH of the soil was estimated using 1:2.5 soil water suspension using Perkin Elmer pH meter (Jackson, 1973).

3.8 ESTIMATION OF MICROBIAL POPULATION

Enumeration of soil microbial population was carried out just before spraying the herbicides and 6 days after spraying the herbicide.

3.8.1 Soil Collection

Soil samples were taken at 0-15 cm depth, from each replication just before herbicide spraying and from each plot 6 days after spraying the herbicide.

3.8.2 Enumeration of Fungi, Bacteria and Actinomycetes

The total count of fungi, bacteria and actinomycetes was assessed by serial dilution technique (Johnson and Curl, 1972). The media and dilution used for isolation of different groups of microorganisms and the composition of the mentioned media are given in Appendix II.

Serial Dilution

One gram of soil was added to 100 ml of sterilized distilled water in a 250 ml conical flask under aseptic condition and shaken for 30 minutes in orbital shaker for uniform mixing for obtaining 10^{-2} dilution. With a sterile pipette, 1 ml of 10^{-2} dilution was transferred to 99 ml sterile water blank and mixed well to obtain a 10^{-4} dilution. Further 1 ml of 10^{-4} dilution was transferred to 99 ml of sterile water blank and mixed well to obtain a 10^{-6} dilution. One ml aliquots of 10^{-4} dilution were transferred to sterile petridishes for enumeration of fungi and bacteria. Similarly 1 ml aliquot of 10^{-6} dilution was used for the estimation of actinomycetes. Melted and cooled Rose

Bengal Agar, Soil Extract Agar and Kenknights Agar media were poured into these petridishes @ 20 ml/dish for the estimation of fungi, bacteria and actinomycetes, respectively. Plates were incubated at 28^{0}C. Observations were recorded for appearances of colonies after 24 hours in the case of bacteria, 72 hours for fungi and 154 hours for actinomycetes.

3.9 ECONOMICS OF CULTIVATION

For analyzing the economics of cultivation, net income and benefit cost ratio were determined based on cost of cultivation and prevailing price of the crop produce.

3.9.1 Net Income

Net income was computed using the formula,

Net income (Rs. ha^{-1}) = Gross income – Total expenditure

3.9.2 Benefit Cost Ratio (BCR)

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.10 STATISTICAL ANALYSIS

The data generated from the experiment were statistically analysed using Analysis of Variance techniques (ANOVA) as applied to Randomized Block Design described by Cochran and Cox (1965).

RESULTS

4. RESULTS

The field experiment was conducted in farmer's field to study the bio-efficacy of the new generation herbicides, fenoxaprop-p-ethyl and carfentrazone-ethyl as well as their combination in comparison with bispyribac sodium, hand weeding twice and weedy check in transplanted rice. The study of the microbial population of the soil samples from the experimental field and chemical analysis were carried out at the College of Agriculture, Vellayani. The data recorded were statistically analysed and the results are presented in this chapter.

4.1. OBSERVATIONS ON WEEDS

The data generated on various aspects of weeds *viz.,* floristic composition, dry weight, weed control efficiency, density, frequency, summed dominance ratio, importance value etc are presented in this section.

4.1.1 Floristic Composition of Weeds

The different weed species found in the experimental field were collected during the period of experimentation and identified. The weeds were grouped as grasses, sedges and broad leaved weeds and the details are furnished in Table 3.

4.1.2 Weed Dry Weight

The major weed flora observed in the experimental field were collected during the period of experimentation at regular intervals and identified. The weeds were classified in to grasses, sedges and broad leaved weeds, dried and dry weight of each category were recorded and the data are furnished in Tables 4 to 7.

4.1.2.1 Total Weed Dry Weight

Data on total weed dry weight presented in Table 4 showed that the dry weight did not vary significantly due to the treatments at 20 DAT. At 20 DAT total weed dry weight was recorded before herbicide application and hand weeding. At 40 DAT the lowest value for total weed dry weight was recorded

Table 3. Major weed flora observed in the experimental field.

Common name	Scientific name	Family	Malayalam name
GRASSES			
Jungle rice	*Echinochloa colona* (L.) Link	Poaceae	Kavada
SEDGES			
Slender sedge	*Cyperus difformis*	Cyperaceae	Muthanga
Forked fimbry	*Fimbristylis dichotoma(L.)* Vahl	Cyperaceae	Karimanchy
Greater club rush	*Scirpus grossus* L.f	Cyperaceae	Kora
BROADLEAVED WEEDS			
Water cabbage	*Limnocharis flava* (L.) Buchenau	Limnocharitaceae	Nagapola
Pickerel weed	*Monochoria vaginalis* (Burm. f.) Presl. Ex Kunth.	Pontederiaceae	Neelolpalam
Water primose	*Ludwigia parviflora* Roxb.	Onagraceae	Neergrambu
Water spinach	*Ipomoea aquatica* Forsk.	Convolvulaceae	-
Baby tears	*Lindernia rotundifolia* blanc vert	Scrophulariaceae	-
Kariba weed	*Salvinia molesta* D.S. Mitch.	Salviniaceae	African payal
Airy pepper wort	*Marsilea quadrifolia* Linn.	Marsiliaceae	Naalila kodiyan
Water lettuce	*Pistia stratiotes* L.Royle	Araceae	Mutta payal

by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}); however, T3 was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT, the lowest value for total weed dry weight was recorded by T3, which was on par with T4, T6 and T5. A similar trend was followed at harvest stage also. At all the stages of observation except at 20 DAT, weed dry weight recorded was the highest in T8 (weedy check) and this treatment was significantly inferior to all other treatments.

4.1.2.2 Dry Weight of Grasses

The results revealed that at 40 DAT, the lowest dry weight of grasses was recorded by T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}), which was on par with T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}), T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}) and T6 (bispyribac sodium @ 30 g ai ha^{-1}); however, T6 was on par with T7 (hand weeding twice) and T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and T4 in turn was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT the lowest dry weight of grasses was recorded by T2, which was on par with T1. At harvest, the same trend was followed. T8 (weedy check) registered the highest value for dry weight of grasses, at all the stages of observation except at 20 DAT.

4.1.2.3 Dry Weight of Sedges

Dry weight of sedges was significantly influenced by the weed control treatments at 40 DAT, 60 DAT and at harvest. At all these stages, the highest dry weight for sedges was recorded by T8 (weedy check), which was significantly inferior to all other treatments. At 40 DAT, the lowest dry weight for sedges was recorded by T6 (bispyribac sodium @ 30 g ai ha^{-1}), which was on par with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}); however, T3 was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT, the lowest dry weight of sedges was recorded by T4, which was on par with T3, T6, T5 and T7 (hand weeding twice). A similar trend was noticed at harvest stage also.

Table 4. Effect of weed management practices on total weed dry weight

Treatments	Total weed dry weight, g m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	23.24	23.15	68.05	96.42
T2	19.08	17.56	62.48	96.10
T3	20.47	8.05	21.07	39.26
T4	15.63	5.72	22.11	45.44
T5	20.55	13.17	30.41	44.38
T6	22.15	5.83	25.05	39.23
T7	22.05	27.77	45.38	89.26
T8	21.86	66.39	119.44	182.54
SE m(±)	-	11.31	32.57	32.45
CD (0.01)	-	5.892	9.996	9.977

Table 5. Effect of weed management practices on dry weight of grasses

Treatments	Dry weight of grasses, g m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	1.27	1.21	3.21	4.41
T2	0.61	0.88	3.04	3.90
T3	0.34	1.97	4.84	9.93
T4	0.42	1.75	6.81	11.66
T5	0.74	0.85	5.61	8.18
T6	0.57	1.37	7.16	9.00
T7	0.56	1.56	5.81	8.72
T8	0.66	4.80	11.42	16.36
SE m(±)	-	0.09	0.76	0.72
CD (0.01)	-	0.543	1.533	1.489

Table 6. Effect of weed management practices on dry weight of sedges

Treatments	Dry weight of sedges, g m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	7.79	6.46	14.06	29.85
T2	7.10	6.46	14.4	26.31
T3	5.82	2.5	8.53	13.79
T4	7.10	1.02	8.06	12.83
T5	6.61	4.53	9.63	17.00
T6	6.83	0.68	9.09	13.13
T7	8.26	8.38	9.97	23.75
T8	6.99	19.26	36.27	61.95
SE m(±)	-	1.78	3.90	7.85
CD (0.01)	-	2.339	3.459	4.822

Table 7. Effect of weed management practices on dry weight of broad leaved weeds

Treatments	Dry weight of broad leaved weeds, g m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	14.19	15.48	43.90	62.15
T2	11.36	9.89	45.04	65.88
T3	14.30	2.58	7.69	15.53
T4	15.44	2.28	7.24	20.95
T5	13.27	7.45	16.68	19.02
T6	13.40	3.11	8.82	17.09
T7	13.23	17.48	32.59	56.78
T8	14.21	43	71.74	103.92
SE m(±)	-	6.16	15.51	19.53
CD (0.01)	-	4.350	6.890	7.740

4.1.2.4 Dry Weight of Broad Leaved Weeds

At all the stages of observation except at 20 DAT, there was significant variation among the treatments with respect to dry weight of broad leaved weeds. At 40 DAT, 60 DAT and at harvest the highest dry weight for broad leaved weeds was recorded by T8 (weedy check), which was significantly inferior to all other treatments. At 40 DAT, the lowest value was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) and T6 (bispyribac sodium @ 30 g ai ha^{-1}); however, T6 was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT also the lowest weed dry weight for broad leaved weeds was recorded by T4, which was on par with T3 and T6. At harvest, the lowest dry weight for broad leaved weeds was recorded by T3, which was on par with T4 and T6.

4.1.3 Weed Control Efficiency

Total weed control efficiency as well as weed control efficiency of grasses, sedges and broad leaved weeds were computed and the result are furnished in Tables 8 to 11.

4.1.3.1 Total Weed Control Efficiency (WCE)

Weed control efficiency was worked out taking T8 (weedy check), *i.e.*, the treatment with maximum weed count as the base treatment. The weed control treatments exerted significant influence on total WCE at 40 and 60 DAT and at harvest. At 40 DAT, the highest total weed control efficiency 91.39 per cent was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}); the lowest value being recorded by T7 (hand weeding twice), which was on par with T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}). At 60 DAT, T3 registered the highest value and it was on par with T4, T6 and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}); the lowest total weed control efficiency was recorded by T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), which was on par with T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}). At harvest, T6 registered the highest value and it was on par with T3, T5 and T4; the lowest total weed control efficiency was recorded by T1, which was on par with T2.

4.1.3.2 Weed Control Efficiency of Grasses

A perusal of the data furnished in Table 9 indicated that the weed control treatments significantly influenced the weed control efficiency of grasses at 40 and 60 DAT and at harvest. At 40 DAT, highest weed control efficiency for grasses was recorded by T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}), which was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}) and T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} at 20). At this stage the lowest weed control efficiency for grasses was recorded by T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}), which was on par with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and T7 (hand weeding twice). At 60 DAT also the highest weed control efficiency for grasses was shown by T2, which was on par with T1; the lowest value being recorded by T6 (bispyribac sodium @ 30 g ai ha^{-1}), which was on par with T4 and T7. At harvest also the highest weed control efficiency for grasses was recorded by T2, which was on par with T1 and the lowest weed control efficiency was registered by T4, which was on par with T3.

4.1.3.3 Weed Control Efficiency of Sedges

The different weed control treatments exerted significant influence on the WCE of sedges at 40 and 60 DAT and at harvest. At 40 DAT, the highest weed control efficiency of sedges was recorded by T6 (bispyribac sodium @ 30 g ai ha^{-1}), which was on par with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}); lowest weed control efficiency of sedges being recorded by T7 (hand weeding twice), which was on par with T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}) and T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}). At 60 DAT also T4 T3, T6, T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}) and T7 were on par and significantly superior to T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}) and T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}). A similar trend was noticed at harvest stage also.

Table 8. Effect of weed management practices on total weed control efficiency

Treatments	Total weed control efficiency, %		
	40 DAT	60 DAT	Harvest
T1	64.55	42.58	47.16
T2	73.25	47.53	47.38
T3	87.74	82.32	78.48
T4	91.39	81.53	75.09
T5	80.05	74.57	75.70
T6	91.21	79.03	78.51
T7	58.00	61.80	51.19
T8	-	-	-
SE m(±)	2.46	2.95	1.86
CD (0.01)	7.588	9.107	5.730

Table 9. Effect of weed management practices on weed control efficiency of grasses

Treatments	Weed control efficiency of grasses, %		
	40 DAT	60 DAT	Harvest
T1	74.63	71.87	73.25
T2	82.75	72.73	74.59
T3	59.02	57.50	38.90
T4	63.38	39.67	28.58
T5	82.32	51.07	50.05
T6	71.25	36.90	44.75
T7	67.27	49.30	46.53
T8	-	-	-
SE m(±)	41.16	60.68	32.78
CD (0.01)	11.415	13.860	10.187

Table 10. Effect of weed management practices on weed control efficiency of sedges

Treatments	Weed control efficiency of sedges, %		
	40 DAT	60 DAT	Harvest
T1	65.96	60.43	51.79
T2	65.90	59.96	57.45
T3	86.87	76.23	77.58
T4	94.79	77.62	79.14
T5	76.61	73.50	72.37
T6	96.48	74.62	77.09
T7	56.28	71.85	61.43
T8	-	-	-
SE m(±)	34.64	12.58	14.20
CD (0.01)	10.472	6.311	6.706

Table 11. Effect of weed management practices on weed control efficiency of broad leave weeds

Treatments	Weed control efficiency of broad leaved weeds, %		
	40 DAT	60 DAT	Harvest
T1	63.5	38.57	39.98
T2	76.62	37.01	36.51
T3	93.99	89.22	85.01
T4	94.63	89.91	79.79
T5	82.29	76.84	81.81
T6	92.77	81.80	83.55
T7	59.01	48.85	44.75
T8	-	-	-
SE m(±)	28.85	41.73	16.14
CD (0.01)	9.557	11.494	7.149

4.1.3.4 Weed Control Efficiency of Broad Leaved Weeds

A perusal of the data presented in Table 11 pointed out that the treatments varied significantly with respect to their effect on weed control efficiency of broad leaved weeds at 40 and 60 DAT and at harvest. At 40 DAT, the highest weed control efficiency of broad leaved weeds was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) and T6 (bispyribac sodium @ 30 g ai ha^{-1}); the lowest value being recorded by T7 (hand weeding twice), which was on par with T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}). At 60 DAT also T4 registered the highest value and it was on par with T3 and T6 and the lowest WCE of broad leaved weeds was recorded by T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}), which was on par with T1 and T7. Almost similar trend was followed at harvest stage also.

4.1.4 Absolute Density of weeds

The data on weed density were recorded at 20, 40 and 60 DAT and at harvest. The results are presented in Tables 12, 13, 14 and 15.

4.1.4.1 Total Absolute Density

The data pertaining to total absolute density of weeds revealed that the weed control treatments significantly influenced this parameter at all the stages of observation except at 20 DAT. At 20 DAT, weed density observations were made before hand weeding and herbicide application. At 40 DAT, the treatments significantly influenced total absolute density of weeds and the lowest value was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}). AT 60 DAT, the lowest total absolute density was recorded by T3, which was on par with T4 and T6; however, T6 was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At harvest also a similar trend was followed. At 40 and 60 DAT and at harvest, highest total density was recorded by T8 (weedy check) which was statistically inferior to the rest of the treatments.

4.1.4.2 Absolute Density of Grasses

The data presented in Table 13 revealed the significant effect of weed management practices on the absolute density of grasses at 40 and 60 DAT and at harvest. At 40 DAT, all treatments having fenoxaprop-p-ethyl (T1, T2 and T5) recorded lowest density of grasses and these treatments were on par with T7 (hand weeding twice), T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T_4 (carfentrazone-ethyl @ 25 g ai ha^{-1}); the highest density of grasses being recorded by T8 (weedy check), which was inferior to all other treatments. At 60 DAT, the lowest density of 2.33 m^{-2} was recorded by T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}) and T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}) which were statistically superior to the rest of the treatments; the highest density of grasses being recorded by T8 (weedy check), which was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}). At harvest, lowest density of grasses was recorded by T1, which was on par with T2. At this stage also the highest density of grasses was recorded by T8 (weedy check), which was statistically inferior to all other treatments.

4.1.4.3 Absolute Density of Sedges

At 20 DAT, observation on density of sedges was made before herbicide application and hand weeding and there was no significant variation among the treatments. At 40 DAT, T6 (bispyribac sodium @ 30 g ai ha$^{-1)}$ recorded the lowest absolute density of sedges, which was statistically on par with treatments T_4 and T_3 (carfentrazone-ethyl@ 25 and 20 g ai ha^{-1} respectively); however, T3 was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT, T4 recorded the lowest density of sedges, which was statistically on par with T3, T6, T7 and T5. At harvest, T4 recorded the lowest density of sedges, which was statistically on par with T6, T3 and T5. T8 (weedy check) recorded highest density of sedges at 40 DAT, 60 DAT and at harvest and this treatment was significantly inferior to all other treatments.

Table 12. Effect of weed management practices on total absolute density of weeds

Treatments	Total absolute density of weeds, number m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	147.00	56.33	92.00	109.00
T2	122.66	43.33	92.66	110.00
T3	134.33	16.33	29.33	47.00
T4	150.67	11.00	29.66	48.33
T5	132.33	32.00	42.66	53.33
T6	143.00	11.33	33.66	48.33
T7	147.33	67.33	52.33	104.66
T8	141.33	145.66	161.33	209.33
SE m(±)	-	49.13	42.11	50.97
CD (0.01)	-	12.277	11.366	12.504

Table 13. Effect of weed management practices on absolute density of grasses

Treatments	Absolute density of grasses, number m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	1.33	1.33	2.33	3.00
T2	0.66	1.33	2.33	3.33
T3	0.33	3.00	4.00	14.00
T4	0.66	2.66	6.00	16.00
T5	1.00	1.33	5.00	10.33
T6	0.66	2.33	6.66	13.33
T7	0.66	2.00	5.00	11.33
T8	1.33	4.33	7.66	20.66
SE m(±)	-	0.83	0.70	5.97
CD (0.01)	-	1.599*	1.474	4.279

* significant at 0.05 level

Table 14. Effect of weed management practices on absolute density of sedges

Treatments	Absolute density of sedges, number m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	49.00	19.00	25.00	31.00
T2	44.66	19.00	24.00	27.33
T3	36.66	7.33	14.00	14.33
T4	44.66	3.00	13.00	13.33
T5	41.00	13.33	18.00	17.66
T6	43.00	2.00	14.00	14.00
T7	52.00	24.66	16.00	24.66
T8	44.00	46.66	58.33	64.33
SE m(±)	-	27.38	10.75	7.95
CD (0.01)	-	9.165	5.744	4.941

Table 15. Effect of weed management practices on absolute density of broad leaved weeds

Treatments	Absolute density of broad leaved weeds, number m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	96.66	36.00	64.66	75.00
T2	77.33	23.00	66.33	79.66
T3	97.33	6.00	11.33	18.66
T4	105.33	5.33	10.66	19.00
T5	90.33	17.33	19.66	25.33
T6	90.33	7.00	13.00	20.66
T7	94.66	40.66	48.00	68.66
T8	96.66	100	105.66	125.66
SE m(±)	-	33.26	41.45	27.17
CD (0.01)	-	10.101	11.277	9.129

4.1.4.4 Absolute Density of Broad Leaved Weeds (BLW)

At 20 DAT, weed count was taken before herbicide application and hand weeding and when the data were subjected to statistical analysis, the magnitude of variation among the treatments did not touch the level of statistical significance. At 40 and 60 DAT and at harvest the weed control treatments significantly influenced the absolute density of broad leaved weeds. At 40 DAT, treatments involving carfentrazone-ethyl had lower broad leaved weed population than all other treatments. T4 (carfentrazone-ethyl @ 25 g ai $ha^{-1})$ recorded lowest absolute density, which was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) and T6 (bispyribac sodium @ 30 g ai ha^{-1}). The same trend was followed at 60 DAT. At harvest, T3 recorded lowest absolute density, which was on par with T4, T6 and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 40 DAT, 60 DAT and at harvest, T8 (weedy check) recorded the highest absolute density of broad leaved weeds and it was statistically inferior to the rest of the treatments.

