EVALUATION OF NEW GENERATION HERBICIDES IN TRANSPLANTED RICE (*ORYZA SATIVA* L.)

by

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(2011 - 11 - 157)

THESIS

Submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM – 695 522
KERALA, INDIA

2013

To

My

BelovedParents

DECLARATION

I hereby declare that this thesis entitled **"Evaluation of new generation 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, fellowship or other similar title, of any other University or Society.

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ACKNOWLEDGEMENT

I wish to profoundly thank THE LORD, who kindly provided the energy and enthusiasm through ramifying the paths of thick and thin of my efforts.

I keep searching for adequate words but in vain to express my profound gratitude to my chairperson of the Advisory Committee, Dr. Sansamma George, Professor, Department of Agronomy and Chairman of Advisory Committee, for her learned counsel, unstinted attention, meticulous supervision, constructive criticism, sustained encouragement, and valuable advices throughout the course of this investigation.

I deem it my privilege in expressing my fidelity to Dr. V. L. Geethakumari, Professor and Head, Department of Agronomy and member of Advisory Committee, for her dexterous help, valuable suggestions and assistance during the study.

I sincerely extend my profound gratitude and appreciation to the member of my advisory committee to Dr. Elizabeth. K. Syriac, Professor, Department of Agronomy, for her explicit instructions, affectionate advices and unaccountable help rendered throughout my study.

I cordially offer my sincere and heartfelt gratitude to Dr. Thomas George, Associate Professor Department of Soil Science and Agricultural Chemistry member of advisory committee for his helpful suggestions and guidance in conducting the research work.

I wish to express my deep sense of gratitude to Dr.R. Pushpakumari, Dr. Meerabai, Dr.Sheela.K.R, Dr.Shahul Hhameed, Dr S.Lakshmi, Dr.Kumari Swadiija, Dr.P. Sukumari, Dr.Sajitharani, Dr.Girija Devi.L,Sri.V.Jayakrishnankumar, Dr.Usha.C.Thomas, Smt Sharu, S. faculty members of the Department of Agronomy, for the help rendered in all aspects for my thesis work.

My special thanks to Dr.Shalini pillai, Associate Professor, Department of Agronomy for her motivation and support during the course of the study.

I am highly thankful to Dr. R.V. Manju, Associate Professor, Department of Plant Physiology for her moral support and encouragement throughout my M.Sc(A.g.) programme.

I place on record my sincere gratitude to Sri.C.E. Ajith Kumar, Programmer of the Agricultural Statistics, for rendering his help in the analysis of data.

I express my immense gratitude to, Shibu chetan, Remani chechi,Viji chechi for their sincere and whole hearted co-operation and help during the entire period of my research work.

I thankfully acknowledge my immense gratitude to Raju chetan and Ally chechi for being with me whenever I was in trouble. Without their help this thesis would not have been realized. I pay homage to Late Mr. Reghu who helped me a lot in my field work.

I express my sincere thanks to the Senior and Junior post graduate students of the Department of Agronomy for their help occasionally.

I am extremely thankful to Sri. Ajith Kumar, owner of the rice field for his whole hearted help during the field work.

I wish to express my loving thanks to my classmates Jyolsna, Asha, Cuckoo, Nilu, Akshay and Murugesh.

It is a pleasure to acknowledge the affection and inspiration rendered by my friends, Sudha, Vijay, Ravi G.B, Ravi boli, Maddy, Ashish, Saddam, Dattha, Gajju, Pavan kumar reddy, Rajashekar, Jayanth Reddy, Dharsan, Jayasheela, Lokesh, Ravi kishore for their love, affection, special care and all time pragmatic help and cooperation which helped for my goal setting and spiritual upliftment during my studies and worries.

I express my heartfelt gratitude and thanks to my Divisional Seniors, Srinivas Sir, Siva kumar Sir, Chandu Sir for their continuous assistance for the completion of work.

My special thanks to Harsha Vardhan Reddy, B. for his motivation, moral support, love and affection contributed to during the course of study.

I express my adorable thanks to Nishan chechi for her continuous assistance for the completion of work.

I owe immense gratitude to Kerala Agricultural University for providing KAU Junior Research Scholarship.

Words cannot express what I owe to my beloved, lovable uncle and Aunty K.Pulla Reddy & Smt K.Venkatasubbamma and my sisters Bhagya and Leela Reddy.

Words are not enough to express my whole-hearted and affectionate gratitude to my beloved parents Sri. K. Sreeramulu Reddy and Smt. K. Lakshmamma for their unbounding love, unparallel affection and unstinted encouragement throughout my educational career and without whose invaluable moral support, the thesis would not have seen the light of the day.

Finally, I wish my humble thanks to one and all who have directly or indirectly contributed to the conduct of the study.

RAJAGOPAL, K.

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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.	–	Co-workers/ Co-authers
Fig.	–	Figure
g	–	Gram
$g\ m^{-2}$	_	Gram per square metre
ha	–	Hectare
HI	_	Harvest index
HW	_	Hand Weeding
$hill^{-1}$	_	Per hill
i.e.	–	That is
K	–	Potassium
KAU	_	Kerala agricultural university
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}	–	Tons per hectare
viz.	–	Namely
WCE	_	Weed Control Efficiency

LIST OF SYMBOLS

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

Introduction

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of more than a half of the world population. India is the second largest producer of rice after China and being the staple food, rice plays vital role in India's economy occupying a central position in shaping the agricultural policy (Dangwal *et al*., 2011). However, the average per hectare yield of paddy in India is less than that of many other countries. The alarming population growth in India which is expected to touch 1.5 billion mark by 2025 AD and more than 2 billion by the end of the century warrants further increments in per hectare yield of rice on a sustained basis. The area expansion under rice being ruled out, the only option left with is the optimum resource utilization.

Among the various factors responsible for low rice productivity, weeds are considered to be one of the major limiting factors due to their manifold harmful effects (Singh *et al*., 2009). Weeds grow profusely in the rice fields and reduce crop yields drastically. They compete for one or more plant growth factors such as water, mineral nutrients, solar energy and space and the factors excluding water are found to be limiting in wetland situations. Normally the yield loss due to weeds in transplanted rice ranges between 15-20 per cent but in severe cases it can be more than 50 percent depending upon the species and intensity of weeds as well as the control methods practiced by the farmers.

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.

Recent trend in herbicide use is the low dose high efficacy herbicides which will not only reduce the total volume of herbicide use but also the application become easier and economic (Kathiresan, 2001). These new-generation herbicides are applied at very low doses with less environmental persistence and exceedingly low toxicity to non-target organisms. Sulfonylureas represent one of these new generation herbicides with 27 different active ingredients currently registered around the world. According to Samanta *et al*. (2010), sulfonylurea (SU) based products are helping farmers around the globe to meet their weed control needs in effective and environmentally sound ways and is one of the most important advances in crop protection technology in the 21st century. The rapid and good acceptance of SUs is reported to be due to high crop selectivity, broad spectrum weed control with low application rates and very low acute and chronic mammalian toxicities (Brown, 1990). Their mechanism is related to the inhibition of aceto lactate synthase (ALS), a key enzyme essential for the biosynthesis of valine, leucine, and isoleucine that is necessary for protein synthesis leading to the rapid cessation of plant cell division and growth. The targeted enzyme is absent in animals and humans (Hay, 1990).

Among the new generation herbicides, both pre emergence as well as post emergence molecules are commercially available. The pre emergence herbicides have the obvious advantage of early season weed control while the post emergence herbicides are becoming popular since their use can be tuned to the actual weed infestation level. Saha (2006) has reported that all the new generation herbicides he tested recorded better weed-control efficiency in comparison with the traditional recommended rice herbicides and gave higher yield of rice irrespective of their dose of application. It is reported that sulfonylurea herbicides are characterized by broad spectrum weed control with broad window of application (3-20 DAT) and an environmental advantage deriving from their very low application rates which markedly reduce the "chemical load" in the environment. Therefore, evaluation of these newer herbicide molecules for the control of the wide spectrum of weed flora in rice is imperative for dealing with the weed problem in rice effectively on a sustainable basis.

In this background, the present investigation was undertaken with following objectives.

1. To evaluate the weed control efficiency of two new generation herbicides *i.e.*,bensulfuron methyl + pretilachlor (combination herbicide) and azimsulfuron in transplanted rice

2. To assess their selectivity and influence on growth and yield of rice

3. To assess the economic feasibility

Review of Literature

2. REVIEW OF LITERATURE

Among the various weed management techniques, herbicide technology offers an easier, quicker and cheaper alternative to traditional hand weeding. But, continuous and indiscriminate use of herbicides is reported to have serious limitations. Of late, low dose high efficacy herbicides have been found promising in rice cultivation. In this chapter, an attempt has been made to review the available literature on weed problem in rice and the efficiency and use of these new generation herbicides.

2.1 WEED FLORA IN WETLAND RICE ECOSYSTEM

Terrestrial, semi aquatic and aquatic plants depending on the type of rice culture and season colonize rice fields (Moody and Drost, 1983) and they can be classified as grasses, sedges and broad-leaved weeds. As many as 350 species in more than 150 genera and 60 families have been reported as weeds in rice (Smith, 1983).

According to Abraham *et al*. (1990) the occurrence of weeds varied with season and methods of sowing in rice. Kuyeonchung *et al*. (2002) also opined that weed diversity and species were strongly affected by the cultivation methods. Changes in cultivation methods resulted in wide variation in species composition and diversity (Tomita *et al*., 2003).

According to Chopra and Chopra (2003) sedges, broad leaved weeds and grasses consisted of 44.5, 44.4 and 11.1 per cent respectively of total weed flora. Ahmad *et al*. (2004) reported that the most problematic weeds in rice were *Echinochloa crusgalli, Echinochloa glabrescens, Echinochloa colona, Cyperus rotundus, Cyperus difformis, Cyperus iria, Cyperus maritimus, Paspalum distichum, Eleusine indica,* and *Marsilea minuta.* Grasses constituted 9.5 per cent, sedges 57.2 per cent and broad leaved weeds 33.3 per cent of the total weed population at 30 days stage of wet direct sown summer rice (Saha, 2006).

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

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. The result highlighted the weed floristic diversity in the wetland ecosystems of Kerala state.

2.2. CROP-WEED COMPETITION IN RICE

Crop plants vary greatly in their ability to compete with associated weeds and the total effect of interference as reflected in the crop growth and yield, results from competition for nutrients, moisture and sunlight. Crop weed competition is complicated because various factors affect the extent to which it occurs and the degree of weed competition is determined by the weed species infesting the area, density of infestation and duration of infestation (Rao, 2000). Weed emergence in relation to crop emergence is an important factor in weed-crop competition (Abdul *et al*., 2009)

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). Umapathi *et al.* (2000) observed that, grasses were the most competitive in rice, followed by sedges and least competitive were the broad leaved plants. Gealy *et al*. (2003) found that Asian rice cultivars were better competitors with good weed suppressing qualities.

2.2.1 Competition for nutrients

Shetty and Gill (1974) observed that crop-weed competition for nutrient was maximum during early period of crop growth and competition for soil nitrogen was maximum during 6 to 8 weeks after transplanting. Weeds were found better in nitrogen uptake while the rice was more efficient in absorbing phosphate and potash from the soil.

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 (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).

In transplanted rice, the nutrient depletion by weeds was estimated to be 10.9, 2.6 and 9.8 kg ha^{-1} of N, P_2O_5 and K_2O respectively (Bhan and Mishra, 1993). Nandal and Singh (1993) reported an increase in the nutrient uptake of rice in weed control treatment. Singh *et al*. (1999) reported that weed free condition resulted in lower uptake of nitrogen by weeds. Rajan (2000) reported that N, P_2O_5 and K_2O uptake by weeds at harvest were 8.53, 4.18 and 9.26 kg ha^{-1} in weedy check.

2.2.2. 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, 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 factor 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).

2.2.3 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 crus-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).

Generally, weeds grow faster and shade the crop plants, if not checked. Even in case of shorter weeds, the lower leaves of crops are shaded by them. Weeds deplete the photosynthetically active radiation resulting in reduction in photosynthesis and shortening the life of lower leaves (Reddy and Reddy, 2008).

A change in light quality due to the presence of canopy cover can affect the development of shaded plants through phytochrome mediated process (Ballare *et al*., 1990). 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 photosynthesis due to the developing grains.

The light transmission ratio was lower in *Echinochloa crus-galli* L. and *Ammania* sp. as compared to rice which decreased shoot, 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.

Hua *et al*. (2000) observed that at closer spacing light penetration of the canopy decreased. Lower PAR penetration in treatments of denser plant population in rice was also reported by Ghuman *et al*. (2008) who studied the role of plant geometry on weed management in transplanted rice. They also reported that unweeded check recorded significantly lesser PAR penetration than pretilachlor treated plots. This might be due to more ground coverage and more LAI of weeds.

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 is affected the weed biomass production and it was highest with lower plant population (Ghuman *et al.*, 2008).

Increased seeding rates and altered plant spatial arrangement to improve crop competitiveness have been proposed and tested as a component to weed management strategies in cereals (Kristensen *et al*., 2008).

Crop row spacing did not influence plant height of *Echinochloa colona* and *Echinochloa crus-galli*, but the height of both species was influenced by their emergence time in the field. *Echinochloa colona* 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 Critical periods of weed competition in transplanted rice

The critical period is one of the important alternative weed management strategies in order to minimize the labour requirement for weeding operations, enhance the efficiency of herbicide use and maximize economic returns (Abdul *et al.*, 2009).

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. 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).

Weeds are as competitive as rice plants in absorbing nutrients at the most critical periods of growth of rice and weeds perform better than rice under deficient situations (Renjan, 1999). Singh *et al.* (1999) reported that mean grain yield was highest in when weeds were up to 60 days after transplanting. Presence of weeds for the entire crop season reduced the grain yield by about 37 per cent (Bhowmick, 2002). According to Dhammu and Sandhu (2002), weedy condition up to the 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. Maximum reduction in rice yield (35.2 per cent) was observed by delaying *C. iria* removal from 30 to 40 DAT, indicating this period as the most critical period of *C. iria* competition in transplanted rice. The increase in yield attributing characters in rice may be attributed to better crop growth owing to decreased weed competition during critical growth stages and increased nutrient supply (Gopinath and Pandey, 2004).

Sagittaria sp. density of 2.5 plants m^{-2} emerging 15 and 30 days after rice emergence decreased rice yield by 8 and 4 per cent respectively compared to a 30 per cent reduction in yield when *Echinochloa crus–galli* emerged with rice (Filizadeh *et al.*, 2004).

Zhang *et al.* (2003) observed that effective weed control up to 6 weeks after emergence of rice crop was important in fields with high weed densities. According to Johnson *et al*. (2004) critical period of weed competition in rice was between 29 – 32 days after sowing. Mukherjee *et al*. (2008) observed that critical period of weed crop competition in transplanted and wet seeded rice was from 20 to 40 DAT and 15 to 60 DAS, respectively. They also observed that the most decisive period in the growth of rice crop was at 40 DAT.

The rice crop recorded the higher plant height (70.63 cm) and dry matter accumulation (1289 g m^{-2}) in weed free plots due to better growth of plants on account of reduced weed competition at critical crop growth stages, resulting in increased availability of nutrients, water and light (Bhat *et al.*, 2008). Normally the loss in yield ranges between 15 – 20 per cent. Yet, in severe cases the yield losses can be more than 50 per cent depending upon the species and intensity of weeds (Hasanuzzaman *et al*., 2009).

Uncontrolled weeds cause a reduction of 35–45 per cent grain yield under transplanted condition (Gupta and Sharma, 2010). The declining productivity through weeds accounts 30 – 50 per cent of grain yield and weed competition usually occur in early stages of crop growth (Nagarajan and Chinnusamy, 2010).

2.3. Effect of weed competition on yield attributing characters and yield

Weeds are considered to be one of the dreaded groups of agricultural pests known to cause direct yield losses to the tune of 100 per cent, when weed pressure is severe at early stages of rice crop growth (WARDA, 1976). Reduction in crop yield due to weeds results from their multifarious ways of interfering with crop growth and culture and weed competition can lower rice grain yield to the extent of 62.6 per cent (Gopinath and Pandey, 2004). Mukherjee *et al*. (2008) estimated that the extent of yield reduction in rice was to the tune of 57 - 61 per cent in transplanted rice and 64 - 66 per cent in wet seeded rice.

Radosevich and Roush (1990) reported that crop plants under competitive stress produced fewer tillers and fewer panicle bearing tillers. Bajapai and Singh (1992) reported that rice crop under unweeded control plots produced lowest number of effective tillers and panicle length.

Mabbayed and Moody (1992) reported that reduction in tiller number, panicle length, thousand grain weight and crop growth rate, delayed ripening and reduced light transmission were noticed due to weed competition in rice. The reduction in panicle number due to weed competition was to the extent of 24 – 38 per cent spikelet panicle^{-1}, spikelet fertility by 6 - 8 per cent and thousand grain weight by 6 - 11 per cent in rice at Palampur during rainy seasons as reported by Angiras and Rano (1998).

The infestation of *Echinochloa crus-galli* significantly decreased productive tillers, crop biomass and grain yield as compared to weed free plots and its effect in decreasing the ear length, filled grain and thousand grain weight was more compared to *Echinochloa colona* (Paradkar *et al*., 1998). The lowest number of panicles per plant, panicle length and number of grains per panicle in the unweeded control treatment was due to suppressed crop growth due to maximum weed growth in unweeded control (Sangeetha *et al*., 2009).

Weed free conditions produced more productive tillers and fertile grains per panicle, compared to weed density of 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.,* 2003).

Weed competition is one of the prime yield limiting biotic constraints resulting into yield reduction of 28-45 per cent (Singh *et al*., 2003). 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 30-100 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 per cent) in transplanted rice (Singh *et al*., 2011).

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

2.4 WEED MANAGEMENT PRACTICES

2.4.1 Hand Weeding

Hand weeding is the most common and effective method of weed control in rice but it is becoming difficult and uneconomical day-by-day due to high wages and non availability of labours at peak period of farm operation (Singh *et al*., 1999).

Hand weeding is generally not a very efficient method. Probably 10-20 per cent or more of the plants with 10 cm or more growth is left in the field after weeding. On an average the efficiency of this method is not more than 70 per cent (Moody, 1998).

Prasad *et al*. (2001) reported that manual weeding in transplanted rice gave the highest values for number of tillers, panicles, filled grains, thousand grain weight, grain and straw yield. Higher weed control efficiency (100 per cent) and lower weed index (0 per cent) values were recorded under the treatment of hand weeding twice followed by anilofos + ethoxysulfuron (67.5 and 7.1 per cent), butachlor (64.1 and 8.6 per cent) and butachlor + almix (64.6 and 11.0 per cent) than other treatments (Bhanurekha *et al.*, 2003). Halder and Patra (2007) observed that in order to realize maximum benefit of applied monetary inputs, two to three hand weedings are essential. In another study it was observed that hand weeding at 20 and 40 DAT treatment significantly reduced the weed density and dry matter (irrespective of summer ploughing) over the rest of the weed control treatments (Rao *et al.*, 2007).

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. 4.2Chemical weed control

With the explosive increase in labour cost and difficulty in labour availability, rice farmers have started replacing manual weeding with herbicide use. Despite the obvious advantages of herbicides, their use has raised concerns relating to human health and the environment**.** Hence there is a need for identifying alternative herbicides to give options to the farmers which will not only reduce the total volume of herbicide use but also, the application become easier and economic (Kathiresan, 2001). Adigun *et al*. (2005) reported that application of herbicides before blossoming had effect on weeds control and increased the performance of rice. Akbar *et al*. (2011), Jayasuria *et al.* (2011) and Khaliq *et al*. (2011) have also reported that herbicides were effective for weed management in rice.

2.4.2.1. New generation herbicides

Recently, a number of low dosage high efficacy herbicides coming under sulfonylurea group have been found to be suitable alternatives to the old herbicides (Karim *et al*., 2004). Sulfonylureas represent one of the largest classes of herbicides with 27 different active ingredients currently registered around the world. These are helping farmers around the globe meet their crop protection needs in effective and environmentally sound ways.

The rapid acceptance of SUs was due to high crop selectivity, broad spectrum weed control with low application rates and very low acute and chronic mammalian toxicities (Brown, 1990). Sulfonylureas continue to be a crucial component of crop protection methodologies legacy as one of the most important advances in crop protection technology in the 21st century (Samanta *et al*., 2010).

The inhibitory mechanism of sulfonyl ureas is related to the inhibition of acetolactate synthase (ALS), a key enzyme essential for the biosynthesis of valine, leucine and isoleucine that is necessary for protein synthesis leading to the rapid cessation of plant cell division and growth which is absent in animals and humans. Sulfonyl ureas are noted for their high specific activity, which is reflected in the very low application rates required to obtain economic levels of weed control (Samanta *et al.,* 2010). Low use rates of these new generation herbicides have allowed farmers to achieve higher yields while applying 95 - 99 per cent less herbicides to their crops (Kathiresan, 2001).

Soil and foliar performance of sulfonylurea herbicides are influenced by many environmental factors such as soil type, rainfall, humidity, temperature, light, soil moisture, and wind (Green and Strek, 2001). Samanta *et al. (*2010) observed that weather conditions can influence sulfonylurea herbicides before during, and after application.

Saha (2006) reported that all the new-generation herbicides he tested showed better control of weeds (weed-control efficiency 79.9–95.1%) in comparison with the traditional recommended rice herbicides (weed-control efficiency 73.3–78%) and gave higher yield of rice irrespective of their dose of application.

2.4.2.1.1 Azimsulfuron

Azimsulfuron, is a new promising post-emergent, sulfonamide herbicide that selectively controls a wide range of weeds in lowland rice (Valle *et al*., 2006). There was no phyto-toxicity of azimsulfuron on rice and also there was no residual toxicity on the succeeding crop of wheat. (Yadav *et al.,* 2008).

