BIO-EFFICACY, PHYTOTOXICITY AND SOIL ENZYME STUDIES OF AZIMSULFURON ON PADDY-ZERO TILLED RAPESEED ALONG WITH BIOLOGY OF MAJOR ASSOCIATED WEEDS

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in

AGRONOMY

By
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Dedicated
To
Beloved
Parents
&
My Sir

APPROVAL OF EXAMINERS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (AGRICULTURE) IN AGRONOMY

We, the undersigned, having been satisfied with the performance of Sr **Kironmay Barui,** in the *viva-voce* Examination, conducted today the 12th March, 2009 recommend that the thesis be accepted for award of the Degree of **Doctor of Philosophy (Agriculture) in Agronomy.**

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This is to certify that the works recorded in the thesis entitled, "**BIO-EFFICACY, PHYTOTOXICITY AND SOIL ENZYME STUDIES OF AZIMSULFURON ON PADDY-ZERO TILLED RAPESEED ALONG WITH BIOLOGY OF MAJOR ASSOCIATED WEEDS**" submitted by Sri Kironmay Barui, in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Agriculture (Agronomy) of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, is a faithful and bonafide research work carried out under my personal guidance and supervision.The result of the investigation reported in this thesis have not so far been submitted for any other Degree or Diploma.

The assistance and help received during the course of investigation have been duly acknowledged.

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Place : Mohanpur, Nadia, W.B
Dated : 25th August '08

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LIST OF ABBREVIATIONS

^{0}C	Degree of centigrade	Min	Minimum
mm	Millimeter	g	Gram
N	Nitrogen	BL	Broad leaf
P	Phosphorus	Sp.	Species
K	Potassium	SEm	Standard error mean
ha	Hectare	CD	Critical difference
m	Meter	@	At the rate of
kg	Kilogram	*et al.*	et alia (and others)
t	Tonne	cm	Centimeter
DAA	Days After Application	m^{-2}	Per square meter
DAT	Days After Transplanting	Re^{-1}	Per rupee
DAS	Days After Sowing	SSP	Single super phosphate
DAE	Days After Emergence	MOP	Muriate of potash
ha^{-1}	per hectare	POE	Post Emergence
%	Percentage	TR	Transplanted
&	And	Rs	Rupees
Fig.	Figure	LAI	Leaf Area Index
RH	Relative humidity	WCE	Weed Control Efficiency
Viz.	Videlicet (Such as)	µg	microgram
G	Grannule	EC	Emulcifiable Concentrate
ppm	Parts per million	No.	Number
NS	Not significant	Max	Maximum
l	Litre	i.e.	id est (that is to why)
etc.	Et cetera	e.g.	examli gracia (for example)
cv	Cultivar	$^{-1}$	Per
PE	Pre-emergence	PoE	Post Emergence
EPoE	Early Post Emergence	DS	Direct seeded
TR	Transplanted	a.i.	Active ingradient
WG	Wettable Grannule	DF	Dry Flourable
m^{-2}	Per square meter	pH	Log ^{10} hydrogen ion concentration
SL	Soluble liquid	SG	Soluble Grannules

ABSTRACT

The field experiment was conducted at the 'C' Block (Incheck) Farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia,West Bengal, India during 2006-07 and 2007-08. The experimental field was medium land with sandy loam in texture having good irrigation and drainage facilities. In Experiment 1, 11 treatments comprising with 6 combination doses of Azim + MSM (among which 2 was only for phytotoxicity), sole use of Azim (2) and MSM (1), standard Pretilachlor and untreated control were evaluated in a randomized block design with three replication in both transplanted paddy cv. IET 4094 (Experiment 1 A) as well as direct seeded paddy cv. IET 4786 (Experiment 1 B) alongwith its residual effect on the follow up zero tilled rapeseed cv. B-9 during winter season. The influence of applied herbicides on soil urease enzyme and soil microflora status of the experimental soil was evaluated in Experiment 2. The biology of the two major important weeds *Echinochloa crus-galli* in anaerobic and *Cyperus rotundus* in aerobic situation (Experiment 3) was observed and in Experiment 4 an attempt was made to findout the ways & means about the most problematic *Cyperus rotundus* through different weed management practices such as ecological, biological and chemical means of control.

The experimental results revealed that in Inceptisol of Indo-Gangetic plains of West Bengal in transplanted paddy during *kharif* season most dominant grassy weed flora were, *Echinochloa crus-galli, Echinochloa formosensis, Paspalum conjugatum* & *Leersia hexendra* among sedges *Cyperus difformis, Fimbristylis littoralis* & *Cyperus iria* while among the broadleaves *Alternanthera philoxeroides,Eclipta alba, Stellaria media* & *Marsilea quadrifolia* whereas in direct seeded paddy *Echinochloa colona, Eleusine indica, Digitaria ciliaris* & *Dactyloctanium aegyptium* (grass); *Cyperus rotundus* & *Cyperus difformis* (sedge) and *Ammania baccifera, Stellaria media, Eclipta alba, Oldenlandia corymbosa, Physalis minima, Phyllanthus niruri,* (broadleaf) were in throughout the experimental period. The anaerobic transplanted paddy recorded significantly lower biomass including individual category of weed than in direct seeded.

In follow-up zero tilled rapeseed the most important weed flora observed during the experimentation were *Echinochloa colona, Digitaria sanguinalis, Eleusine indica, Dactyloctaniun aegyptium, Cyperus rotundus,* (sedge) *Cleome viscosa* , *Argemone mexicana, Blumea lacera, Gnaphalium luteoalbum, Melilotus alba, Chenopodium album, Physalis minima, Anagallis arvensis* are the most dominant broadleaf weeds present.