4.1.5 Relative density

4.1.5.1 Relative Density of Grasses

The results revealed that the relative density of grasses varied significantly among the treatments at all the stages of observation except at 20 DAT. At 40 DAT, the highest relative density for grasses was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was statistically on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}); the lowest relative density of grasses being recorded by T1(fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), followed by T7 (hand weeding twice), which was on par with T8 (weedy check), T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}) and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT, highest relative density of grasses was recorded by T4, which was significantly higher than all other treatments; the lowest relative density of grasses being recorded by T1, indicating that fenoxaprop-p-ethyl is effective for grasses. At harvest also lowest relative density of grasses was recorded by T2, which was on par with T1 conforming the effectiveness of the herbicide for controlling grassy weeds.

4.1.5.2 Relative Density of Sedges

A perusal of the data on the relative density of sedges showed that, at 40 DAT, highest value was recorded by T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}), followed by T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}), which was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}), T8 (weedy check) and T7 (hand weeding twice) and the lowest relative density of sedges was recorded by T6 (bispyribac sodium @ 30 g ai ha^{-1}) , which was statistically superior to all other treatments. At 60 DAT, the highest relative density of sedges was recorded by T3, which was statistically on par with T4 (carfentrazone-ethyl@ 25 g ai ha^{-1}), however T4 was on par with T5 and T6; the lowest relative density of sedges being recorded by T2 which was on par with T1(fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), T7 and T8. At harvest, highest relative density of sedges was recorded by T5, which was statistically on par with T3 and T8; the lowest relative density of sedges being recorded by T7, which was statistically on par with T2.

4.1.5.3 Relative Density of Broad Leaved Weeds

Relative density of broad leaved weeds was statistically significant at 40 and 60 DAT and at harvest. At 40 DAT, highest relative density of broad leaved weeds was registered by T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), which was statistically on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}), T7 (hand weeding twice), T8 (weedy check), T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}) and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). The lowest relative density of broad leaved weeds was recorded by T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}), which was statistically on par with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}). At 60 DAT, the highest relative density of broad leaved weeds was recorded by T2 which was on par with T1; the lowest relative density of broad leaved weeds was recorded by T4, which was statistically on par with T6 and T3. At harvest, highest relative density of broad leaved weeds was recorded by

Table 16. Effect of weed management practices on relative density of grasses

Treatments	Relative density of grasses, %			
	20 DAT	40 DAT	60 DAT	Harvest
T1	0.97	2.36	2.51	2.72
T2	0.54	3.37	7.35	2.69
T3	0.26	18.16	13.55	29.72
T4	0.46	24.35	20.24	31.36
T5	0.72	4.41	12.06	19.54
T6	0.41	19.64	19.88	27.55
T7	0.46	3.00	9.60	10.91
T8	0.44	3.04	4.76	9.77
SE m(±)	-	10.71	9.50	7.32
CD (0.01)	-	5.733	5.398	4.739

Table 17. Effect of weed management practices on relative density of sedges

Treatments	Relative density of sedges, %			
	20 DAT	40 DAT	60 DAT	Harvest
T1	33.23	34.05	27.17	28.50
T2	37.00	43.88	25.99	24.87
T3	27.14	44.96	47.88	30.45
T4	27.47	27.13	43.91	27.57
T5	30.98	42.93	42.98	33.12
T6	28.05	16.86	41.75	28.93
T7	35.23	36.65	30.55	23.48
T8	31.21	39.78	31.85	30.20
SE m(±)	-	34.09	12.17	4.46
CD (0.01)	-	10.227	6.110	3.701

Table 18. Effect of weed management practices on relative density of broad leaved weeds

Treatments	Relative density of broad leaved weeds, %			
	20 DAT	40 DAT	60 DAT	Harvest
T1	65.78	63.56	70.29	68.76
T2	62.44	52.73	71.66	72.38
T3	72.58	36.86	38.57	39.81
T4	70.31	48.50	35.83	39.07
T5	68.28	52.63	44.94	47.34
T6	69.46	63.49	38.36	42.81
T7	64.28	60.33	59.83	58.92
T8	68.32	57.26	63.36	60.01
SE m(±)	-	55.75	16.17	30.37
CD (0.01)	-	13.078	7.044	9.652

Table 19. Effect of weed management practices on total absolute weed frequency

Treatments	Total absolute weed frequency, %			
	20 DAT	40 DAT	60 DAT	Harvest
T1	250.00	250.00	266.66	283.33
T2	233.33	266.66	266.66	266.66
T3	216.66	266.66	300.00	300.00
T4	233.33	266.66	300.00	300.00
T5	250.00	266.66	300.00	300.00
T6	233.33	250.00	300.00	300.00
T7	233.33	283.33	300.00	300.00
T8	233.33	300.00	300.00	300.00
SE m(±)	-	-	-	-
CD	-	-	-	-

T2, which was on par with T1; lowest value was recorded by T4, which was statistically on par with T3 and T6.

4.1.6 Absolute Frequency

The data on total absolute weed frequency and absolute frequency of grasses, sedges and broadleaved weeds are presented in Table 19, 20, 21 and 22.

4.1.6.1 Total Absolute Weed Frequency

A perusal of the data on total absolute weed frequency furnished in table 19 showed that even though there was variation among the treatments with respect to this character, the magnitude of variation did not touch the level of statistical significance. At 60 DAT and at harvest absolute frequency was 300 per cent in most of the treatments indicating the presence of all the three categories of weeds in all the sampling quadrates.

4.1.6.2 Absolute Frequency of Grasses

The data on absolute frequency of grasses given in Table 20 shows that there is no significant variation among the treatments for absolute frequency of grasses at 20 and 40 DAT and at harvest. However at 60 DAT absolute frequency of grasses was significantly lower in T1 and T2 compared to the other treatments.

4.1.6.3 Absolute Frequency of Sedges

The data presented in Table 21 on absolute frequency of sedges indicated that the treatments did not vary significantly with respect to their influence on this character.

4.1.6.4 Absolute Frequency of Broad Leaved Weeds

The data presented in Table 22 on absolute frequency of broad leaved weeds indicated that different weed control treatments did not significantly influence this aspect.

Table 20. Effect of weed management practices on absolute frequency of grasses

Treatments	Absolute frequency of grasses			
	20 DAT	40 DAT	60 DAT	Harvest
T1	50.00	50.00	66.66	83.33
T2	33.33	66.66	66.66	66.66
T3	16.66	66.66	100.00	100.00
T4	33.33	83.33	100.00	100.00
T5	50.00	66.66	100.00	100.00
T6	33.33	83.33	100.00	100.00
T7	33.33	100.00	100.00	100.00
T8	33.33	100.00	100.00	100.00
SE m(±)	-	-	223.21	-
CD	-	-	26.166	-

Table 21. Effect of weed management practices on absolute frequency of sedges

Treatments	Absolute frequency of sedges			
	20 DAT	40 DAT	60 DAT	Harvest
T1	100.00	100.00	100.00	100.00
T2	100.00	100.00	100.00	100.00
T3	100.00	100.00	100.00	100.00
T4	100.00	83.33	100.00	100.00
T5	100.00	100.00	100.00	100.00
T6	100.00	83.33	100.00	100.00
T7	100.00	100.00	100.00	100.00
T8	100.00	100.00	100.00	100.00
SE m(±)	-	-	-	-
CD	-	-	-	-

Table 22. Effect of weed management practices on absolute frequency of broad leaved weeds

Treatments	Absolute frequency of broad leaved weeds			
	20 DAT	40 DAT	60 DAT	Harvest
T1	100.00	100.00	100.00	100.00
T2	100.00	100.00	100.00	100.00
T3	100.00	83.33	100.00	100.00
T4	100.00	83.33	100.00	100.00
T5	100.00	100.00	100.00	100.00
T6	100.00	83.33	100.00	100.00
T7	100.00	100.00	100.00	100.00
T8	100.00	100.00	100.00	100.00
SE m(±)	-	-	-	-
CD	-	-	-	-

Table 23. Effect of weed management practices on relative frequency of grasses

Treatments	Relative frequency of grasses			
	20 DAT	40 DAT	60 DAT	Harvest
T1	17.77	20.00	24.44	28.88
T2	11.11	24.44	28.88	24.44
T3	6.66	31.11	33.33	33.33
T4	11.11	37.77	33.33	33.33
T5	17.77	24.44	33.33	33.33
T6	13.33	33.33	33.32	33.33
T7	13.33	28.88	33.33	33.33
T8	11.11	33.33	33.33	33.33
SE m(±)	-	36.76	-	-
CD	-	10.619	-	-

4.1.7 Relative frequency

With respect to the relative frequency of grasses, sedges and broad leaved weeds, the treatments did not vary significantly except at 40 DAT for grasses and at 60 DAT for sedges and broad leaved weeds.

4.1.7.1 Relative Frequency of Grasses

At 40 DAT, relative frequency of grass weeds was significantly lower in treatments having fenoxaprop-p-ethyl, *i.e.,* T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}) and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-}) compared to other weed control treatments.

4.1.7.2 Relative Frequency of Sedges

The data presented in Table 24 on relative frequency of sedges at 60 DAT pointed out that the values are significantly higher for T1 and T2, *i.e.,* treatments involving fenoxaprop-p-ethyl.

4.1.7.3 Relative Frequency of Broad Leaved Weeds

Relative frequency of broadleaved weeds was significantly higher at 60 DAT in T1 and T2 conforming the earlier observation that fenoxaprop-p-ethyl is a herbicide effective only for grasses.

4.1.8 Summed Dominance Ratio (SDR)

The data on summed dominance ratio of grasses, sedges and broad leaved weeds are presented in Tables 26 to 28.

4.1.8.1 Summed Dominance Ratio of Grasses

A perusal of the data on SDR of grasses pointed out that it was significantly influenced by the treatments at 40 and 60 DAT and at harvest. At 40 DAT, the highest value was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}); the lowest value being recorded by T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), which was on par with T2 (fenoxaprop-p-ethyl

Table 24. Effect of weed management practices on relative frequency of sedges

Treatments	Relative frequency of sedges			
	20 DAT	40 DAT	60 DAT	Harvest
T1	41.11	40.00	37.77	35.55
T2	44.44	37.77	37.77	37.77
T3	46.66	37.77	33.33	33.33
T4	44.44	31.11	33.33	33.33
T5	41.11	37.77	33.33	33.33
T6	43.33	33.33	33.33	33.33
T7	43.33	35.55	33.33	33.33
T8	44.44	33.33	33.33	33.33
SE m(±)	-	-	3.97	-
CD (0.05)	-	-	3.490	-

Table 25. Effect of weed management practices on relative frequency of broad leaved weeds

Treatments	Relative frequency of broad leaved weeds			
	20 DAT	40 DAT	60 DAT	Harvest
T1	41.11	40.00	37.77	35.55
T2	44.44	37.77	37.77	37.77
T3	46.66	31.11	33.33	33.33
T4	44.44	31.11	33.33	33.33
T5	41.11	37.77	33.33	33.33
T6	43.33	33.33	33.33	33.33
T7	43.33	35.55	33.33	33.33
T8	41.11	33.33	33.33	33.33
SE m(±)	-	-	3.97	-
CD (0.05)	-	-	3.490	-

@ 90 g ai ha^{-1}) and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT, the highest SDR of grasses was recorded by T4, which was on par with T6 and T3; the lowest value being recorded by T1, which was on par with T2. At harvest, the highest SDR of grasses was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T3 and T6, the lowest value being recorded by T2, which was on par with T1.

4.1.8.2 Summed Dominance Ratio of Sedges

The weed control treatments significantly influenced the SDR of sedges at 40 and 60 DAT only. At 40 DAT, highest SDR of sedges was recorded by T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}), which was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}), T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}), T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), T8 (weedy check) and T7 (hand weeding twice), the lowest value being recorded by T6 (bispyribac sodium @ 30 g ai ha^{-1}), which was on par with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}). At 60 DAT, the highest SDR for sedges was recorded by T3, which was on par with T4, T5 and T6; the lowest value being recorded by T2, which was on par with T7, T1 and T8 (weedy check). At harvest, there were no significance difference among treatments.

4.1.8.3 Summed Dominance Ratio of Broad Leaved Weeds

The data furnished in Table 28 shows that SDR of broad leaved weeds is significantly influenced by the treatments at 40 and 60 DAT and at harvest. At 40 DAT, the highest SDR of broad leaved weeds was recorded by T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), which was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}), T7 (hand weeding twice), T8 (weedy check) and T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}); the lowest value being recorded by T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}), which was on par with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), however T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}) and T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}). At 60 DAT, the highest SDR of broad leaved weeds was

Table 26. Effect of weed management practices on summed dominance ratio of grasses

Treatments	Summed dominance ratio of grasses			
	20 DAT	40 DAT	60 DAT	Harvest
T1	9.37	11.18	13.42	15.80
T2	5.82	13.90	15.89	13.58
T3	3.46	24.63	23.44	31.52
T4	5.78	31.01	26.78	32.34
T5	9.25	14.42	22.80	26.43
T6	6.87	26.14	26.60	30.43
T7	6.89	15.93	21.46	22.11
T8	5.87	18.18	19.04	21.55
SE m(±)	-	15.78	5.62	7.30
CD (0.01)	-	6.957	4.152	4.732

Table 27. Effect of weed management practices on summed dominance ratio of sedges

Treatments	Summed dominance ratio of sedges			
	20 DAT	40 DAT	60 DAT	Harvest
T1	37.17	37.02	32.47	32.03
T2	40.72	39.16	31.88	31.32
T3	36.90	41.36	40.60	31.89
T4	35.95	29.12	38.49	30.39
T5	36.09	40.35	38.15	33.22
T6	35.69	26.20	37.53	31.12
T7	39.28	36.1	31.93	28.40
T8	37.82	36.55	32.59	31.76
SE m(±)	-	11.66	3.73	-
CD (0.01)	-	5.982	3.385	-

Table 28. Effect of weed management practices on summed dominance ratio of broad leaved weeds

Treatments	Summed dominance ratio of broad leaved weeds			
	20 DAT	40 DAT	60 DAT	Harvest
T1	53.27	51.78	54.11	52.18
T2	53.31	45.24	55.01	55.02
T3	59.62	34.05	36.57	36.23
T4	58.24	39.80	36.19	36.20
T5	54.80	43.49	40.33	40.42
T6	57.42	48.45	38.06	37.73
T7	53.80	47.94	46.12	46.12
T8	56.38	45.29	46.66	46.66
SE m(±)	-	18.89	8.61	8.60
CD (0.01)	-	7.613	5.142	5.139

Table 29. Effect of weed management practices on importance value of grasses

Treatments	Importance value of grasses			
	20 DAT	40 DAT	60 DAT	Harvest
T1	18.75	22.36	26.85	31.60
T2	11.65	27.81	31.79	27.17
T3	6.92	49.27	46.88	63.05
T4	11.57	62.02	53.57	64.69
T5	18.50	28.86	45.37	52.87
T6	13.75	52.97	53.21	60.88
T7	13.79	31.87	42.93	44.24
T8	11.55	36.37	38.09	43.10
SE m(±)	-	63.78	22.43	29.21
CD (0.01)	-	13.987	8.296	9.466

recorded by T2, which was on par with T1, the lowest value being recorded by T4, which was on par with T3, T6 and T5. At harvest, the highest SDR of broad leaved weeds was recorded by T2, which was on par with T1, the lowest value being recorded by T4, which was on par with T3, T6 and T5.

4.1.9 Importance Value (IV)

The data on importance value of grasses, sedges and broad leaved weeds are furnished in Tables 29, 30 and 31.

4.1.9.1 Importance Value of Grasses

Importance value of grasses varied significantly due to the weed control treatments at 40 60 DAT and at harvest. At 40 DAT , the highest value was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}); the lowest value being recorded by T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), which was par with T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}) and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT, the highest value was recorded by T4, which was on par with T6, T3 and T5; the lowest value being recorded by T1, which was on par with T2. At harvest, the highest importance value for grasses was recorded by T4, which was on par with T3 and T6; the lowest value being recorded by T2, which was on par with T1.

4.1.9.2 Importance Value of Sedges

The data pertaining to importance value of sedges revealed that the treatments exerted significant impact on this observation at 40 and 60 DAT only. At 40 DAT, the highest value was recorded by T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}), which was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}), T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}), T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), T8 (weedy check) and T7 (hand weeding twice); the lowest value being recorded by T6 (bispyribac sodium @ 30 g ai ha^{-1}), which was on par with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}). At 60 DAT, the highest value was recorded by T3, which was on par with T4, T5 and T6; the

Table 30. Effect of weed management practices on importance value of sedges

Treatments	Importance value of sedges			
	20 DAT	40 DAT	60 DAT	Harvest
TI	74.34	74.05	64.95	64.06
T2	81.44	78.32	63.67	62.65
T3	73.81	82.73	81.21	63.78
T4	71.91	58.24	77.23	60.80
T5	72.09	80.71	76.38	66.45
T6	71.38	52.41	75.08	62.26
T7	78.57	72.20	63.88	56.81
T8	75.65	73.11	65.18	63.53
SE m(±)	-	46.65	15.27	-
CD (0.01)	-	11.963	6.844	-

Table 31. Effect of weed management practices on importance value of broad leaved weeds

Treatments	Importance value of broad leaved weeds			
	20 DAT	40 DAT	60 DAT	Harvest
TI	106.89	103.57	108.22	104.31
T2	106.89	90.51	110.16	110.16
T3	119.38	68.16	73.15	73.14
T4	116.49	79.61	72.20	72.40
T5	109.39	87.16	80.67	80.67
T6	114.85	96.91	76.14	76.14
T7	107.62	95.88	92.25	92.25
T8	112.77	90.59	93.34	93.34
SE m(±)	-	76.25	34.15	35.31
CD (0.01)	-	15.294	10.236	10.408

lowest value being recorded by T2, which was on par with T7 (hand weeding twice), T1 and T8 (weedy check). At harvest, there were no significance difference among treatments.