Nishan (2012) who worked on management of water cabbage *(Limnocharis flava* (L.) Buchenau) observed that in plants treated with azimsulfuron, visual symptoms of phytotoxicity were observed by the 3rd day of herbicide spraying. Yellowing of leaves was the earliest visual symptom in 2-3 leaf stage plants while symptoms started as intervienal chlorosis in older plants. By the 5th day the affected plants started decaying, wherein the leaf petiole got separated out and by 7th day the entire plants including the roots turned into an undistinguishable mass and were self incorporated into the wetland soil.

Shiracura *et al.* (1995) stated that azimsulfuron applied at very low doses of 6 to 25 g ai ha^{-1} registered excellent control of perennial weeds, whereas higher concentrations are needed to control annual weeds. According to Yadav *et al*. (2007) azimsulfuron is a new herbicide for post-emergence weed control in transplanted rice; however, its efficacy against sedges has been found excellent but not as good against broad leaved weeds.

Yadav *et al.* (2008) observed excellent control of broad leaved weeds and sedges (90–100 per cent) under all the treatments of azimsulfuron (10-30 g ai ha^{-1}) alone or almix with metsulfuron. They have also reported that azimsulfuron and metsulfuron being safe for rice crop were compatible and post emergence application of azimsulfuron alone or in combination with metsulfuron methyl efficiently controlled broad leaved weeds and sedges (90-100 per cent) in transplanted rice. They concluded that azimsulfuron @ 30 g ai ha^{-1} applied at 15 DAT could be most suitable treatment against complex weed flora pre dominated by sedges in transplanted rice.

Ravi *et al.* (2010) reported that azimsulfuron @ 25–30 g ai ha^{-1} applied 25 days after sowing effectively controlled broad leaved weeds while azimsulfuron alone or tank mixed with almix was not effective against grasses.

Jayadeva *et al.* (2009) reported that azimsulfuron @ 35 g ai ha^{-1} applied at 19 DAT recorded significantly lower dry weight of grasses, sedges and broadleaved weeds but the highest grain and straw yield was under azimsulfuron @ 30 g ai ha^{-1}. In another field study, Pacanoski and Glatkova (2009) observed that azimsulfuron gave excellent control of annual and perennial weeds in direct sown rice.

Jayadeva *et al.* (2010) reported that application of azimsulfuron @ 27.5 - 30 g *ai* ha^{-1} combined with metsulfuron methyl @ 2 g *ai* ha^{-1} + 0.2 per cent surfactant was found most effective in controlling weeds in transplanted rice.

Azimsulfuron @ 25 g ai ha^{-1} or ethoxysulfuron @ 15-18 g ai ha^{-1} post emergence application was found effective to control broadleaf weeds and sedges in direct sown rice. These herbicides need saturated soil conditions for better actions. Azimsulfuron is particularly very effective on *Cyperus rotundus (*Gopal *et al.*, 2010).

Application of azimsulfuron @ 30 g *ai* ha^{-1} + 0.2 per cent non-ionic surfactant applied at 19 DAT followed by one hand weeding at 40 DAT recorded significantly lower total weed density and total weed dry weight and was found to be superior in producing higher grain and straw yield of transplanted rice by effective control of weeds (Jayadeva *et al.,* 2011).

2.4.2.1.2 Bensulfuron methyl + pretilachlor

Pretilachlor is a selective herbicide introduced for the control of broad leaved weeds and sedges in transplanted rice and direct seeded rice (Vidotto *et al.,* 2004). Mode of action of pretilachlor is by inhibition of cell division and protein synthesis. Application of pretilachlor @ 0.75 kg ai ha^{-1} as pre-emergence proved to be very effective in reducing weed dry matter and increasing grain yield up to a significant level as compared to unweeded check (Ghuman *et al.,* 2008)

There was marginal increase in grain yield due to tank mixing of pretilachlor (450 g ai ha^{-1}) with bensulfuron methyl at 40 and 50 g ai ha^{-1} over the application of bensulfuron methyl alone at 50 and 60 g ai ha^{-1}. Saha and Rao (2010) reported that bensulfuron-methyl alone @ 60 g ai ha $^{-1}$ or as tank mixture with pretilachlor (50+450 g ai ha^{-1}) applied at 20 DAS were found to be equally effective in controlling weeds (weed control efficiency 90.0 and 92.2 per cent, respectively) and produced comparable grain yield. They observed that bensulfuron methyl + pretilachlor (30 +450 g ai ha^{-1}), bensulfuron methyl +pretilachlor (40 +450 g ai ha^{-1}), and bensulfuron methyl + pretilachlor (50 + 450 g ai ha^{-1}) recorded weed control efficiency of 85.9, 88.7,and 92.2 per cent and yield 5.17, 5.39, and 5.53t ha^{-1} respectively. They concluded that application of bensulfuron-methyl either alone at 60 g ai ha^{-1} and tank mixture of bensulfuron methyl+ pretilachlor at relatively lower dose of 50 +450 g ai ha^{-1} proved to be effective for wide spectrum weed control in wet direct-sown rice during dry season.

Sunil *et al*. (2010) reported that pre-emergence application of bensulfuronmethyl + pretilachlor (6.6 GR) @ 6+60 g ai ha^{-1} + one inter cultivation at 40 days after sowing recorded significantly higher grain and straw yield, lower weed population and dry weight. Further the net returns and B: C ratio were also high.

2.4.2.1.2. Herbicide transformation and residual effect

In the environment, sulfonylurea herbicides are mainly decomposed by microbial degradation (Beyer *et al.,* 1988) and chemical hydrolysis (Sarmah and Sabadie, 2002). Some recent reports suggest that photolysis may be an alternative pathway to hydrolysis (Vulliet *et al.,* 2004). Chemical hydrolysis is pH and temperature dependent. In most cases the degradation is faster at high temperature in acidic rather than in neutral or in weakly basic conditions (Boschin, 2007).

However, depending on environmental conditions, sulfonylureas or their metabolites may persist excessively in the environment with a residual phytotoxicity. They can also reach the aquifer (Battaglin *et al.,* 2000).

Barefoot *et al.* (1996) reported that azimsulfuron was more persistent at neutral and basic pH than in acidic conditions with a half life of 70–120 days. In soil and water, indirect photolysis and microbial activity were considered as the most important azimsulfuron degradation mechanisms. The highest levels of sorption had been observed in soil at low pH values and with high organic carbon or clay content (Pusino *et al.,* 2004).

2.4.2.2 Effect on soil microbial population

Population size of microorganisms serves as bioindicators of the impact of herbicide application in the agro-ecosystem (Milosevic and Govedarca, 2002).

Enhancement of microbial population in herbicide treated plots was reported earlier by Radosevich *et al.* (1995) who observed that the herbicides and their metabolites as sources of biogenous elements resulting in increased population. Valle *et al.* (2006) observed that the soil treated with azimsulfuron had a higher number of bands than the control profiles. Positive effect of herbicide treatment on soil microbial population in wetland rice ecosystem was reported by Sreethu (2011) and according to her, the presence of decayed weed biomass in the herbicide treated plots probably had triggered the microbial flora. Nishan (2012) also reported an enhancement in the count of bacteria and fungi in wetlands treated with azimsulfuron as well as metsulfuron methyl + chlorimuron ethyl.

Allievi and Gigliotti (2001) reported an inhibition in the growth of nitrifiers and azotobacter species with sulfonyl ureas whereas El-Ghamry *et al.* (2002) reported that at field rates of (2–100 g ha^{-1}), and even at higher concentrations, sulfonylurea herbicides did not affect the total number of bacteria.

According to Valle *et al.* (2006) azimsulfuron treatment had the ability to cause changes in the bacterial community structure that are detectable by Dgge analyses. It was easily biodegraded both in microcosms and in batch tests, with the formation of an intermediate that was identified as 2-methyl-4-(2-methyl-2h-tetrazol-5-yl)-2h-pyrazole-3-sulfonamide.

Materials and Methods

3. MATERIALS AND METHODS

Field experiments were carried out to evaluate the weed control efficiency of two new generation herbicides, *i.e.*, bensulfuron methyl + pretilachlor and azimsulfuron in transplanted rice. The materials used and the methods adopted during the investigation are presented in this chapter.

3.1 Site description

The investigations were conducted in a farmer's field viz., Kanjirathadi padasekharam, in Nemom Panchayath, Thiruvananthapuram district, Kerala state, located at 8.5º N latitude and 76.9º E longitude at an altitude of 29 m above mean sea level (MSL).

3.1.1 Climate and season

The experimental site experiences warm humid tropical climate. The experiment was conducted during the puncha season, i.e., December 2011 to April 2012. The data on various weather parameters, viz., weekly rainfall, maximum and minimum temperature, relative humidity and sun shine hours during the period are presented in Appendix- 1 and graphically represented in Fig.1.

3.1.2 Soil

Soil samples were collected prior to the experiment 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 clayey and the taxonomical order is Oxisol. The soil pH was 6.1 and it was low in cation exchange capacity (CEC), high in organic carbon, available P and medium in available N and K content.

3.1.3 Cropping history of the experimental site

The experimental site selected was under continuous rice cultivation for the past three years.

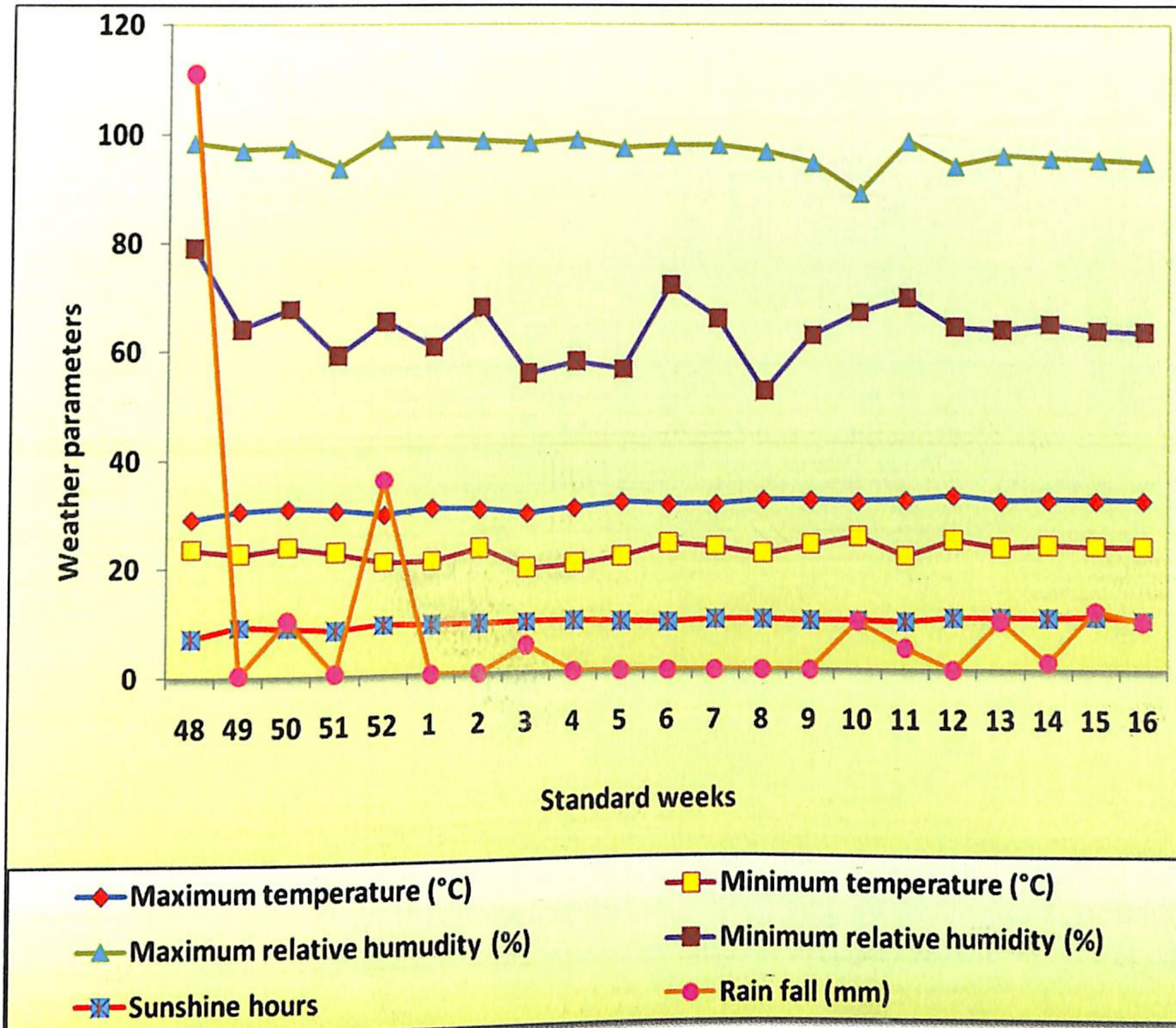

Fig .1 Weather data during the crop period (December 2011-April 2012)

Table 1. Physico-chemical properties of soil at experiment site

Parameters	Content	Status	Methodology
A. Mechanical composition			
Coarse sand (%)	47.65		Bouyoucos Hydrometer method (Bouyoucos,1962)
Fine sand (%)	10.90		
Silt (%)	9. 05		
Clay (%)	32.40		
Texture		Sandy clay loam	
B. Chemical properties			
Soil reaction (pH)	6.1	Slightly acidic	1:2.5 soil solution ratio using pH meter (Jackson, 1973)
CEC (cmol/kg)	14.65	low	Ammonium saturation using neutral normal ammonium acetate (Jackson, 1973)
Organic carbon (%)	1.16	High	Walkley and Black's rapid titration (Jackson, 1973)
Available N (kg ha^{-1})	536.5	Medium	Alkaline permanganate method (Subbaih & Asija, 1956)
Available P_2O_5 (kg ha^{-1})	27.3	High	Bray colorimetric method (Jackson, 1973)
Available K_2O(kg ha^{-1})	196.1	Medium	Ammonium acetate method (Jackson, 1973)

Plate 1. General view of the experimental field

3.2 Materials

3.2.1 Crop and variety

The rice variety used for the experiment was *Uma*, the most popular rice variety of the state developed by Rice Research Station, Moncompu, Kerala (MO6 X Pokkali (Pedigree selection, 1998). Dwarf, medium tillering, non lodging, resistant to BPH, GM Biotype-5 and other major pests. Dormancy up to 3 weeks. Suited to three seasons especially to additional crop season of kuttanad. Medium duration variety.

3.2.2 Manures and fertilizers

Well decomposed dry cow dung containing 0.55 per cent N, 0.23 per cent P_2O_5 and 0.46 per cent K_2O was used as the organic manure source. N, P and K were applied as urea (46 per cent N), factomphos (20 per cent N and P_2O_5) and muriate of potash (60 per cent K_2O), respectively.

3.2.3 Herbicides

The technical information, toxicity data and other available information of the herbicides azimsulfuron and bensulfuron methyl+pretilachlor are given in Table 2.

3.3 Methods

3.3.1 Design and Layout

Design	:	Randomised Block Design
No. of treatments	:	8
Replication	:	3
Plot size	:	5 m X 4 m

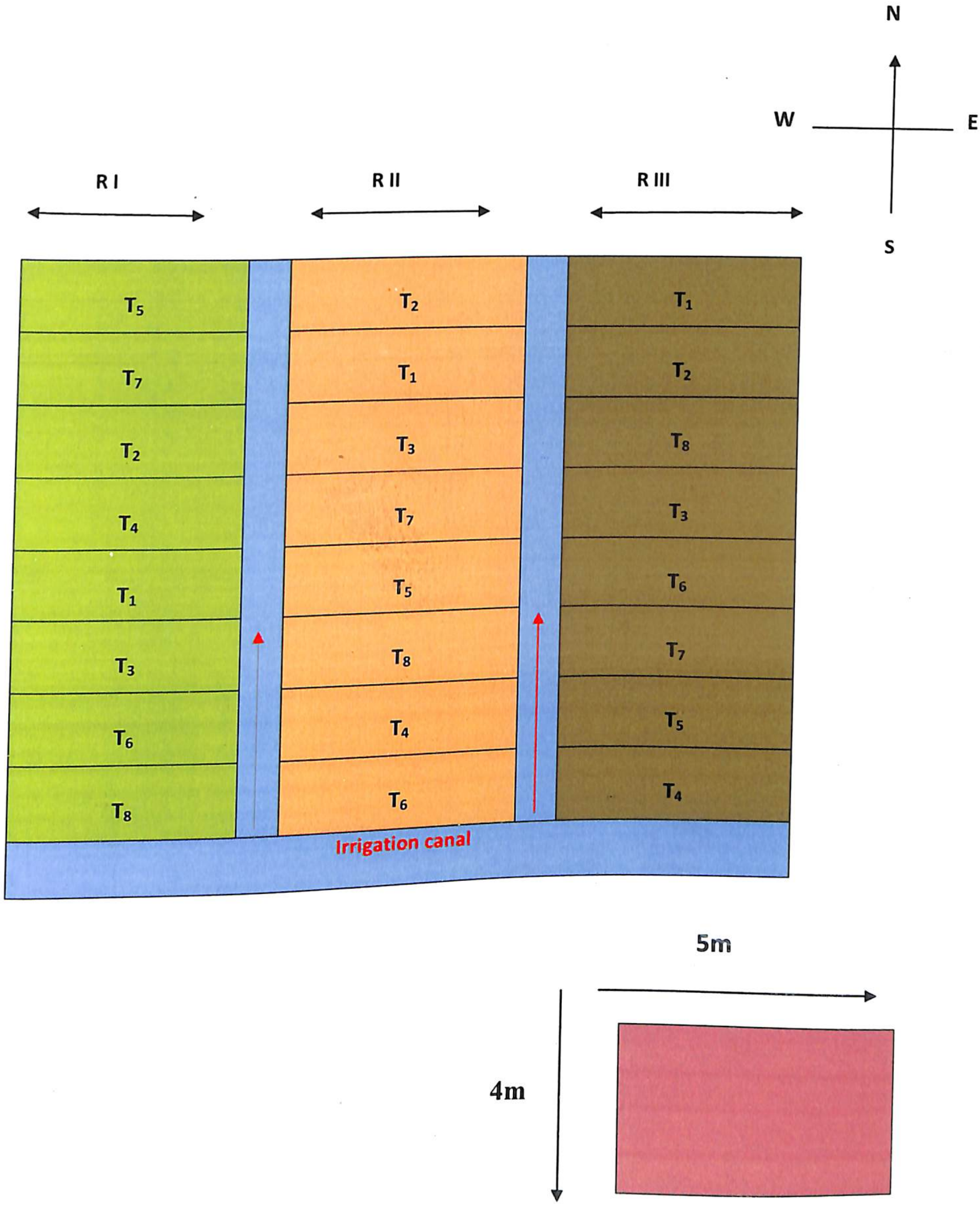

Plate 2. Lay out plan of the field experiment

Table 2. Technical information of herbicides

Common name	Bensulfuronmethyl+ pretilachlor	Azimsulfuron
Trade name	Londax Power	Segment
Chemical name	Methyl α- (4,6 – dimethoxypyrimidin – 2 ylcarbamoylsulfamoyl)-o-toluate +2-chloro-N-(2,6-diethylphenyl)-N-(2-propoxyethyl)acetamide.	1-(4,6-dimethoxypyrimidin-2-yl)-3-[1-methyl-4-(2-methyl-2*H*-tetrazol-5-yl)pyrazol-5-ylsulfonyl]urea
Formulation	0.6%+6% GR	50% Dry flowable (DF)
Molecular weight	410.4+311.9 $gmol^{-1}$	424.4 $gmol^{-1}$
Physical state, colour,odour	Free flowing granules, Light brown, No appreciable odor	White powdered solid with a phenolic odour
Acute oral toxicityLD_{50} (Rats)	>5000 $mgkg^{-1}$	>5000 $mgkg^{-1}$
Acute dermal toxicity (Rats)	>2000 $mgkg^{-1}$	>2000 $mgkg^{-1}$
Price	Rs. 690 /4kg	Rs.960 /28 g
Manufacturer	DuPont	DuPont

3.3.2 Treatments

T_1- (Bensulfuron – methyl + pretilachlor) @ 45+450 g ai ha^{-1}

T_2 - (Bensulfuron – methyl + pretilachlor) @ 60+600 g ai ha^{-1}

T_3- (Bensulfuron – methyl + pretilachlor) @ 75+750 g ai ha^{-1}

T_4- Azimsulfuron @ 25 g ai ha^{-1}

T_5 - Azimsulfuron @ 30 g ai ha^{-1}

T_6- Azimsulfuron @ 35 g ai ha^{-1}

T_7 – Hand weeding at 20 and 40 days after transplanting

T_8 – Weedy check

Bensulfuron – methyl + pretilachlor (pre emergence herbicide) was applied on the next day of transplanting and azimsulfuron (post emergence herbicide) was applied 18 days after transplanting (DAT).

3.3.3 Crop management

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

3.3.3.1 Nursery

The land was puddled and leveled thoroughly and pre germinated seeds were sown in the nursery @ 80 kg ha^{-1}. The nursery area was ploughed thoroughly after the application of FYM @ 1 kg m^{-2} to raise beds of 5 to 10 cm height and 1 to 1.5 m width and of convenient length. Water was drained for 9 hours once in 5 days to encourage production of vigorous seedlings. Bird scaring was carried out for seven days initially.

3.3.3.2 Main field preparation

The experimental area was puddled twice and leveled. Weeds and stubbles were removed by hand picking. Three blocks with eight plots each were laid out in randomized design. The blocks were separated with channels of 60 cm width. Each experimental plot was of 5 X 4 m^2 size and there were 24 plots for the experiment.

3.3.3.3 Application of manures and fertilizers

Cow dung was incorporated at the time of last ploughing. Full dose of phosphorus along with half dose of nitrogen and potassium were applied as basal dose. Top dressing of the remaining dose of chemical fertilizers was carried out at 45 days after transplanting (DAT) as per the Package of Practices Recommendations ‘Crops’ (KAU, 2011).