At 30 DAA, the highest weed control efficiency 79.08 % & 75.25 % and at 45 DAA 76.47 % &72.55 % were recorded from Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} in transplanted and direct seeded paddy, respectively.

No phytotoxocity symptom regarding epinasty, hyponasty, leaf tip yellowing, surface injury, wilting and chlorotic or necrotic symptoms as well as stunting growth of the plant in both TR and DS paddy was observed with the application of Azim either as sole or as mixture with MSM with or without surf even with its double dose or even to the germination or seedling growth of the follow-up rapeseed due to low to moderate persistency and high selectivity. All the crop plants looked healthy in the experimental field during both the years.

The maximum grain (4.76 t ha^{-1}) and straw yield (5.76 t ha^{-1}) of transplanted paddy was achieved by Azim 40 + MSM 2 + 0.2 % surf which was 74.33 % & 52.78 % over to control, respectively. In direct seeded paddy the corresponding figure were 3.56 t ha^{-1}, 4.28 yield t ha^{-1}, 71.15 % and 44.59 %.

Despite of giving highest net return of Rs 14,595.00 in transplanted paddy, application of Azim 40 + MSM 2 + 0.2 % surf was found to be more remunerative and economical with maximum return per rupee investment (1.96) which was 66.10 % higher return over control and in direct seeded paddy also same treatment realizing best in economic point of view and recorded highest return of Rs 9,126.00 with highest return per rupee invested (1.92) which was 56.48 % higher than to control.

Chemical weed management in the paddy crops also played a vital role in the follow-up rapeseed crop growth and yield by influencing weed-competition by minimizing the first flash weed infestation. Adoption of Azim 40 combining with MSM 2 and adding 0.2 % surf to the preceding TR rice recorded 14.45 % & 10.46 % higher seed and stover yield, respectively over untreated control. Rapeseed after DS paddy also increased seed and stover yield to the tune of 23.55 % &11.46 % than that of control plot where no chemical was used in the earlier crop of the same sequence.

The zero tilled rapeseed grown with the residual soil moisture after transplanted paddy was more economical when herbicides were used in the previous crop of same system. Azim 40 + MSM 2 + 0.2 % surf when applied to paddy recorded the maximum net return per rupee invested were 1.56 & 1.50 which were 13.04% & 23.96 % more than untreated control in TR and DS follow-up crop, respectively. In the crop sequence, paddy – rapeseed as a whole, application of the testing Azim with its highest dose of 40 + MSM 2 and adding 0.2 % surf in paddy was found to be economical and exhibited highest return per rupee investment 1.84 & 1.63 which was 48.18% & 44.24 % more than control in TR and DS rice sequence, respectively.

In follow up zero tilled rapeseed, initially recorded significantly lower number of weeds unit^{-1} area where Azim + MSM + 0.2 % surf was applied to the preceding rice could able to control the broad spectrum of weeds in situ condition in addition to inhibited the viable weed seeds present in the upper soil surface (0-15 cm) very effectively and reduced the first flash emergence of weeds in the follow up crop.

In transplanted paddy field all the chemicals exerted only a detrimental influence on the proliferation of total bacteria, actinomycetes and fungi in the rhizosphere soil upto third week after application of the herbicides but thereafter a rapid recovery in growth and a notable increasing trend was observed over to untreated control excepting the sole MSM which showed a long lasting detrimental effect upto another two weeks. The urease enzyme activity of soil during the experimentation was also increased with application of all types of herbicide than that of untreated control except MSM where the uraese activity was decreased in all the dates of observation.

Regarding all the treatments used in this investigation chemical control, was found to be more superior than the other physical, ecological and biological methods for controlling *Cyperus rotundus*. XL-COMBI-SG (35 % Glyphosate + 35 % 2,4-D ammonium salt) @ 5g l^{-1} was the best for controlling this most problematic weeds. Glyphosate 41 % SL @ 10 ml and Azimsulfuron 50 G + MSM + 0.2 % surf @ 40 + 2 g a.i. ha^{-1} may also be applied according to the land situation where less regrowth was observed. Application of extracts of *Calotropis gigantea* @ 10 ml l^{-1} water also recorded a good control of *Cyperus* at very early stage but this activity persists only for a month. Extracts of *Parthenium hysterophorus* @ 10 ml l^{-1} water showed similar results with further lesser duration of its' activity in controlling purple nut sedge.

From the findings of this experiment conducted in the Inceptisol of India it can be concluded that in paddy-rapeseed crop sequence, Azim @ 40 g a.i. ha^{-1} applied in combination with another sulfonyl urea MSM @ 2 g a.i. ha^{-1} and in addition to 0.2 % surf in paddy is the most economical, effective and eco-friendly herbicide replacing the traditional hand weeding method~~s~~ of controlling weed in both paddy cultures and for managing *Cyperus rotundus*, XL-COMBI-SG @ 5 g l^{-1} at is the most suitable technique.

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CHAPTER I

Introduction

INTRODUCTION

Multiplicity of cropping systems has become one of the main features of Indian agriculture which is attributed mostly to rainfed agriculture and prevailing socio-economic conditions of the farming community. It has been estimated that more than 250 double cropping systems are followed throughout the country and based on rationale of spread of crops and the agro-climatic situations of each district in the country, 30 important cropping systems so far have been identified. Rainfed rice based cropping system covers nearly half of the cultivated land area in India. Rapeseed (*Brassica campestris* L.) during winter as a follow up *kharif* rice (*Oryza sativa* L.) is being appreciated as an important cropping system from the view point of food security as well as national economy. Adoption of appropriate high yielding rice and rapeseed cultivars, adequately supported by improved production technology in time can ensure desired productivity of the system.