4.1.9.3 Importance Value of Broad Leaved Weeds

With respect to the importance value of broad leaved weeds also there noticed significant variation among the treatments at 40 and 60 DAT and at harvest. At 40 DAT, the highest value was recorded by T1(fenoxaprop-p-ethyl @ 60 g ai ha^{-1}), which was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}), T7 (hand weeding twice), T8 (weedy check) and T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}); the lowest value being recorded by T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) which was on par with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}). However, T4 was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT, highest importance value of broad leaved weeds was recorded by T2, which was on par with T1; the lowest value being recorded by T4, which was on par with T3. However, T3 was on par with T6 and T5. Almost similar trend was followed at the harvest stage.

4.2. OBSERVATIONS ON CROP

4.2.1 Growth and Growth Attributes

4.2.1.1 Phytotoxicity Rating

Phytotoxicity in rice plants was recorded 7 days after herbicide spraying (DAS). Phytotoxicity was rated on a visual scale of 1-10 where 1 indicates no phytotoxicity and 10 indicates total crop damage. The highest toxicity rate was recorded by T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}), which was on par with T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}) and these treatments were significantly different from the rest of the treatments. Except T1, T2 and T5 *i.e.*, treatments involving fenoxaprop-p-ethyl, all the treatments recorded phytotoxicity rate as 1.

4.2.1.2 Plant Height

The plant height was significantly influenced by the treatments at all the stages of observation except at 20 DAT. At 20 DAT the observation was recorded before herbicide application and hand weeding. At 40 DAT and 60 DAT and at harvest, the highest value was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}). However, at 40 DAT it was statistically on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) and T6 (bispyribac sodium @ 30 g ai ha^{-1}); at 60 DAT, it was statistically superior to all other treatments and at harvest, this treatment was statistically on par with T3. At all the stages of observation, the lowest plant height was recorded by T8 (weedy check), which was significantly inferior to all the treatments.

4.2.1.3 Number of Tillers

The data summarised in Table 33 indicated that the treatments influenced the number of tillers m^{-2} significantly at 40 and 60 DAT and at harvest. At 40 DAT, highest number of tillers m^{-2} was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and it was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}); however, T3 was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T7 (hand weeding twice). The lowest number of tillers m^{-2} was recorded by T8 (weedy check) and it was on par with T1(fenoxaprop-p-ethyl @ 60 g ai ha^{-1}). At 60 DAT, the highest numbers of tillers m^{-2} was recorded by T4 and it was on par with T3, T6 and T7. At this stage also the lowest value was recorded by T8 and it was on par with T1 and T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}). At harvest, the highest number of tillers m^{-2} was recorded by T4 and it was on par with T3. The next best treatment was T6 and it was on par with T7. The lowest numbers of tillers m^{-2} was recorded by T8 and it was on par with T1.

4.2.1.4 Dry Matter Production

Dry matter production was recorded at 20, 40, 60 DAT and at harvest and the data are presented in table 34. The weed management practices did significantly influence the dry matter production of the crop at all the stages of observation except

Table 32. Effect of weed management practices on phytotixicity and plant height

Treatments	Phytotoxicity rating and plant height, cm				
	Phytotoxicity rating(1-10 scale)	plant height, cm			
		20 DAT	40 DAT	60 DAT	Harvest
T1	3.33	33.20	54.18	85.02	92.12
T2	3.67	35.79	56.34	86.91	92.88
T3	1.00	34.80	59.70	89.70	96.98
T4	1.00	36.61	60.19	92.76	98.23
T5	2.67	36.30	57.44	88.93	94.59
T6	1.00	36.17	59.64	89.16	95.33
T7	1.00	35.45	59.60	90.38	95.10
T8	1.00	35.82	51.21	78.96	81.21
SE m(±)	0.10	-	0.65	0.51	1.01
CD (0.01)	0.696	-	1.417	1.259	1.768

Table 33. Effect of weed management practices on number of tillers

Treatments	Number of tillers m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	270.50	334.80	554.00	459.00
T2	281.20	360.70	561.00	480.00
T3	263.30	409.30	621.00	575.00
T4	282.00	431.10	621.00	585.00
T5	273.40	393.50	570.00	483.00
T6	252.50	397.90	607.00	536.00
T7	266.30	390.70	605.00	527.00
T8	258.30	346.00	522.20	434.00
SE m(±)	-	302.34	572.32	487.04
CD (0.01)	-	30.453	41.899	38.651

at 20 DAT. At 40 DAT, the highest plant dry matter production was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) , T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T7 (hand weeding twice), however, T7 was on par with T5(fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}), T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}) and T1(fenoxaprop-p-ethyl @ 60 g ai ha^{-1}. At 60 DAT, the highest plant dry matter production was recorded by T4 which was on par with T3 and T6, however, T6 was on par with T7. At harvest also, the highest plant dry matter production was recorded by T4, which was on par with T3, T3 was on par with T6; however, T6 was on par with T7. At 40, 60 DAT and at harvest the lowest dry matter yield was recorded by T8 (weedy check) which was significantly inferior to all other treatments.

4.2.2 Yield Attributes and Yield

4.2.2.1 Number of Productive Tillers m^{-2}

The data on number of productive tillers m^{-2} furnished in Table 35 showed that this yield attribute is significantly influenced by the weed control treatments. The highest number of productive tillers m^{-2} was registered by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was statistically on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) and T3 was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}); however, T6 was statistically on par with T7 (hand weeding twice) and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). The lowest number of productive tillers was recorded by T8 (weedy check), which was on par with T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}) and T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}).

4.2.2.2 Grain Weight Panicle^{-1}

The data on grain weight per panicle presented in Table 35 indicated the profound influence on the weed control treatments on this yield attribute. The highest grain weight per panicle was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and it was statistically on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1});

however T3 was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T7 (hand weeding twice). T7 was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). The lowest grain weight per panicle was recorded by T8 (weedy check) and it was statistically inferior to all other treatments.

4.2.2.3 Number of Spikelets Panicle^{-1}

The data on number of spikelets per panicle indicated that different weed control treatments had significant effect on this yield parameter. The highest number of spikelets per panicle was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and it was statistically superior to all other treatments. The lowest value was recorded by T8 (weedy check) and it was statistically inferior to other treatments.

4.2.2.4 Number of Filled Grains Panicle^{-1}

The highest number of filled grains per panicle was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and it was statistically superior to all other treatments. The lowest number of filled grain per panicle was recorded by T8 (weedy check) and it was statistically inferior to all other treatments.

4.2.2.5 Sterility Percent

The treatments exerted significant influence on this yield attribute also. The highest value for percentage sterility was recorded by T8 (weedy check) and it was statistically inferior to all other treatments. The lowest sterility percent was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and this treatment was statistically superior to all other treatments.

4.2.2.6 Thousand Grain Weight

A critical analysis of the data on thousand grain weight presented in table 35 indicated that the treatments varied significantly with respect to this yield attribute. The highest value for thousand grain weight was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and it was statistically on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}), T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T7 (hand weeding twice); however T7 was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-

Table 34. Effect of weed management practices on plant dry matter production

Treatments	Plant dry matter production, kg ha^{-1}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	1196.50	3330.00	7166.70	12722.20
T2	1196.70	3366.70	7283.30	13486.63
T3	1215.50	3680.00	7716.70	16008.87
T4	1225.60	3826.70	7856.70	16238.65
T5	1184.80	3466.70	7346.70	14153.60
T6	1199.00	3613.30	7713.30	15565.73
T7	1199.70	3573.30	7626.70	15176.13
T8	1141.30	3003.30	6913.30	11006.33
SE m(±)	-	3476.25	1712.10	147.02
CD (0.01)	-	326.540	229.170	445.971

Table 35. Effect of weed management practices on yield attributes of rice

Treatments	Productive tillers (number m^{-2})	Grain wt panicle^{-1}, g	No. of spikelets panicle^{-1}	No. of filled grains panicle^{-1}	Sterility %	1000 grain wt, g
T1	388.20	2.40	130.00	110.00	18.18	20.97
T2	416.57	2.50	133.00	113.00	17.69	21.23
T3	514.90	2.72	145.00	125.00	16.00	21.99
T4	536.73	2.84	151.00	131.00	15.26	22.12
T5	449.07	2.57	136.00	116.00	17.24	21.27
T6	477.10	2.68	141.00	121.00	16.52	21.56
T7	462.86	2.66	140.67	119.67	16.71	21.40
T8	375.67	1.97	117.00	97.00	20.56	20.72
SE m(±)	662.32	0.118	1.08	0.25	0.165	0.24
CD (0.01)	45.073	0.118	1.079	0.883	0.165	0.854

ethyl @ 20 g ai ha^{-1}), T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}), T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}) and T8 (weedy check).

4.2.2.7 Grain Yield

A critical analysis of the data on grain yield furnished in Table 36 revealed that grain yield was significantly influenced by the weed management practices. The highest grain yield of 6790 kg ha^{-1} was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was statistically on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) which recorded a grain yield of 6677 kg ha^{-1}. T6 (bispyribac sodium @ 30 g ai ha^{-1}) was the next best treatment with a grain yield of 6401 kg ha^{-1} and it was on par with T3; however, T7 (hand weeding twice) which registered grain yield of 6111 kg ha^{-1} was on par with T6 . T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}) was the next best treatment with a grain yield of 5789 kg ha^{-1} and it was on par with T7. The lowest grain yield 3981kg ha^{-1} was recorded by T8 (weedy check), which was significantly inferior to all other treatments. The percentage increase in grain yield in T4, T3 and T6 compared to weedy check were 70.53, 67.70 and 60.79 respectively.

4.2.2.8 Straw Yield

A perusal of the data on straw yield kg ha^{-1} showed that there was significant difference among treatments with respect to this character. The highest straw yield was recorded by recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was statistically on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) which was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}). However T6 was on par with T7 (hand weeding twice). The lowest grain yield was recorded by T8 (weedy check), which was significantly inferior to all other treatments.

4.2.2.9 Harvest Index

A critical analysis of the data presented in Table 36 on harvest index revealed that this yield attribute is also statistically significant. T4 registered the highest

Table 36. Effect of weed management practices on grain yield, straw yield, harvest index and weed index

Treatments	Grain yield, kg/ha	Straw yield, kg/ha	Harvest index	Weed index, %
T1	4962	7560	0.40	28.54
T2	5605	7682	0.42	19.27
T3	6677	9132	0.42	6.034
T4	6790	9249	0.43	0.00
T5	5789	8165	0.41	16.61
T6	6401	8964	0.42	7.79
T7	6111	8765	0.41	11.98
T8	3981	6825	0.37	42.66
SE m(±)	117.48	73.96	0.005	1.31
CD (0.01)	356.389	224.365	0.016	3.966

Table 37. Effect of weed management practices on nitrogen content of crop

Treatments	Nitrogen content of crop, %			
	20 DAT	40 DAT	60 DAT	Harvest
T1	0.87	0.85	0.86	0.85
T2	0.87	0.85	0.87	0.87
T3	0.87	0.86	0.87	0.88
T4	0.85	0.87	0.86	0.88
T5	0.85	0.89	0.89	0.86
T6	0.87	0.88	0.86	0.85
T7	0.86	0.86	0.87	0.88
T8	0.85	0.85	0.86	0.85
SE m(±)	-	-	-	-
CD	-	-	-	-

harvest index of 0.43 and it was statistically on par with all other treatments except T8 (weedy check).

4.2.2.10 Weed Index

The data on weed index are presented in Table 36. Weed index, which is a measure of yield loss due to weeds, was calculated by taking the treatment with least weed count *i.e.*, T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), as the base. The treatment which recorded lowest weed index was T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) with an yield loss of 6.03 per cent and it was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}). Highest weed index value of 42.66 per cent was recorded in T8 (weedy check) and it was significantly inferior to all other treatments.

4.3 CHEMICAL ANALYSIS

4.3.1 Nutrient (NPK) Content of Crop

4.3.1.1 Nitrogen Content

No significant difference in nitrogen content was observed due to treatments.

4.3.1.2 Phosphorus Content

There was no significant difference in phosphorus content due to treatments.

4.3.1.3 Potassium Content

Potassium content of crop also did not vary significantly due to treatments.

4.3.2 Uptake of Nutriens by Crop

4.3.2.1 Nitrogen Uptake of Crop

The data on nitrogen uptake of crop at various stages of observation are presented in Table 40. Except at 20 DAT, at all other stages of observation nitrogen uptake varied significantly due to treatments. At 40 DAT, the highest nitrogen uptake of crop was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) and T7 (hand weeding twice) . However, T7 was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}). At

Table 38. Effect of weed management practices on phosphorus content of crop

Treatments	Phosphorus content of crop, %			
	20 DAT	40 DAT	60 DAT	Harvest
T1	0.21	0.22	0.21	0.23
T2	0.23	0.21	0.22	0.21
T3	0.22	0.23	0.22	0.21
T4	0.24	0.23	0.24	0.23
T5	0.22	0.23	0.22	0.21
T6	0.22	0.23	0.23	0.23
T7	0.22	0.23	0.22	0.22
T8	0.21	0.21	0.21	0.21
SE m(±)	-	-	-	-
CD	-	-	-	-

Table 39. Effect of weed management practices on potassium content of crop

Treatments	Potassium content of crop, %			
	20 DAT	40 DAT	60 DAT	Harvest
T1	1.18	1.16	1.16	1.16
T2	1.17	1.16	1.16	1.16
T3	1.18	1.16	1.17	1.17
T4	1.16	1.17	1.18	1.18
T5	1.16	1.16	1.15	1.15
T6	1.17	1.16	1.17	1.17
T7	1.16	1.16	1.17	1.17
T8	1.17	1.15	1.16	1.15
SE m(±)	-	-	-	-
CD	-	-	-	-

60 DAT, the highest nitrogen uptake of crop was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was statistically on par with T7, T3 and T6. At harvest also a similar trend as that at 60 DAT was noticed. At all the stages of observation the lowest nitrogen uptake of crop was recorded by T8 (weedy check) which was significantly inferior to all the treatments.

4.3.2.2 Phosphorus Uptake of Crop

A critical analysis of the data on phosphorus uptake of the crop furnished in Table 41 shows that it is significantly influenced by the weed control treatments at 40 and 60 DAT and at harvest.

At 40 DAT, the highest phosphorus uptake was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) and T6 (bispyribac sodium-@ 30 g ai ha^{-1}), however, T6 was on par with T7 (hand weeding twice) and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). The lowest phosphorus uptake of crop was recorded by T8 (weedy check), which was statistically on par with T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}) and T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}). At 60 DAT also the highest phosphorous uptake of crop was recorded by T4 which was statistically on par with T3. The next treatment which recorded highest phosphorus uptake was T6 (bispyribac sodium @ 30 g ai ha^{-1}) and it was on par with T7. The lowest phosphorus uptake of crop was recorded by T8 which was on par with T1 and T2. At harvest stage also the highest phosphorus uptake was recorded by T4, which was statistically on par with T3; however, T3 was on par with T7 and T6. At harvest, the lowest phosphorus uptake of crop was recorded by T8, which was statistically inferior to all other treatments.

4.3.2.3 Potassium Uptake of Crop

The data presented in the Table 42 shows that the treatments exerted significant influence on the potassium uptake of crop at all the stages of observation except at 20 DAT. At 40 DAT, the highest potassium uptake was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T3 (carfentrazone-ethyl

Table 40. Effect of weed management practices on nitrogen uptake of crop

Treatments	Nitrogen uptake of crop, kg ha^{-1}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	10.16	28.29	60.96	108.16
T2	10.45	28.95	63.63	117.78
T3	11.03	34.09	71.01	149.25
T4	11.79	35.42	75.63	156.32
T5	10.61	29.33	65.82	129.53
T6	10.87	32.48	70.98	147.88
T7	11.55	33.12	73.42	150.19
T8	10.62	25.43	55.25	92.30
SE m(±)	-	2.37	8.27	24.79
CD (0.01)	-	2.699	5.039	8.795

Table 41. Effect of weed management practices on phosphorus uptake of crop

Treatments	Phosphorus uptake of crop, kg ha^{-1}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	2.54	7.27	15.24	27.04
T2	2.61	7.03	15.90	29.44
T3	2.75	10.02	18.70	37.31
T4	2.95	10.85	19.91	39.08
T5	2.65	8.88	16.45	32.38
T6	2.72	9.77	18.29	36.62
T7	2.88	9.27	18.15	35.05
T8	2.40	6.35	14.56	23.07
SE m(±)	-	3.49	2.84	6.92
CD (0.01)	-	1.274	1.450	2.393

@ 20 g ai ha^{-1}) and T7 (hand weeding twice); however, T7 was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) and the lowest potassium uptake was recorded by T8 (weedy check), which was statistically inferior to all other treatments. At 60 DAT also, the highest potassium uptake was recorded by T4 which was statistically on par with T3, T6 and T7; however T7 was on par with T5 (fenoxaprop-p-ethyl @60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}); the lowest potassium uptake being recorded by T8, which was on par with T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}). At harvest, highest potassium uptake of crop was recorded by T4 which was statistically on par with T3 and T7, however, T7 was on par with T6 and T5. At this stage also the lowest potassium uptake was recorded by T8, which was significantly inferior to all other treatments.

4.3.3 Nutrient (NPK) Content of Weeds

4.3.3.1 Nitrogen Content

The data furnished in Table 43 indicated that there was no significant difference among the treatments with respect to nitrogen content of weeds, at all the stages of observation.

4.3.3.2 Phosphorus Content

There was no significant difference among the treatments with respect to phosphorus content of weeds at any of the stages of observation and the data are furnished in Table 44.

4.3.3.3 Potassium Content

With respect to potassium content of weeds (Table 45) also there was no significant variation among the treatments.