3.3.3.4 Application of lime

Lime @ 600kg $ha^{-1}$was applied in two split doses viz., just after the second tillage and at tillering stage.

3.3.3.5 Transplanting

Twenty days old seedlings were transplanted and the water level was maintained at about 1.5 cm during transplanting. Thereafter, the water level was increased gradually to about 5cm and the water level was maintained at 5 to 10 cm throughout the growth period except when drained for fertilizer application. Field bunds were strengthened as and when necessary.

3.3.3.6 Weed management

Herbicide solutions were prepared in water as per the treatments and sprayed with pneumatic sprayer. Care was taken to ensure uniformity in spraying and to avoid drift .Hand weeding was done at 20 and 40 DAT.

3.3.3.7 Harvest

The crop was harvested leaving two rows on all sides as border space. The net plot area was harvested separately, threshed, winnowed and weight of grains and straw from individual plots were recorded.

3.4 Observations

3.4.1 Observations on weeds

3.4.1.1 Weed flora of the experimental field

Major weed species that infested the experimental site during the period of experiment were identified and grouped into grasses, sedges and broad leaved weeds.

3.4.1.2 Vegetative parameters

In the weed sampling area of each plot, quadrate of size 25 cm x 25 cm was placed at random at two sites. The following observations were recorded from weeds in this area and average values worked out.

3.4.1.3 Absolute density (Ad)

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

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

3.4.1.4 Relative density (Rd)

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

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

3.4.1.5 Absolute frequency (Af)

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

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

3.4.1.6 Relative frequency (Rf)

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

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

3.4.1.7 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)

3.4.1.8 Summed dominance ratio (SDR)

Mean Summed dominance ratio (sdr) for each species was worked out based on the equation developed by Sen (1981).

$$\text{Summed dominance ratio} = \frac{\text{Relative density + Relative frequency}}{2}$$

3.4.1.9 Weed dry weight

Weeds were pulled out along with roots, washed and dried under shade and later they were oven dried at 80 ^{0}C to a constant weight. The dry weight of broad leaved, sedges and grasses were separately recorded and units expressed as g m^{-2}.

3.4.1.10 Herbicide phytotoxicity symptoms

The treated plots were observed closely and the visual symptom of herbicide phytotoxicity on various weeds was recorded.

3.4.1.11 Weed control efficiency(WCE)

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

WCE = (X - Y) / X × 100

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.

3.4.2 Observations on the crop

Ten sample plants were selected at random from the net plot area of each plot and tagged. The following observations were recorded from the sample plants and the mean values worked out.

3.4.2.1 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 centimeters.

3.4.2.2 Number of tillers hill^{-1}

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

3.4.2.3 Number of productive tillers m^{-2}

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

3.4.2.4 Sterility percentage

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

$$\text{Sterility percentage (\%)} = \frac{\text{Number of unfilled grains per panicle}}{\text{Number of total grains per panicle}} \times 100$$

3.4.2.5 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 grams.

3.4.2.6 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.

3.4.2.7 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}.

3.4.2.8 Harvest Index (HI)

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

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

3.4.2.9 Pest and disease incidence

One spray of quinalphos @ 0.05 per cent against case worm attack and one application of cartap hydrochloride @ 0.1 per cent against leaf folder was applied during the crop period. Few grains were affected with ubbetta disease but the effect was negligible.

3.4.2.10 Herbicide phytotoxicity

The treated plots were observed closely and the visual symptoms of herbicide phytotoxicity if any on the rice plants were recorded.

3.5 Chemical analysis

3.5.1. NPK content of crop and weeds

The plant samples were dried in an electric hot air oven 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, 60 DAT and harvest as well as rice hills uprooted at 20, 40, 60 DAT and at harvest were analyzed for total N, P_2O_5 and K_2O.

3.5.1.1Total nitrogen content

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

3.5.1.2Total phosphorus content

Total phosphorus content was found out using Spectrophotometer method.

3.5.1.3Total potassium content

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

3.5.2 Nutrient uptake by crop and weeds

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}.

3.5.3 Nutrient status of the soil before and after the experiment

Soil samples were collected from the experimental area before and after the experiment. The air dried soil samples were analyzed for available nitrogen, phosphorus and potassium status.

3.6. Economic analysis

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.

3.6.1 Net income

Net income was computed using the formula,

Net income (Rs. ha^{-1}) = Gross income – Cost of cultivation

3.6.2 Benefit Cost Ratio (BCR)

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

3.7 Microbial studies

The effect of herbicide treatments on the soil micro flora was studied by observing the microbial population of the soil one week after herbicide application. The study was carried out at room temperature in the laboratory. Nutrient agar medium was used for growing bacteria, Kenknight's agar medium for actinomycetes and Martin's Rose Bengal agar medium for fungi.The microbes were grown in petridishes containing the respective media.

3.8. 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). The data which required transformation were appropriately transformed and analyzed.

Results

4. RESULTS

Field experiments were conducted at farmer's field to evaluate two new generation herbicides, i.e., bensulfuron methyl+pretilachlor and azimsulfuron in transplanted rice. The data recorded from the study was analyzed statistically and the results are presented in this chapter.

4.1 Observation on weeds

4.1.1 Major weed flora of the experimental field

The different weed species found in the experimental field during the study were collected before and during the period of experimentation and identified. The weeds classified into grasses, sedges and broad leaved weeds are presented in the Table 3.

4.1.2. Vegetative parameters

4.1.2.1 Absolute density

4.1.2.1 Absolute density of grasses (number m^{-2})

Data on absolute density of grasses at 20, 40, 60 days after transplanting (DAT) and at harvest is presented in the Table 4.

The data indicated that there were only very few grassy weeds in the experimental field. When observed at 20 DAT, the weed density was zero under all three doses of bensulfuron methyl + pretilachlor ($T_{1,}$ T_2 and $T_{3)}$. Other treatments also recorded low grass weed density and between them the variation did not show any specific trend. At 40 DAT the weed management practices showed significant influence on the absolute density of the grassy weeds. Azimsulfuron @ 35 g ai ha^{-1} (T_6) recorded zero absolute density followed by T_5 and T_4 while bensulfuron methyl + pretilachlor treated plots ($T_{1,}$ T_2 and T_3) had higher grassy weeds than both the azimsulfuron treatments and hand weeding. At 60 DAT and at harvest stage all the plots had a few grassy weeds, but the trend was similar to that at 40 DAT. Weedy check recorded the highest density at all the three stages.

Table 3. Major weed flora observed in experimental field

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

4.1.2.2 Absolute density of broad leaved weeds (number m^{-2})

Data on absolute density of broad leaved weeds at 20, 40, 60 DAT and at harvest is presented in the Table 5.

The absolute density of broad leaved weeds was significantly influenced by the weed management practices on at all the crop growth stages. At 20 DAT, bensulfuron methyl + pretilachlor (T_1, T_2 and T_3) recorded zero weed density while in all the other plots the weed population recorded was very high. AT 40 DAT azimsulfuron @ 35g ai ha^{-1} (T_6) recorded zero absolute density and in azimsulfuron @ 30 g ai ha^{-1} and 25g ai ha^{-1}, the weed number was 5 and 10.33 m^{-2} respectively which in turn were significantly lower than that in all other treatments. The weed population values under the different doses of bensulfuron methyl + pretilachlor (T_1, T_2 and T_3) were on par with hand weeding (T_7).

At 60 DAT also the lowest BLW density was recorded in the azimsulfuron treated plots. T_6 recorded the lowest density of 8.67 m^{-2} and was significantly superior to all other treatments. The weed population in hand weeded plots was significantly lower than that in the bensulfuron methyl + pretilachlor treated plots (T_1, T_2 and T_3) while weedy check recorded the highest number of broad leaved weeds (114.33 m^{-2}). The trend was more or less the same at the harvest stage also.

4.1.2.3 Absolute density of sedges (number m^{-2})

Data on absolute density of sedges at 20, 40, 60 DAT and harvest is presented in the Table 6.

The data indicated that at 20 DAT, the sedge population was completely controlled by bensulfuron methyl + pretilachlor at all three doses (T_1, T_2 and T_3). AT 40 DAT, azimsulfuron @ 35 g ai ha^{-1} (T_6) and 25 g ai ha^{-1} (T_4) recorded zero density and in T_5 the density recorded was 2 m^{-2} and all three treatments were significantly superior to the other treatments. The trend was similar at the later stages also. The sedge population in bensulfuron methyl + pretilachlor treatments was less than that under hand weeding at 40 DAT but by 60 DAT and at harvest, the hand weeding treatment was superior to the former. At harvest stage weedy check recorded 71.33 sedges m^{-2} while under T_6 the recorded sedge density was only 12 m^{-2}.

4.1.2.4 Total weed density (number m^{-2})

Data on total weed density at 20, 40, 60 DAT and at harvest is presented in the Table7.The total weed density was significantly influenced by the weed management practices on at all growth stages. At 20 DAT there were no weeds under bensulfuron methyl + pretilachlor treatments ($T_{1,}$ T_2 and $T_{3)}$. In all the other plots the weed population recorded was high, but between them there was no specific trend observed. At 40 DAT azimsulfuron @ 35 g ai ha^{-1} (T_6) recorded zero weed density and in azimsulfuron @ 30 g ai ha^{-1} and 25gai ha^{-1}, the density were 8 and 12.67m^{-2} respectively. The total weed population under bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1} was on par with hand weeding but much higher than that in azimsulfuron treatments. At 60 DAT also the lowest absolute density was recorded in the azimsulfuron treated plots. T_6 recorded the lowest density of 15.7m^{-2} and was significantly superior to all other treatments. The weed population in bensulfuron methyl + pretilachlor treated plots ($T_{1,}$ T_2 and T_3) was significantly higher than that in both azimsulfuron treatments and hand weeding. The trend was more or less the same at the harvest stage also. Weedy check recorded significantly higher number of weeds all throughout except at the early stage of observation.

4.1.3 Relative density (Rd)

4.1.3.1 Relative density of grasses

Data on relative density of grasses at 20, 40, 60 DAT and harvest is presented in the Table 8.

At 20 DAT, the relative density of grasses recorded by bensulfuron methyl + pretilachlor at all doses ($T_{1,}$ T_2 and T_3) was zero and the other treatments also recorded very low values. At 40 DAT the relative grass density was zero in azimsulfuron @ 35 g ai ha^{-1} (T_6). At 60 DAT T_6 recorded the higher relative density while at harvest the effect was insignificant.

Table 4. Effect of weed management practices on the absolute density of grasses (number m^{-2})

Treatments	20DAT		40DAT		60DAT		harvest	
T_1	0.00	(1.00)	6.67	(2.76)	9.00	(3.16)	15.33	(4.04)
T_2	0.00	(1.00)	5.33	(2.51)	7.67	(2.94)	12.33	(3.65)
T_3	0.00	(1.00)	3.67	(2.16)	6.00	(2.64)	9.00	(3.16)
T_4	3.33	(2.09)	2.33	(1.82)	5.00	(2.44)	7.00	(2.82)
T_5	4.00	(2.24)	1.00	(1.41)	3.33	(2.09)	6.00	(2.64)
T_6	2.67	(1.89)	0.00	(1.00)	2.00	(1.73)	4.00	(2.24)
T_7	2.00	(1.73)	2.00	(1.73)	4.00	(2.24)	10.00	(3.31)
T_8	2.33	(1.82)	9.00	(3.16)	13.00	(3.74)	18.67	(4.43)
SEm (±)		0.02		0.01		0.03		0.04
CD(0.05)		0.24		0.193		0.27		0.34

Table 5. Effect of weed management practices on the absolute density of broad leaved weeds (number m^{-2})

Treatments	20DAT		40DAT		60DAT		harvest	
T_1	0.00	(1.00)	40.33	(6.42)	53.33	(7.37)	80.00	(9.00)
T_2	0.00	(1.00)	31.67	(5.71)	42.00	(6.55)	78.33	(8.90)
T_3	0.00	(1.00)	25.00	(5.09)	36.00	(6.08)	65.60	(8.16)
T_4	67.00	(8.24)	10.33	(3.36)	28.33	(5.41)	42.67	(6.60)
T_5	74.67	(8.68)	5.00	(2.44)	11.67	(3.55)	32.33	(5.77)
T_6	99.33	(10.16)	0.00	(1.00)	8.67	(3.11)	24.00	(5.00)
T_7	89.33	(9.50)	23.67	(4.96)	28.67	(5.45)	67.67	(8.28)
T_8	69.00	(8.36)	103.33	(10.21)	114.33	(10.74)	126.67	(11.29)
SEm (±)		0.17		0.15		0.06		0.11
CD(0.05)		0.722		0.69		0.44		0.58

DAT: Days after transplanting
(Transformed values are given in parenthesis)

Table 6. Effect of weed management practices on the absolute density of sedges (number m^{-2})

Treatments	20DAT		40DAT		60DAT		harvest	
T_1	0.00	(1.00)	18.67	(4.43)	31.33	(5.68)	42.67	(6.60)
T_2	0.00	(1.00)	16.00	(4.12)	28.33	(5.41)	37.33	(6.19)
T_3	0.00	(1.00)	11.00	(3.64)	21.33	(4.72)	32.00	(5.74)
T_4	55.33	(7.50)	0.00	(1.00)	13.67	(3.83)	28.00	(5.38)
T_5	37.33	(6.19)	2.00	(1.73)	10.33	(3.36)	20.00	(4.58)
T_6	49.00	(7.07)	0.00	(1.00)	5.00	(2.45)	12.00	(3.60)
T_7	42.33	(6.58)	12.33	(3.65)	16.00	(4.12)	30.00	(5.56)
T_8	61.67	(7.91)	55.33	(7.50)	60.67	(7.85)	71.33	(8.50)
SEm (±)		0.13		0.06		0.07		0.07
CD(0.05)		0.56		0.44		0.45		0.57

Table 7. Effect of weed management practices on total weed density (number m^{-2})

Treatments	20DAT		40DAT		60DAT		harvest	
T_1	0.00	(1.00)	65.67	(8.16)	93.67	(9.72)	138.00	(11.79)
T_2	0.00	(1.00)	51.33	(7.23)	72.00	(8.54)	128.00	(11.35)
T_3	0.00	(1.00)	41.33	(6.50)	69.33	(8.39)	106.67	(10.37)
T_4	125.67	(12.96)	12.67	(3.69)	35.00	(6.00)	77.67	(8.87)
T_5	116.00	(10.94)	8.00	(3.00)	25.33	(5.13)	55.33	(7.50)
T_6	151.00	(12.49)	0.00	(1.00)	15.67	(4.08)	40.00	(6.41)
T_7	133.67	(11.60)	38.00	(6.24)	48.67	(7.07)	107.67	(10.42)
T_8	133.00	(11.57)	167.67	(12.98)	188.00	(13.74)	216.67	(14.75)
SEm (±)		0.10		0.12		0.07		0.08
CD(0.05)		0.57		0.61		0.45		0.47

DAT: Days after transplanting
(Transformed values are given in parenthesis)

4.1.3.2 Relative density of broad leaved weeds

Data on relative density of broad leaved weeds at 20, 40, 60 DAT and harvest is presented in the Table 9.

When observed at 20 DAT bensulfuron methyl +pretilachlor treatments (T_1, T_2 and T_3) recorded zero value while all the other treatments were on par with each other.

AT 40 DAT, in all the treatments the relative density of broad leaved weeds was more than fifty per cent except in T_6 where there were no weeds recorded. At the later stages also the trend was more or less similar, and between treatments the effect was insignificant at harvest stage.

4.1.3.3 Relative density of sedges

Data on relative density of sedges at 20, 40, 60 DAT and harvest is presented in the Table 10.

The data indicated that the weed management practices had significant influence on relative density of sedges at all stages. At 20 DAT bensulfuron methyl + pretilachlor treatments (T_1, T_2 and T_3) recorded zero value and in the other treatments, there was no specific pattern noticed. In the later stages also the effect of the treatments on the relative density of sedges was more or less in similar lines.

4.14 Absolute frequency

4.14.1 Absolute frequency of grasses

The data on absolute frequency of grass weeds at four stages of crop growth is given in Table 11. At 20 DAT, bensulfuron methyl + pretilachlor treatments (T_1, T_2 and T_3) recorded zero percent while T_5 and hand weeding recorded the highest frequency of 66.7 per cent. At 40 DAT, azimsulfuron @ 35 g ai ha^{-1} (T_6) had zero absolute frequency while T_1 and T_8 recorded 100 per cent frequency. Both T_1 and T_8 recorded 100 per cent absolute frequency at 60 DAT as well as at harvest stage.

Table 8. Effect of weed management practices on the relative density of grasses (%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	10.13	9.63	11.11
T_2	0.00	7.13	8.63	8.64
T_3	0.00	13.04	10.72	9.63
T_4	2.69	18.65	14.31	9.01
T_5	3.53	12.63	13.18	5.56
T_6	1.78	0.00	12.81	10.00
T_7	1.50	5.33	8.24	9.28
T_8	1.75	5.42	6.93	8.64
SEm (±)	0.51	8.34	2.31	3.29
CD(0.05)	1.25	5.06	2.66	NS

Table 9. Effect of weed management practices on the relative density of broad leaved weeds (%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	61.50	57.05	57.94
T_2	0.00	61.67	60.63	61.18
T_3	0.00	60.04	49.94	61.36
T_4	53.31	81.35	46.55	54.90
T_5	64.18	62.10	46.00	58.32
T_6	65.79	0.00	55.42	60.01
T_7	66.80	61.95	58.95	62.83
T_8	51.83	61.67	60.77	58.44
SEm (±)	4.20	16.20	16.06	4.80
CD(0.05)	3.59	7.05	7.02	NS

DAT:Days after transplanting

Table 10. Effect of weed management practices on the relative density of sedges(%)

Treatments	**20DAT**	**40DAT**	**60DAT**	**harvest**
T_1	0.00	28.37	33.32	30.95
T_2	0.00	31.21	30.74	30.00
T_3	0.00	26.92	39.34	29.19
T_4	44.00	0.00	39.14	36.08
T_5	32.29	25.26	40.82	36.13
T_6	32.42	0.00	31.76	29.99
T_7	31.70	32.72	32.81	27.89
T_8	46.42	32.92	32.30	32.91
SEm (±)	1.53	3.28	2.82	1.81
CD(0.05)	3.27	7.02	6.02	7.03

Table 11. Effect of weed management practices on the absolute frequency of grasses

Treatments	**20DAT**	**40DAT**	**60DAT**	**harvest**
T_1	0.00	100.00	100.00	100.00
T_2	0.00	83.33	83.33	83.33
T_3	0.00	50.00	66.67	66.67
T_4	50.00	50.00	66.67	66.67
T_5	66.67	50.00	50.00	66.67
T_6	50.00	0.00	50.00	50.00
T_7	66.67	50.00	83.33	83.33
T_8	50.00	100.00	100.00	100.00

 # worked out the mean values

DAT- Days after transplanting

4.1.4.2 Absolute frequency of broad leaved weeds

Data on absolute frequency of broad leaved weeds at 20, 40, 60 DAT and harvest are presented in the Table12.

Absolute frequency of BLW was zero in bensulfuron methyl + pretilachlor treatments (T_1, T_2 and T_3) at 20 DAT as well as in azimsulfuron @ 35 g ai ha^{-1} (T_6) at 40 DAT. In all the other treatments and at all the stages of observation the absolute frequency recorded was 100 per cent.

4.1.4.3 Absolute frequency of sedges.

Data on absolute frequency of broad leaved weeds at 20, 40, 60 DAT and harvest are presented in the Table 13.

The trend in absolute frequency of sedges was more or less similar to that of BLW except that both T_6 and T_4 recorded zero value at 40 DAT.

4.1.5 Relative frequency

4.1.5.1 Relative frequency of grasses

Data on relative frequency of broad leaved weeds at 20, 40, 60 DAT and harvest is presented in the Table 14.

The relative frequency was zero in T_1, T_2 and T_3 (bensulfuron methyl + pretilachlor) at 20 DAT and in T_6 (azimsulfuron @ 35 g ai ha^{-1}) at 40 DAT. At 60 DAT and at harvest, the effect of the treatments on the absolute frequency was insignificant.

4.1.5.2 Relative frequency of broad leaved weeds

Data on relative frequency of broad leaved weeds at 20, 40, 60 DAT and harvest is presented in the Table 15.

At 20 DAT T_1, T_2 and T_3 (bensulfuron methyl +pretilachlor) recorded zero value for relative frequency of broad leaved weeds. At 40 DAT the value recorded by T_6 was zero and that by T_4 was 100, while at 60 DAT, the relative frequency ranged between 33.33 and 46.7. The influence of the treatments on the relative BLW frequency was insignificant at the harvest stage.

Table 12. Effect of weed management practices on the absolute frequency of broad leaved weeds

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0	100	100	100
T_2	0	100	100	100
T_3	0	100	100	100
T_4	100	100	100	100
T_5	100	100	100	100
T_6	100	0	100	100
T_7	100	100	100	100
T_8	100	100	100	100

Table 13. Effect of weed management practices on the absolute frequency of sedges

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	100.00	100.00	100.00
T_2	0.00	100.00	100.00	100.00
T_3	0.00	100.00	100.00	100.00
T_4	100.00	0.00	100.00	100.00
T_5	100.00	50.00	83.33	100.00
T_6	100.00	0.00	66.67	100.00
T_7	100.00	100.00	100.00	100.00
T_8	100.00	100.00	100.00	100.00

 # worked out the mean values

DAT:Days after transplanting

Table 14. Effect of weed management practices on the relative frequency of grasses (%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	33.33	33.33	33.33
T_2	0.00	28.89	28.89	28.89
T_3	0.00	20.00	24.44	24.44
T_4	20.00	33.33	24.44	24.44
T_5	24.44	25.00	21.67	24.44
T_6	20.00	0.00	23.33	20.00
T_7	24.44	20.00	28.89	28.89
T_8	20.00	33.33	33.33	33.33
SEm (±)	15.87	7.40	10.06	9.30
CD(0.05)	6.98	4.77	NS	NS

Table 15. Effect of weed management practices on the relative frequency of broad leaved weeds (%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	33.33	33.33	33.33
T_2	0.00	35.55	35.55	37.78
T_3	0.00	40.00	37.78	35.55
T_4	40.00	100.00	37.78	37.78
T_5	37.78	66.67	43.33	37.78
T_6	40.00	0.00	46.67	40.00
T_7	37.78	40.00	35.55	35.55
T_8	40.00	33.33	33.33	33.33
SEm (±)	3.97	1.85	17.20	4.68
CD(0.05)	3.49	2.39	7.26	NS

DAT- Days after transplanting

4.1.5.3 Relative frequency of sedges.

Data on relative frequency of sedges at 20, 40, 60 DAT and harvest is presented in the Table 16.