Rice (*Oryza sativa* L.) is one of the most important staple food crops grown all over the world in terms of area and production, next to wheat. The slogan 'Rice is life', the most appropriate for our country, plays a vital role in food security and is a means of livelihood for millions of rural households. It has the largest acreage of 44.6 m ha with a production of about 90 m t .The important rice growing states are: West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Assam, Bihar, Tamil Nadu and Kerala. West Bengal is the leading state which produces the highest amount of rice (14.39 m t) with cultivating only in 5.84 m ha area followed by Uttar Pradesh.

It is estimated that the demand of rice will be 100 m t during 2010 and 140 m t in 2025 (The Hindu Survey of Indian Agriculture, 2004). The country calls for an additional 3 m t food grains annum^{-1} in the coming years as our burgeoning population is expected to reach 1.5 billion by 2025. For achieving this target, it is a major challenge in view of the fact that the increased production is expected to come from an increase productivity under depleting and diminishing resources, decreasing total factor productivity as well as to meet the demands of sustainability and preservation of environmental quality.

In India, rice is grown under diverse ecosystems starting from aerobic unbunded upland to anaerobic low land. The area under irrigated land, upland, rainfed low lands and deep water rice occupies 20.5, 6.0, 13.0 and 4.0 m ha producing 60.0, 5.5, 16.0, and 3.0 m t with 2.9, 0.9, 1.2 and 0.8 t ha^{-1} productivity, respectively (Singh, 2002). Furthermore, 84.5 m t rice is mainly grown by two different cultures, direct seeding (aerobic and anaerobic) and transplanting (anaerobic). Weed competition is more severe in direct seeded compared with transplanted situation.

Utilization of high rate of ground water particularly for Summer paddy has resulted sharp decline in water table during the last two decades. It has been estimated that ground water in the major rice growing areas of the state is declining at the rate 0.23 m $year^{-1}$ causing serious concern and raising doubt about the future sustainability of anaerobic rice based cropping systems. India has 12 m ha (28 %) of rice area under direct seeding (Palaniappan and Purushothaman, 1991) out of which eastern zone covers more than 50 % area. Ironically, direct seeded rice culture has not been given due importance; however, SRI technology becoming another option is eliminating the need for nursery raising , saving ground water use and reducing labour cost by about 30 %. The transplanting of rice requires huge quantity of water during its growth period, highly labour intensive and a costly method of cultivation (Moody, 1991and 1993). To increase the production of rice to the estimated level, it needs to use the concept of advanced technology of all around development; the improved weed free HYV seeds, INM, IPM and quality produce through organic culture, besides using the concept of rice production through global water technology.

Major competition with weeds in rice field occurs during initial 15-30 days after seeding or germination in direct seeded rice and 30-60 days in transplanted rice (Kumar *et al.*, 1998). Desoki (2003) also reported that in direct seeded paddy between 20 and 40 days after sowing weeds competed maximum and caused drastic reduction towards the number of panicles m^{-2} and thereby grain yield. Therefore, it calls for a detailed study on weed flora in different paddy cultures (transplanted as well as direct seeded puddled) keeping an eye to develop an efficient eco-safe weed management practice for rice cultivation to replace those indigenous method of weed control through the use of effective, economic, socially and environmentally safe chemicals at proper dose, proper time and method of application.

Production of rice in our country is stagnant around 90 m t during the last five years with a productivity of only 2086 kg ha^{-1}. Weeds are considered as a major pest and constraint to increase the production of rice (Labrada, 1996).Weed causes around 18-20 % yield losses in low land situation and 35-45 % in upland situations in the developing countries like India (Ghosh *et al.*,2005). In India, weed control takes 30-35 % share of total cost of crop production and the average yield loss is caused to the tune of 41.2 % (Bhan, 1997). This illustrates the importance of weed control in minimising the yield losses and boosting up the crop productivity.

Management of weeds at farm level is still largely restricted to mechanical and cultural methods (Yaduraju and Mishra 2002). Proper management of weeds, in time, to reduce the crop-weed competition is not possible due to sharp increase in the wage and unavailability of labour due to industrialization and urbanization. In view of this, chemical weed control is becoming more popular throughout the world. With only 4% of the global cropped area, India is the third largest consumer of pesticides in the world and highest among the South Asian countries. At present, India has the share of 1.7% world pesticide consumption .The use of herbicide, in India, has expanded rapidly and as against growth rate of 2.5 % in case of insecticides, 3.3 % in case of fungicides the herbicides' growth rate is 5.0 % $annum^{-1}$.

Chemical weed management through the use of herbicides, due to their effectiveness and easiness in application, has become the major weed control measure in most Asian rice production systems (Kit-ung Kim 2004).Herbicides have dramatically reduced the time spent for eliminating weeds. Recently developed organic herbicides posses some characteristics such as high effectiveness by adding safener and surfactants, less environmental pollution, low toxicity; high selectivity and less persistence in soil. Sulfonylurea, a recent class of organic herbicide, controls a wide range of annual and perennial grasses as well as broadleaved weeds and is noted for their high specific activity, which is reflected in the very low application rates required to obtain economic level of weed control. The herbicide ready mixtures are gradually becoming more popular for controlling all categories of weed flora.

A dynamic research program is needed to develop the innovative and effective weed management strategies to improve crop stability, more economical herbicide treatments with reduced handling and environmental hazards without loss of herbicidal efficacy (Moody, 1992).