4.3.4 Uptake of Nutrients by Weeds

4.3.4.1 Nitrogen Uptake of Weeds

The data on nitrogen uptake of weeds are presented in Table 46. At 40 DAT, 60 DAT and at harvest, the treatments exerted significant influence on this character. At 40 DAT, the highest nitrogen uptake of weeds was recorded by

Table 42. Effect of weed management practices on potassium uptake of crop

Treatments	Potassium uptake of crop, kg ha^{-1}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	13.95	31.89	83.58	148.37
T2	14.00	34.33	84.96	157.34
T3	14.61	44.22	95.70	189.07
T4	14.30	44.72	98.78	192.35
T5	12.63	36.89	88.33	168.98
T6	12.35	39.37	93.78	174.83
T7	13.19	42.30	92.89	179.84
T8	12.61	27.89	76.03	121.06
SE m(±)	-	8.66	22.30	111.25
CD (0.01)	-	3.154	6.270	16.817

Table 43. Effect of weed management practices on nitrogen content of weeds

Treatments	Nitrogen content of weeds, %			
	20 DAT	40 DAT	60 DAT	Harvest
T1	0.85	0.85	0.85	0.85
T2	0.87	0.85	0.87	0.87
T3	0.90	0.92	0.90	0.90
T4	0.96	0.92	0.96	0.96
T5	0.89	0.93	0.89	0.91
T6	0.90	0.92	0.90	0.94
T7	0.96	0.92	0.96	0.90
T8	0.84	0.84	0.84	0.83
SE m(±)	-	-	-	-
CD (0.01)	-	-	-	-

Table 44. Effect of weed management practices on phosphorus content of weeds

Treatments	Phosphorus content of weeds, %			
	20 DAT	40 DAT	60 DAT	Harvest
T1	0.26	0.21	0.23	0.25
T2	0.27	0.22	0.21	0.22
T3	0.23	0.23	0.22	0.23
T4	0.24	0.23	0.25	0.24
T5	0.22	0.23	0.22	0.22
T6	0.22	0.23	0.22	0.23
T7	0.24	0.23	0.24	0.22
T8	0.21	0.25	0.21	0.21
SE m(±)	-	-	-	-
CD	-	-	-	-

Table 45. Effect of weed management practices on potassium content of weeds

Treatments	Potassium content of weeds, %			
	20 DAT	40 DAT	60 DAT	Harvest
T1	1.10	1.16	1.16	1.16
T2	1.16	1.16	1.16	1.14
T3	1.22	1.29	1.23	1.27
T4	1.16	1.16	1.14	1.17
T5	1.06	1.06	1.06	1.06
T6	1.03	1.03	1.03	1.03
T7	1.12	1.13	1.17	1.14
T8	1.15	1.12	1.14	1.17
SE m(±)	-	-	-	-
CD	-	-	-	-

T8 (weedy check), which was statistically inferior to all other treatments, the lowest nitrogen uptake of weeds was recorded in T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) and T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}), however, T3 was on par with T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT also the highest nitrogen uptake of weeds was recorded by T8 which was statistically inferior to all other treatments and the lowest nitrogen uptake of weeds was recorded by T3 which was on par with T4, T6 and T5. At harvest, the trend in nitrogen uptake of weeds was the same as that at 60 DAT.

4.3.4.2 Phosphorus Uptake of Weeds

A perusal of the data on phosphorus uptake of weeds (Table 47) at 40 and 60 DAT and at harvest revealed that the treatments varied significantly due to treatments. At 40 DAT, the highest phosphorus uptake was recorded by T8 (weedy check), which was statistically inferior to all other treatments. The lowest phosphorus uptake was recorded by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}), which was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}), T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT also highest phosphorus uptake of weeds was recorded by T8 which was statistically inferior to all other treatments. The lowest phosphorus uptake was recorded by T3 which was on par with T4, T6 and T5. At harvest also the phosphorus uptake pattern was the same as that at 60 DAT.

4.3.4.3 Potassium Uptake of Weeds

The treatments exerted significant influence on the potassium uptake of weeds at 40 DAT and 60 DAT and at harvest as evident from the data presented in the Table 48. At 40 DAT, the lowest potassium uptake was recorded by T6 (bispyribac sodium @ 30 g ai ha^{-1}), which was on par with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}). At 60 DAT, the lowest value for potassium uptake of weeds was recorded by T3 which was on par with T4, T6 and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai

Table 46. Effect of weed management practices on nitrogen uptake of weeds

Treatments	Nitrogen uptake of weeds, kg ha^{-1}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	1.98	1.98	5.81	8.19
T2	1.67	1.51	5.46	8.40
T3	1.86	0.74	1.91	3.56
T4	2.40	0.53	2.13	4.37
T5	1.84	1.23	2.72	4.07
T6	2.13	0.54	2.27	3.69
T7	2.12	2.57	4.37	8.10
T8	1.84	5.61	10.06	15.31
SE m(±)	-	0.11	0.32	0.55
CD (0.01)	-	0.578	0.989	1.296

Table 47. Effect of weed management practices on phosphorus uptake of weeds

Treatments	Phosphorus uptake of weeds, kg ha^{-1}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	0.49	0.49	1.45	2.05
T2	0.42	0.38	1.36	2.10
T3	0.46	0.19	0.48	0.89
T4	0.60	0.13	0.53	1.09
T5	0.46	0.31	0.68	1.02
T6	0.53	0.14	0.57	0.92
T7	0.53	0.64	1.09	2.03
T8	0.46	1.40	2.51	3.83
SE m(±)	-	0.12	0.04	0.06
CD (0.01)	-	0.204	0.190	0.277

Table 48. Effect of weed management practices on potassium uptake of weeds

Treatments	Potassium uptake of weeds, kg ha^{-1}			
	20 DAT	40 DAT	60 DAT	Harvest
T1	2.70	2.69	7.94	11.23
T2	2.23	2.03	7.30	11.21
T3	2.46	0.96	2.52	4.70
T4	2.90	0.67	2.57	5.30
T5	2.20	1.41	3.25	4.74
T6	2.43	0.61	2.59	4.05
T7	2.43	3.05	4.99	9.82
T8	2.40	7.31	13.13	20.07
SE m(±)	-	0.25	0.82	0.81
CD (0.01)	-	0.880	1.588	1.578

Table 49. Effect of weed management practices on post harvest soil nutrient status.

Treatments	Available N, kg ha^{-1}	Available P, kg ha^{-1}	Available K, kg ha^{-1}
T1	458.94	17.36	187.77
T2	467.64	18.45	193.10
T3	491.51	22.91	206.46
T4	497.52	23.40	211.54
T5	471.49	18.62	184.40
T6	483.37	21.28	203.17
T7	479.52	20.19	199.06
T8	442.54	15.74	171.23
SE m(±)	4.91	0.38	2.08
CD (0.01)	14.883	1.166	6.303

ha^{-1}). At harvest, the lowest potassium uptake was recorded by T6 which was on par with T3, T5 and T4. At all the stages of observation, the highest uptake by weeds was in T8 (weedy check) and it was significantly inferior to all the other treatments.

4.4 POST HARVEST SOIL NUTRIENT STATUS

The data on the post harvest soil nutrient status are presented in Table 49. The content of N, P and K in soil after the experiment was significantly influenced by various weed management practices. The nitrogen content of the soil after harvest was the highest under T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) which was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) and T6 (bispyribac sodium @ 30 g ai ha^{-1}), however, T6 was on par with T7 (hand weeding twice) and T5 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}). The lowest N content was estimated with T8 (weedy check), which was inferior to all other treatments. With respect to phosphorus content of soil, the highest P content was estimated with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) which was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) while the T8 (weedy check) recorded the lowest P content and it was inferior to all other treatments. In the case of potassium also, content was higher under T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and it was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}); however, T3 was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) and again T6 was on par with T7 (hand weeding twice). The lowest K content was estimated with T8 (weedy check), which was inferior to all other treatments.

4.5 POPULATION DYNAMICS OF SOIL MICROORGANISMS

The total microbial population of the soil *viz.*, bacteria, fungi and actinomycetes were counted six days after spraying (DAS) the herbicides and the data are presented in Table 50.

4.5.1 Soil Bacterial Population

Before herbicides spraying composite soil sample collected from the experimental area had a total bacterial population of 68×10^6 cfu g^{-1} soil. A perusal of the data on soil bacterial population recorded at 6 DAS showed that there is significant variation among the treatments. The highest count was registered by T8 (weedy check) and it was on par with T7 (hand weeding twice), and significantly higher than that recorded in the herbicide treated plots. The lowest bacterial count was registered by T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}) and it was on par with T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}).

4.5.2 Soil Fungal Population

In the case of soil fungal population, composite soil sample collected from the experimental area before herbicide application was analyzed and it was almost similar to that observed at 6 DAS in weedy check treatment (18.70×10^4 cfu g^{-1} soil). However, significant difference was observed among the treatments. Maximum number of 18.67×10^4 cfu g^{-1} soil was registered by T8 (weedy check) which was statistically on par with T7 (hand weeding twice) and significantly higher than that recorded in all the herbicide treated plots. However, T7 was on par with T6 (bispyribac sodium @ 30 g ai ha^{-1}) which was again on par with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}). The minimum number of 15.33 was recorded by T5 (fenoxaprop-p-ethyl @60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}) which was statistically on par with T2 (fenoxaprop-p-ethyl @ 90 g ai ha^{-1}) and T1 (fenoxaprop-p-ethyl @ 60 g ai ha^{-1}).

4.5.3 Soil Actinomycetes Population

The effect of weed management treatments on soil actinomycetes population at 6 DAS, was not significant. The actinomycetes count in the herbicide treated plots did not vary much compared to pre-treatment value (6.80×10^4 cfu g^{-1} soil).

4.6 ECONOMICS OF CULTIVATION

The data on net income and benefit : cost ratio (BCR) computed for weed control treatments are presented in Table 51. Among the various treatments, the maximum net income (Rs. 67833) and BCR (2.03) were observed for T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and this was on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) with a net income and BCR of Rs. 65808 and

Table 50. Effect of weed management practices on the population of soil bacteria, fungi and actinomycetes, 6 DAS.

Treatments	Population of soil bacteria, ($\times 10^6$ cfu g^{-1} soil)	Popualtion of soil fungi, ($\times 10^4$ cfu g^{-1} soil)	Population of soil actinomycetes ($\times 10^4$ cfu g^{-1} soil)
T1	51.67	16.00	5.33
T2	53.00	15.67	4.00
T3	63.67	16.33	5.67
T4	64.37	16.67	6.00
T5	55.00	15.33	5.00
T6	64.33	17.33	6.67
T7	66.67	18.00	6.00
T8	67.67	18.67	6.67
SE m(±)	0.75	0.368	-
CD (0.01)	2.276	1.114	NS

Table 51. Effect of weed management practices on net income and benefit:cost ratio

Treatments	Net income, Rs. ha^{-1}	Benefit : cost ratio
T1	33089	1.50
T2	43808	1.65
T3	65808	2.00
T4	67833	2.03
T5	47911	1.72
T6	58619	1.86
T7	38494	1.46
T8	17166	1.27
SE m(±)	2022.27	0.03
CD (0.01)	6134.523	0.092

2.00 respectively. The next best treatment was T6 (bispyribac sodium @ 30 g ai ha^{-1}) with net income, Rs. 58619 and BCR 1.86. Even though hand weeding twice treatment (T7) recorded grain yield comparable to bispyribac sodium, net income and BCR were comparatively low for this treatment (Rs. 38494 and 1.46 respectively). The weedy check registered the lowest values for net income (Rs. 17166) and BCR (1.27).

DISCUSSION

5. DISCUSSION

Traditional herbicides poses residue related problems in the rice ecosystem due to high application rates. Some of the widely used herbicides like anilofos were banned for use in Kerala State recently. Hence, there is urgent need to identify alternate herbicides to give options to the farmers. Oflate, low dose high efficacy herbicides and mixed/ sequential application of herbicides to control mixed weed flora have been found promising (Kurchania *et al.* 2000; Moorthy, 2002). In this context, results of the investigation undertaken to assess the bio-efficacy of two post-emergence micro herbicides, fenoxaprop-p-ethyl and carfentrazone-ethyl, in transplanted rice in comparison with the micro herbicide bispyribac sodium, hand weeding twice (farmer's practice) and weedy check, are discussed in this chapter.

5.1. OBSERVATIONS ON THE WEEDS

5.1.1 Effect of Weed Management Practices on Weed Flora

A critical analysis of the weed spectrum of the experimental site indicated that there is considerable diversity in weed species infesting the plots. All the three morphological classes of weeds *viz.*, grasses, sedges and broadleaved weeds could be observed in the field. Among the twelve weed specii identified, only one belonged to grasses; three were sedges and eight were broadleaved weeds. According to Holm *et al.,* 1979, about 350 species have been reported as weeds of rice, of which grasses are ranked first followed by sedges and broadleaved weeds. Observation on diverse weed spectrum with dominance of broad leaved weeds and sedges infesting rice fields of the low lands of Vellayani were reported earlier by many weed scientists (Ravindran, 1976; Jacob, 2002; Yadav, 2006). It has been rightly pointed out by Juraimi *et al.* (2013) that weed- rice ecological relationship is very complex and dynamic and weed spectrum and degree of infestations in rice fields are often determined by rice ecosystems and establishment methods. Conforming this statement, weed flora of the rice fields of Vellayani area has already been documented by the above weed scientists as diverse with predominance of broad leaved weeds and sedges.

5.1.2 Quantitative Assessment of Weed Response

The most commonly used methods for quantitative assessment of weed response are weed count and weed weight (Rao, 2000). The vegetation analysis parameters *viz.*, weed dry weight, weed control efficiency (WCE), absolute density, relative density, absolute frequency, relative frequency, summed dominance ratio and importance value were used for determining the effect of the treatments on weed growth in the present study.

The results of the study indicated that the dry matter accumulation by weeds could be substantially reduced by all weed management treatments. The herbicide treatments involving carfentrazone-ethyl @ 20 and 25 g ai ha^{-1} (T3 and T4), bispyribac sodium @ 30 g ai ha^{-1} (T6) and the herbicide mixture fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1} (T5) recorded significantly lower total dry matter production of weeds compared to, hand weeding twice (T7), fenoxaprop-p-ethyl @ 60 and 90 g ai ha^{-1} (T1 and T2) and weedy check (T8). These results clearly indicated that the dry matter accumulation by weeds could be substantially reduced by the herbicide carfentrazone-ethyl either alone or in combination and by bispyribac sodium. The effectiveness of carfentrazone-ethyl in reducing dry weight of weeds, especially broad leaved weeds has been reported earlier (Wersal and Madsen, 2012; Ellis *et al.*, 2003; Yongin and OhDo, 2003). The pre-dominant weed flora observed in the experimental field were of the broad leaved category which explains the better efficacy of carferntrazone-ethyl for weed control, in the experiment. The broad spectrum weed control efficacy of the post-emergence micro herbicide bispyribac sodium has already been reported (Yadav *et al.*, 2009; Walia *et al.*, 2008; Walia *et al.*, 2008a).

Another interesting observation is that, among the herbicides, fenoxaprop-p-ethyl registerd significantly high total dry weight of weeds compared to carfentrazone-ethyl and bispyribac sodium. Fenoxaprop-p-ethyl is reported as an effective herbicide for post-emergent control of grasses (Snipes and Street, 1987; Khodayari *et al.*, 1989; Smith,1988). In the experimental field only a single species of grass was observed as against eight broad leaved weed specii and three specii of sedges. However, the herbicide mixture (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1} (T5) registered low total weed dry weight comparable to the lower dose of carfentrazone-ethyl at 40 DAT, the most critical period of weed competition in transplanted rice.

With respect to hand weeding twice (HWT) treatment, eventhough weeds were completely removed at 20 DAT, when sampling was done at 40 DAT weed regrowth was substantial compared to the herbicide treated plots. This intensive weed growth during the most critical period *i.e.*, 20 - 40 DAT could be the probable reason for the relatively poor performance of this treatment at the later stages of crop growth. Total weed dry weight was comparatively low for bispyribac sodium also at all the stages of observation.

Total weed dry weight was the highest in weedy check at all the four stages of observation, significantly higher than the rest of the treatments. The unchecked weed growth must have exploited the available nutrients in greater amounts resulting in better weed growth and dry matter production. This explains the poor growth and yield of the crop in this treatment. Similar observations were made by Ravindran (1976), Jacob (2002) and Yadav (2006), Saini and Angiras (2002) and Kumar *et al.* (2010).