The data indicated that the effect of the weed management practices on relative frequency of sedges at various crop growth stages was more or less similar to that on BLW at 20 and 40 DAT. The effect was insignificant at the later two stages.

4.1.6 Importance value (IV)

4.1.6.1 Importance value of grasses

Data on Importance valve of grasses at 20, 40, 60 DAT and harvest is presented in the Table 17.

At 20 DAT, the bensulfuron methyl +pretilachlor treatments ($T_{1,}$ T_2 and T_3) recorded zero and was significantly superior while all the other treatments were on par with each other. At 40 DAT, the importance value was zero in azimsulfuron @ 35 g ai ha^{-1}(T_6). At 60 DAT, the effect was insignificant and at harvest the Importance value of grasses was highest under T_1.

4.1.6.2 Importance value of broad leaved weeds

Data on Importance valve of broad leaved weeds at 20, 40, 60 DAT and harvest is presented in the Table 18.

At 20 DAT, the Importance Value of BLW was zero for all the three doses of bensulfuron methyl + pretilachlor treatments ($T_{1,}$ T_2 and $T_{3).}$ At 40 DAT, azimsulfuron @ 35 g ai ha^{-1} (T_6) recorded zero while T_4 recorded the highest IV value (181.35). At 60 DAT the effect of the weed management practices on the IV of broad leaved weeds was insignificant while at harvest T_6 recorded the highest value.

Table 16. Effect of weed management practices on the relative frequency of sedges (%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	33.33	33.33	33.33
T_2	0.00	35.55	35.55	35.55
T_3	0.00	40.00	37.78	37.78
T_4	40.00	0.00	37.78	37.78
T_5	37.78	33.33	35.00	37.78
T_6	40.00	0.00	30.00	40.00
T_7	37.78	40.00	35.55	35.55
T_8	40.00	33.33	33.33	33.33
SEm (±)	3.97	1.85	9.44	4.68
CD(0.05)	3.49	2.38	NS	NS

Table 17. Effect of weed management practices on the importance value of grasses

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	43.46	42.97	44.45
T_2	0.00	36.02	37.52	37.53
T_3	0.00	33.04	35.17	34.07
T_4	22.69	51.98	38.75	33.46
T_5	27.97	37.63	34.85	30.00
T_6	21.78	0.00	36.14	30.00
T_7	25.95	25.33	37.12	38.17
T_8	21.75	38.75	40.26	41.97
SEm (±)	17.97	17.76	10.79	29.44
CD(0.05)	7.43	7.38	NS	9.50

DAT- Days after transplanting

4.1.6.3 Importance value of sedges

Data on Importance valve of sedges at 20, 40, 60 DAT and harvest is presented in the Table 19.

At 20 DAT, the Importance value of sedges in T_1, T_2 and T_3 were zero. At 40 DAT, T_4 and T_6 recorded zero while IV was 58.60 in T_5. At 60 DAT, the effect of the treatments on IV of sedges was insignificant. At harvest stage, the effect was significant but did not follow any specific pattern.

4.1.7 Summed dominance ratio (SDR)

4.1.7.1 Summed dominance ratio of grasses

Data on Summed dominance ratio of grasses at 20, 40, 60 DAT and harvest is presented in the Table 20.

At 20 DAT, SDR was zero in bensulfuron methyl + pretilachlor treatments (T_1, T_2 and T_3) and the remaining treatments were on par with each other. Azimsulfuron @ 35g ai ha^{-1}(T_6) recorded zero at 40 DAT and at 60 DAT, the effect of the treatments on SDR of grasses was insignificant. At harvest the SDR values of all the treatments were on par with the weedy check.

4.1.7.2 Summed dominance ratio of broad leaved weeds

Data on Summed dominance ratio of broad leaved weeds at 20, 40, 60 DAT and harvest is presented in the Table 21.

At 20 DAT, the SDR of BLW was zero for all the three doses of bensulfuron methyl + pretilachlor (T_1, T_2 and T_3). At 40 DAT, azimsulfuron @ 35 g ai ha^{-1}(T_6) recorded zero while T_4recorded the highest SDR (95.53). At 60 DAT the effect of the treatments on SDR of BLW was insignificant and at the harvest stage there was no specific pattern for their influence.

Table 18. Effect of weed management practices on the importance value of broad leaved weeds

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	94.83	90.38	91.27
T_2	0.00	97.22	96.18	98.96
T_3	0.00	100.04	87.72	96.92
T_4	93.31	181.35	84.33	92.68
T_5	101.96	128.77	89.33	96.10
T_6	105.79	0.00	102.09	100.01
T_7	104.57	101.95	94.50	98.38
T_8	91.83	95.00	94.11	91.78
SEm (±)	11.31	19.28	12.79	12.79
CD(0.05)	5.89	7.69	NS	6.26

Table 19. Effect of weed management practices on the importance value of sedges

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	61.70	66.65	64.28
T_2	0.00	66.76	66.30	65.55
T_3	0.00	66.92	77.11	66.98
T_4	84.00	0.00	76.92	73.86
T_5	70.07	58.60	75.82	73.91
T_6	72.42	0.00	61.76	69.99
T_7	69.48	72.72	68.37	63.44
T_8	86.42	66.25	65.64	66.25
SEm (±)	5.16	17.85	11.66	12.66
CD(0.05)	3.98	7.40	NS	6.23

DAT: Days after transplanting

4.1.7.3 Summed dominance ratio of sedges

Data on Summed dominance ratio of sedges at 20, 40, 60 DAT and harvest is presented in the Table 22.

The effect of the treatments on SDR of sedges was found to be more or less similar to that on the broad leaved weeds.

4.1.8 Weed dry weight (g m^{-2})

4.1.8.1 Dry weight of grasses (g m^{-2})

The data on dry weight of grassy weeds at 20, 40, 60 DAT and harvest is presented in the Table 23.

At 20 DAT, dry weight of grassy weeds was zero in all the three bensulfuron methyl + pretilachlor treatments (T_1, T_2 and T_3). All the other treatments had grassy weeds and the dry weight recorded were on par with each other.

At 40 DAT the azimsulfuron treatment T_6 recorded weed dry weight as zero and the highest dry weight was recorded by weedy check (4.46 g m^{-2}). All the other treatments had significantly lower values than the weedy check and were on par with each other.

At 60 DAT also T_6 (azimsulfuron @ 35 g ai ha^{-1}) recorded the lowest dry weight but was on par with T_7 (hand weeding), T_4 (azimsulfuron @ 25 g ai ha^{-1}) and T_1 (bensulfuron methyl + pretilachlor @ 45+450 g ai ha^{-1}).

At harvest stage dry weight was lowest in hand weeded plots which in turn were on par with T_6, T_5 and T_3. In all the growth stages except 20 DAT, weed dry weight recorded by weedy check was significantly higher than that in all other treatments.

Table 20. Effect of weed management practices on the summed dominance ratio of grasses

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0	21.73	21.48	22.22
T_2	0	18.00	18.76	18.76
T_3	0	16.51	17.58	17.03
T_4	11.34	25.9	19.37	16.73
T_5	13.98	18.81	17.42	14.99
T_6	10.89	0	18.07	15.00
T_7	12.97	12.66	18.56	19.08
T_8	10.87	19.37	20.13	20.99
SEm (±)	4.49	4.44	5.40	7.36
CD(0.05)	3.71	3.69	NS	4.75

Table 21. Effect of weed management practices on the summed dominance ratio of broad leaved weeds

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0	47.42	45.19	45.63
T_2	0	48.61	48.09	49.47
T_3	0	50.02	43.86	48.45
T_4	48.83	90.68	42.16	46.34
T_5	51.09	64.38	44.67	48.05
T_6	53.14	0	51.05	50.00
T_7	49.94	50.97	47.25	49.19
T_8	43.77	47.50	47.06	45.89
SEm (±)	95.97	4.82	6.39	3.20
CD(0.05)	17.16	3.85	NS	3.13

DAT- Days after transplanting

Table 22. Effect of weed management practices on the summed dominance ratio of sedges

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0	30.85	33.32	32.14
T_2	0	33.38	33.15	32.78
T_3	0	33.46	38.56	33.48
T_4	41.20	0	38.46	36.93
T_5	35.03	29.3	37.91	36.95
T_6	36.21	0	30.88	34.993
T_7	34.74	36.36	34.19	31.72
T_8	43.21	33.12	32.81	33.12
SEm (±)	1.29	4.46	5.83	3.16
CD(0.05)	1.99	3.69	NS	3.12

DAT- Days after transplanting

4.1.8.2 Dry weight of broad leaved weeds (g m^{-2})

The data on dry weight of broad leaved weeds at 20, 40, 60 DAT and at harvest is presented in the Table 24.

At 20 DAT, dry weight of broad leaved weeds was zero in all the three bensulfuron methyl + pretilachlor treatments (T_1, T_2 and T_3). In all the other treatments except T_4 (azimsulfuron @ 25 g ai ha^{-1}), the dry weight recorded were on par with each other. At 40 DAT, T_6 (azimsulfuron @ 35 g ai ha^{-1}) recorded zero dry weight and in T_4 and T_5 (azimsulfuron @ 25 and 30 g ai ha^{-1} respectively) the weed dry weight values were significantly lower than that of all the other treatments. At 60 DAT and harvest also T_6 (azimsulfuron @ 35 g ai ha^{-1}) recorded the lowest dry weight and was on par with T_5 and T_7. At all the stages except 20 DAT, BLW dry weight was highest under the weedy check.

4.1.8.3 Dry weight of sedges (gm^{-2})

The data on dry weight of sedges at 20, 40, 60 DAT and harvest is presented in the Table 25.

At 20 DAT bensulfuron methyl + pretilachlor treatments (T_1, T_2 and T_3) recorded zero dry weight. All the other treatments had significantly higher dry weight values. At 40 DAT, T_6 (azimsulfuron @ 35 g ai ha^{-1}) and T_4 (azimsulfuron @ 25 g ai ha^{-1}) recorded zero and T_5 also had significantly lower dry weight when compared to the other treatments. At 60 DAT and harvest also, the sedge dry weight was the lowest in T_6. When compared to all the other treatments, the sedge weed dry weight recorded by the weedy check was significantly higher in all growth stages except at 20 DAT.

4.1.8.4 Total weeds dry weight (g m^{-2})

The data on total weed dry weight at 20, 40, 60 DAT and harvest is presented in the Table 26.

The data on total weed dry weight showed that at 20 DAT, there were no weeds in plots treated with different doses of bensulfuron methyl +pretilachlor (T_1, T_2 and T_3). At this stage, all the other treatments recorded significantly higher weed dry weight and were more or less on par with each other.

Table 23. Effect of weed management practices on the dry weight of grasses (g m^{-2})

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0	1.66	3.91	11.50
T_2	0	2.03	5.1	12.79
T_3	0	1.33	4.51	8.58
T_4	1.48	1.09	3.55	10.20
T_5	2.29	0.67	4.36	6.85
T_6	1.47	0.00	2.53	6.73
T_7	3.07	1.77	2.73	6.63
T_8	1.78	4.46	14.66	16.36
SEm (±)	0.23	0.75	0.90	1.34
CD(0.05)	0.50	1.61	1.66	2.03

Table 24. Effect of weed management practices on the dry weight of broad leaved weeds (g m^{-2})

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0	13.56	24.88	56.55
T_2	0	10.47	21.26	41.56
T_3	0	8.50	18.95	36.25
T_4	19.39	3.53	16.66	38.68
T_5	19.26	2.50	17.41	28.29
T_6	20.36	0.00	11.93	22.08
T_7	20.04	9.67	16.61	34.67
T_8	23.59	37.00	69.52	119.70
SEm (±)	0.93	1.87	8.14	5.8
CD(0.05)	1.98	5.00	4.99	12.45

DAT- Days after transplanting

At 40 DAT, T_6 (azimsulfuron @35 g ai ha^{-1}) was the most effective among all the treatments and recorded zero value and was followed by T_5 (azimsulfuron @ 30 g ai ha^{-1}) and T_4 (azimsulfuron @ 25 g ai ha^{-1}) which in turn was on par with hand weeding. At 60 DAT and at harvest also weed dry weight was the lowest under T_6 and in hand weeded plots; the weed dry weight was significantly lower than that in bensulfuron+pretilachlor treatments. When compared to all the other treatments, the total weed dry weight recorded by the weedy check was significantly higher in all growth stages except at 20 DAT.

4.2.9 Visual symptoms of herbicide phytotoxicity

***4.2.9.1* Azimsulfuron**

In weed plants treated with azimsulfuron, yellowing of leaves was the earliest visual symptom. When observed on three days after spraying (DAS), the susceptible weed seedlings were found chlorotic. By the 5th day these plants turned yellow and started decaying and within 10 days the entire plants turned into an undistinguishable mass.

4.2.9.2 Bensulfuron methyl +pretilachlor

In plots treated with bensulfuron methyl +pretilachlor, the weed propagules failed to emerge out and there were no weed growth in the early stages of observation. However, plants started to emerge out by about 25 days after application and the freshly emerging plants showed no phytotoxicity symptoms.

4.1.10 Weed control efficiency (WCE)

4.1.10.1 Weed control efficiency of grasses

The data on weed control efficiency of the management practices for grasses is presented in the Table 27. At 20 DAT, WCE was 100 per cent in all the three bensulfuron methyl +pretilachlor treatments (T_1, T_2 and T_3) and in others, the treatments effect was negligible or even negative. At 40 DAT the WCE was higher for the azimsulfuron treatments and among them T_6 (azimsulfuron @ 35 g ai ha^{-1}) recorded 100 per cent efficiency. On 60 DAT also T_6 recorded the highest WCE but was closely followed by hand weeding while at harvest the highest value was for hand weeding.

Table 25.Effect of weed management practices on the dry weight of sedges(g m^{-2})

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	4.57	14.00	31.17
T_2	0.00	3.87	11.14	26.00
T_3	0.00	3.01	9.42	20.35
T_4	7.16	0.00	7.36	18.96
T_5	8.01	0.89	6.39	15.66
T_6	9.21	0.00	3.37	8.32
T_7	13.54	3.80	7.97	19.67
T_8	10.83	15.10	27.80	55.66
SEm (±)	1.69	0.50	1.65	4.62
CD(0.05)	3.62	1.07	3.53	9.87

Table 26. Effect of weed management practices on total weed dry weight (g m^{-2})

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0	19.79	42.79	99.22
T_2	0	16.37	37.5	80.35
T_3	0	12.84	32.88	65.18
T_4	28.03	4.62	27.57	67.84
T_5	29.56	4.06	28.16	50.8
T_6	31.04	0	17.83	37.13
T_7	36.65	15.24	27.31	60.97
T_8	36.21	56.56	111.98	191.72
SEm (±)	2.12	1.33	2.89	8.88
CD(0.05)	4.52	2.86	6.17	18.97

DAT- Days after transplanting

4.1.10.2 Weed control efficiency of broad leaved weeds

The data on weed control efficiency of the management practices for broad leaved weeds is presented in the Table 28.

At 20 DAT, WCE was 100 per cent in all the three bensulfuron methyl + pretilachlor treatments ($T_{1,}$ T_2 and $T_{3)}$ and in others, the treatments effect was negligible or even negative. On 40 DAT, T_6 (azimsulfuron @ 35 g ai ha^{-1}) recorded 100 per cent efficiency at 60 DAT also T_6 (azimsulfuron @ 35 g ai ha^{-1}) recorded the highest WCE and was closely followed by hand weeding and the trend was similar at harvest also with a slight edge for hand weeding.

4.1.10.3 Weed control efficiency of sedges

The data on weed control efficiency of the management practices for sedges is presented in the Table 29.

At 20 DAT, WCE for sedges was 100 per cent in all the three bensulfuron methyl + pretilachlor treatments ($T_{1,}$ T_2 and $T_{3)}$ and the effect of the other treatments was negligible or negative. At 40 DAT, T_6 (azimsulfuron @ 35 g ai ha^{-1}) and T_4 (azimsulfuron @ 25 g ai ha^{-1}) recorded 100 per cent efficiency and was followed by T_5 which recorded 94.06 per cent. At 60 DAT and at harvest also azimsulfuron @ 35 g ai ha^{-1} was superior to other treatments.

4.1.10.4 Total weed control efficiency

The data on weed control efficiency of the management practices for total weeds is presented in the Table 30.

At 20 DAT, WCE was 100 per cent in all the three bensulfuron methyl + pretilachlor treatments ($T_{1,}T_2$ and $T_{3)}$ and the effect of the other treatments was negligible. At 40 DA,T_6 (azimsulfuron @ 35 g ai ha^{-1}) recorded 100 per cent efficiency and was followed by T_5 which recorded 94.58per cent and T_4 with 91.97 per cent. At 60 DAT and at harvest also azimsulfuron @ 35 g ai ha^{-1} was superior to other treatments in controlling all types of weeds.

Table 27. Effect of weed management practices on weed control efficiency of grassy weeds(%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	100	51.33	72.86	29.89
T_2	100	50.90	64.40	22.00
T_3	100	71.90	68.52	47.43
T_4	16.16	74.30	76.05	37.32
T_5	-33.75	81.68	70.10	58.20
T_6	18.76	100.00	82.64	58.46
T_7	-77.73	54.68	81.25	59.14
T_8	-	-	-	-

Table 28. Effect of weed management practices on weed control efficiency of broad leaved weeds(%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	100	62.51	64.07	52.04
T_2	100	76.84	72.76	65.73
T_3	100	71.34	70.64	67.40
T_4	17.73	90.27	75.96	69.74
T_5	18.14	95.39	74.76	76.14
T_6	13.43	100.00	82.67	83.15
T_7	14.85	72.99	75.92	70.62
T_8	-	-	-	-

DAT- Days after transplanting

Table 29. Effect of weed management practices on weed control efficiency of sedges(%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	100.00	69.51	66.01	65.403
T_2	100.00	74.99	66.38	70.77
T_3	100.00	80.25	61.33	68.29
T_4	34.24	100.00	77.36	64.95
T_5	26.00	94.06	76.75	69.07
T_6	14.60	100.00	87.72	84.62
T_7	-25.63	74.71	77.08	64.66
T_8	-	-	-	

Table30.Effect of weed management practices on total weed control efficiency(%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	100	67.20	61.62	47.37
T_2	100	71.33	69.11	60.26
T_3	100	72.48	66.90	66.42
T_4	22.71	91.97	75.31	65.70
T_5	18.18	94.58	74.78	73.15
T_6	14.32	100.00	84.01	80.46
T_7	-1.58	72.89	75.37	67.64
T_8	-	-	-	-

DAT- Days after transplanting

4.2 Observationws on crop

4.2.1 Plant height

The data on the influence of the weed management practices on plant height are given in Table 31.

The Plant height was significantly influenced by the weed management practices at different growth stages of the crop viz., 20, 40, 60 DAT and harvest.

At 20 DAT, the plant height was comparatively lower in the plots treated with bensulfuron +pretilachlor (T_1,T_2 and T_3). At 40 DAT maximum plant height(64.80) was recorded by the azimsulfuron @ 35 g ai ha^{-1} (T_6), and the lowest height was (49.47)under the weedy check and the trend was the same at the two later stages also.

4.2.2 Number of tillers hill^{-1}

Different weed management treatments influenced the number of tillers hill^{-1} significantly and the results are presented in Table 32.

At 20 DAT, the tiller number was comparatively lower in plots treated with bensulfuron methyl + pretilachlor in various doses and in the other treatments; it was on par with each other. At 40 DAT and the later stages, the tiller production was the highes(14.86)t in azimsulfuron @ 35 g ai ha^{-1} (T_6) and the lowest(11.63) in the weedy check (T_8). The tiller production in hand weeded plots was on par with that of the azimsulfuron treated plots throughout the crop growth. Bensulfuron +pretilachlor @ 75+750 g ai ha $^{-1}$ was on par with azimsulfuron @ 35 g ai ha^{-1} but its lower doses recorded lesser number of tillers throughout the growth stages.

4.2.3 Productive tillers m^{-2}

Number of productive tillers m^{-2} was significantly influenced by the treatments and the results are presented in Table 33.

Highest productive tiller number (536.62) was recorded by azimsulfuron @ 35 g ai ha^{-1} (T_6) which was on par with hand weeding (T_7) and significantly superior to all the other treatments.

The lowest value (375.88) was registered by unweeded check (T_8). Among the bensulfuron methyl + pretilachlor treatments T_6 was significantly superior to the two lower doses (T_1 and T_2) and on par with hand weeding.

4.2.4 Sterility percentage

Data on sterility percentage showed that weed management practices influenced the sterility percentage is presented in Table 33.

The sterility percentage was lowest(8.29) in azimsulfuron @ 35 g ai ha^{-1} (T_6) and it was on par with T_3 and T_7 (Hand weeding). The sterility percentage was maximum(11.64) in the weedy check (T_8).

4.2.5 Thousand grain weight

The thousand grain weight was found significantly influenced by the weed management practices and the results are presented in Table 33.

Azimsulfuron @ 35 g ai ha^{-1} (T_6) recorded the highest thousand grain weight (23.45 g) followed by hand weeding (22.22 g) and the value was the lowest in weedy check(20.72g).

4.2.6 Grain yield

The data on grain yield as influenced by the weed management practices are presented in Table34.