Rapeseed (*Brassica campestris* L.) cultivation as one of the major *rabi* crops after rice (Oryza sativa L.) in paddy fields is considerably is being appreciated in recent years. Under rainfed condition, mustard, rapeseed, safflower, linseed can be grown as paira crop after *kharif* paddy with residual moisture (Das, 1991). In India, it is the third most important edible oilseed after groundnut sharing 27.8 % in the India's oilseed economy, meeting the fat requirement of about 50% population in the states like Uttar Pradesh, Punjab, Rajasthan, Madhya Pradesh, Orissa, West Bengal and Assam, besides, contributing 28.3 and 19.8 % in world acreage and production, respectively. The country witnessed Yellow Revolution through a phenomenal increase in production and productivity from 2.68 m t and 650 kg ha^{-1} in 1985-86 to 6.96 m t and 1022 kg ha^{-1} in 1996-97, respectively.

Weed infestation is a limiting factor in oilseed production during all the three seasons. Among the different factors responsible for low productivity, weeds alone cause 20 -30 % (Gill *et al.*, 1984, Bhan, 1992) yield reduction, which may go upto 62 % (Singh, 1992). Recent advances in developing effective weed management practices are very much important in oilseed production.

In plain areas of West Bengal, the optimum time of sowing of the crop is third week of October to first week of November (Ghosh *et al.*, 1987). For obtaining higher yield in rapeseed and mustard, time of sowing is the most important criteria and the best way to avoid delay in sowing after rice is to adopt appropriate relay cropping system technology at zero-tillage. All though the conventional tillage generally produced higher grain yield than minimum tillage, yet the later could be improved to achieve higher yields (Omidi *et al.*, 2004). At the same time tillage mightresult soil structure demolition, splitting soil particles, reduction of top soil and reducing it's hydraulic conductivity and led to erosion hazards.

With zero-tillage technology, farmers can produce more with less cost, with fewer inputs as well as saving on diesel fuel, tractor time and conserving irrigation water as well as reduced soil water losses. This system can provide higher spring soil moisture and lower evaporation losses compared with conventional tillage system.

Zero tillage, enhanced cultural control and gave rise to vigorous growth of crops thereby developed the potential to reduce the need for herbicide use within our crop rotations (Rourke and Hargrave, 1992). So, the incentive for a change from conventional to zero tillage has to come from three directions, viz, improved profitability, productivity and sustainability of a cropping system in addition saving of million top soils. Zero tillage technology offers several advantages in the spheres of economic efficiency, effective weed management and resistance and forms an important component in IWM to ensure profit, productivity and sustainability (Thanh, 2005).

Weed management in present day context of agriculture is now the most important crop protection practice for increasing the global food production. Among the different methods, chemical weed control through herbicide is popular throughout the world because of its several advantages. Herbicide effectiveness is greatly influenced and varies with plant factors (age, size and the growing conditions). A way to minimize the variations in post emergence herbicide performance is to use an adjuvant or surfactant in the spray solution. Surfactants are non herbicidal compounds or adjuvant that enhance the absorption of aqueous solutions of herbicides mainly polar herbicides .These are the chemicals which add to herbicides to improve the herbicide selectivity to the non-target plants, to reduce the dose of herbicides by reducing its different hazards and to help the chemicals safer for the applicants (Ghosh *et al.*,2007). Use of surfactant with the herbicide enhance or modify its performance and improve weed control from 46% to 86% (Atefeh Mousavi *et al.*, 2008)

The production and usage of herbicides have increased tremendously in recent years. Agricultural soils are the ultimate recipient and depository of most of the foliar and soil applied herbicides. Because of the public health awareness, the fate and behaviour of the herbicides in the natural environment has become a matter of great concern, particularly the possible long-term effects on soil fertility may result from disturbance of the soil micro flora as well as soil enzyme activity with a view to determining or predicting possible short- term or long-term effects which may be of practical significance (Greaves *et al.*, 1976). Normally, the herbicides applied at recommended rates to soils are not sufficient to appreciably depress the growth and activity of specific soil microbes (Olsen *et al.*, 1984), instead some of them exert a stimulatory effect on them (Ghosh *et al.*, 2005, Dey and Ganguly, 1984).

The critical period for crop weed competition is very much important for assessing the perfect time to control the weeds. Often this period is approximately the first one fourth to one third of crop life (Kandasamy, 1996). For achieving the information with regard to the crop-weed competition period, the biology of the most important weeds is also very important which is related to the study of weeds in relation to their geographic distribution, habitat growth and population dynamics of the weed species and communities. Development of an appropriate and effective weed management programme is dependent on the sound knowledge of weed biology (Rao, 2000). Therefore, in this present investigation the biology of some important weeds was studied.

The perennials, *Cyperus rotundus* along with *Cynodon dactylon* are the most problematic weeds through out the World. *Cyperus rotundus*, the purple nut sedge, is found in every upland agricultural field as it prefers to grow in aerobic cultures and the nut remains viable for several years. Purple nut sedge is one of the most troublesome weeds in tropical and subtropical regions. It is particularly a challenging pernicious weed as it can increase very rapidly and will cause significant yield loss. In developing countries, the use of effective herbicides to manage this weed is seldom cost effective on one hand and on the other, cause pollution hazards besides affecting quality of the produce (Neeser and Varshney, 2001). Under upland direct-seeded conditions, yield reduction due to sedges varied from 23-48% (Ramprasad *et al.*, 1999); however, in various horticultural crops, the yield loss is upto of 20-89% (Shabana *et al.*, 2008).

Hand weeding some time has been effective against the annual sedges but is often ineffective in controlling perennial sedge species like *Cyperus rotundus*. Cultural practices like sowing or planting patterns, higher crop density, intercropping, raising green manure in the off-season, continuous submergence, integration of other farming elements such as fishes and poultry in the farming system have also been used in controlling sedges. Allelopathic control of sedges in rice using leaves of *Eucalyptus globulus* and *Leucaena leucocephala* has also been reported to be promising (Kathiresan and Bhowmik, 2005), through soil solarization (Patel *et al.*, 2005) and also by means of using different bio-agents like *Bactra verusana*, a shoot boring moth or *Meloidogyne incognita* (Schroeder *et al.*, 2008) and with some bioherbicide like Dr. Biosedge. A range of new herbicide molecules, including the direct application of Glyphosate 41 % SL could reduce the density of *Cyperus rotundus* effectively (AICRP-WC Annual Report 07-08).Now Glyphosate 71 % SL or Glyphosate 41 % SL mixed with 2,4-D are also using to control this pernicious weed.