The WCE of carfentrazone-ethyl @ 25 g ai ha^{-1} was 91.39 per cent at 40 DAT, comparable with its lower dose and bispyribac sodium. Better control of existing weed population and regrowth during the most critical period of crop-weed competition, reduced the weed biomass resulting in higher weed control efficiency for these treatments. The treatments fenoxaprop-p-ethyl @ 60 and 90 g ai ha^{-1} and HWT were least effective with regard to WCE. Weed control efficiency computed for different morphological groups, *viz.*, grasses, sedges and broad leaved weeds also showed that HWT was less effective in controlling all

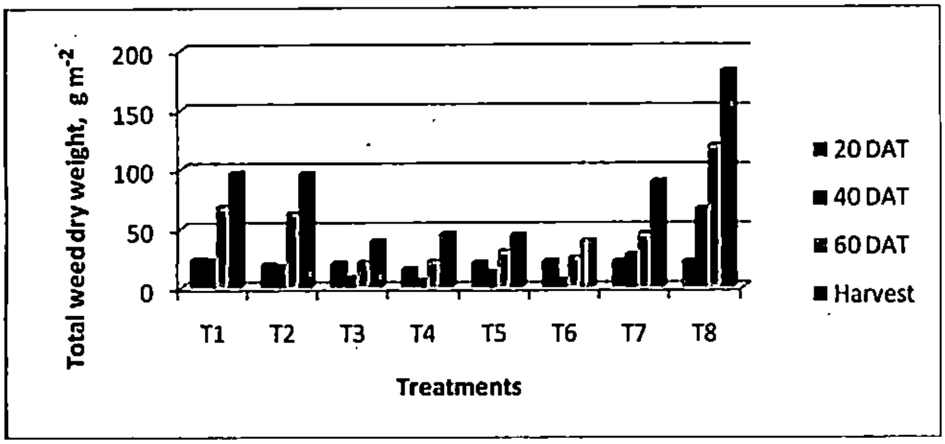


Fig. 3. Effect of weed management practices on total weed dry weight

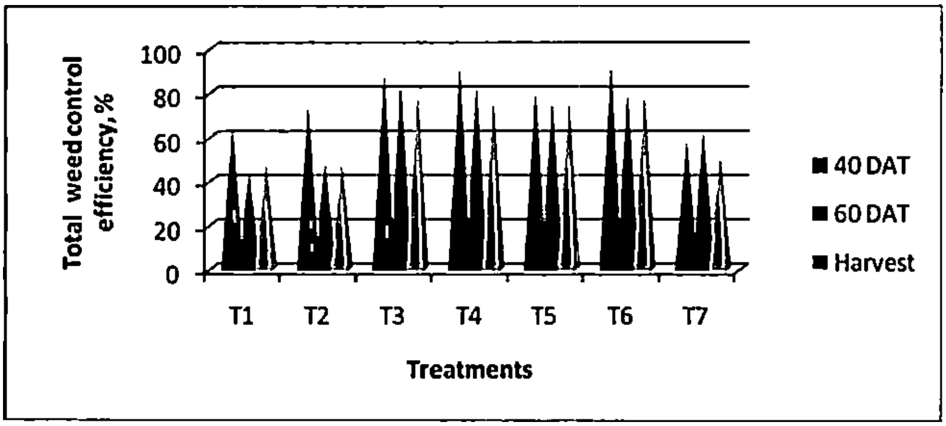


Fig. 4. Effect of weed management practices on total weed control efficiency

Plate 2. Plot treated with carfentrazone -ethyl @ 20 g ai ha^{-1} (T3)

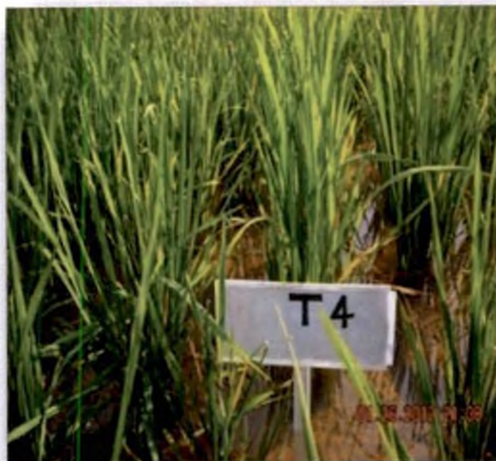


Plate 3. Plot treated with carfentrazone -ethyl @ 25 g ai ha^{-1} (T4)

Plate 4. Plot treated with bispyribac sodium @ 30 g ai ha^{-1} (T6)

Plate 5. Weedy check (T8)

Plate 6. Plot treated with carfentrazone -ethyl @ 20 g ai ha^{-1} (T3)

Plate 7. Plot treated with carfentrazone -ethyl @ 25 g ai ha^{-1} (T4)

Plate 8. Plot treated with bispyribac sodium @ 30 g ai ha^{-1} (T6)

Plate 9. Hand weeding twice at 20 and 40 DAT (T7)

Plate 10. Plot treated with fenoxaprop -p-ethyl @ 60 g ai ha^{-1} (T1)

plate 11. Plot treated with fenoxaprop -p-ethyl @ 90 g ai ha^{-1} (T2)

Plate 12. Plot treated with fenoxaprop -p-ethyl + carfentrazone-ethyl (T5)

Plate 13. Weedy check (T8)

the three groups of weeds while fenoxaprop-p-ethyl (60 and 90 g ai ha^{-1}) was less effective in controlling sedges and broad leaved weeds and it was most effective in controlling grasses. These results revealed that the dry matter accumulated by weeds had a direct bearing on weed control efficiency. Veeraputhiran and Balasubramanian (2010) recorded significant reduction in total weed dry weight and highest WCE of 98 percent with application of bispyribac sodium. Corroboratory results are reported by Mehta *et al.*, (2010).

The weed management practices adopted reduced the growth of different categories of weeds and resulted in significantly lower weed population. The relative dominance of various morphological groups of weeds indicated that treatments involving carfentrazone-ethyl (20 and 25 g ai ha^{-1}) recorded lower absolute density of sedges, broad leaved weeds and total density compared to the herbicide mixture, fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}, HWT and fenoxaprop-p-ethyl @ 60 and 90 g ai ha^{-1}. However, fenoxaprop-p-ethyl @ 60 and 90 g ai ha^{-1} recorded lower absolute density of grasses. The only grass species present in the experimental field was *Echinochloa colona.* Dixit and Varshney (2008) reported that fenoxaprop-p-ethyl is highly effective in reducing the density of *Echinochloa* sp. infesting rice fields. So it can be inferred that carfentrazone-ethyl at both the doses (20 and 25 g ai ha^{-1}) and bispyribac sodium @ 30 g ai ha^{-1} effectively reduced the density and dry weight of sedges and broad leaved weeds and grasses to a lesser extent, while fenoxaprop-p-ethyl at both the doses (60 and 90 g ai ha^{-1}) effectively reduced the density of grass weeds as evidenced by the relative density and relative frequency values of all categories of weeds, for these treatments. The effectiveness of carfentrazone-ethyl for weed control was reported by earlier workers as well (Glomski and Getsinger, 2006; Cauchy, 2000; Yongin and OhDo, 2003). However, compared to weedy check, fenoxaprop-p-ethyl (both the doses) caused significant reduction in the sedge and broad leaved weed population. Corroboratory results were reported by Saini and Angiras, 2002. Similarly carfentrazone-ethyl (both doses) and herbicide mixture also reduced *Echinochloa* population significantly compared to weedy check as evidenced by the relative density values for grasses for these treatments. The effectiveness of bispyribac sodium in reducing the density of all the three morphological groups of weeds has been well documented (Yadav *et al.* 2007; Yadav *et al.* 2009; Walia *et al.,* 2008; Walia *et al.,* 2008a).

Biswas and Sattar (1991) pointed out that when weed density exceeded 40 m^{-2}, rice grain yield was significantly reduced. In the present study, in the weedy check the total absolute density of weeds at 40, 60 DAT and at harvest were 145.66, 161.33 and 209. The corresponding values for the most effective herbicide treatment T_4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) were 11.00, 29.66 and 48.33. During the critical period of crop-weed competition, *i.e.*, 20-40 DAT, in none of the weed control treatments other than fenoxaprop-p-ethyl and HWT, density of weeds exceeded this limit as evidenced by the data on total weed density at 40 DAT. Based on these results it can be inferred that weeds grew luxuriantly in the experimental field which enjoyed favorable weather conditions resulting in very high intensity of weeds. This intense and uncontrolled weed growth had adversely affected crop growth and yield in weedy check. Similar observations were reported by Dixit and Varshney (2008) and Subramanian *et al.* (2006).

With respect to stage of crop growth, there was considerable increase in the density and dry weight of weeds, at 60 DAT compared to that at 40 DAT, in all the treatments except HWT where weeding was done at 40 DAT. However this incremental weed growth, due to the emergence of new flushes of weeds at later stages, did not have any negative impact on crop growth and yield. The data on crop growth characters, yield attributes and yield confirms this inference. Ghosh (2010) observed that 3-4 weeks after transplanting was the critical perod of crop weed competition. Similar observations were made by Dhammu and Sandhu (2002) also.

5.1.3 Nutrient Uptake by Weeds

Results of the study revealed that the uptake of N, P and K by weeds was maximum under weedy check. The weeds grow faster and absorb nutrients,

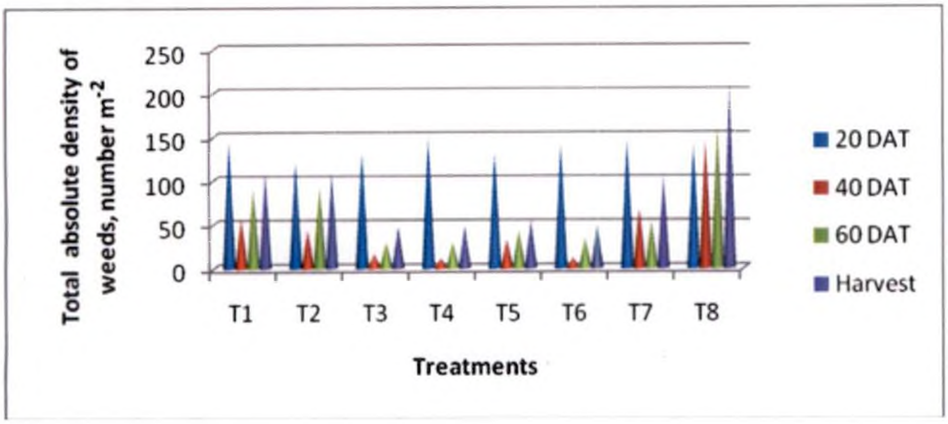


Fig. 5. Effect of weed management practices on total absolute density of weeds

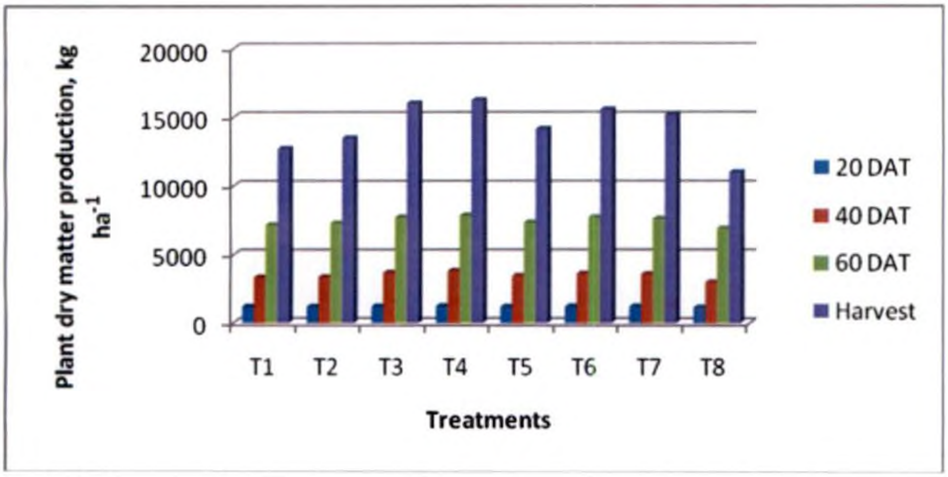


Fig. 6. Effect of weed management practices on plant dry matter production

which results in the reduced availability of nutrients for crop plant. Further, the weeds are capable of absorbing just as much or even bigger amounts of nutrients than crop plants (Rao, 2000). Similar observation on the significantly higher nutrient uptake by weeds in weedy check was reported by Kohle *et al.*, 1987 and Punyia *et al.*, 2008. Weeds remove a large amount of plant nutrients from the soil. An estimate showed that weeds could deprive the crops 47 per cent N, 42 per cent P, 50 per cent K, 39 per cent Ca and 24 per cent Mg of their nutrient uptake (Balasubramaniyam and Palaniappan, 2001). Uninterrupted weed growth in rice depleted 59.3 kg N, 10.5 kg P_2O_5 and 35.0 kg K_2O on per hectare basis (Rāju and Gangwar, 2004).

All weed management practices including carfentrazone-ethyl, fenoxarop-p-ethyl, bispyribac sodium and HWT registered lower uptake values for nutrients by weeds, compared to weedy check. Nutrient uptake by weeds was minimum under carfentrazone-ethyl treatments at both the doses *viz.*, 20 and 25 g ai ha^{-1} and bispyribac sodium @ 30 g ai ha^{-1} (T6). These three treatments were on par and superior to fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl@ 20 g ai ha^{-1} (T5), HWT (T7), fenoxaprop-p-ethyl @ 60 and 90 g ai ha^{-1} (T1 and T2), in most of the stages. The reduced weed growth and lesser dry matter accumulation by weeds in these treatments might have resulted in reduced nutrient uptake by weeds. The nutrient uptake by weeds is directly related with weed population and dry matter of weeds and inversely related to rice grain yield (Raju and Reddy, 1986). Reduction in the uptake of nutrients by weeds due to weed control treatments were reported earlier by Lekhsmi (1983), Singh *et al.* (1999), Soman (1988), Jacob (2002), Yadav (2006) , Puniya *et al.* (2008) conforming the fact that timely weed control is a must in rice crop for reducing nutrient loss through weeds.

5.2 OBSERVATIONS ON THE CROP

5.2.1 Phytotoxicity

Consequent to the application of fenoxaprop-p-ethyl @ 60 and 90 g ai ha^{-1} and the tank mix dose of fenoxaprop @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}, phytotoxicity was noticed on the rice crop. The data on visual phytotoxicity rating, recorded seven days after herbicide spraying, using 1-10 scale, indicated that there was slight to moderate toxicity on the rice crop as evidenced by discoloration and scorching of the leaves. However, the affected plants recovered within a period of one week (within a period of two weeks after herbicide application). Similar observation on the phytotoxic effect of fenoxaprop-p-ethyl on rice crop as well as the recovery of the crop from the toxicity was reported by Chankrachang *et al.* (2006). As against this, no phytotoxicity was noticed in rice crop due to fenoxaprop-p-ethyl application up to the dose of 90 g ai ha^{-1} as reported by Singh *et al.* (2003).

None of the other herbicides tested *viz.*, carfentrazone-ethyl and bispyribac sodium had any phytotoxic effect on the rice crop. Similar view was expressed by earlier workers also (Ellis *et al.*,2003; Yadav *et al.*, 2009).

5.2.2 Crop Growth Characters

It is evident from the data that various weed management practices did have a positive role in determining the growth characters like plant height, tiller number and dry matter production (DMP). In general, carfentrazone-ethyl @ 25 g ai ha^{-1} recorded maximum values for all the growth characters. All weed management practices including different doses of fenoxaprop-p-ethyl, carfentrazone-ethyl, bispyribac sodium and hand weeding twice at 20 and 40 DAT (HWT) recorded better crop growth characters than weedy check, which registered the lowest value for all growth characters. The superiority of weed control treatments may be due to comparatively low competition from weeds (Jacob, 2002; Moorthy, 2002; Chopra and Chopra, 2003). At the same time, in weedy check, the uncontrolled growth of weeds throughout the lifecycle of rice adversely affected the crop growth characters. The severe competition from weeds might have led to the poor growth of rice plants in these treatments.

Plant height was higher in all weed control treatments at all the stages of observation compared to weedy check. At 40 DAT, the most critical period of weed competition, it was the highest in carfentrazone-ethyl comparable to bispyribac sodium. The crop weed competition was less in carfentrazone-ethyl and bispyribac sodium treated plots that can be observed from the low values of absolute density and weed dry matter production in these plots, which could be the probable reason for the higher plant height in T3, T4 and T6. Corroboratory results on the beneficial effect of weed control treatments on height of rice plants was reported by Gill and Kollar (1980), Jacob (2002) and Yadav (2006).

Compared to herbicide treatments, values for plant height were lower in plots which were hand weeded twice (T7). This could be because manual weeding allowed unchecked weed growth during the most critical period of weed competition *i.e.*, 20- 40 DAT, depleting valuable resources from the soil at a time when it is highly essential for the crop to put forth proper growth. According to Gupta and Lamba (1978) by manual weeding, weeds are removed after they have put forth considerable competition to crop and rarely at ideal time whereas herbicides provided the benefit of timely weed control.

With respect to tiller number^{-2} also carfentrazone-ethyl treatments registered significantly higher values comparable with bispyribac sodium and HWT at 40 and 60 DAT. The reduction in weed parameters like density, dry matter production and nutrient uptake by weeds in these treatments enabled rice to put forth better growth resulting in enhanced tiller number. Weed control by herbicides at early stages enabled better rice growth (Ali and Sankaran, 1975; Sumner *et al.*, 1981; Mabbayad and Moody, 1992; Balasubramaniyan, 1996).

At all the stages of observation, the lowest plant height and tiller number were registered by weedy check. Ali and Sankaran (1975) and Ravindran (1976) reported that severe weed infestation suppressed the height and tiller number of rice plants. The adverse effect on tiller production of rice due to weed competition at critical growth stages of crop was reported by Sankaran and Thiagarajan (1982) and Mabbayad and Moody (1992) also. This result is in conformity with the observations of Rao (2000) that for every unit of weed growth, there will be one unit less of crop growth.

The DMP of rice estimated at different growth stages emphasized the favorable influence of weed management practices on this character. The highest and lowest DMP were registered by T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) and T8 (weedy check) at all stages of observation. The low weed growth in the treatments involving carfentrazone-ethyl and bispyribac sodium and in HWT (T3,T4 ,T6, T5 and T7) enabled the crop to utilize the available nutrients, water and sunlight for maximum production of photosynthates leading to higher dry matter accumulation.

Any weed growing in association with the crop will reduce vegetative potential of the crop and ultimately result in loss of yield (Moody, 1978). The reduction in dry matter production and nutrient uptake by weeds helped the rice plants to absorb more nutrients from soil, which in turn resulted in high DMP of rice at different growth stages. The result of this experiment is in conformity with the findings of Chaudhary *et al.* (1995), Balasubramaniyan (1996), Jacob (2002), Seema (2004), Yadav (2006) and Yadav *et al.* (2009) in rice. The antagonistic effects of weeds on rice dry matter production was earlier reported by Ravindran (1976) and Lekshmi (1983).

5.2.3 Crop Yield Attributes and Yield

From the data on yield attributing characters it is evident that effective weed management practices did have a positive role in determining the yield attributes and yield of rice. The carfentrazone-ethyl @ 25 g ai ha^{-1} (T4) registered the highest value for all the yield attributes *viz.*, number of productive tillers m^{-2}, number of spikelets per panicle, grain weight per panicle, number of filled grains per panicle and thousand grain weight and the lowest value for percentage sterility. This is mainly due to the comparatively low competition from weeds, which allowed the crop to express its full genetic potential in this treatment. The lower dose of carfentrazone-ethyl (T3), bispyribac sodium (T6), herbicide mixture (T5) and HWT also recorded comparable values with respect to number of productive tillers m^{-2}, grain weight per panicle and thousand grain weight. With respect to weed vegetation analysis parameters also, these treatments elicited comparable performance as that of T4.

The lowest values for all the yield attributes was registered by weedy check. Severe weed competition might have reduced the availability of sunlight and nutrients to the rice plants in weedy check resulting in poor expression of yield attributes. Yield can be limited either by the supply of assimilates (source) during grain filling or by the number and capacity of kernels to be filled (sink) or by source and sink simultaneously (Fischer, 1983; Venkateswaralu and Visperas, 1987; Evans, 1993). In the present investigation, both source and sink were limited due to competition of weeds in weedy check (T8) resulting in significantly low grain yield in this treatment. Corroboratory results were reported by Jacob (2002) , Seema (2004) and Yadav (2006).

From the above discussions it is clear that weed management treatments involving the micro herbicide carfentrazone-ethyl were effective in reducing the weed competition in rice which is manifested in crop yield attributing characters. Thus the extent of weed growth and consequent competition appeared to be the main factor, which decided the expression of yield attributes in rice. Sukumari (1982) and Lekshmi (1983) have reported significant negative influence of weed growth on the filled grain $panicle^{-1}$. The control of weeds promoted the yield and yield attributes including productive tillers m^{-2}, number of filled grains per panicle and thousand grain weight in rice (Raju *et al.* 2002). Mahapatra *et al.* (2002) and Saini and Angiras (2002) reported a decrease in thousand-grain weight due to weed competition. Positive influence of herbicide application on yield attributes of rice was reported by Singh and Sharma (1984) and Pandey *et al*. (1997).