The results indicated that the grain yield was significantly influenced by the various weed management practices. Grain yield recorded was the highest (7970.97 kg ha^{-1}) under azimsulfuron @ 35 g ai ha^{-1} (T_6) and it was significantly superior to all the other treatments. Hand weeding recorded the next higher yield and it was on par with bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1} (T_3) and azimsulfuron @ 30 g ai ha^{-1}(T_5). The lowest yield (5652.14kg ha^{-1}) was registered by unweeded check (T_8) which was significantly inferior to all the other treatments.

4.2.7 Straw yield

The data on straw yield as influenced by the weed management practices are presented in Table.34.

Among all the treatments, highest straw yield (10974.8kg ha^{-1}) was recorded by azimsulfuron @ 35 g ai ha^{-1} and was on par with bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1},azimsulfuron @ 30 g ai ha^{-1} and hand weeding .The lowest straw yield (9676.93kg ha^{-1}) was registered by weedy check which was significantly inferior to all the others.

4.2.8 Harvest index (HI)

The data on harvest index as influenced by the weed management practices are presented in Table 34. Harvest Index was the highest (0.424) in plots treated with azimsulfuron @ 35 g ai ha^{-1} (T_6) and it was significantly superior to all other treatments. The next best HI was recorded by hand weeding (T_7) and it was on par with T_3,T_2 and T_5. Weedy check (T_8) recorded the lowest HI (0.369) and was inferior to all the other treatments.

4.2.9 Pest and disease incidence

During the cropping period there was random incidence of case worm and leaf folder and was effectively managed at the initial stage itself. Few grains were affected with ubbetta disease but effect was negligible.

4.2.10 Visual symptoms of herbicide phytotoxicity

There was no phytotoxic symptom on rice in any of the herbicide treatments

4.3 Chemical analysis

4.3.1.1Nitrogen content in crop

Results obtained at 20, 40, 60 DAT and at harvest are presented in Table 35.

Nitrogen content in crop was not significantly influenced by the weed management treatments at any of the growth stages of the crop.

Table 31. Effect of weed management practices on plant height (cm)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	33.38	53.27	84.98	94.11
T_2	30.12	60.04	87.64	96.53
T_3	33.61	56.04	90.08	100.97
T_4	39.20	58.59	89.28	97.11
T_5	38.04	60.39	92.40	101.91
T_6	40.46	64.80	97.67	106.20
T_7	35.23	61.67	90.27	97.98
T_8	36.88	49.47	78.67	84.41
SEm (±)	1.08	1.24	1.35	1.64
CD(0.05)	2.31	1.76	2.9	3.50

Table 32. Effect of weed management practices on the number of tillers hill^{-1}

Treatments	20DAT	40DAT	60DAT	harvest
T_1	9.02	12.15	17.87	16.76
T_2	8.40	12.35	19.29	17.53
T_3	8.14	13.15	20.25	19.2
T_4	9.65	13.63	19.45	17.86
T_5	9.80	13.21	20.66	17.93
T_6	10.07	14.86	21.37	19.53
T_7	10.3	13.96	20.69	18.29
T_8	9.02	11.63	17.57	14.76
SEm (±)	0.50	0.72	1.12	0.94
CD(0.05)	1.08	1.55	2.40	2.00

DAT- Days after transplanting

Table 33. Effect of weed management practices on the productive tillers m^{-2}, sterility % and thousand grain weight (g)

Treatments	Productive tillers m^{-2}	Sterility %	Thousand grain weight(g)
T_1	414.35	11.14	21.53
T_2	429.53	10.38	21.74
T_3	493.89	9.17	22.11
T_4	446.83	9.85	21.15
T_5	483.66	9.65	22.01
T_6	536.62	8.29	23.45
T_7	508.17	9.09	22.22
T_8	375.88	11.64	20.72
SEm (±)	19.66	0.89	0.44
CD(0.05)	41.97	1.32	0.95

Table 34. Effect of weed management practices on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1	6591.37	10337.2	0.389
T_2	6785.49	10194.6	0.400
T_3	7376.06	10797	0.406
T_4	6918.6	10419.6	0.399
T_5	7236.09	10711.3	0.403
T_6	7970.97	10974.8	0.421
T_7	7462.27	10649.6	0.412
T_8	5652.14	9676.93	0.369
SEm (±)	147.97	175.86	0.005
CD(0.05)	315.92	375.46	0.012

DAT -Days after transplanting

4.3.1.2 Phosphorus content in crop

Results obtained at 20, 40, 60 DAT and at harvest are presented in Table 36.

Phosphorus content in crop was not significantly influenced by the different treatments at any of the growth stages of the crop.

4.3.1.3 Photassium content in crop

Results obtained at 20, 40, 60 DAT and at harvest are presented in Table 37.

The effect of the treatments on the potassium content in crop was not insignificant throughout the growth stages of the crop.

4.3.2 Nutrient content in weed

4.3.2.1 Nitrogen content in weed

Results obtained at 20, 40, 60 DAT and at harvest are presented in Table 38.

Nitrogen content in weed was significantly influenced by different treatments at 20, 40 DAT but did not follow any specific pattern. At the later stages, the effect was insignificant.

4.3.2.2 Phosphorus content in weed

Results obtained at 20, 40, 60 DAT and at harvest are presented in Table 39.

The influence of the treatments on phosphorus in weed was similar to that of nitrogen content.

4.3.2.3 Potassium content in weed

Results obtained at 20, 40, 60 DAT and at harvest are presented in Table 40.

At 20 DAT, T_1,T_2 and potassium content in weed was significantly influenced by different treatments at 20, 40 DAT but at later stages the effect was insignificant. Here again no specific pattern of the treatment effect could be elucidated from the data.

Table 35. Effect of weed management practices on nitrogen content of rice (%)

Treatments	20 DAT	40 DAT	60 DAT	harvest
T_1	0.74	0.70	0.74	0.72
T_2	0.72	0.70	0.74	0.73
T_3	0.74	0.74	0.73	0.72
T_4	0.74	0.74	0.74	0.69
T_5	0.76	0.72	0.74	0.70
T_6	0.72	0.72	0.70	0.78
T_7	0.70	0.70	0.74	0.69
T_8	0.74	0.76	0.74	0.78
SEm (±)	0.19	0.09	0.36	0.57
CD(0.05)	NS	NS	NS	NS

Table 36. Effect of weed management practices on phosphorus content of rice (%)

Ttretments	20 DAT	40 DAT	60 DAT	harvest
T_1	0.34	0.23	0.26	0.27
T_2	0.34	0.22	0.25	0.28
T_3	0.34	0.22	0.26	0.27
T_4	0.32	0.24	0.29	0.27
T_5	0.33	0.23	0.30	0.28
T_6	0.30	0.25	0.27	0.27
T_7	0.31	0.24	0.30	0.27
T_8	0.33	0.25	0.27	0.28
SEm (±)	0.04	0.41	0.30	0.15
CD(0.05)	NS	NS	NS	NS

DAT- Days after transplanting

Table 37. Effect o f weed management practices on the potassium content of rice (%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	1.87	1.63	1.52	1.53
T_2	1.88	1.76	1.59	1.48
T_3	1.82	1.70	1.62	1.43
T_4	1.83	1.84	1.61	1.31
T_5	1.90	1.89	1.72	1.53
T_6	1.83	1.69	1.55	1.56
T_7	1.91	1.75	1.66	1.52
T_8	1.81	1.73	1.55	1.52
SEm (±)	0.34	0.28	0.26	0.06
CD(0.05)	NS	NS	NS	NS

Table 38. Effect of weed management practices on nitrogen content of weed (%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	1.01	1.19	1.25
T_2	0.00	1.06	1.15	1.15
T_3	0.00	0.98	1.12	1.23
T_4	1.01	1.00	1.08	1.19
T_5	1.02	0.98	0.91	1.23
T_6	1.08	0.00	1.00	1.19
T_7	0.93	1.01	1.06	1.23
T_8	1.02	1.04	1.21	1.21
SEm (±)	0.08	0.06	0.09	0.18
CD(0.05)	0.16	0.12	NS	NS

DAT- Days after transplanting

Table 39 .Effect of weed management practices on phosphorus content of weed (%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	0.63	0.74	0.72
T_2	0.00	0.62	0.69	0.70
T_3	0.00	0.62	0.72	0.68
T_4	0.81	0.60	0.75	0.72
T_5	0.84	0.55	0.69	0.72
T_6	0.86	0.00	0.70	0.71
T_7	0.85	0.63	0.74	0.79
T_8	0.89	0.62	0.73	0.79
SEm (±)	0.02	0.03	0.09	0.15
CD(0.05)	0.04	0.06	NS	NS

Table 40. Effect of weed management practices on the potassium content of weed (%)

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0.00	1.69	1.53	1.62
T_2	0.00	1.68	1.54	1.73
T_3	0.00	1.71	1.61	1.70
T_4	1.79	1.68	1.69	1.67
T_5	1.81	1.72	1.66	1.73
T_6	1.84	0.00	1.73	1.68
T_7	1.81	1.75	1.63	1.65
T_8	1.82	1.79	1.74	1.67
SEm (±)	0.03	0.03	0.09	0.08
CD(0.05)	0.07	0.05	NS	NS

DAT- Days after transplanting

4.3.3 Nutrient uptake by crop

4.3.3.1 Nitrogen uptake by the crop

Results obtained at 20, 40, 60 DAT and harvest are presented in Table 41.

Nitrogen uptake by the crop was significantly influenced by the weed management practices at all stages of observation. At 20 DAT, the uptake values were lowest in bensulfuron methyl + pretilachlor treatments. At 40 DAT, 60 DAT and at harvest the nitrogen uptake was highest in the azimsulfuron @ 35 g ai ha^{-1} (T_6) followed by hand weeding (T_7). The uptake was lowest under the weedy check in all later stages of crop growth.

4.3.3.2 Phosphorus uptake by the crop

Results obtained at 20, 40, 60 DAT and harvest are presented in Table 42.

Phosphorus uptake by the crop was significantly influenced by the weed management practices at all stages of observation. In the case of phosphorus also at 20 DAT, the uptake values were lowest in bensulfuron methyl + pretilachlor treatments, and in all other treatments weedy check recorded the lowest value. At 40 DAT, and at harvest the phosphorus uptake was highest in the azimsulfuron@ 35 g ai ha^{-1} (T_6) followed by hand weeding (T_7) while at 60 DAT, T_5 had the highest value.

4.3.3.3 Potassium uptake by the crop

Results on crop uptake of potassium at 20, 40, 60 DAT and at harvest are presented in Table 43.

Potassium uptake by crop was significantly influenced by the weed management practices at all stages of observation. At 20 DAT potassium uptake in bensulfuron methyl + pretilachlor was lower and on par with that in weedy check. At 40 DAT, T_5 recorded the highest potassium uptake and was and was on par with T_6, T_4, and T_7. At 60 DAT, the uptake values under T_6, T_5, and T_7 were on par and superior to others. The trend was more or less similar at harvest stage also. At all the later stages of the crop growth weedy check recorded significantly lower potassium uptake.

4.3.4 Nutrient uptake by weed

4.3.4.1 Nitrogen uptake by the weed

Results obtained at 20, 40, 60 DAT and at harvest are presented in Table 44.

Nitrogen uptake by the weeds was significantly influenced by the weed management practices at all stages of observation. At 20 DAT under T_1,T_2 and T_3 the nitrogen uptake was zero. At the later stages, the weed uptake of nitrogen was the lowest in T_6 (azimsulfuron @ 35 g ai ha^{-1}), followed by T_5. At 40 DAT, 60 DAT and at harvest, uptake of nitrogen by the weeds was significantly higher under weedy check (T_8).

4.3.4.2 Phosphorus uptake by weed

Results obtained at 20, 40, 60 DAT and at harvest are presented in Table 45.

Phosphorus uptake by weeds was significantly influenced by the weed management practices at all stages of observation. At 20 DAT, T_1,T_2 and T_3 recorded zero, while at 40 DAT, T_6 had the zero value. At all the later stages, the uptake of phosphorus by weeds was lowest in T_6 followed by T_5. Phosphorus uptake by weeds was the highest under the weedy check (T_8) at 40, 60 DAT and at the harvest stage and the values were significantly higher than that in all other treatments.

4.3.4.3 Potassium uptake by weed

Results obtained at 20, 40, 60 DAT and at harvest are presented in Table 46.

Potassium uptake by weed was significantly influenced by the weed management practices. At 20 DAT, the potassium uptake by weeds was zero in T_1,T_2 and T_3 and at later stages, the uptake was the lowest in the azimsulfuron @ 35 g ai ha^{-1} closely was followed by T_5. At all stages of crop growth except at 20 DAT, potassium uptake was the highest under weedy check (T_8).

Table 41. Effect of weed management practices on nitrogen uptake of crop(kg ha^{-1})

Treatments	20DAT	40DAT	60DAT	harvest
T_1	13.17	32.19	61.69	97.23
T_2	13.69	38.55	67.43	97.58
T_3	15.15	36.54	68.05	103.20
T_4	15.55	40.71	71.61	106.84
T_5	16.55	43.61	79.03	111.17
T_6	16.55	45.38	81.72	137.55
T_7	16.03	41.76	73.60	112.85
T_8	15.42	30.54	54.45	92.82
SEm (±)	1.88	6.93	36.74	72.36
CD(0.05)	2.40	4.61	10.62	14.90

Table 42. Effect of weed management practices on phosphorus uptake of crop (kg ha^{-1})

Treatments	20DAT	40DAT	60DAT	harvest
T_1	6.15	10.41	21.94	36.43
T_2	6.52	12.18	23.32	37.78
T_3	6.99	10.96	24.52	38.55
T_4	6.78	13.05	28.53	41.61
T_5	7.21	13.93	32.31	44.92
T_6	6.97	15.57	31.60	48.52
T_7	7.09	14.32	30.22	44.16
T_8	6.84	9.94	19.81	33.07
SEm (±)	1.90	5.60	34.28	42.43
CD(0.05)	2.41	4.15	10.25	11.41

Table 43. Effect of weed management practices on potassium uptake of crop (kg ha^{-1})

Treatments	20DAT	40DAT	60DAT	harvest
T_1	33.22	74.65	126.04	203.96
T_2	35.88	96.25	144.41	209.43
T_3	37.11	84.04	150.33	211.65
T_4	38.48	101.14	159.98	203.96
T_5	42.93	114.69	180.37	248.24
T_6	42.16	105.57	184.07	268.02
T_7	43.56	103.92	165.48	249.50
T_8	37.60	71.06	113.92	184.51
SEm (±)	9.69	99.99	143.92	275.08
CD	5.45	17.51	21.01	29.05

Table 44. Effect of weed management practices on nitrogen uptake of weed (kg ha^{-1})

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0	1.50	4.52	10.79
T_2	0	1.47	3.84	6.47
T_3	0	1.48	4.08	8.33
T_4	2.71	0.38	2.84	7.76
T_5	3.31	0.23	2.57	6.37
T_6	3.27	0.00	1.76	4.43
T_7	2.84	2.34	2.70	12.60
T_8	2.77	5.23	13.45	23.18
SEm (±)	0.21	0.03	0.71	1.87
CD	0.80	0.30	1.47	2.39

DAT-Days after transplanting

Table 45. Effect of weed management practices on phosphorus uptake of weed (kg ha^{-1})

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0	0.88	2.82	6.21
T_2	0	0.85	2.30	3.93
T_3	0	0.92	2.63	4.62
T_4	2.16	0.22	1.97	4.68
T_5	2.74	0.13	1.93	3.72
T_6	2.57	0.00	1.23	2.65
T_7	2.60	1.39	1.88	8.13
T_8	2.44	3.34	7.68	15.09
SEm (±)	0.09	0.02	0.14	0.61
CD(0.05)	0.52	0.26	0.66	1.37

Table 46. Effect of weed management practices on potassium uptake of weed (kg ha^{-1})

Treatments	20DAT	40DAT	60DAT	harvest
T_1	0	2.37	5.51	14.04
T_2	0	2.31	5.12	9.71
T_3	0	2.56	5.85	11.58
T_4	4.77	0.63	4.57	10.92
T_5	5.88	0.40	4.67	8.98
T_6	5.53	0.00	3.05	6.23
T_7	5.51	3.87	4.16	16.83
T_8	4.98	9.67	19.53	32.14
SEm (±)	0.40	0.11	1.24	1.69
CD(0.05)	1.11	0.59	1.95	3.61

DAT-Days after transplanting

4.3.5 Nutrient status of soil after the experiment

The data on nutrient status of the soil after the experiment are presented in Table 47.

The content of nitrogen, phosphorus and potassium in soil after the experiment was found significantly influenced by various weed management practices.

4.3.5.1Available nitrogen

The data indicated that the available nitrogen status of the soil after the experiment was in general lower than the initial status (536.5 kg ha^{-1}). The nitrogen content of soil was the highest under T_6 (501.17 kg ha^{-1}) and was on par withT_5. The lowest nitrogen content of 439.04 kg ha^{-1} was under the weedy check (T_8).

4.3.5.2 Available phosphorus

The highest available phosphorus (24.57 kg ha^{-1}) was estimated under T_6 which was on par withT_5, while weedy check recorded the lowest phosphorus status (16.45 kg ha^{-1}).

4.3.5.3Available potassium

In case of available potassium also, the value was the highest under T_6 (212.53kg ha^{-1}) and the lowest (171.9kg ha^{-1}) under the weedy check (T_8).

Table 47. Effect of weed management practices on nutrient status of soil after the experiment (kg ha^{-1})

Treatments	Nitrogen	Phosphorus	Potassium
T_1	457.06	19.87	187.06
T_2	475.11	21.84	199.48
T_3	485.03	22.57	206.83
T_4	480.85	19.20	193.5
T_5	489.21	23.91	204.17
T_6	501.17	24.57	212.53
T_7	459.8	18.45	188.77
T_8	439.04	16.45	171.9
SEm (±)	55.75	0.59	9.33
CD(0.05)	13.07	1.34	5.35

DAT -Days after transplanting

4.3.6 Economic analysis

4.3.6.1 Net income

Data on economics of various treatments worked out were statistically analysed and presented in Table 48.

The data on economics of rice cultivation as influenced by the weed management practices showed that the net income was significantly higher (Rs.91704ha^{-1}) under T_6 (azimsulfuron @ 35 g ai ha^{-1}). The next higher net income was recorded under T_3 (bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1}) which was on par with T_5 (azimsulfuron @ 30 g ai ha^{-1}). The net income from the unweeded control was significantly inferior to all the other treatments. Income from hand weeded plots was found on par with that from T_2, T_4 and T_1.

4.3.6.2 Benefit cost ratio

The benefit cost ratio from T_6 (azimsulfuron @35 g ai ha^{-1}) was found significantly higher than that from all other treatments.T_3 (bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1}) was the nest best treatment and was on par with T_5. Lowest B: C ratio was recorded by the weedy check, which was on par with that from hand weeded plots (T_7) and both these treatments were statistically inferior to all the herbicide treatments.

Table 48. Effect of weed management practices on economics of the treatments

Treatments	Gross income (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net income (Rs ha^{-1})	B:C ratio
T_1	132728	71704	61024	1.85
T_2	135743	72135	63608	1.88
T_3	146987	72567	74420	2.02
T_4	138455	72125	66330	1.91
T_5	143003	72468	70535	1.97
T_6	157457	72810	84647	2.16
T_7	148158	86160	61998	1.71
T_8	105441	67410	48031	1.56
SEm (±)	2429.61	89.3	2555.43	0.03
CD(0.05)	5186.98	199.66	5455.59	0.06

Seed-Rs .27/kg   Grain -Rs-17/kg   Straw Rs-2/kg   Lime -Rs 15/kg

FYM-Rs 400/ton   Urea -Rs 8/kg   Factomphos -Rs 20/kg   MOP- Rs 17/kg

Men-Rs 500/day   Women-250/day

4.3.7 Microbial studies

Data on microbial population of the different treatments presented in Table 49.

The data on the microbial population of the soil collected 5 days after herbicide spraying indicated that both bensulfuron methyl +pretilachlor and azimsulfuron had positive impact on microbial population. When treated with bensulfuron methyl + pretilachlor and azimsulfuron, the count of bacteria and fungi in the soil showed substantial increase over that in the untreated soil. The count was highest in azimsulfuron @ 25 g ai ha^{-1} (T_4), followed by azimsulfuron @ 30 g ai ha^{-1} (T_5) and T_6 (azimsulfuron @ 35 g ai ha^{-1}). In bensulfuron methyl +pretilachlor treated plots the microbial population was lower than that of azimsulfuron treatments but higher than that of untreated control plots. Actinomycete count in the herbicide treated plots in general was comparable to that of control plots.

Table 49. Effect of weed management practices on soil microbial population

Treatments	Nutrient agar mediumBacteria		Rosebengal agar mediumFungi		Kennight agar medium Actinomycetes	
	10^{-6}	10^{-7}	10^{-3}	10^{-4}	10^{-3}	10^{-4}
T_1	112	75	142	92	3	2
T_2	72	52	102	72	5	2
T_3	99	61	98	13	6	3
T_4	215	145	250	172	4	2
T_5	196	105	240	90	3	1
T_6	156	78	174	89	4	2
T_7	65	29	98	44	7	4
T_8	78	32	86	39	4	3

Discussion

5. Discussion

Despite the obvious advantages of herbicides, their use has raised concerns relating to human health and the environment. The new generation herbicides are applied at very low doses with less environmental persistence and low toxicity to non-target organisms and the present focus is to popularise them. The results of the field experiment conducted to evaluate the efficacy of two new generation herbicides (azimsulfuron and bensulfuron methyl + pretilachlor) in transplanted rice presented in the previous chapter are discussed hereunder.