With these above background information in view, an investigation was undertaken at the 'C' Block Farm (Incheck), Bidhan Chandra Krishi Viswavidyalaya, Kalyani, during 2006-07 and 2007-08 with the following objectives:

1. To evaluate the bioefficacy of the chemical herbicide Azimsulfuron as sole and mixture with Metsulfuron methyl on the weed flora in both aerobic and anaerobic rice cultures;
2. to study on the residual bioefficacy effect of Azimsulfuron as sole and mixture with Metsulfuron methyl in the following zero till rapeseed (*Brassica campestris* var yellow sarson);
3. to evaluate the phytotoxicity of Azimsulfuron on rice and follow up rapeseed crop;
4. to study the effect of Azimsulfuron on the soil microflora as well as on the soil urease enzyme;
5. to study on the weed biology of *Echinochloa crus-galli* and *Cyperus rotundus* in *kharif* season;
6. to find out the management practices for controlling *Cyperus rotundus* in pre-*kharif* season.

CHAPTER II

Review of Literature

REVIEW OF LITERATURE

Several research works were conducted in weed management. In this chapter, an attempt has been made to critically review the literature relating to weed ecology and biology, critical period of crop-weed competition, different methods of weed management in cropping sequences with special reference to paddy – zero till rapeseed including chemical weed control, weed flora dynamics, impact of herbicides on environment particularly on beneficial soil micro flora and soil enzyme and management of some problematic weeds of this region.

2.1 Dynamics of weed flora and its management in different paddy cultures

2.1.1 Dynamics of weed flora

Weed problem in transplanted rice culture (anaerobic) is less acute than in direct seeded rice (aerobic) due to the fact that pre-planting tillage operation kills the existing weeds in this case. Furthermore, continuous submergence causes checks in weed growth.

Besides, transplanting of sturdy seedlings give the crop a steady start against weeds which are just germinating into the transplanted field (IRRI, Annual Report, 1970).

Bhattacharya (1975) reported a loss of 87 cent^{-1} in upland direct seeded rice crop as compared to a loss of only 11.6 cent^{-1} in transplanted paddy.

Under the transplanted condition, early suppression of initial weeds was achieved due to puddling and it resulted in lowering the weed population in transplanted rice (Ranjan and Mahapatra, 1979).

The losses in yield ranged between 9 and 51 cent^{-1} in irrigated rice depending upon the agroclimatic conditions and the methods of cultivation (Mahapatra and Yaduraju, 1981).

Boro rice or summer rice is cultivated in a season where there is spell of winter covering almost 60% of its growing period. Due to cold weather and transplanting under puddled condition, the weed problem is different from the main warm wet (kharif or winter) season rice cultivation. Thus, unlike kharif season where grasses are predominant weeds, in boro season sedge weeds belonging to the family Poaceae (Cyperaceae) are dominant. Some broad-leaved weeds were also found to be more during boro season than kharif season (Moody and Mukhopadhyay, 1982).

Though the weed problem is not so acute in transplanted rice as compared to direct seeded, with the introduction of fertilizer responsive early maturing semi-dwarf rice varieties, timely and early weed control had become highly critical obtaining satisfactory yield (De Datta and Herdt, 1983).

In case of direct seeding in puddled fields because of initial saturated soil condition and susceptibility of young rice seedlings to weed competition, higher losses in grain yield upto 40 $cent^{-1}$ due to unchecked weed growth had been reported (Moorthy and Manna, 1989).

The extent of yield reduction in rice, as evidence from the data collected over a number of seasons at different locations, in India, in the multilocational testing programme of the All India Co-ordinated Rice Improvement Project, had been estimated to be around 15-20% due to weeds alone for transplanted rice, 30-35% for direct seeded rice under puddled condition and over 50% for upland rice (Balasubramanian and Duraisamy, 1996).Balasubramanian and Ravichandran (1996) also reported alike.

Ghosh *et al.*(2007) reported that the major weed flora found in the coastal flood plain of West Bengal in transplanted rice are *Echinochloa cruss-galli, Echinochloa formosensis, Paspalum conjugetum, Leersia hehandra, Cyperus difformis, Cyperus iria, Drynmaria cordata, Eclipta porstrata, Ladwijia octovalis and Scirpus validas.*

2.1.1.1 Dynamics of weed flora in direct seeded aerobic paddy culture

Weed flora in direct seeded rice consists of various kinds of grasses, sedges and broad leaves.

Tiwari and Singh (1991), working at Kanpur during *kharif* season, observed that the weed flora in upland direct seeded rice comprised of *Cyperus rotundus, Echinochloa colona, Phyllanthus niruri, Trianthema monogyna, Digera arvensis, Commelina benghalensis and Digitara sanguinalis.*

Ku *et al* (1993) found that with continuous rice growing under direct seeded cultivation in dry paddy fields, grasses and annual weeds occurred more often while broadleaf and perennial weeds were diminished.