A critical analysis of yield data clearly showed that grain yield was higher in treatments, which were effective in controlling weeds. Significantly higher grain and straw yield were obtained by the treatments involving carfentrazone-ethyl *i.e.*, T4 and T3. Bispyribac sodium (T6) also registered comparable yield, showing the

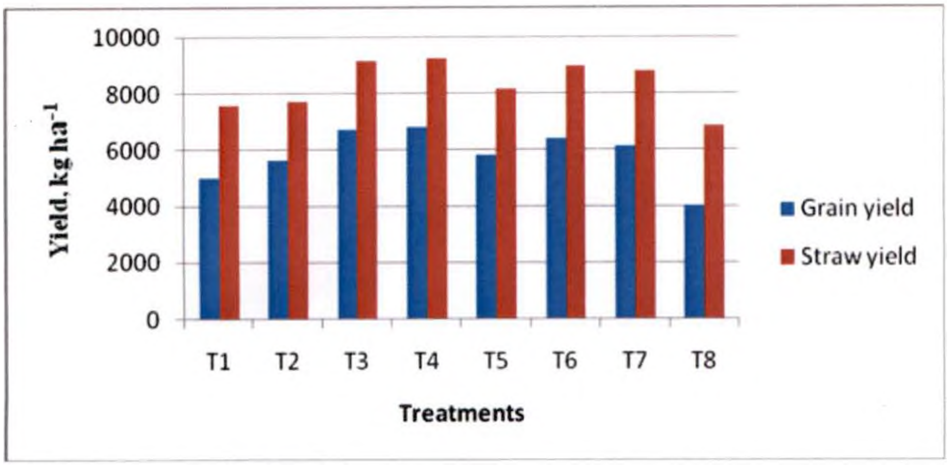


Fig. 7. Effect of weed management practices on grain yield and straw yield

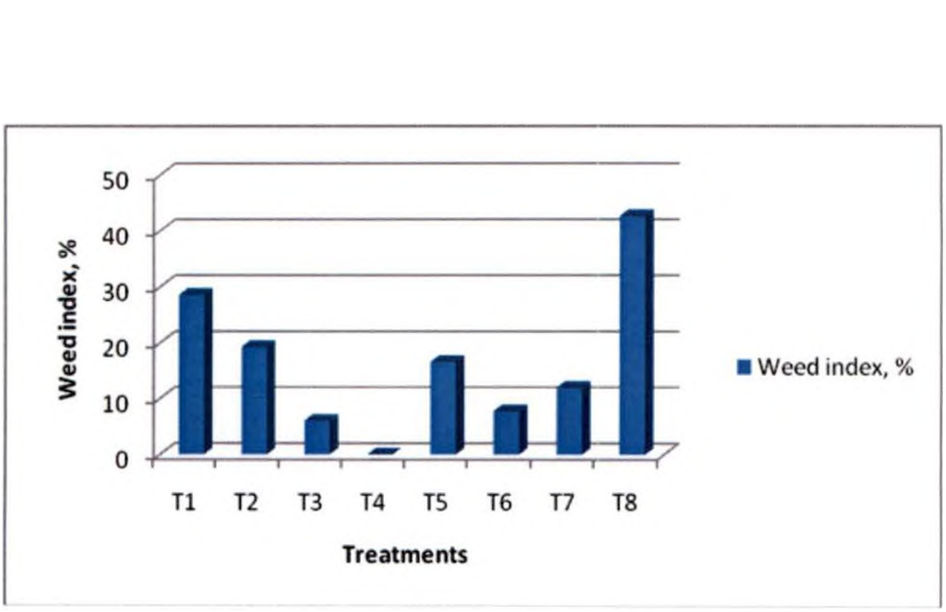


Fig. 8. Effect of weed management practices on weed index

effectiveness of these herbicides in increasing yield through its indirect effect on weed control . The percentage increase in grain yield in T4, T3 and T6 over weedy check were 70.53, 67.70 and 60.79 respectively. The enhanced yield was consistent with the growth characters and yield attributes discussed earlier. In rice, grain yield is a function of number of productive tillers hill^{-1}, number of grains per panicle and thousand grain weight. The higher values for these yield attributes recorded under the treatments involving carfentrazone-ethyl @ 25 and 20 g ai ha^{-1} (T4 and T3), bispyribac sodium @ 30 g ai ha^{-1} (T6) and HWT (T7) might have resulted in higher grain yield (> 6 t ha^{-1}) for these treatments. Corroboratory results on the favourable effect of new generation herbicides on grain yield was reported by Yadav, 2006; Dixit and Varshney, 2008; Saini and Angiras, 2002; Walia *et al.*, 2008; Yadav *et al.*, 2009).

Jacob (2002) and Yadav (2006) reported significant and positive correlation between grain yield and yield attributes in rice *i.e.*, number of productive tillers, weight of panicle, filled grain per cent and thousand grain weight.

The weed management practices increased the plant height, tiller count, nutrient uptake and DMP, which in turn might have increased the straw yield in T4, T3, T6 and T7. This is in conformity with the findings of Jacob (2002) and Seema (2004) and Yadav (2006).

Yield loss due to weeds, as indicated by weed index in the present study was 42.66 per cent. Yadav (2006) reported a weed index of 46.11 per cent in her studies using pyrazosulfuron-ethyl. Raju and Reddy (1995) reported that uncontrolled weeds caused 39 per cent yield loss in transplanted rice. However, the yield reduction was 42 per cent according to Saha *et al.* (2003) and 46 per cent according to Mukerjee and Singh (2004).

5.2.4 Nutrient Uptake by Crop

Treatments with comparatively low density and dry weight of weeds *viz.*, all treatments involving carfentrazone-ethyl and bispyribac sodium recorded the maximum uptake of N, P and K by the crop and the minimum was recorded in weedy check. The enhanced growth characters in these treatments contributed to high DMP. Nutrient uptake being a product of DMP and nutrient content was enhanced under such situations. It was also evident that with minimum weeds to compete with, the uptake of nutrients by the crop was facilitated resulting in more vigorous growth of crop and better uptake of nutrients. But the rice plants in weedy check failed to utilize the available nutrients present in the soil due to severe competition from weeds. Similar observations were made earlier by several workers (Nanjappa and Krishnamoorthy, 1980; Chaudhary *et al.*, 1995; Rajan, 2000 and Jacob, 2002).

Carfentrazone-ethyl @ 20 and 25 g ai ha^{-1}, bispyribac sodium @ 30 g ai ha^{-1} and fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1} (T5) recorded higher uptake of nitrogen, phosphorus and potassium. Throughout the growth period, the N and K uptake by the crop was higher than P uptake. Nutrient uptake by rice plants in plots treated with fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}, fenoxaprop-p-ethyl @ 60 and 90 g ai ha^{-1} and HWT was also higher than the nutrient uptake by rice plants in weedy check. The increased uptake in the herbicide treated plots was due to the effective control of weeds by these herbicides, which resulted in lower weed dry weight, and lower nutrient removal by weeds. Hence the competition by weeds was also lower in these treatments.

Varughese (1978) reported that the maximum uptake of nutrients by rice crop was between 31 and 40 days after transplanting and out of the total uptake 55.07 per cent N, 60.18 per cent P and 64.57 per cent K was during the critical period of weed competition *i.e.*, 21 - 40 days after transplanting.

Biswas and Sattar (1991) opined that uptake of nitrogen by rice decreased as weed density increased and this was reflected in decreased yields (13 per cent reduction at 20 weeds m^{-2} and 17 per cent reduction at 40 weeds m^{-2}). Increased N, P and K uptake by rice plants through weed control using herbicides was reported by several earlier workers (Ali and Sankaran, 1984;

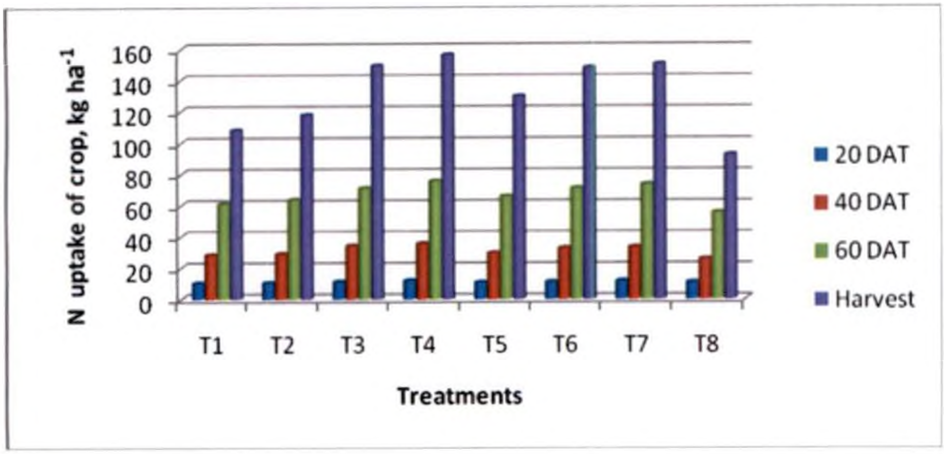


Fig. 9. Effect of weed management practices on nitrogen uptake of crop

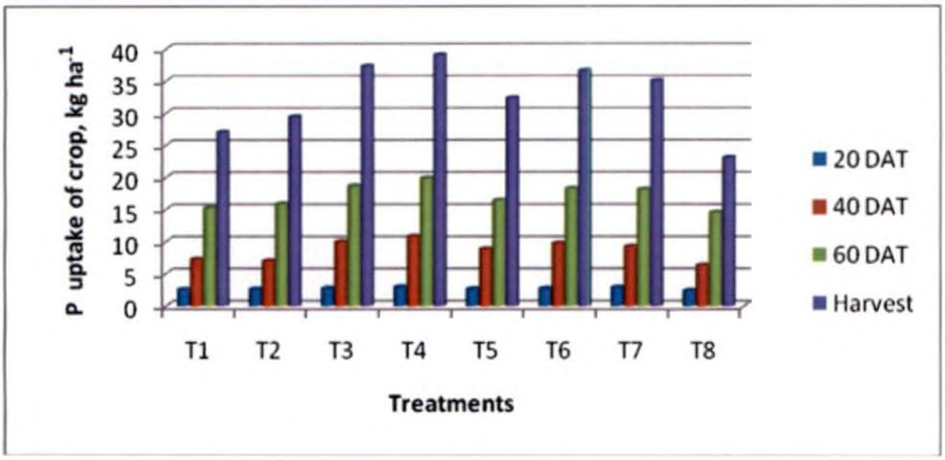


Fig. 10. Effect of weed management practices on phosphorus uptake of crop

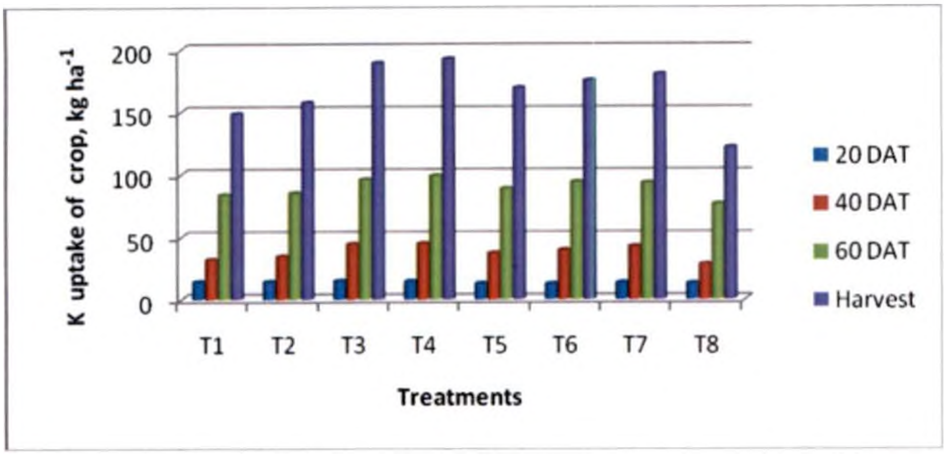


Fig.11. Effect of weed management practices on potassium uptake of crop

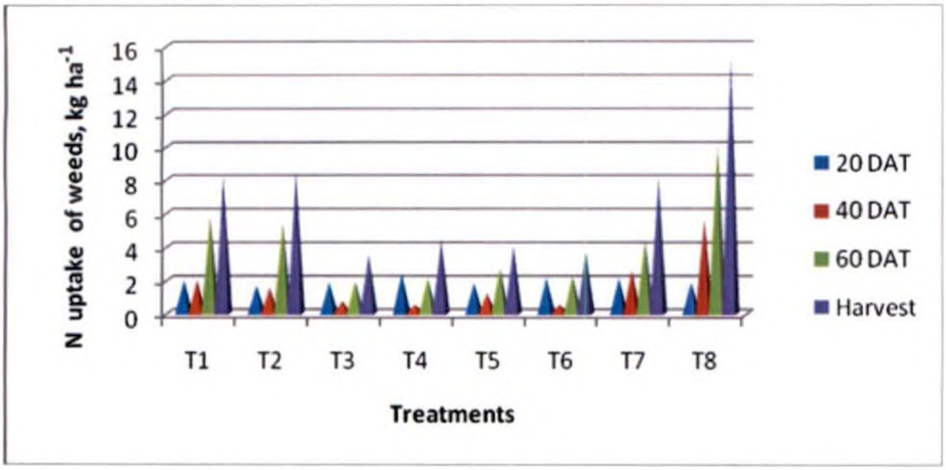


Fig. 12. Effect of weed management practices on nitrogen uptake of weeds

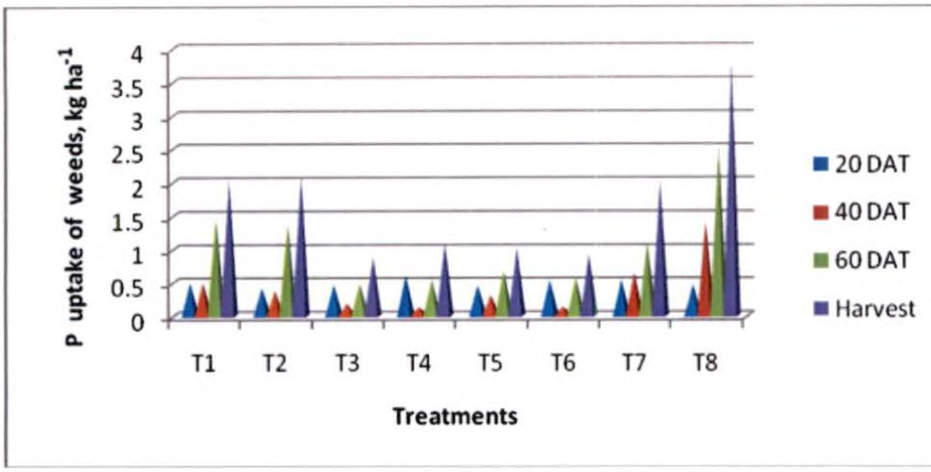


Fig. 13. Effect of weed management practices on phosphorus uptake of weeds

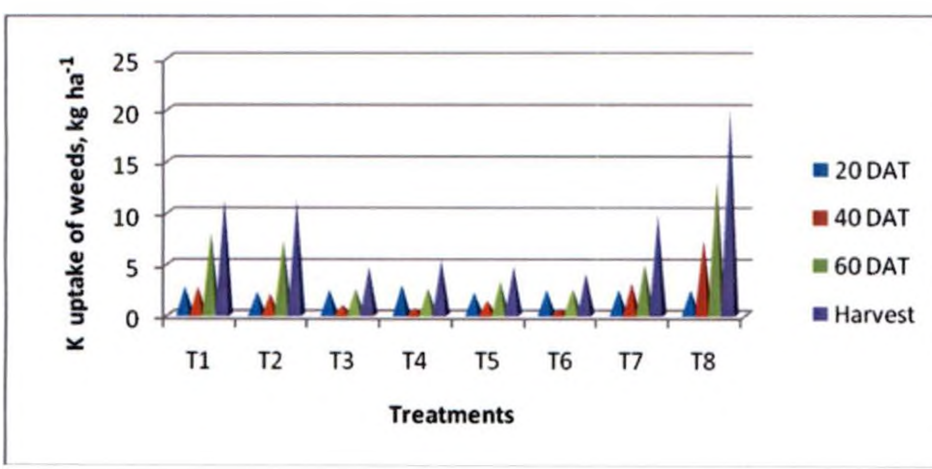


Fig. 14. Effect of weed management practices on potassium uptake of weeds

Madhu and Nanjappa, 1997; Rajan, 2000; Jacob, 2002; Seema, 2004 and Yadav, 2006).

5.3 POST HARVEST NUTRIENT STATUS OF THE SOIL

The nutrient status of the soil after the harvest of the crop revealed a marginal decrease in the nitrogen, phosphorus and potassium content over the initial status. The treatment which registered comparatively low values for the density and dry weight of weeds *viz*., T4, T3, T6, T7 and T5 recorded the higher available nutrient status in the post experiment soil, evidently because there was less nutrient removal by weeds in these treatments. The nutrient status was the lowest in weedy check. Lowest N, P and K status in weedy check was due to the high nutrient removal by weeds along with crop from these plots. These finding are in conformity with that of Rajkhowa *et al*. (2001), Jacob (2002) Seema (2004) and (Yadav, 2006).

5.4 ECONOMICS

A critical analysis of the data indicated that the new generation micro herbicide carfentrazone-ethyl at both the doses registered significantly higher net income and benefit cost ratio. Among these treatments, carfentrazone-ethyl @ 25 g ai ha^{-1} was found to be the best one which gave a net income and benefit cost ratio of Rs. 67833 and 2.03 respectively. Eventhough bispyribac sodium registered WCE and grain yield comparable to carfentrazone-ethyl (T3), this treatment failed to have comparable net income and B: C ratio because of the high market price of this herbicide. However, compared to HWT, this herbicide could produce significantly higher net income and B:C ratio. Eventhough WCE and yield were comparatively high for the hand weeding twice (HWT) treatment, net income and benefit cost ratio were significantly low for this treatment compared to all herbicide treatments involving carfentrazone-ethyl and bispyribac sodium (T4,T3,T6,T5), owing to the huge expenditure incurred for manual weeding.