5.1. Observations on the weeds

5.1.1 Weed spectrum

The degree and nature of weed crop competition is dependent on the weed species infesting the area, density of infestation and duration of infestation (Rao, 2000). The results of the present study revealed that there was substantial diversity of weed flora in the experimental site. There were one grass species, three species of sedges and eight broad leaved species competing with the rice crop. Such diversity in rice weed flora has been documented earlier by Smith (1983) who reported as many as 350 species in more than 150 genera and 60 families as weeds in rice. The result also reflects the floristic diversity of Kerala state in general and is in conformity with the reports of Sajithbabu (2010) who recorded 46 weed specii associated with the cultivated wetland rice ecosystems of Thiruvananthapuram district in Kerala, during the first crop season. In his study, the broad leaved weeds and grasses topped the list with 16 specii each while in the present study, the diversity for the broad leaved weeds was much higher than that of grasses. Such differences in species composition and diversity may be attributed to differences in soil types and cultural practices as opined by several earlier workers (Tomita *et al.*, 2003; Vidya *et al.*, 2004).

5.1.2. Effect of weed management practices on relative dominance of weed flora

In the present study, the relative dominance of different classes of weeds as influenced by the weed management practices was determined by working out the vegetation analysis parameters *viz*., Absolute density (Ad), Relative density (Rd), Absolute frequency (Af), Relative frequency (Rf), Importance value (IV) and Summed dominance ratio (SDR) of grasses, sedges and broad leaved weeds. These observations were taken on 20 DAT, 40 DAT, 60 DAT and at harvest stage.

The results of the vegetation analysis parameters clearly indicated that the grass weed density in the experimental field was comparatively low especially during the early stages. The broad leaved weeds were the most dominant both in terms of species diversity and infestation density. Another major indication from the data was that both bensulfuron methyl + pretilachlor and azimsulfuron, were effective as broad spectrum herbicides. Between different classes of weeds, ie., grasses, sedges and broad leaved weeds, there was no apparent differentiation in their weed control efficiency. The broad spectrum weed control efficiency of sulfonyl urea group of herbicides has been reported by several earlier workers (Mukerjee and Singh, 2004; Saha and Rao, 2007). Saha (2006) has reported that all the new generation herbicides he tested recorded better weed-control efficiency in comparison with the traditional recommended rice herbicides and gave higher yield of rice irrespective of their dose of application.

Being a pre emergence herbicide, bensulfuron methyl + pretilachlor was applied on the next day of transplanting and when observed on 20 DAT, the absolute density of all classes of weeds in these treated plots was zero irrespective of the doses tried. The weed density under all the other treatments was substantial and between treatments, they were on par with each other. However, on 40 DAT as well as in the later stages, the weed density in bensulfuron methyl + pretilachlor treated fields were either on par with or greater than that in the hand weeded plots. Among the three doses tried, bensulfuron methyl +pretilachlor @ 75+750 g ai ha^{-1}was found to be performing better than the lower doses.

From the results it was evident that the pre emergence herbicide bensulfuron methyl + pretilachlor had inhibited weed seed germination and the initial flushes of weeds had failed to emerge out. The results are in line with the reports of Kathirvelan and Vaiyapuri (2003) who observed that pre emergence application of bensulfuron methyl was found to be the very effective treatment in controlling all types of weed population and their growth. However, on 40 DAT the weed population was on par or higher than that in the hand weeded plots and significantly inferior to the azimsulfuron treatments. The trend was more or less similar in the observations taken on later stages also. Thus, it could be inferred that bensulfuron methyl + pretilachlor was a promising broad spectrum herbicide for early season weed control, but for season long weed management, it would be better to integrate it with any other control measures such a hand weeding at 40 DAT and the inference is supported by reports of Sunil *et al*. (2010) who observed that pre-emergence application of bensulfuronmethyl+pretilachlor (6.6 GR) had to be integrated with one manual weeding at 40 days after sowing to obtain satisfactory weed control and higher grain and straw yield.

The post emergence herbicide, azimsulfuron was applied on 18 DAT and the treatment effect in reducing weed density was not evident on 20 DAT. However, its efficiency in managing weeds was clearly shown in the data taken on 40 DAT and the later stages. At these stages, the weed growth was lower in the plots treated with azimsulfuron at various doses. There were no weeds of any class in azimsulfuron @ 35 g ai ha^{-1} and under the lower doses of the herbicide also, the weed count was comparatively less. The observations on herbicide phytotoxicity as discussed later in this chapter had shown that by about 10 days after spraying (DAS), the treated weed seedlings decayed out completely. Here again, weeds of all three classes were found susceptible to the herbicide and the effect was found maintained throughout the

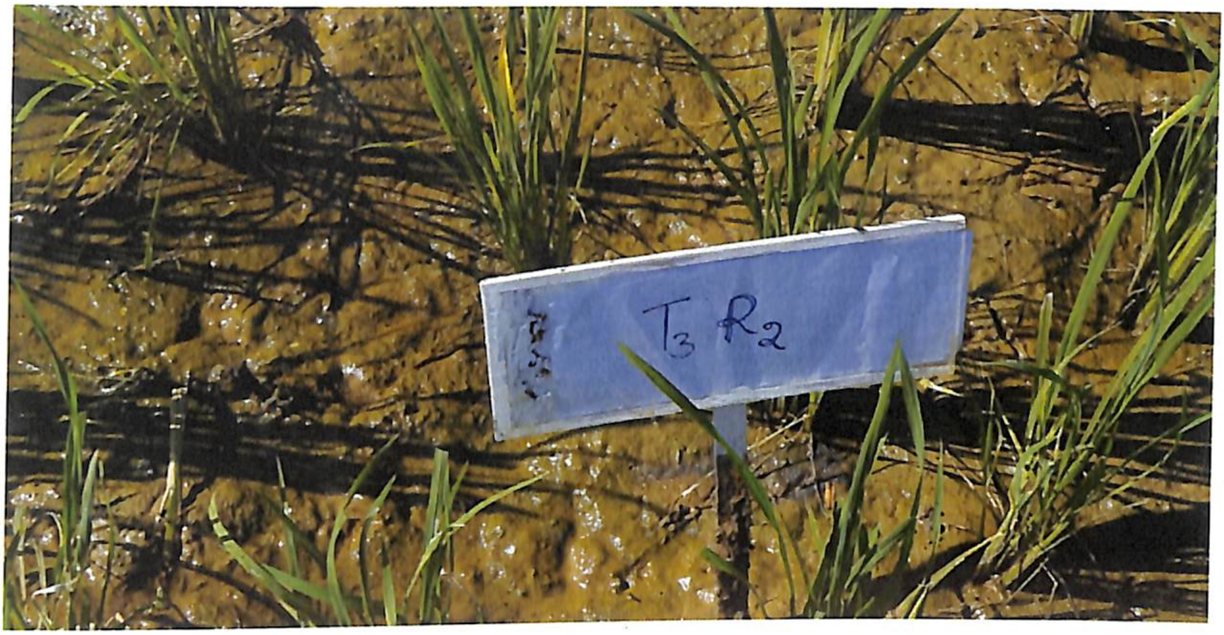

Plate 3. Plot treated with Bensulfuron – methyl + pretilachlor @ 75+750g a.i. ha^{-1} (T_3)

Plate 4. Weedy check (T_8) at 20 DAT

Plate 5. Plot treated with Azimsulfuron @ 35 g ai ha^{-1} (T_6) at 40 DAT

Plate 6. Weedy check (T_8) at 40 DAT

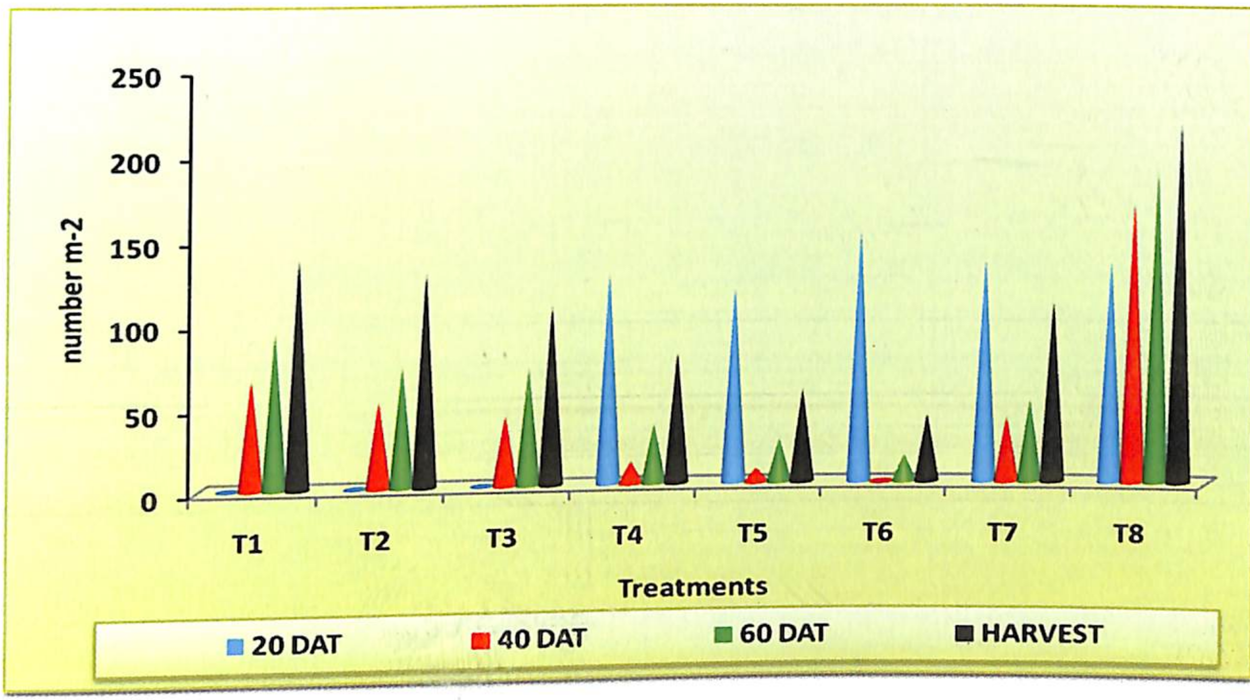

Fig 2.Effect of weed management practices on total weed density (number m^{-2})

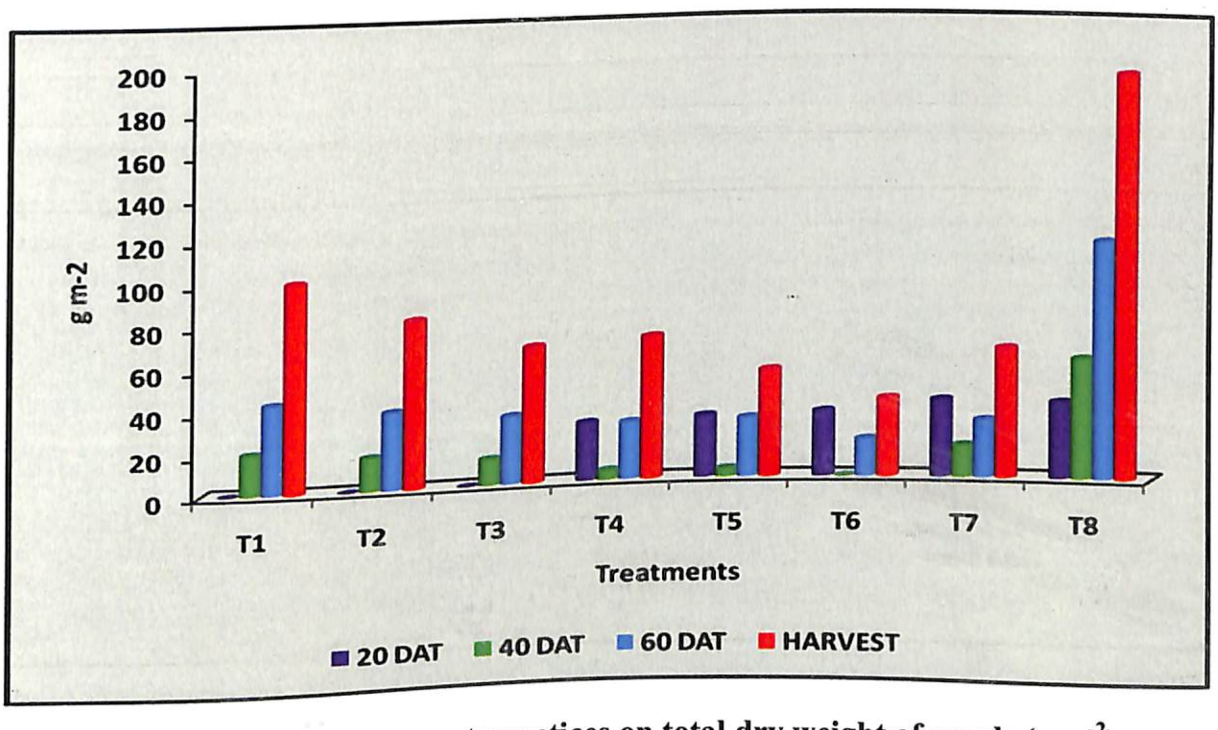

Fig 3. Effect of weed management practices on total dry weight of weeds (g m^{-2})

season. Valle *et al*. (2006) reported that azimsulfuron could selectively control a wide range of weeds in lowland rice. Jayadeva *et al.* (2009) reported that azimsulfuron @ 35 g ai ha^{-1}applied at 19 DAT recorded significantly lower dry weight of grasses, sedges and broadleaved weeds but, the highest grain and straw yield was under azimsulfuron @ 30 g ai ha^{-1}. In another field study, Pacanoski and Glatkova (2009) observed that azimsulfuron gave excellent control of annual and perennial weeds in direct sown rice. However, contrary to these reports and the results of the present study Yadav *et al*. (2007) observed that efficacy of azimsulfuron was not satisfactory against broad leaved weeds. Such contradiction could be attributed to weed species diversity in different localities.

5.1.3 Weed dry weight and weed control efficiency

The influence of the weed management practices on weed dry weight was more or less in conformity with the results on weed growth pattern discussed earlier. In bensulfuron methyl + pretilachlor treated plots weed dry weight was zero at 20 DAT and increased steadily at later stages. As already mentioned, the effect of the post emergence herbicide azimsulfuron was not evident at 20 DAT while at 40 DAT, azimsulfuron @ 35 g ai ha^{-1} was the most effective among all the treatments and the weed dry weight was zero. The total weed dry weight in the unweeded plot was 56.56 g m^{-2} at this stage. The weed dry weight in bensulfuron + pretilachlor treatments was higher than that in azimsulfuron treatments, but they were superior to the hand weeded plots. At later stages also azimsulfuron @ 35 g ai ha^{-1} was superior in terms of reducing weed dry weight. The weed dry weight recorded by the weedy check remained high all throughout the crop growth and showed a steady increase with increasing crop age. At the harvest stage, the total weed dry weight was as high as 191.72 g m^{-2} under weedy check while that under azimsulfuron @ 35 g ai ha^{-1}which recorded the lowest value, the weed dry weight was only 37.13 g m^{-2}.

The data on weed control efficiency of the management practices revealed that bensulfuron methyl + pretilachlor was a very efficient for controlling weed

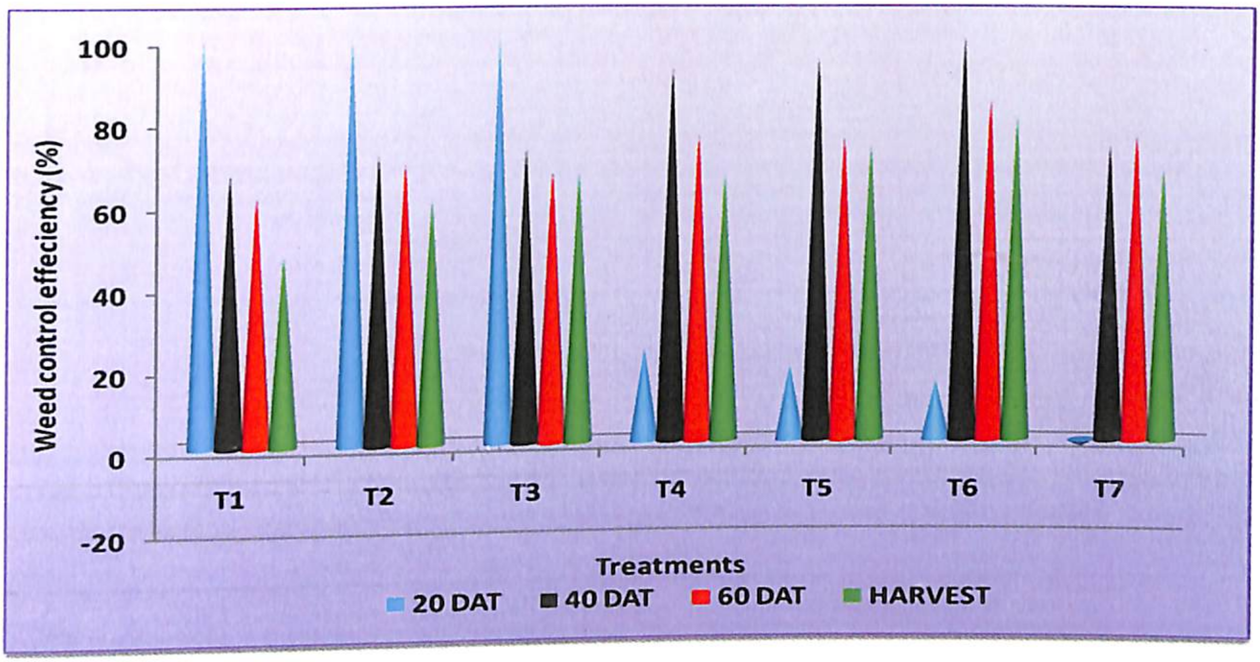

Fig 4. Effect of weed management practices on total weed control efficiency (%)

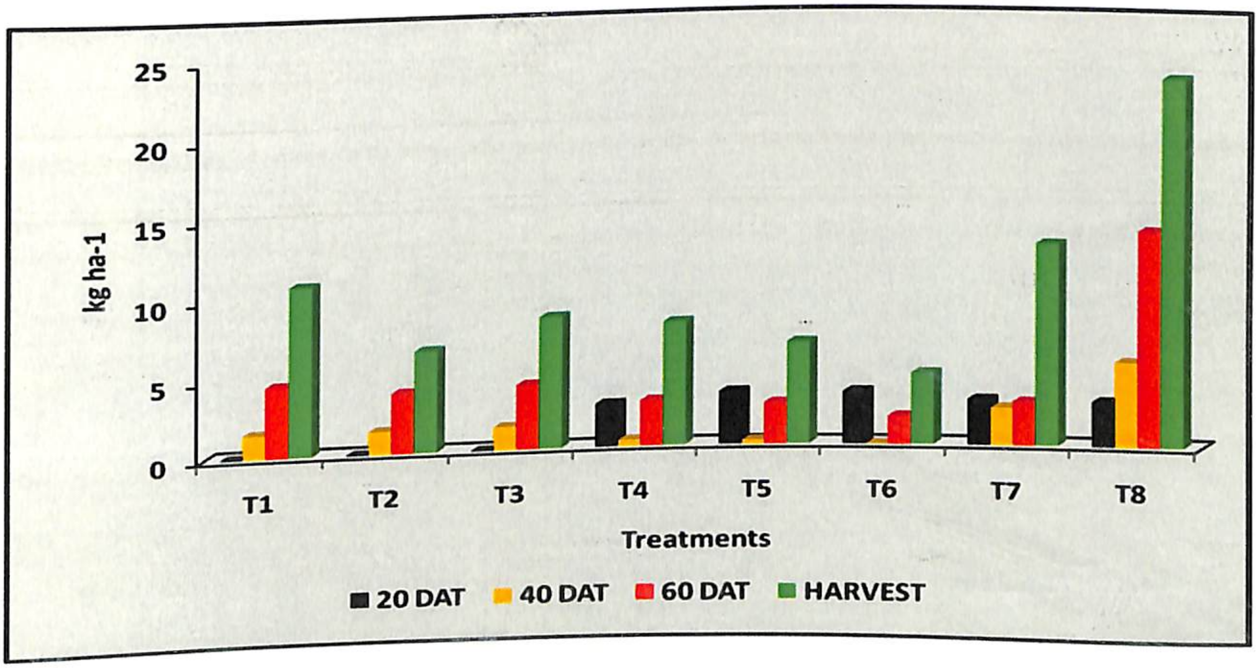

Fig 5. Effect of weed management practices on nitrogen uptake of weeds (kg ha^{-1})

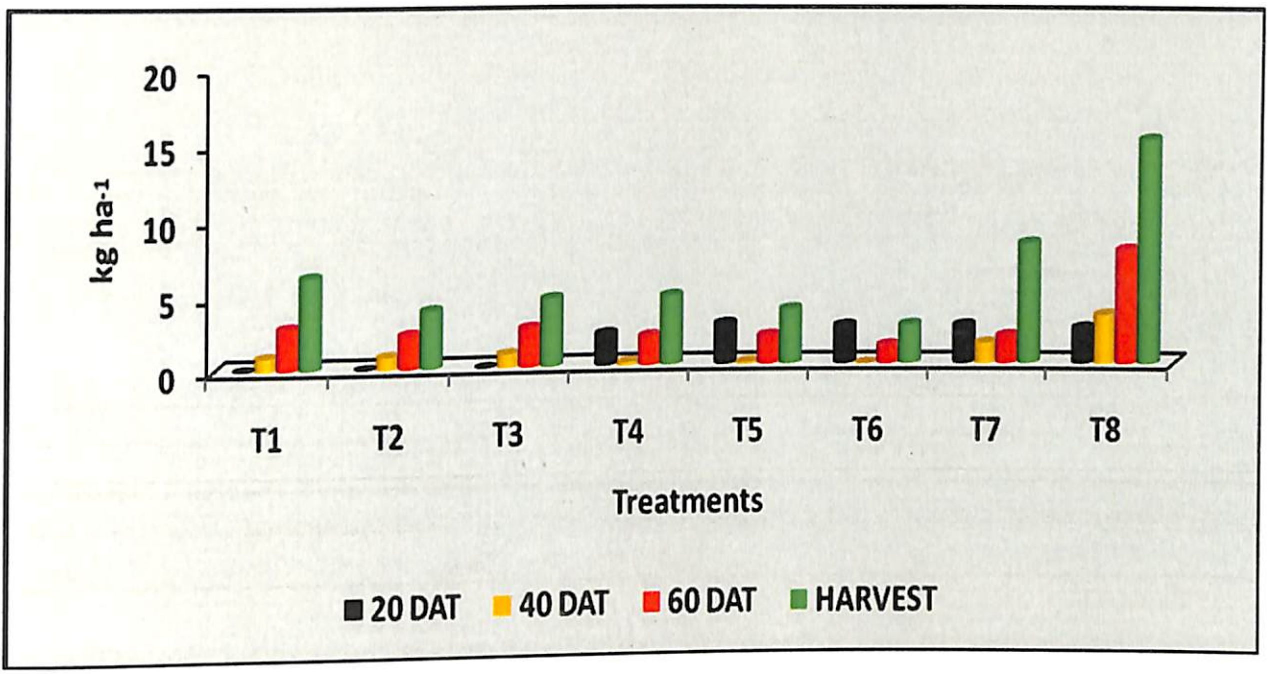

Fig 6. Effect of weed management practices on phosphorus uptake of weeds (kg ha^{-1})