Field experiments conducted at various locations during *kharif* season (Angiras *et al.*, (1998) in Palampur, Kolhe and Tripathy, 1998 in Raipur, Singh *et al.*, 2005 in Pantnagar,) revealed that *Echinochloa colona* and *Echinochloa crus-galli* were the most serious weeds affecting direct seeded rice. *Echinochloa colona* required less moisture than *Echinochloa crus-galli* and the density of these weeds in direct seeded rice rely on moisture conditions of field. *Cyperus rotundus* and *Cynodon dactylon* were the major problem in upland conditions particularly in poorly managed fields. The other weeds of major concern identified in direct seeded rice were *Digitaria sanguinalis*, *Dactyloctenium aegyptium, Paspalum* sp., *Ischaemum rugosum, Leptochloa chinensis, Commelina* sp., *Caesulia axillaries, Ludwigia parviflora, Euphorbia* sp., *Cyperus iria, Fimbristylis miliacea* and *Cyperus difformis.*

In upland situation at Varanasi, *Echinochloa colona, Cyperus rotundus, Cynodon dactylon, Phyllanthus niruri, Ageratum conyzoides, Fimbristylis littoralis, Convolvulus arvensis* were identified as major weeds in rice during *kharif* season in sandy loam soil (Singh and Singh, 1998).

Moorthy and Saha (2001) at Central Rice Research Institute, Cuttack, during the *kharif* season in alluvial sandy loam, identified *Echionchloa colona, Digitaria sanguinalis, Cyperus rotundus, Cyperus iria, Aeschynomene indica, Sphenoclea zeylanica, Ludwigia parviflora, Scirpus articulatus, Ottelia alismoides, Limnophila heterophylla* and *Ceratopteris thalictroides* as major weeds in rainfed lowland direct seeded rice.

Working in the same province at Lakhaoti for two years during the *kharif* seasons, Tomar *et al.* (2002) reported that *Echinochloa colona* among the grasses, *Trianthema monogyna* among the non-grasses and *Cyperus iria* and *Cyperus rotundus* among the sedges were the dominating weed flora in upland direct seeded rice.

Singh *et al.* (2002) found that the dominant weeds in upland direct seeded rice, in Nagaland, were *Eleusine indica, Digitaria sanguinalis, Cynodon dactylon, Setaria glauca, Imperata cylindrica, Cyperus rotundus, Borerhavia hispida, Ageratum conyzoides, Mikania micrantha, Eupatorium odoratum, Valeriana alliariifolia, Erechtites uderianalfelia, Euphorbia hirta, Amaranthus viridis* and *Mimosa pudica.*

2.1.1.2 Dynamics of weed flora in direct seeded anaerobic paddy culture

The most common weeds associated with rice under direct seeded puddled condition are *Echinochloa crus-galli, Echinochloa glabrescens, Echinochloa colona, Leptochloa chinensis, Paspalum distichum, Brachiaria mutica, Ischaemum rugosum,* *Fimbristylis littoralis, Cyperus iria, Cyperus difformis, Scirpus maritimus, Eclipta alba* (IRRI, 1987).

Nandal and Singh (1995) observed that the weed flora was dominated by *Echinochloa colona* and *Cyperus iria* in both the years while *Setaria glauca, Panicum repens* and *Commelina benghalensis* were present only in 1989 while working at Palampur during *kharif* seasons of 1989-90 in silty clay loam soil.

However, at the same location, Angiras and Rana (1998) found diversified weed flora like *Echinochloa crus-galli, Echinochloa colona, Scirpus* sp., *Ammania baccifera, Cyperus iria, Cyperus esculentus, Cyprus difformis, Aeschynomene indica, Monochoria vaginalis, Panicum* sp. and *Commelina forskalli* were prevalent during *kharif* season. Similar weed flora was noticed by Shekhar and Mankotia (2005) in silty clay loam soil at Malan, Himachal Predesh during *kharif* season.

The major weeds reported by Moorthy and Saha (1999) at Central Rice Research Institute, Cuttack, to be *Cyperus difformis*, *Ludwigia parviflora* and *Eclipta prostrata* among the broadleaf weeds. Kathiresan and Manohoran (2002) found *Echinochloa crus-galli*, *Echinochloa glabrescens* and *Echinochloa colona* among the grasses, *Cyperus difformis* and *Cyperus iria* in sedges and *Marsilea minuta* and *Ammania baccifera* in dicots and aquatics as the predominant weeds in clay loam soil during *sambha* season (August-December) under direct sown puddled condition in Tiruchirapalli.

Working at Bidhan Chandra Krishi Viswavidyalaya, West Bengal during the *Kharif* season, Ghosh and Bhowmick (2000) reported that *Echinochloa crus-galli, Cyperus rotundus, Ammania baccifera, Commelina benghalensis* and *Eclipta alba* were the dominant weeds.

Subramanian *et al.* (2002) observed weeds like *Cynodon dactylon, Cyperus rotundus, Eclipta alba, Phyllanthus niruri* as well while working at Madurai during *rabi* season in sandy clay loam soil. Likewise, *Echinochloa* sp., *Cyperus* sp. and *Commelina* sp. were recorded as the major weeds infesting direct seeded puddled rice in Dindor, Madhya Pradesh in clayey soil during the *kharif* season (Tiwari *et al.*, 2002). Those associated weeds are in conformity with those of Urkurkar and Chandrakar (1992). Similar weed flora also was observed by Mahajan *et al.* (2003) in Punjab.

In Indo-Gangetic plains, weeds like *Echinochloa colona* and *Fimbristylis littoralis* predominate while *Cyperus iria* and *Cyperus difformis* also occurerd, However, but grasses offered greater competition under puddled direct seeded condition as they emerged simultaneously with the direct seeded rice crop (Tewari *et al.*, 2005).

2.1.1.3 Dynamics of weed flora in transplanted anaerobic paddy culture

The most predominant weeds in transplanted rice culture in rice growing states of India were reported to be *Sagittaria sagitifolia, Ludwigia parviflora, Monochoria vaginalis, Ammania bacifera, Cyperus iria, Scirpus* sp. and in some cases *Echinochloa crus-galli* (Sahu and Bhattacharya, 1964; Mukhopadhyay, 1968, 1969 and 1971; Singh and Rao, 1970; Ray, 1973).