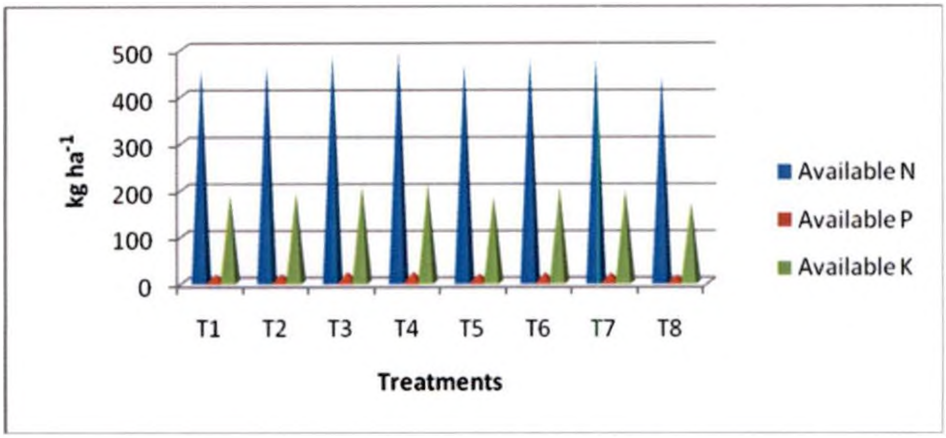


Fig. 15. **Effect of weed management practices on post harvest soil nutrient status**

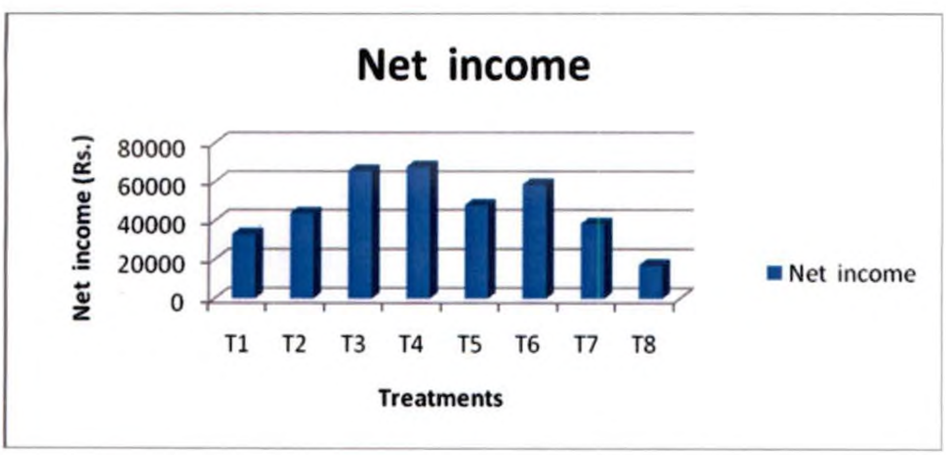


Fig. 16. Effect of weed management practices on net income

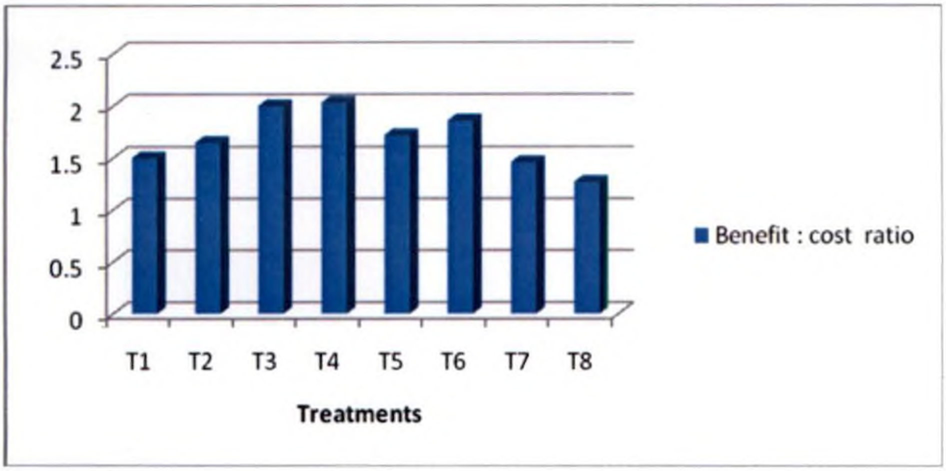


Fig. 17. Effect of weed management practices on benefit : cost ratio

Agriculture is far more profitable when chemical weed management is adopted (Rao, 2000) and the present results also emphasises this observation conforming the need for successful chemical weed control for profitable rice production in the State. As the total labour requirement for a single manual weeding ranges from 300 to 700 man hours ha^{-1}, the use of herbicides could result in considerable savings to the farmer (Ray, 1973). According to Gogoi *et al.* (2001), manual weeding is difficult, many a time due to continuous rains prevailing during rainy seasons and also due to scanty labour. Ravindran (1976) reported that hand weeding on 20th and 40th day after transplanting rice, although gave higher yields, the net profit was lower due to increased labour charges. According to Singh (1985) hand weeding was laborious and expensive and benefit cost ratio showed a negative value due to high labour charges. Singh *et al.* (2000), Jacob (2002), Seema (2004), Yadav (2006) and Kiran *et al.*(2010). reported that herbicide application resulted in higher net income and benefit cost ratio compared to manual weeding. Herbicides offer economic and efficient weed control if applied at proper dose and stage (Kumar and Sharma. 2005). Economic benefit of herbicide application over manual weed control was reported earlier too (Rangiah *et al.*, 1975; Versteeg and Maldonado, 1978; Lekshmi, 1983).

Prasad *et al.* (1992) opined that use of herbicide could save upto 75 per cent energy input than hand weeding. He also pointed out that energy use efficiency was higher with herbicide than with hand weeding. Apart from its favorable effect on crop growth characters and yield attributes, the economic advantage of using micro herbicides is of profound significance by virtue of its non-dependence on manual labour. This is of much significance for a state like Kerala where labour is scarce and costly.

5.5 EFFECT OF WEED CONTROL TREATMENTS ON POPULATION DYNAMICS OF SOIL MICRO ORGANISMS

Dynamics of population of soil micro flora consequent to the application of the micro herbicides, fenoxaprop-p-ethyl, carfentrazone-ethyl and bispyribac sodium were monitored by conducting soil plate dilution study on soil samples taken from the treated plots at six days after herbicide spraying..

Total microbial population in a soil is the direct measurement of qualitative change appearing after herbicide treatment. Highly contrasting reports are available in the literature in respect to the side effect of herbicide on soil micro flora, the observation varied from adverse to no effect or even stimulatory effect on microbial group after herbicide application. Reports indicate the adverse effect of herbicides on selected species of microorganism in pure culture and many a times at the higher concentration level that is unlikely to occur in the actual field condition at recommended rates of application. There are very few reports of permanent injury to soil micro-fauna or invertebrates from herbicides used at normal field use rates.

5.5.1 Effect on Soil Fungi

The results revealed that the population of fungi in the soil was substantially reduced in the herbicide treated plots compared to that in weedy check, where the rhizosphere was undisturbed. However, HWT treatment also had comparable fungal population in the soil at 6 DAS. Another interesting observation is that weedy check registered a fungal population same as that observed in the field before herbicide spraying.

Herbicides caused an inhibitory effect on the growth of fungi in the initial stages, however fungal population increased after 30 days (Deshmukh and Khande, 1977). Application of herbicides above field dose, *i.e.*, at higher concentration, affected the population of fungi and bacteria (Chauhan *et al.*, 1994; Allievi and Gigliotti, 2001).

The application of the post emergence herbicides fenoxaprop-p-ethyl and ethoxysulforon, which were sprayed at 20 days after transplanting suppressed the fungal population from 46.3×10^3 to 34.7×10^3 ((20 DAE) which again increased to 53.8×10^3 at 50 DAE. (Choudhary *et al.*; 2008).

5.5.2 Effect on Soil Bacteria

The results indicated that there was a decline in the population of bacteria at 6 DAS (days after spraying) in all herbicide treatments, compared to weedy check and HWT. In weedy check the bacterial population at 6 DAS was found to be same as that recorded before herbicide spraying.

After the application of the new generation herbicide, pyrazo sulfuron-ethyl there was significant reduction in the population of bacteria at 3, 6 and 15 DAS; from 15 DAS onwards the bacterial count started to increase (Yadav, 2006). Similar observation was made by Devi (2002) too. According to her though 2,4-D had a negative influence on soil bacteria, their population was restored within 30 DAS. This type of short term inhibitory effect of herbicides was also reported earlier by several workers (Mukhopadhyay, 1980; Singh, 1990; Nalayini and Sankaran, 1992; AICRPWC, 1994).

Butachlor at 5.5, 11 and 22 μg/g soil showed temporary inhibition of aerobic heterotrophic bacteria within the early period of 8 days followed by a recovery during the later period in paddy soil (Min *et al.*, 2002).

Herbicides generally appear to have no adverse effect on total bacterial population in soil except at concentrations exceeding recommended rates (Anderson, 1978). Generally in field condition, a short time initial depressive effect is followed by an increase in the total bacterial number to the normal level. This delayed stimulation is caused by the adaptation time of the bacteria. Initial depression could be due to the adverse impact on susceptible strains and subsequent increase in the growth rate of the relatively resistant strains with course of time. The subsequent increase in the bacterial number could also be due to the increase in the nutrient content that come from weeds killed by the herbicide or by the utilization of the herbicides as substrates by the resistant strains (Burman and Varshney, 2008)

5.5.3 Effect on Soil Actinomycetes

The actinomycetes population was not affected by any of the herbicides or its concentration when observed at 6 DAS. The actinomycetes population recorded in the weed control treatments did not vary from the pre treatment values also. Their constant population in soil is extremely useful as these microbes play a major role in the biodegradation of pesticides in soil. Generally these micro organisms are very important in the degradation of herbicides (Rao, 2000). According to Beyer *et al.* (1988), the soil actinomycetes *Streptomyces griseolus* rapidly metabolises chlorsulfuron.

This steady level of microbial population recorded implies that the delicate biological balance of the soil is very little affected by application of the herbicides fenoxaprop-p-ethyl, carfentrazone-ethyl and bispyribac sodium. On one hand, this result points to the very low residual effect of the herbicide and very low environmental hazard.

Samanata *et al.* (2005) reported that application of post emergence herbicides carfentrazone-ethyl, 2-4-D and pyrazosulfuron-ethyl inhibited the microbial growth in soil up to 10 days of its application and in later stage significantly augmented the population of total bacteria, actinomycetes and fungi over that of control in the rhizosphere soil of rainy season rice.

The monitoring period is a most important part for the assessment of pesticide effect and a minimum of 30 days has been recommended for the recognition of persistent effects on soil. A delay of 30 days in the restitution of normality (recovery period) after herbicide application should be considered normal with ecological consequences being negligible, a delay of 60 days is not unusual, and the ecological consequences are tolerable and a delay of greater than 60 days is unusual with ecological consequences which may eventually be critical (Domseh *et al.* 1983).

Raut *et al.,* 1997 observed that except for a slight initial suppressing effect, butachlor stimulated the microbial population of rice rhizosphere. Similarly, at field rate a short term transient or stimulatory effect of propanil, butachlor, molinate and nitrofen on microbial population in transplanted rice was reported by Shetty, 1977. Burman and Varshney (2008) reported that at recommended rate of herbicide application, often a reversible change in the equilibrium of the population of micro-flora and fauna takes place in soil for a short period of time under field conditions.

SUMMARY

6. SUMMARY

An investigation entitled "Bio-efficacy of post-emergence micro herbicides in transplanted rice (*Oryza sativa* L.)" was undertaken during the third crop/ summer season of 2011 –'12. The field experiment was conducted in farmer's field in Kanjirathady padasekharam, Nemom block,Thiruvananthapuram, Kerala. The objective of the study was to assess the bio-efficacy of two post-emergence micro herbicides, *i.e.,* fenoxaprop-p-ethyl and carfentrazone-ethyl in transplanted rice and to work out a suitable and economic weed management strategy. The experiment was laid out in RBD with eight treatments and three replications. The treatments included fenoxaprop-p-ethyl at two doses *viz.,* 60 (T1), and 90 (T2) g ai ha^{-1}, carfentrazone-ethyl at two doses *viz.,* 20 (T3), and 25 (T4) g ai ha^{-1}, the herbicide combination, fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1} (T5), bispyribac sodium @ 30 g ai ha^{-1}(T6), hand weeding at 20 and 40 days after transplanting (DAT) (T7) *i.e.,* farmers' practice and weedy check (T8).

The salient results emanating from the study are summarized in this chapter.

Results of the study revealed that among the weeds, *Echinochloa colona* (L.) Link., *Cyperus difformis, Fimbristylis dichotoma (L.)* Vahl., *Scirpus grossus* L.f., *Limnocharis flava* (L.) Buchenau., *Monochoria vaginalis* (Burm. f.) Presl. Ex Kunth., *Ludwigia parviflora* Roxb., *Ipomoea aquatic* Forsk., *Lindernia rotundifolia* blanc vert ., *Salvinia molesta* D.S. Mitch., *Marsilea quadrifolia* Linn. and *Pistia stratiotes* L.Royle. were the most predominant species in the experimental field. The results indicated the predominance of broad leaved weeds and sedges compared to grasses, in the experimental field.

The study revealed that the dry matter accumulation by weeds could be substantially reduced by all weed management treatments. The herbicide treatments involving carfentrazone-ethyl @ 20 and 25 g ai ha^{-1} and bispyribac sodium @ 30 g ai ha^{-1} and the herbicide mixture fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1} (T5) recorded significantly lower total dry matter production of weeds compared to, hand weeding twice (T7), fenoxaprop- p-ethyl @ 60 and 90 g ai ha^{-1} (T1 and T2) and weedy check (T8). Weedy check registered maximum weed growth throughout the crop growth period. Total dry weight of weeds in this treatment was significantly higher than that in all the weed control treatments.

With respect to weed control efficiency, carfentrazone-ethyl @ 25 g ai ha^{-1} (T4) recorded the highest value (91.39 %) and it was statistically comparable to the lower dose of carfentrazone-ethyl (T3) and bispyribac sodium (T6) and superior to the herbicide combination, fenoxaprop-p-ethyl + carfentrazone-ethyl (T5) and HWT (T7) at 40 DAT. However, at later stages, the herbicide combination also registered comparable values. In general WCE of treatments with respect to grasses, sedges and broad leaved weeds showed that HWT was less effective in controlling all the three types of weeds; fenoxaprop-p-ethyl at both doses were less effective in controlling broad leaved weeds and sedges and it was very effective in controlling grasses when compared to carfentrazone-ethyl at both doses. Carfentrazone-ethyl at both doses were effective in controlling all the three types of weeds, particularly broad leaved ones comparable to bispyribac sodium.

In general, carfentrazone-ethyl @ 25 g ai ha^{-1} recorded lowest absolute density of weeds and it was comparable to carfentrazone-ethyl @ 20 g ai ha^{-1}, bispyribac sodium @ 30 g ai ha^{-1} and the combination, fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}. The weedy check registered the highest weed density during all stages of observation and was significantly inferior to all other treatments.

With respect to nutrient uptake by weeds, all weed management treatments registered significantly lower values compared to weedy check, which recorded the highest nutrient uptake (17.03:11.57:22.50 kg N:P:K ha^{-1}). However, nutrient uptake by weeds was comparatively low for both doses of carfentrazone-ethyl *i.e.*, carfentrazone-ethyl @ 25 and 20 g ai ha^{-1} , bispyribac sodium @ 30 g ai ha^{-1} and the herbicide combination, fenoxaprop- p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}.

Carfentrazone-ethyl @ 25 g ai ha^{-1} and weedy check registered the highest and lowest values for all growth characters *viz.*, plant height, tiller number m^{-2}, and DMP at most of the growth stages. The lower dose of carfentrazone-ethyl @ 20 g ai ha^{-1} which was statastically on par with bispyribac sodium @ 30 g ai ha^{-1} and hand weeding twice also registered comparable values.

Carfentrazone-ethyl @ 25 g ai ha^{-1} (T4) registered the highest value for all the yield attributing characters *viz.*, number of productive tillers per m^{-2}, grain weight $panicle^{-1}$, number of spikelets $panicle^{-1}$, number of filled grains $panicle^{-1}$ and thousand grain weight. The sterility percent was the minimum for this treatment. The lower dose of carfentrazone-ethyl (T3), bispyribac sodium @ 30 g ai ha^{-1} and hand weeding twice also recorded comparable values for all the yield attributes except number of spikelets $panicle^{-1}$, number of filled grains $panicle^{-1}$ and sterility percentage. Thus all the herbicide treatments and HWT effectively improved the yield attributes and yield when compared to weedy check.

There was significant increase in grain yield in all the weed control treatments over weedy check. Among the different treatments, carfentrazone-ethyl @ 25 g ai ha^{-1} (T4) recorded the highest yield (6790) and it was statistically on par with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}) which recorded a grain yield of 6677 kg ha^{-1}. T6 (bispyribac sodium @ 30 g ai ha^{-1}) was the next best treatment with a grain yield of 6401 kg ha^{-1} and it was on par with T3; however, T7 (hand weeding twice) also registered grain yield (6111 kg ha^{-1}) comparable with T6. The herbicide combination,fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1} (T5) was the next best treatment with a grain yield of 5789 kg ha^{-1} and it was on par with T7. The lowest grain yield 3981 kg ha^{-1} was recorded by T8 (weedy check), which was significantly inferior to all other treatments. The percentage increase ingrain yield in T4, T3 and T6 over weedy check were 70.53, 67.70 and 60.79 respectively. The enhanced yield was consistent with the growth characters and yield attributes.

The straw yield also followed a similar pattern as that of grain yield with T4 (carfentrazone-ethyl @ 25 g ai ha^{-1}) recording the highest yield which was statistically comparable with T3 (carfentrazone-ethyl @ 20 g ai ha^{-1}). Comparable straw yield was recorded by T6 (bispyribac sodium @ 30 g ai ha^{-1}) also. However, T6 was on par with T7 (hand weeding twice). Lowest straw yield was recorded by T8 (weedy check), which was significantly inferior to all the weed control treatments.

The yield loss due to weeds was maximum in weedy check as evident from the highest weed index recorded in this plot (42.66 per cent) compared to lower weed indices ranging from 6.03 to 11.98 per cent in the most effective treatments *viz.*, carfentrazone-ethyl, bispyribac sodium and hand weeding twice.

Throughout the crop growth, uptake of nitrogen, phosphorus and potassium by rice plants was the highest in carfentrazone-ethyl @ 25 g ai ha^{-1}. The uptake values of N, P and K in carfentrazone-ethyl @ 20 g ai ha^{-1}, bispyribac sodium @ 30 g ai ha^{-1} and HWT treatments were also comparable.

Economic analysis revealed that the new generation micro herbicide carfentrazone-ethyl at both doses *viz.*, 25, and 20 g ai ha^{-1} gave significantly higher net income and B:C ratio. The highest net income and B:C ratio of Rs. 67833 and 2.03 respectively, were realized by carfentrazone-ethyl @ 25 g ai ha^{-1} and it was statistically on par with carfentrazone-ethyl @ 20 g ai ha^{-1} having net income and B:C ratio of Rs. 65808 and 2.00 respectively. Eventhough bispyribac sodium registered WCE and grain yield comparable to carfentrazone-ethyl (T3), this treatment failed to have comparable net income and B: C ratio because of the high market price of this herbicide. However, net income and B:C ratio (Rs. 58619 and 1.86) of bispyribac sodium treatment was significantly higher than fenoxaprop-p-ethyl at both doses and the treatment combination, fenoxaprop-p-ethyl + carfentrazone-ethyl and HWT. Even though WCE was comparatively high for HWT treatment resulting in better grain yield, net income and benefit cost ratio were comparatively low for this treatment due to the huge expenditure incurred for manual weeding. The weedy check registered the lowest net income and B:C ratio implying the essentiality for weed management in transplanted rice for realizing economic returns.