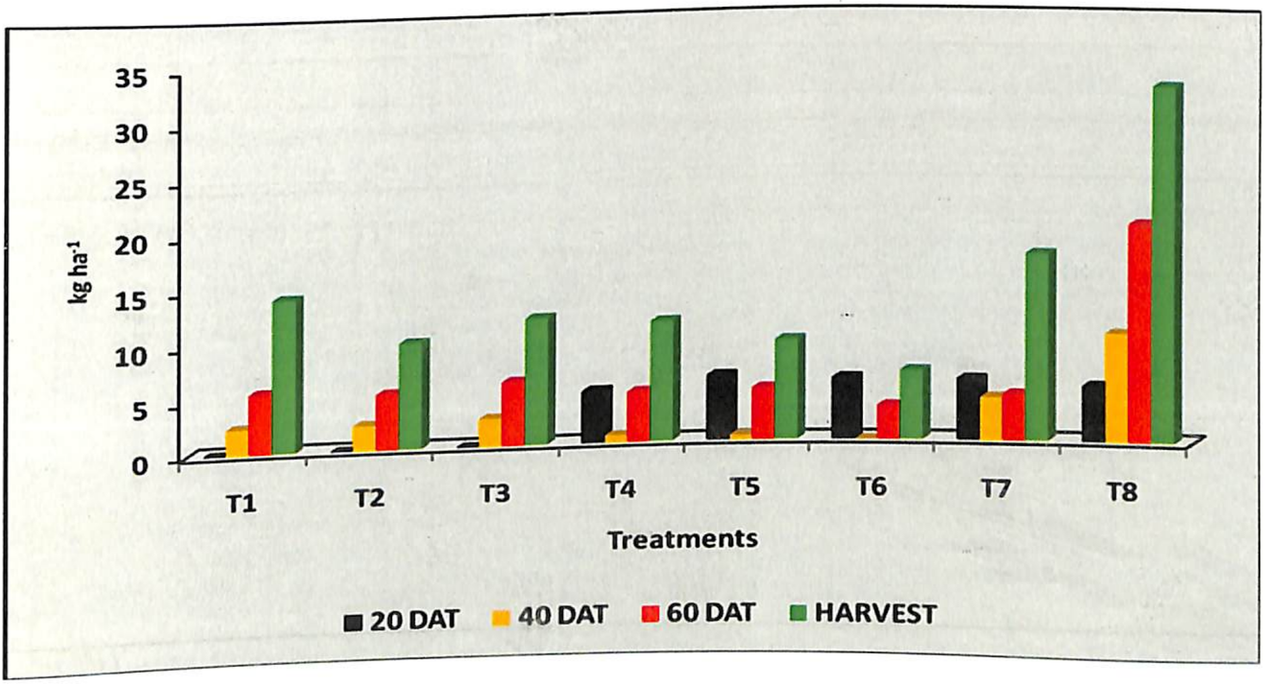

Fig 7. Effect of weed management practices on potassium uptake of weeds (kg ha^{-1})

growth in the early crop growth stage. In this connection it has to be mentioned that this granular herbicide is recommended to be applied in a 3-4 inches standing column of water and the water level is to be maintained for a period of one week after application. This standing column of water must have improved the overall efficiency of the herbicide in inhibiting weed seed germination. However with advancing crop stages, weeds started emerging out and the WCE came down substantially. At 20 DAT, the effect was negligible or even negative in azimsulfuron treatments but the data on 40 DAT, 60 DAT and harvest stage clearly showed that azimsulfuron was very promising for transplanted rice and among the three doses tried, azimsulfuron @ 35 g ai $ha^{-1}$was found superior. The results reaffirms the observations made by Samanta *et al*. (2010) that sulfonylurea (SU) based products are helping farmers around the globe to meet their crop protection needs in effective and environmentally sound ways and is one of the most important advances in crop protection technology in the 21^{st} century.

5.1.4 Nutrient uptake by weeds

The nutrient removal in all the treated plots was found much less than that in weedy check at all the four stages of observation. Among the three nutrients analysed, nitrogen uptake by weeds was found higher than that of phosphorus and potassium and the results are in line with the observation made by Shetty and Gill (1974) who reported that the weeds were better in nitrogen uptake while the crop was more efficient in absorbing phosphate and potash from the soil. Dry matter accumulated by weeds was maximum under the weedy check throughout the crop period and evidently the unchecked weed growth had exploited all the available nutrients to the maximum. The results reaffirms the need for weed management in transplanted rice for reducing nutrient loss as reported by several earlier workers (Holm *et al*., 1991; Srinivasan *et al*.,2008). An estimate has shown that weeds could deprive the crops 47 per cent N, 42 per cent P, 50 per cent K, 39 percent Ca and 24 per cent Mg of their nutrient uptake (Balasubramaniyam and Palaniappan, 2001).

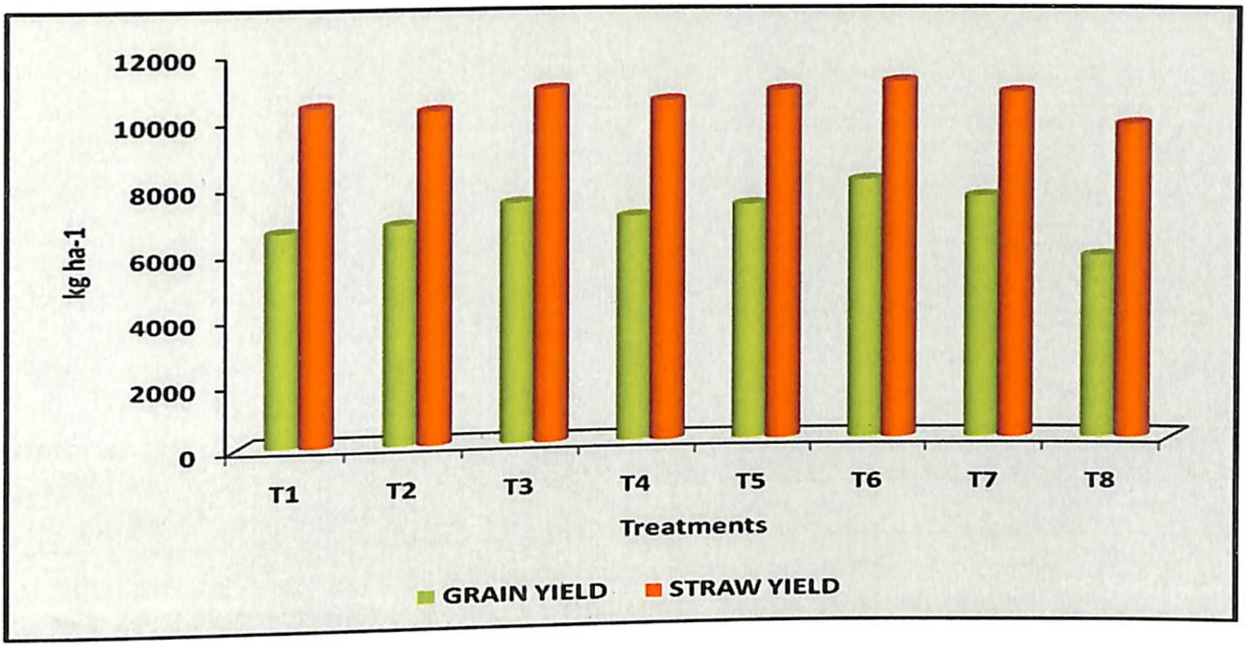

Fig 8. Effect of weed management practices on grain and straw yield (kg ha^{-1})

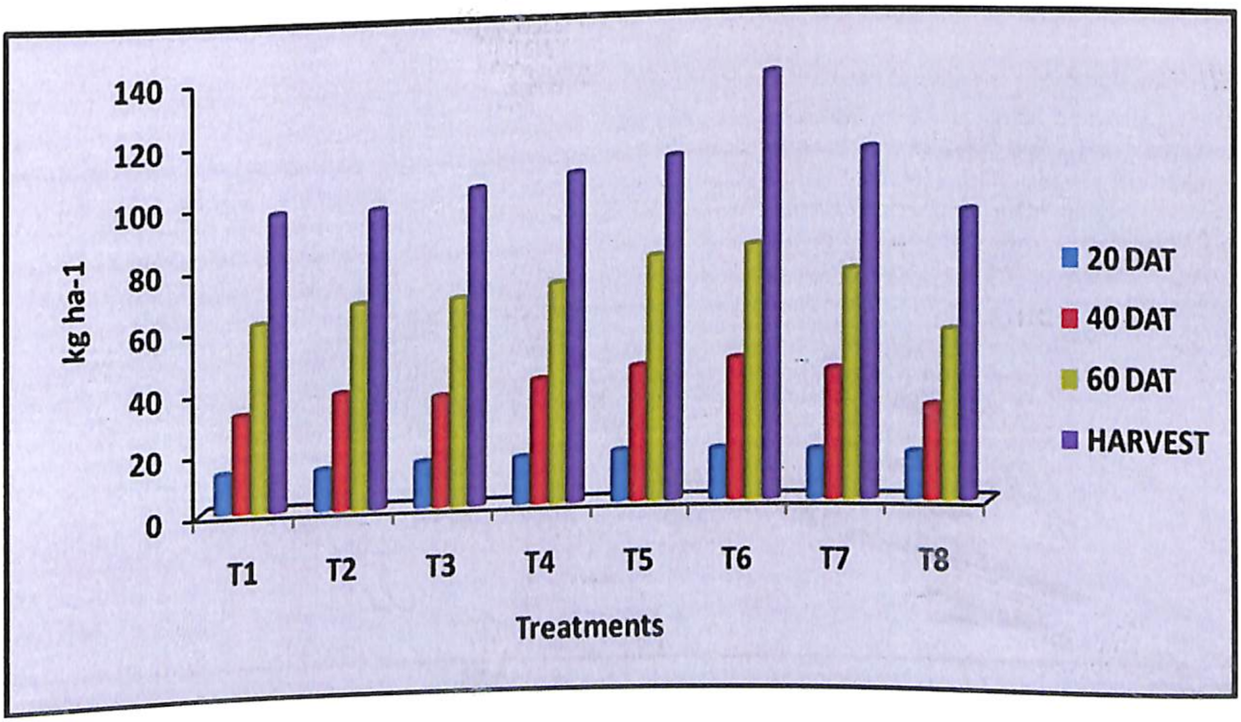

Fig 9. Effect of weed management practices on nitrogen uptake of crop (kg ha^{-1})

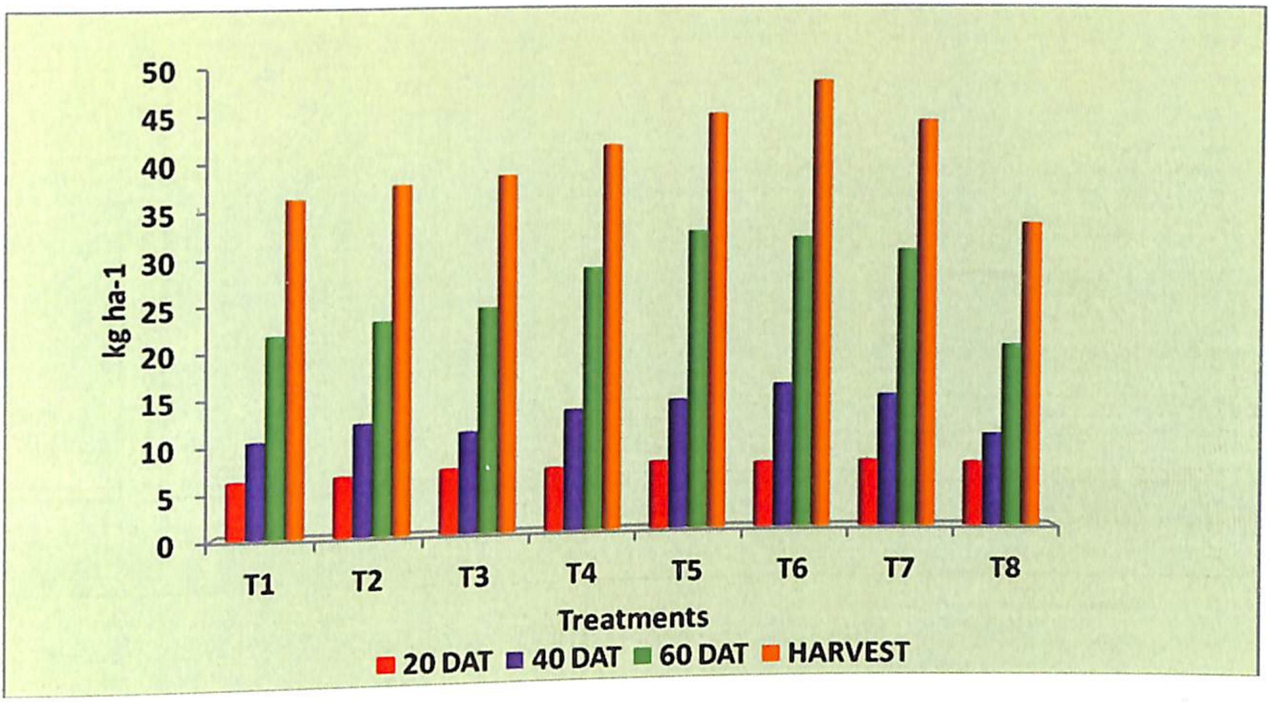

Fig10. Effect of weed management practices on phosphorus uptake of crop (kg ha^{-1})

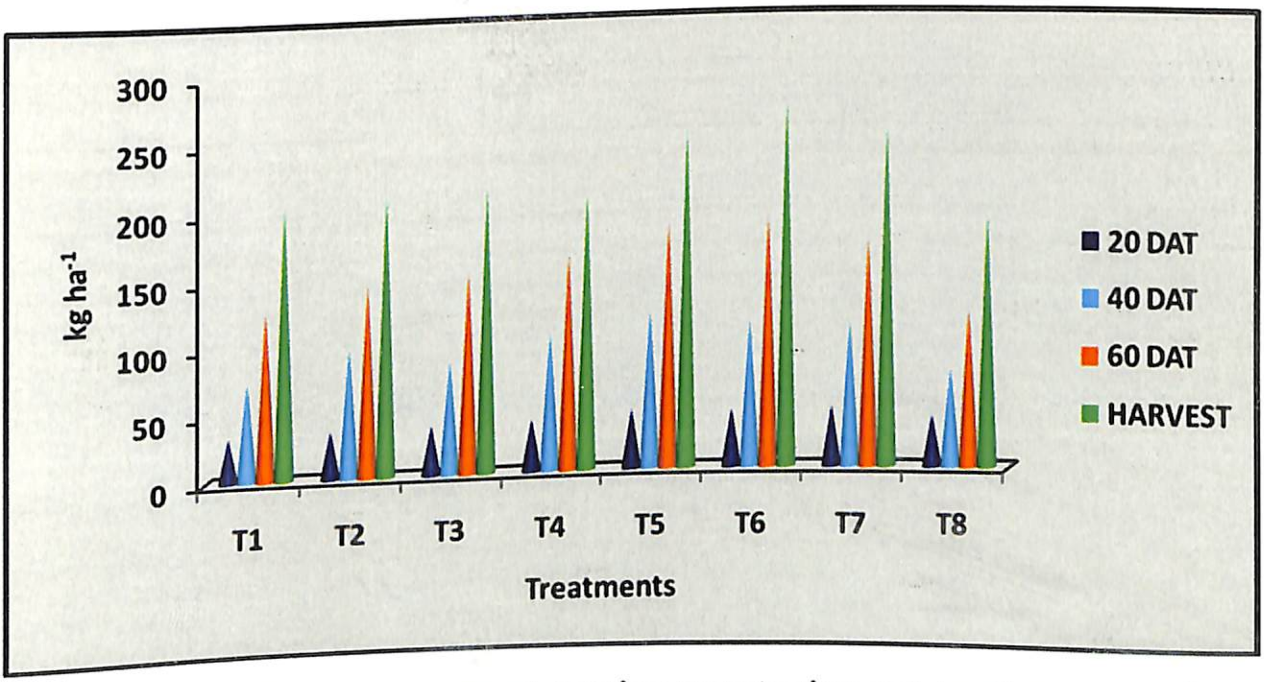

Fig 11. Effect of weed management practices on potassium uptake of crop (kg ha^{-1})

5.2 Influence of weed management practices on crop growth characters

The results of the present study were indicative of the importance and significance of efficient weed management in enhancing growth and vigour of rice crop. It was interesting to note that inspite of the weed free condition, the crop under the pre emergence herbicide was less vigorous in terms of plant height and tillering during the early growth stages. They had regained vigour towards later stages and among the three doses tried bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1} was found performing better than the two lower doses in terms of crop vigour. In this connection, it must be mentioned that the water management recommendation for rice crop is to maintain water level at about 1.5 cm during transplanting. Thereafter the water level is to be increased gradually to about 5 cm until maximum tillering stage (KAU, 2011). It is quite possible that the maintenance of 7-10 cm column of standing water for about a week immediately after transplanting (which was a pre requisite for application of the granular pre emergence herbicide) had a negative influence on the tillering of the rice seedlings especially during the early growth stage. On the other hand the influence of the azimsufuron treatments on plant vigour was found to be on par with hand weeding and the effect was maximum under azimsulfuron @ 35 g ai ha^{-1}.

5.2.1 Influence weed management practices on yield attributing characters and yield

From the data it was evident that effective weed control especially during the critical period of crop weed competition had a positive role in determining the yield attributing characters and yield of rice. The productive tiller count was found maximum under azimsulfuron @ 35 g ai ha^{-1} and the superiority of the treatment was found on par with that of hand weeding and statistically significant over others. In terms of productive tiller production bensulfuron methyl + pretilachlor @ bensulfuron methyl +pretilachlor @ 75+750 g ai ha^{-1} was on par with hand weeding and significantly superior to the two lower doses. The sterility percentage also followed more or less a similar trend. The grain filling as evidenced by thousand grain weight was also better in the more vigorous plants and lowest in plants which were constantly competing with weeds for resources. Similar, results have been obtained by Mabbayed and Moody (1992) who reported that reduction in tiller number, panicle length, thousand grain weight and crop growth rate, delayed ripening and reduced light transmission were noticed due to weed competition in rice. The increase in yield attributing characters in rice may be attributed to better crop growth owing to decreased weed competition during critical growth stages and increased nutrient supply as opined earlier by Gopinath and Pandey (2004).

The positive influence of efficient weed management on yield attributing characters was reflected in final grain and straw yield of the crop also. In general, the yield recorded was much higher than the state average and reemphasized the reason for the high popularity of the variety Uma used for the present study. Maximum grain yield of 7970.97 was recorded by azimsulfuron @ 35 g ai ha^{-1}which was found significantly superior to all the other treatments in the study. Hand weeding was the next best treatment, closely followed by bensulfuron methyl + pretilachlor @ 75+750 g ai $ha^{-1}$and azimsulfuron @ 30 g ai ha^{-1}. The straw yield recorded was also maximum for azimsulfuron @ 35g ai ha^{-1} but, was statistically on par with bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1}, azimsulfuron @ 30 g ai $ha^{-1}$and hand weeding. As in the case of the yield contributing characters, grain and straw yield were also lowest under the weedy check.

The yield trend in the present study re emphasize the significance of critical period of crop-weed competition and the need for keeping the field weed free during the critical period. As per KAU (2011) recommendation, rice field has to be kept weed free up to 45 days either by hand weeding or by use of herbicides. It was obvious that the yield realized was maximum in treatments which could keep the field weed free during the critical period and that is specifically the reason attributable for the better performance of azimsulfuron @ 35 g ai ha^{-1} as well asbensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1}. The direct influence of weed competition on yield characters and yield of transplanted rice has been reported by several earlier workers (Singh *et al*., 2003; Gopinath and Pandey, 2004). In treatments with minimum weeds to compete with and share the resources, the crop growth was more vigorous and ultimately it was reflected in the final grain and straw yield as well. Efficiency of azimsulfuron for weed control and yield increase in rice crop has been reported by Jayadeva *et al.* (2009) while the effectiveness of bensulfuron methyl + pretilachlor for weed control and consequent yield increase was reported by Saha and Rao (2010).

5.2.3 Effect of weed management on nutrient removal by the crop

Nutrient removal by the crop was also found influenced by the weed management practices at all stages of observation. In the present study, the nutrient uptake was more in treatments under which the crop was more vigorous. On 20 DAT, the uptake values were lower under plots treated with bensulfuron methyl + pretilachlor where in the growth was found less vigorous during the early stage. Throughout the growth, the uptake values were higher in the azimsulfuron @ 35 g $aiha^{-1}$and lowest in weedy check.

Unlike in the case of weeds which removed more of nitrogen, crop uptake of potassium was more than that of nitrogen and phosphorus. The results are in line with Shetty and Gill (1974) who observed that weeds were found better in nitrogen uptake while the crop was more efficient in absorbing phosphate and potash from the soil. However, the results are contrary to the earlier reports by Jacob and Syriac (2005) and Sajithbabu (2010) who reported higher crop uptake values for nitrogen.