Mandal *et al.* (1986) found *Cyperus iria* and *Fimbristylis miliacea* as the major sedge weeds in transplanted rice while among the broadleaf weeds at Kalyani in alluvial soil. *Ludwigia parviflora, Eclipta alba* and *Marsilea quadrifolia* were dominant.

Singh and Bhan (1993) reported that continuous flooding and transplanted rice culture resulted un-interrupted vegetative reproduction of aquatic and semi aquatic weeds such as *Monochoria vaginalis, Najas minor, Potamogeton* sp, *Ammania* sp. and *Ipomoea aquatica.* Contrastingly, a field experiment conducted by Thakur *et al.* (1995) in silty clay soils of Bihar, *Cyperus rotundus* and *Cynodon dactylon* were found to be the most dominant weeds covering more than 60 per cent of total weed flora in *kharif* transplanted rice.

Shukla *et al.* (1996) at Jabalpur found five dominant weed species, viz, *Echinochloa crus-galli, Commelina benghalensis, Paspalum distichum, Eclipta alba* and *Cyperus iria* accounted for 58.27 cent^{-1} of the total weed intensity in transplanted *kharif* rice. They also noticed remarkable occurrence of *Echinochloa crus-galli, Commelina benghalensis, Cyperus iria* and *Paspalum distichum* continuously from early stage of the crop to final stage.

Phogat and Pandey (1998) at New Delhi, reported that *Leptochloa chinensis, Echinochloa crus-galli, Eclipta alba and Cyperus iria* were the dominant weed species in transplanted rice during *kharif* season.

Bhanurekha *et al.* (2002) conducted experiment at Rajendranagar, Hyderabad, during *kharif* season and revealed *Echinochloa colona* (24.6 %), *Panicum repens*

(9.55 %), *Paspalum distichum* (5.5 %), *Caesulia axillaris* (7.59 %), *Eclipta alba* (6.54 %) and *Ammania baccifera* (6.54%), as the major weeds infesting transplanted rice in clayey loam soil.

Field experiment conducted by Anadhakrishnan and Jayakumar (2003) at Tamil Nadu Agriculture University, Coimbatore, in a cropping system of rice-rice-rice revealed that the major weed florae consisted of *Echinochloa crus-galli* and *Leptochloa chinensis* among the grasses, *Cyperus difformis* among the sedges while *Eclipta alba and Marsilea quadrifolia* among the broadleaved weeds under transplanted situation.

Singh *et al* (2004) working at Pantnagar in clay loam observed similar weedflora but the intensity was different viz, *Echinochloa colona* was 33.1 % followed by *Caesulia axillaris* (18.5 %), *Cyperus iria* (14.0 %), *Commelina benghalensis* (11.5 %) and *Fimbristylis miliacea* (11.5 %). Similarly at the same location in silty loam soil, Dubey *et al.,* (2005) observed *Cyperus* sp. (36 %) dominating the weed flora followed by *Echinochloa* sp. (16 %), *Caesulia axillaris* (25 %) *Commelina benghalensis* (14 %).

Under rice based cropping system in inceptisol soils in India Ghosh *et al.,* (2005) observed that the field was mainly composed of *Echinochloa sp. (Echinochloa crus-galli. colona, glabrescens), Leersia hexandra, Cyperus iria, Cyperus difformis, Ammania baccifera, Eclipta alba, Marsilea quadrifolia, Blainvillea latifolia, Sphenochlea zeylanica* and *Stellaria media* and the most important weed in the flora was purple nut sedge (*Cyperus difformis*) through out the season in upland.

2.1.2 Management of weeds in different paddy cultures

Weed spectrum is dynamic in crop field and depends largely upon the type of soil, climate and season. Weed problem is 50% more in the *kharif* season than in the summer and also more under irrigated condition than rainfed situation. Before planning or designing any weed control measure, it is imperative to know the major weeds associated with the crop which is mostly regulated by growing conditions, irrigation practice and agro-ecological factors (Bhan, 1994).

Weeds generally compete with the crops for nutrients, solar energy, and water and also for space. Weed control appeared to be the most important one to secure higher grain yield.

2.1.2.1 Non- chemical method of weed control

Sahu and Mandal (1966) suggested that Japanese paddy weeder in transplanted crops checked weed growth considerably. Although labour required for two rotary weedings (115 man hours ha^{-1}) was half that of two hand weedings (202 man hours ha^{-1}), the grain yield was lower. This was due to the inability of rotary weeding to remove weeds within or close to rice hills (De Datta, 1979).

Manual removal of weeds in rice was, however, difficult and time consuming due to the morphological similarity between grass type weeds and the rice crop, especially at the early growth stage (Sharma *et al.*, 1977). For transplanted rice, in tropical Asia, weeds were usually controlled by hand pulling or by hand rotary weeders (Moomaw *et al.,* 1966 and IRRI 1969).

Continuous submergence reduced weed density and dry matter production considerably due to reduced weed population caused by possible inhibition of germination of weed seeds under anaerobic condition (Subhulakshmi and Pandian, 2002). Similar observation was earlier made by Muthukrishnan and Purushothaman (1992).

Working on different paddy cultures, Singh and Singh (1996) observed significantly higher dry weight of weeds in direct sown (non-puddled) as compared to the direct sown (puddled) or transplanted cultures. Though the weed population was quite higher after hand weeding twice, but the dry weight at 60 DAS was significantly less than herbicidal treatments like Butachlor or Pendimethalin. Weed control efficiency was lowest (38 %) as compared to direct sown puddled (79 %) or transplanted (90 %) condition.