Dynamics of soil microbial population consequent to the application of the micro herbicides, fenoxaprop-p-ethyl, carfentrazone-ethyl and the herbicide combination, fenoxaprop-p-ethyl + carfentrazone-ethyl revealed that the herbicide caused an inhibitory effect on the growth of fungi and bacteria at the initial stages *i.e.,* 6 days after herbicide spraying (DAS), but there was no change in actinomycetes population compared to weedy check where the rhizosphere was undisturbed.

The present investigation emphasised the superiority of the micro herbicides carfentrazone-ethyl @ 20 and 25 g ai ha^{-1} and bispyribac sodium @ 30 g ai ha^{-1} applied at 20 DAT on weed control efficiency and yield of transplanted rice. However, based on economic analysis carfentrazone-ethyl @ 20 and 25 g ai ha^{-1} applied at 20 DAT could be adjudged as the best treatments for effective weed management in transplanted lowland rice.

Hence, considering weed control efficiency, yield, economics and the minimal application rate, the new generation herbicide carfentrazone-ethyl @ 20 g ai ha^{-1} can be recommended for weed management in transplanted rice.

FUTURE LINE OF WORK

- The present study needs multi locational trials to verify the results.
- A detailed study to find out the changes in weed flora consequent to fenoxaprop-p-ethyl and carfentrazone-ethyl application in the major rice growing tracts of Kerala, under different systems of rice culture.
- A detailed investigation on the dynamics of soil microbial population at varying time intervals, consequent to the use of these new herbicides.
- Study of persistence of the chemical in soil and the factors affecting its degradation.
- A detailed investigation to assess the residue level of fenoxaprop-p-ethyl and carfentrazone-ethyl in plant parts and soil at varying time interval.

- Investigation on the effect of fenoxaprop-p-ethyl and carfentrazone-ethyl on beneficial microorganisms involved in the nutrient transformations in soil.
- A field level study on the effect of fenoxaprop-p-ethyl and carfentrazone-ethyl on major soil borne rice pathogens.

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BIO-EFFICACY OF POST-EMERGENCE MICRO HERBICIDES IN TRANSPLANTED RICE (*ORYZA SATIVA* L.)

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Abstract of the
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ABSTRACT

The study entitled "Bio- efficacy of post-emergence micro herbicides in transplanted rice (*Oryza sativa* L.)" was undertaken during the third crop/ summer season of 2011-'12. The field experiment envisaged in the study was carried out in farmer's field in Kanjirathady padasekharam, in Nemom Block of Thiruvananthapuram district. The objective of the study was to assess the bio-efficacy of two post-emergence micro herbicides, *i.e.,* fenoxaprop-p-ethyl and cerfentrazone-ethyl in transplanted rice and to work out a suitable and economic weed management strategy.

The experiment was laid out in randomized block design with eight treatments and three replications. Two levels each of the new generation herbicides, fenoxaprop-p-ethyl (60 and 90 g ai ha^{-1}) and carfentrazone-ethyl (20 and 25 g ai ha^{-1}) and their combination (fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1}), bispyribac sodium @ 30 g ai ha^{-1}, hand weeding twice (HWT) at 20 and 40 days after transplanting and weedy check constituted the treatments.

A critical analysis of the data clearly pointed out that among the two new generation micro herbicides tested, carfentrazone-ethyl was a broad spectrum one comparable to or even better than the proven and popular new generation herbicide bispyribac sodium in many weed vegetation analysis parameters studied *viz.*, absolute density, relative density, absolute frequency, relative frequency, weed dry weight, weed control efficiency etc. However, fenoxaprop-p-ethyl was observed to be an effective herbicide for grasses. The combination treatment ,*i.e.,* fenoxaprop-p-ethyl @ 60 g ai ha^{-1} + carfentrazone-ethyl @ 20 g ai ha^{-1} also registered comparable values. The two doses of carfentrazone-ethyl tested, *i.e.,* 20 and 25 g ai ha^{-1}, were statistically on par with regard to their effect on the weed control parameters studied.

A perusal of the data on growth attributes of rice clearly indicated the favorable effect of weed management practices on plant height, number of tillers m^{-2} and dry matter production ha^{-1} especially with carfentrazone-ethyl @ 20 and 25 g ai ha^{-1}, bispyribac sodium @ 30 g ai ha^{-1} and hand weeding twice treatments. All the weed management practices significantly improved the yield attributes of rice, *viz.*, number of productive

tillers m^{-2}, grain weight $panicle^{-1}$, number of spikelets $panicle^{-1}$, number of filled grains $panicle^{-1}$ and thousand grain weight compared to weedy check.

The different weed control treatments had significant impact on grain yield and economics also. The higher dose of carfentrazone-ethyl tested *i.e.,* 25 g ai ha^{-1}, recorded the highest grain yield, net income and B:C ratio (6790 kg ha^{-1}, Rs. 67833 and 2.03 respectively) and it was statistically on par with its lower dose of 20 g ai ha^{-1} . However, bispyribac sodium @ 30 g ai ha^{-1} also registered higher grain yield (6401 kg ha^{-1}) comparable to carfentrazone-ethyl @ 20 g ai ha^{-1}; however, this positive effect was not manifested in net income and B: C ratio due to the high cost of this herbicide compared to carfentrazone-ethyl. The lowest yield was recorded by weedy check, which was significantly inferior to all other weed control treatments. Yield loss due to weeds was also maximum in weedy check (42.66 %). Net income and B:C ratio were comparatively low in HWT treatment eventhough yield obtained was substantially high (6111 kg ha^{-1}), due to the high labour cost involved in the treatment.

Study of soil microbial population indicated that there was an initial reduction in the population of bacteria and fungi consequent to the application of the herbicides, compared to weedy check. However no significant change was noticed in actinomycetes population.

Conclusion

Considering the weed control efficiency, yield, economics and minimal application rate, the new generation herbicide carfentrazone-ethyl @ 20 g ai ha^{-1} at 20 DAT can be recommended for weed management in transplanted rice.

സംഗ്രഹം

പറിച്ചു നടുന്ന പാടങ്ങളിൽ പുതിയ ജനുസ്സിൽപ്പെട്ട നിർഗ്ഗമനോത്തര കളനാശിനികളുടെ ഉപയോഗം സംബന്ധിച്ചുള്ള ഒരു പരീക്ഷണം 2011-2012 ലെ മൂന്നാം വിളക്കാലത്ത് നടത്തപ്പെടുകയുണ്ടായി. തിരുവനന്തപുരം ജില്ലയിലെ നേമം ബ്ലോക്കിൽപ്പെട്ട കാഞ്ഞിരത്തടി പാടശേഖരത്തിലെ കർഷകന്റെ കൃഷിയിടത്തിലാണ് പ്രസ്തുത പരീക്ഷണം നടത്തിയത്. പുതിയ ജനുസ്സിൽപെട്ട കളനാശിനികളായ ഫെനാക്സോ പ്രോപ്-പി-ഈതൈൽ, കാർഫെൻട്രാസോൺ ഈതൈൽ എന്നീ കളനാശിനികളുടെ കാര്യക്ഷമത പരിശോധിക്കുകയും നടീൽ കൃഷിക്ക് അനുയോജ്യമായ ഒരു കളനിയന്ത്രണ രീതി ആവിഷ്കരിക്കുകയും ചെയ്യുക എന്നതായിരുന്നു ഈ പരീക്ഷണത്തിന്റെ ഉദ്ദേശം.

പ്രസ്തുത പരീക്ഷണത്തിന് റാംഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന പരീക്ഷണ രീതിയാണ് അവലംബിച്ചത്. എട്ട് കളനിയന്ത്രണ പ്രയോഗങ്ങൾ 3 തവണ ആവർത്തിക്കപ്പെട്ടു. ഫെനാക്സോപ്രോപ്-പി-ഈതൈൽ ഹെക്ടറിന് 60 ഗ്രാം വിഷവസ്തു (T1), ഫെനാക്സോ പ്രോപ്-പി-ഈതൈൽ ഹെക്ടറിന് 90 ഗ്രാം വിഷവസ്തു (T2), കാർഫെൻട്രാസോൺ ഈതൈൽ ഹെക്ടറിന് 20 ഗ്രാം വിഷവസ്തു (T3), കാർഫെൻട്രാസോൺ ഈതൈൽ ഹെക്ടറിന് 25 ഗ്രാം വിഷവസ്തു (T4), ഫെനാക്സോപ്രാപ്-പി-ഈതൈലും (ഹെക്ടറിന് 60 ഗ്രാം വിഷവസ്തു) കാർഫെൻട്രാസോൺ ഈതൈലും (ഹെക്ടറിന് 20 ഗ്രാം വിഷവസ്തു) ചേർന്ന മിശ്രിതം (T5), ബിസ്പൈറിബാക് സോഡിയം ഹെക്ടറിന് 30 ഗ്രാം വിഷവസ്തു (T6), നട്ട് 20-ാം ദിവസവും 40 -ാം ദിവസവും രണ്ടു തവണ കൈകൊണ്ട് കള പറിച്ചുനീക്കൽ (T7), കള നീക്കം ചെയ്യാത്ത വീഡിചെക്ക് (T8), എന്നിവയായിരുന്നു പ്രസ്തുത പഠനത്തിലെ കളനിയന്ത്രണ പ്രയോഗങ്ങൾ.

പഠനവിധേയമാക്കിയ പുതിയ ജനുസ്സിൽപ്പെട്ട രണ്ടുകളനാശിനികളും താരതമ്യപ്പെടുത്തിയപ്പോൾ കാർഫെൻട്രാസോൺ ഈതൈൽ, എല്ലാത്തരം കളകളെയും ഫലപ്രദമായി നിയന്ത്രിക്കുന്ന ഒരു കളനാശിനിയാണെന്നും ഇപ്പോൾ പ്രചാരത്തിലുള്ള പുതിയ ജനുസ്സിലെ ഒരു ബ്രോഡ്സ്പെക്ടം കളനാശിനിയായ ബിസ്പൈറിബാകിനോട് തുല്യമോ അതിലും മെച്ചപ്പെട്ടതോ ആണെന്നും, ഫെനാക്സോപ്രോപ്-പി-ഈതൈൽ തൃണവർഗ്ഗ കളകൾക്ക് വളരെ ഫലപ്രദമായ ഒരു കളനാശിനി ആണെന്നും ബോദ്ധ്യമായി. കളകളുടെ സാന്ദ്രത, ഫ്രീക്വൻസി, ഉണക്കുമ്പോഴുള്ള തൂക്കം, കളനിയന്ത്രണത്തിനുള്ള കഴിവ് എന്നീ ഘടകങ്ങളാണ് പഠന വിധേയമാക്കിയത്. ഫെനാക്സോപ്രോപും കാർഫെൻട്രേസോൺ ഈതൈലും ചേർന്ന കളനാശിനി മിശ്രിതവും കളനിയന്ത്രണത്തിന് ഫലപ്രദമാണെന്നും മനസ്സിലാക്കി. കാർഫെൻട്രാസോൺ

ഈഥൈലിന്റെ പഠനവിധേയമാക്കിയ 2 തോതുകളും (ഹെക്ടറിന് 20 ഗ്രാം വിഷവസ്തുവും 25 ഗ്രാം വിഷവസ്തുവും) കളനിയന്ത്രണത്തിന് ഒരേപോലെ ഫലപ്രദമാണെന്നും കാണപ്പെട്ടു.

നെൽച്ചെടിയുടെ വളർച്ചാ മാനദണ്ഡങ്ങളായ ചിനപ്പുകളുടെ എണ്ണം, ചെടിയുടെ പൊക്കം, ഉണക്കുമ്പോഴുള്ള തൂക്കം ഇവ താരതമ്യപ്പെടുത്തിയപ്പോൾ എല്ലാ കളനിയന്ത്രണ പ്രയോഗങ്ങളും പ്രത്യേകിച്ച് കാർഫെൻട്രോസോൺ ഈഥൈൽ ഹെക്ടറിന് 20 ഗ്രാം അല്ലെങ്കിൽ 25 ഗ്രാം വിഷവസ്തു എന്ന തോതിൽ ഉപയോഗിക്കുന്നത് നെൽച്ചെടിയുടെ വളർച്ച മെച്ചപ്പെടുത്താൻ വളരെ സഹായകമാണെന്ന് കണ്ടു. കളനിയന്ത്രണം നടത്താത്ത പ്ലോട്ടുകളെ അപേക്ഷിച്ച്, എല്ലാ കളനിയന്ത്രണ പ്രയോഗങ്ങളും, ചെടിയുടെ വിളവിന്റെ മാനദണ്ഡങ്ങളായ ഒരു ചതുരശ്രമീറ്ററിലെ കതിരുകളുടെ എണ്ണം, ആയിരം നെൽമണികളുടെ തൂക്കം ഇവ മെച്ച പ്പെടുത്തുന്നതായും ബോദ്ധ്യപ്പെട്ടു.

കൂടാതെ, നെല്ലിന്റെ മെച്ചപ്പെട്ട വിളവിനും നെൽകൃഷിയുടെ ലാഭത്തിനും എല്ലാ കളനിയന്ത്രണ മാർഗ്ഗങ്ങളും വളരെ സഹായകമാണെന്ന് മനസ്സിലായി. ഏറ്റവും കൂടുതൽ അറ്റാദായവും വരവ്–ചിലവ് അനുപാതവും ലഭിച്ചത് കാർഫെൻട്രാസോൺ ഈഥൈൽ 25 ഗ്രാം വിഷവസ്തു ഒരു ഹെക്ടറിന് എന്നതോതിൽ ഉപയോഗിച്ചപ്പോഴാണ്. എന്നാൽ, കാർഫെൻട്രാ സോൺ ഈഥൈൽ 20 ഗ്രാം വിഷവസ്തു ഒരു ഹെക്ടറിന് എന്ന തോതിൽ ഉപയോഗിച്ചപ്പോഴും സാംഖ്യകീയമായി തത്തുല്യമായ അറ്റാദായവും വരവ്–ചിലവ് അനുപാതവും ലഭിക്കുകയുണ്ടായി. കളകൾ മൂലമുള്ള വിളനഷ്ടം 42.66 ശതമാനം ആണെന്നും ബോദ്ധ്യപ്പെട്ടു. എന്നാൽ, താരതമ്യേന മെച്ചപ്പെട്ട കളനിയന്ത്രണവും വിളവും രേഖപ്പെടുത്തിയ, രണ്ടുതവണ കൈകൊണ്ട് കളകൾ നീക്കം ചെയ്ത പ്ലോട്ടുകളിൽ, അറ്റാദായവും വരവ്–ചെലവ് അനുപാതവും താരതമ്യേന കുറവായിരുന്നു. കളനിയന്ത്രണത്തിനു വേണ്ടി വന്ന കൂടിയ കൂലി ചെലവാണ് ഇതിനു കാരണം.

കളനിയന്ത്രണത്തിനുള്ള കഴിവ്, വിളവ്, അറ്റാദായം, ഉപയോഗിക്കേണ്ടി വരുന്ന കളനാ ശിനിയുടെ കുറഞ്ഞ തോത് തുടങ്ങിയ വിവിധ ഘടകങ്ങൾ കണക്കിലെടുക്കുമ്പോൾ, കാർഫെൻട്രാസോൺ ഈഥൈൽ എന്ന പുതിയ ജനുസ്സിൽപ്പെട്ട നിർഗ്ഗമനോത്തര കളനാശിനി, ഹെക്ടറിന്, 20 ഗ്രാം വിഷവസ്തു എന്ന തോതിൽ ഉപയോഗിക്കുന്നത് പറിച്ചു നടുന്ന പാടങ്ങ ളിലെ കളനിയന്ത്രണത്തിന് വളരെ അനുയോജ്യമാണെന്ന് ഈ പഠനത്തിൽ നിന്നും ബോദ്ധ്യപ്പെട്ടു.

APPENDICES

APPENDIX – I

Weather parameters during the experimental period (December 2011-April 2012)

Standard weeks	Maximum temperature (°C)	Minimum temperature (°C)	Max. R.H (%)	Min R.H (%)	Sun shine hours	Rain fall(mm)
48	29.2	23.6	98.4	79.3	7.2	111
49	30.7	22.7	97	64.1	9.3	0.5
50	31	23.8	97.4	67.7	9	10.5
51	30.5	22.7	93.7	59.1	8.4	0.5
52	29.6	20.8	99	65.3	9.3	36
1	30.7	20.8	99	60.4	9.2	0
2	30.3	23	98.6	67.6	9.2	0
3	29.4	19.2	98.1	55.3	9.3	5
4	30.3	19.9	98.7	57.4	9.4	0
5	31.3	21.2	97.1	55.9	9.2	0
6	30.8	23.5	97.6	71.6	8.9	0
7	30.8	22.9	97.7	65.3	9.4	0
8	31.6	21.6	96.4	51.7	9.4	0
9	31.5	23.2	94.3	62.1	9.2	0
10	31.2	24.7	88.6	66.3	9.2	9
11	31.4	21	98.3	69.1	8.9	4
12	32.2	24	93.7	63.6	9.6	0
13	31.2	22.6	95.7	63.1	9.6	9
14	31.4	23.0	95.2	64.2	9.6	1.5
15	31.4	22.9	95.0	63.0	9.9	11
16	31.5	22.9	94.6	62.9	9.3	9

APPENDIX – II

Media composition for Microbial study

1. Nutrient Agar Medium

Sl.No:	Reagents	Quantity
1.	Peptone	5 g
2.	Sodium chloride	5 g
3.	Beef extract	3 g
4.	Agar	20 g
5.	Distlled water	1000 ml
6.	pH	7

2. Kenknight's Agar medium

Sl.No:	Reagents	Quantity
1.	Dextrose	1. 0 g
2.	KH_2PO_4	0. 1 g
3.	$NaNO_3$	0. 1 g
4.	Kcl	0. 1 g
5.	$MgSO_4.7\ H_2O$	0. 1 g
6.	Agar	15. 0 g
7.	Distlled water	1000 ml

3. Martin's Rose Bengal Agar medium

Sl.No:	Reagents	Quantity
1.	Glucose	10 g
2.	Peptone	5 g
3.	KH_2PO_4	1 g
4.	$MgSO_4.7\ H_2O$	0.5 g
5.	Streptomycin	30 mg
6.	Agar	15 g
7	Rose Bengal	35 mg
8.	Distlled water	1000 ml