5.2.4 Visual symptoms of herbicide phytotoxicity

In plants treated with azimsulfuron, yellowing of leaves was the earliest visual symptom. When observed on three days after spraying (DAS), the susceptible weed seedlings were found chlorotic. By the 5th day the affected plants started decaying, and within ten days the entire plants turned into an undistinguishable mass. Nishan (2012) who worked on management of water cabbage (*Limnocharis flava)* has made similar observations on visual symptoms of azimsulfuron phytotoxicity.

In plots treated with bensulfuron methyl + pretilachlor, the weed propagules failed to emerge out and there were no weed growth in the early stages of observation. However, plants started to emerge out by about 25 days after application and the freshly emerging plants showed no phytotoxicity symptoms.

In the present study, none of the herbicide treatments showed any phytotoxic symptoms on the rice plants. It could be safely concluded both azimsulfuron and bensulfuron methyl + pretilachlor were broad spectrum selective herbicides for transplanted rice. The results are supported by the observations of Yadav *et al*. (2008) that there was no phyto-toxicity of azimsulfuron on rice and also there was no residual toxicity on the succeeding crop of wheat.

5.3 Nutrient status of soil after the experiment

The content of nitrogen, phosphorus and potassium in soil after the experiment was found significantly influenced by various weed management practices. The data indicated that the status of all the available nutrients in the soil after the experiment was lower than that of the initial status. Sajithbabu (2010) who studied crop weed competition in rice has reported that when compared to the initial status, the available nitrogen and potassium content of the soil was found declined while there was an improvement in available phosphorus. The soil nutrient status was highest under azimsulfuron @ 35 g ai ha^{-1} followed by azimsulfuron @ 30 g ai ha^{-1}. The effectiveness of azimsulfuron for controlling the weeds must have indirectly conserved soil nutrients also. The low nutrient status under weedy check re emphasized that weeds are capable of removing large quantities of plant nutrients from the soil and starve the crop.

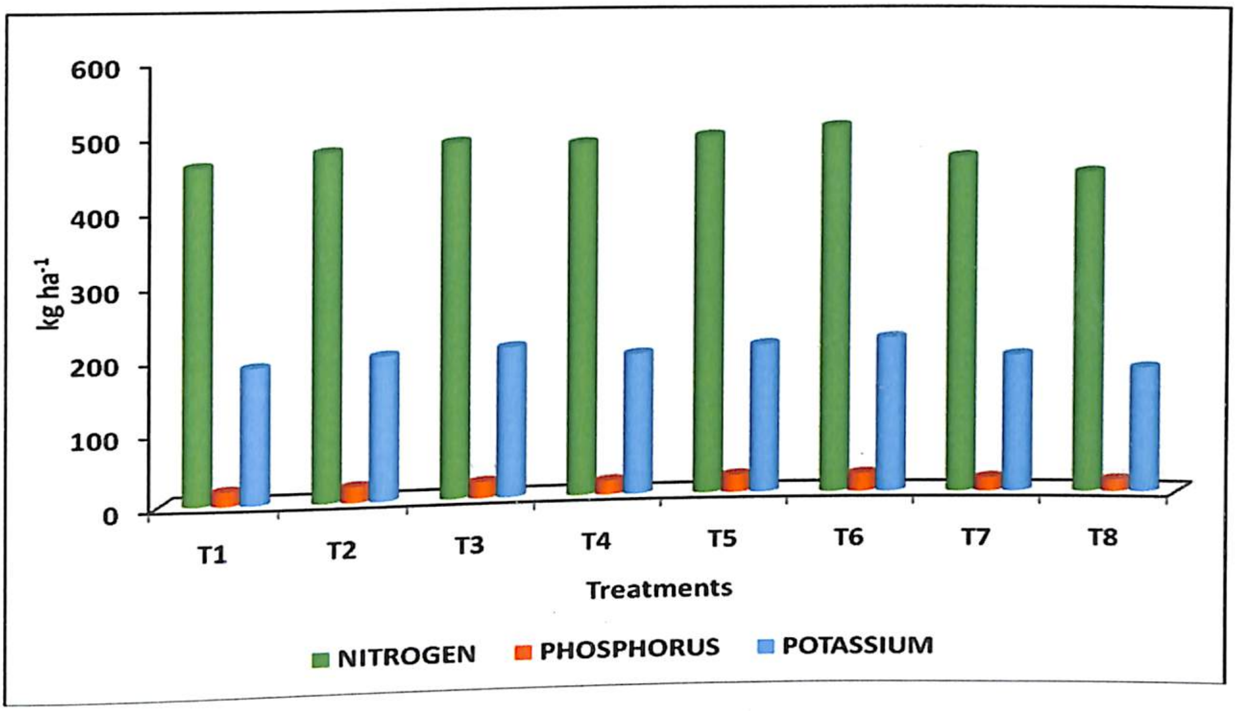

Fig 12. Effect of weed management practices on nutrient status of soil after the experiment (kg ha^{-1})

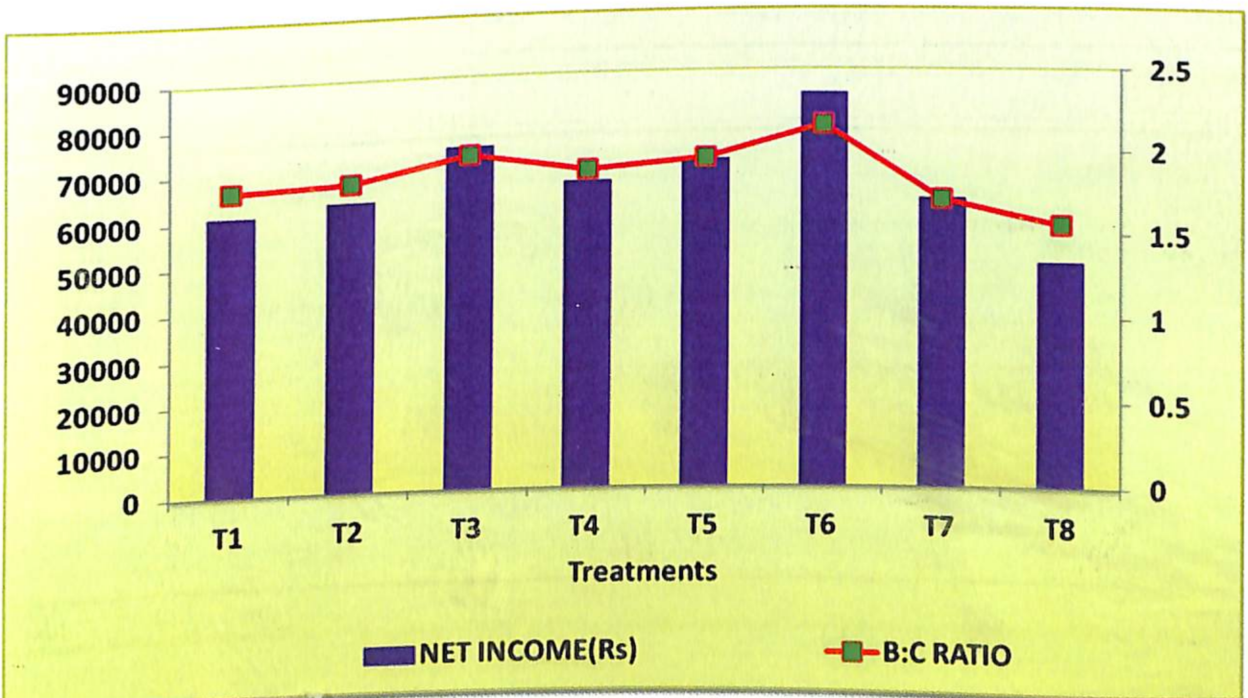

Fig.13 Effect of weed management practices on economics of the treatments

5.4 Microbial studies

Population size of microorganisms serves as bioindicators of the impact of herbicide application in the agro-ecosystem (Milosevic and Govedarca, 2002). In the present study, the microbial populations in soils treated with the new generation herbicides were compared with that of the untreated control to study the effect of herbicide application on agro ecosystem.

The data on the microbial population of the soil collected 5 days after herbicide spraying indicated that the herbicides bensulfuron methyl + pretilachlor and azimsulfuron, did not have any harmful effect on the microbial population of the soil at any of the concentrations tried. In fact, the count of bacteria and fungi showed substantial increase in soils treated with the herbicides than the untreated soil. Between the two herbicides, in bensulfuron methyl + pretilachlor treated plots the microbial population was lower than that of azimsulfuron treatments. Actinomycete count in the herbicide treated plots in general was comparable to that of control plots. Enhancement of microbial population in herbicide treated plots was reported earlier by Radosevich *et al.* (1995) who observed that the herbicides and their metabolites as sources of biogenous elements resulting in increased population. Positive effect of herbicide treatment on soil microbial population in wetland rice ecosystem was reported by Sreethu (2011) and according to her, the presence of decayed weed biomass in the herbicide treated plots probably had triggered the microbial flora. The enhancement in the microbial activity of these herbicides indicated the rapid microbial degradation of sulfonylurea herbicides and confirms their environmental safety (Li *et al.*, 1999). The results are in conformity with the reports of Nishan (2012) who observed similar effect of azimsulfuron and metsulfuron methyl + chlorimuron ethyl on soil micro organisms.

5.5 Economics of weed management

The data on economics of weed management and rice cultivation revealed that remuneration from rice cultivation was significantly influenced by the weed management practices followed. The net income and the benefit cost ratio were substantially higher under all the herbicide treated plots and among them the best was azimsulfuron @ 35 g a.i ha^{-1} followed by bensulfuron methyl + pretilachlor @ 75+750 g ai $ha^{-1.}$ The net income from the unweeded control was significantly inferior to all the other treatments. The variation in net income between azimsulfuron @ 35 g ai ha^{-1} which recorded the highest income and that from the weedy check was Rs. 37490/- which was substantial for a crop season. The B: C ratio also confirmed the superiority of the new generation herbicides for weed management in transplanted rice. It was obvious that hand weeding was effective in controlling the weeds but the cost of cultivation was much higher bringing down the net income and B: C ratio and favoring chemical weed control in terms of economics of rice cultivation. The results of the present study supports the observations made by Kathiresan (2001) that the use of the low dose high efficiency herbicides will reduce the total volume of herbicide use and make herbicide application easier and economic.

Summary

6. SUMMARY

An investigation entitled "Evaluation of new generation herbicides in transplanted rice (*Oryza sativa* L.)" was undertaken in a farmer's field viz., Kanjirathadi padasekharam, in Nemom Panchayath, Thiruvananthapuram district, Kerala state. The period of study was from December 2011 to April 2012. The main objectives of the experiment were to evaluate the weed control efficiency of two new generation herbicides; *i.e;* bensulfuron methyl + pretilachlor and azimsulfuron, in transplanted rice, to assess their selectivity and influence on growth and yield of rice and to work out the economics.

The field experiment was laid out in Randomised Block Design with eight treatments and three replications. The treatments included were, bensulfuron methyl + pretilachlor @ 45+450 g ai ha^{-1}, 60+600 g ai ha^{-1} and 75+750 g ai ha^{-1}, azimsulfuron @ 25 g ai ha^{-1}, 30 g ai ha^{-1} and 35 g ai ha^{-1}, hand weeding at 20 and 40 days after transplanting (DAT) and weedy check (control). Lab studies were also conducted at College of Agriculture, Vellayani to assess the effect of the herbicides on soil micro organisms.

The results of the experiment are summarized below.

1. There was substantial diversity of weed flora in the experimental site. There were one grass species, three species of sedges and eight broad leaved species competing with the rice crop.
2. The broad leaved weeds were the most dominant both in terms of species diversity and infestation density.
3. Both bensulfuron methyl + pretilachlor and azimsulfuron were effective as broad spectrum herbicides. Between different classes of weeds,ie., grasses, sedges and broad leaved weeds, there was no apparent differentiation in their weed control efficiency

4. The pre emergence herbicide bensulfuron methyl + pretilachlor had inhibited weed seed germination and the initial flushes of weeds had failed to emerge out. When observed on 20 DAT, the absolute density of all classes of weeds in these treated plots was zero irrespective of the doses tried.
5. However, on 40 DAT as well as in the later stages, the weed density in bensulfuron methyl + pretilachlor treated fields were either on par with or greater than that in the hand weeded plots.
6. Among the three doses tried bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1} was found performing better than the lower doses.
7. The post emergence herbicide azimsulfuron was applied at 18 DAT, at 2-3 leaf stage of the weeds and the weed flushes were observed to decay out within 10 days of spraying.
8. When observed at 40 DAT, azimsulfuron @ 35 g ai ha^{-1} recorded 100 per cent weed control efficiency. Under the two lower doses of azimsulfuron also, the weed growth was found substantially controlled.
9. Although some weeds re emerged and established later, the overall weed control efficiency of azimsulfuron treatments at advanced crop growth stages was found to be better than that in the other treatments.
10. The nutrient removal by weeds in all the treated plots was found much less than that in weedy check at all the four stages of observation. Among the three nutrients analysed, nitrogen uptake by weeds was found higher than that of phosphorus and potassium.
11. The results on crop response to the weed management practices indicated that effective weed control especially during the critical period of crop weed competition had a significant positive role in determining the yield attributing characters and yield of rice.
12. Inspite of the weed free condition, the crop under the pre emergence herbicide was less vigorous in terms of plant height and tillering during the early growth stages. They had regained vigour towards later stages and among the three

doses tried bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1} was found performing better than the two lower doses in terms of crop vigour.

13. Both grain and straw yield were highest under azimsulfuron @ 35 g ai ha^{-1} and the lowest yield was recorded under the weedy check.
14. Inspite of the weed free condition during the early crop growth stages, the crop treated with bensulfuron methyl + pretilachlor yielded less than that under azimsulfuron @ 35 g ai ha^{-1}, implying that the application of the pre emergence herbicide could be integrated with one hand weeding at 40 DAT for better yield advantage.
15. Nutrient removal by the crop was also found to be influenced by the weed management practices at all stages of observation. On 20 DAT, the uptake values were lower under plots treated with bensulfuron methyl + pretilachlor wherein the growth was found less vigorous during the early stage. Throughout the growth, the uptake values were higher in the azimsulfuron @ 35 g ai ha^{-1} and lowest in weedy check.
16. Crop uptake of potassium was more than that of nitrogen and phosphorus.
17. The status of all the available nutrients in the soil after the experiment was lower than that of the initial status. The soil nutrient status was highest under azimsulfuron @ 35 g ai ha^{-1} followed by azimsulfuron @ 30 g ai ha^{-1} and lowest under weedy check.
18. The net income under the herbicide treated plots was found to be substantially higher than that of hand weeding and among them the best was azimsulfuron @ 35 g ai ha^{-1}.The B: C ratio also confirmed the superiority of the new generation herbicides for weed management in transplanted rice.
19. None of the treatments showed any phototoxic symptoms on the rice plants.
20. Soil microbial population showed that the soil samples from the herbicide treated plots had a higher microbial population than that of the untreated plots.

21. Overall inference from the study was that both azimsulfuron and bensulfuron methyl+ pretilachlor are promising broad spectrum herbicides for transplanted rice.

Future lines of Research

In the present study, the treatments were limited to different doses of the herbicides only. The advantage of integrating herbicide application with manual weeding may be studied especially in the case of the pre emergence herbicide. Similarly, the efficiency of these herbicides on direct seeded rice need to be investigated since direct-seeding is gaining popularity among farmers of Kerala. More detailed studies on the fate of these herbicides on agro – ecosystem may also be undertaken as a future line of work.

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EVALUATION OF NEW GENERATION HERBICIDES IN TRANSPLANTED RICE (*ORYZA SATIVA* L.)

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(2011 - 11 - 157)

Abstract of the
Thesis Submitted in partial fulfillment of the
requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
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2013

ABSTRACT

An investigation entitled "Evaluation of new generation herbicides in transplanted rice (*Oryza sativa* L.)" was undertaken during December 2011 to April 2012. The main objectives were to evaluate the weed control efficiency of two new generation herbicides; *ie;*bensulfuron methyl + pretilachlor and azimsulfuron, in transplanted rice, to assess their selectivity and influence on growth and yield of rice, and to work out the economics.

The design was Randomised Block Design and the treatments were , bensulfuron methyl + pretilachlor @ 45+450 g ai ha^{-1}, 60+600 g ai ha^{-1} and 75+750 g ai ha^{-1}, azimsulfuron @ 25 g ai ha^{-1}, 30 g ai ha^{-1} and 35 g ai ha^{-1}, hand weeding at 20 and 40 days after transplanting (DAT) and weedy check.

The results indicated that both bensulfuron methyl + pretilachlor and azimsulfuron were broad spectrum herbicides. Bensulfuron methyl + pretilachlor, applied as pre emergence herbicide was found effective for controlling weed growth especially during the early crop growth stages and among the three doses tried, bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1} was found performing better than the lower doses. The efficiency of azimsulfuron for managing weeds as a broad spectrum post emergence herbicide was evident from observations on 40 DAT, 60 DAT and at harvest stage. On 40 DAT azimsulfuron @ 35 g ai ha^{-1} recorded 100 per cent weed control efficiency and at later stages also it was superior to other treatments.

Grain yield recorded was significantly higher under azimsulfuron @ 35 g ai ha^{-1}. The next best treatment was hand weeding andit was followed by bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1} and azimsulfuron @ 30 g ai ha-^{1}. Straw yield also was highestin azimsulfuron @ 35 g ai ha^{-1} but it was on par with bensulfuron methyl + pretilachlor @ 75+750 g ai ha^{-1}, hand weeding and

azimsulfuron @ 30 g ai ha^{-1}.The lowest grain and straw yield were recorded underweedy check.

The net income under the herbicide treated plots was found to be substantially higher than that of hand weeding and weedy check. Among the various herbicide treatments, the best result was under azimsulfuron @ 35 g ai ha^{-1}.The B: C ratio also confirmed the superiority of the new generation herbicides for weed management in transplanted rice.

None of the treatments showed any phytotoxic symptoms on rice plants.

The results on soil microbial population showed that the soil samples from the herbicide treated plots had a higher microbial population than that of the untreated plots.

Overall inference from the study is that both azimsulfuron and bensulfuron methyl + pretilachlor are promising broad spectrum herbicides for transplanted rice.

സംഗ്രഹം

പുത്തൻ തലമുറയിൽപ്പെട്ട കളനാശിനികളുടെ കാര്യക്ഷമത സംബന്ധിച്ച് ഒരു പഠനം ഡിസംബർ 2011 മുതൽ ഏപ്രിൽ 2012 വരെയുള്ള കാലയളവിൽ നടത്തുകയുണ്ടായി. തിരുവനന്തപുരം ജില്ലയിലെ കാഞ്ഞിരത്തടി പാടശേഖരത്തിൽ പറിച്ചുനടീൽ രീതിയിലുള്ള നെൽകൃഷിയിൽ നടത്തിയ ഈ പരീക്ഷണത്തിൽ ബെൻസൾഫ്യൂറോൺ മീതൈൽ+പ്രെട്ടിലാക്ളോർ (സംയുക്ത ഉൽപ്പന്നം), അസിംസൾഫ്യൂറോൺ എന്നീ നൂതന കളനാശിനികളാണ് ഉൾപ്പെടുത്തിയത്.

ബൻസൾഫ്യൂറോൺ മീതൈൽ + പ്രെട്ടിലാക്ളോർ ഹെക്ടറിന് 75 + 750 ഗ്രാം എന്ന തോതിൽ കളകൾ മുളയ്ക്കുന്നതിന് മുൻപ് അതായത് ഞാറ് പറിച്ചുനട്ടതിന്റെ പിറ്റേദിവസം പ്രയോഗിക്കുന്നത് വഴി നെല്ലിന്റെ ആദ്യവളർച്ചാ ഘട്ടങ്ങളിലെ മിക്കവാറും എല്ലാത്തരം കളകളെയും ഫലപ്രദമായി നിയന്ത്രിക്കാമെന്ന് പരീക്ഷണഫലം തെളിയിക്കുകയുണ്ടായി. അതുപോലെതന്നെ അസിംസൾഫ്യൂറോൺ ഹെക്ടറിന് 35 ഗ്രാം എന്ന തോതിൽ കളകളുടെ 2 – 4 ഇല പരുവത്തിൽ അഥവാ ഞാറുനട്ട് പതിനെട്ടാം ദിവസം പ്രയോഗിക്കുന്നതും നെല്ലിലെ കളനിയന്ത്രണത്തിന് വളരെ ഫലപ്രദമാണെന്ന് കാണുകയുണ്ടായി.

വരണാത്മക സ്വഭാവമുള്ള ഈ രണ്ടു കളനാശിനികളുടെയും പ്രയോഗം നെല്ലിന്റെ വളർച്ചയെയോ, മണ്ണിലെ സൂക്ഷ്മ ജീവികളുടെ പ്രവർത്തനത്തെയോ പ്രതികൂലമായി ബാധിക്കുന്നില്ലെന്നും മനസിലാക്കാൻ സാധിച്ചു.

പ്രസ്തുത കളനാശിനികളുടെ പ്രയോഗംവഴിയുള്ള ഫലപ്രദമായ കളനിയന്ത്രണത്തിലൂടെ നെല്ലിന്റെ ഉൽപാദനം വർദ്ധിക്കുകയും ഉൽപാദനചെലവ് ഗണ്യമായി കുറയുകയും ചെയ്യുന്നുവെന്നും ഈ പഠനം തെളിയിച്ചു. ഈവക കാരണങ്ങളാൽ ഈ രണ്ടു കളനാശിനികളുടെയും ഉപയോഗം നെൽകൃഷിയിൽ പ്രതീക്ഷയ്ക്ക് വക നൽകുന്നു.

Appendices

APPENDIX – I

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

Standard weeks	Maximum temperature (^{0}C)	Minimum temperature (^{0}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