The total weed dry matter production was always higher under broadcasting followed by drum seeding and transplanting and the reasons attributed might be due to weeds emerged simultaneously with the emergence of the crop (Padhi, 1999).

Hand weeding twice at 20 and 40 days after sowing reported to be producing the lowest weed dry matter and the highest weed control efficiency in direct seeded upland rice in Nagaland during *kharif* season (Singh *et al.*, 2002). However, Desoki (2003) found that hand weeding thrice at 20, 40 and 60 days after sowing gave results equal to hand weeding upto harvest.

Biasi ploughing at 30-45 days after sowing (DAS) could not arrest the growth of weeds and recorded lower yield and yield components in *kharif* rainfed rice.

However, use of Ambika paddy weeder at 25-35 DAS coupled with pre-emergence application of butachlor and sowing of seeds with suitable seed-cum-fertilizer drill resulted in lower weed dry weight and significantly higher crop yield over biasi treatment (Dev and Mishra, 2003).

Hand weeding twice (25 and 45 DAT) and chemical weed management through herbicides were equally effective as weed free plots in reducing population and dry matter of weeds, improving grain yield and other yield attributing characters. Besides, significantly superior to un weeded check and 12.3 % to 21.9 % higher grain yield was recorded from herbicide treated plot (Bandyopadhyay *et al.*, 2005)

Experiments conducted at different locations of India on the impact of rice establishment methods towards weeds indicated that transplanting recorded lowest weed density and weed dry matter followed by puddled sowing of sprouted seeds and dry drilling. (Gogoi, 1986; Prasad *et al.,* 2001; Singh *et al.* 2005; Tomar *et al.,* 2005).

Saha (2007) stated from Central Rice Research Institute, Cuttack,that ecologically based weed management technologies depending upon the distribution and abundance of weed species in relation to environment, crop-weed competition and integration of preventive, weed-free seed, well decomposed organic matter, deep ploughing at beginning, harrowing, stale seed bed technique, closer spacing, growing of cover crops, crop-rotation might be adopted.

2.1.2. 2 Chemical method of weed control

Chatterjee *et al.* (1971) from Kalyani informed that Phenmediphan in non-flooded condition, in puddled wet land condition Molinate with or without 2,4-D IPE, and in transplanted paddy during dry season Propachlor + 2,4-D IOE and Nitrofen + 2,4-D IPE gave best performances.

Mandal *et al.* (1986) reported that 2-Chloro-2,6 diethyl-N (butaoxymethyl) acetanilide (butachlor) 5 G @ 1.5 kg a.i. ha^{-1} could effectively controlled grasses, reduced DMA in broad-leaved weeds, and increasing yield.

Maximum control (86-94%) of weeds (mainly *Cyperus iria, C. difformis, C. rotundus, Echinochloa colona, Eleusine indica* and *Cynodon dactylon*) increased yield and high benefit: cost ratios were obtained with 1.2 kg ha^{-1} of butachlor (Machete) applied at 1 DAT of rice seedlings. On the contrary, unsatisfactory weed control, low yields and minimum benefit: cost ratios were obtained with the use of butachlor applied at 9 DAT or when the dose was reduced to 0.96 kg ha^{-1} (Zafar and Sabri, 1989).

Suzaki *et al.* (1990) reported about the activity of pyrazosulfuron-ethyl, a new sulfonyl urea type of herbicide for rice. In green house studies, pyrazosulfuron-ethyl application showed excellent herbicidal activity when applied both as pre and post - emergence. They also reported that Pyrazosulfuron ethyl controlled 12 major weeds of rice specially broad-leaves and sedges which were very sensitive to that herbicide.

Pre-emergence application of butachlor at 1.5 kg a.i. ha^{-1} gave an effective control of 27 weed species dominated by *Cyperus rotundus, E. colona* and *Cleome viscosa* in semi-dry rice culture. Again, spraying of butachlor had an immediate effect (within 3 days) on weed emergence while broadcasting in the form of granule had a more delayed effect (Bhargavi and Reddy, 1990).

Pretilachlor is a selective chloroacetamide rice herbicide applied either as pre or early post emergence. Pretilachlor @ 0.6 kg ha^{-1} was tolerated by transplanted rice, but it could not be used on direct seeded rice without an antitode (Ampong-Nyarko and De Datta, 1991).

A fundamental reason for the wide use of chemical herbicides in modern agriculture by the farmers was, perhaps their abilities to control selectively and immediately a wide spectrum of weeds in a variety of crops and in some situations where all other methods failed or could not be adopted (Mukhopadhyay, 1992).

Pre-emergence applications of Pretilachlor @ 0.75 kg ha-1 and Anilophos @ 0.6 kg ha-1 at 5 DAT were promising herbicides in controlling weeds and increasing rice yields (Janardhan *et al.*, 1993).

Marqulz and Garcia (1993) reviewed the chemistry and properties of sulfonyl urea herbicides, stressing the low rates used, low toxicity to human, wild life and environment in general and their suitabilities for integrated weed control.

Application of Pretilachlor (@ 0.75 to 1.25 kg ha^{-1}) at 3 DAT of rice reduced the weed dry weight resulting an increase in grain yield of rice over the unweeded control (Kurmi and Das, 1993). Nandal and Singh (1993) observed the lowest number of weeds was recorded in Pretilachlor treatment @ 0.75 kg ha^{-1} as pre-emergence and that treatment was better than Butachlor @ 1.0 kg ha^{-1} and Oxadiazon @ 5.0 kg ha^{-1} as pre-emergent application.

Pretilachlor, a selective herbicide effective against particularly annual grasses, broadleaved weeds and sedges in transplanted and direct seeded rice, was readily taken up by the hypocotyls, mesocotyls and coleoptiles and to a less extent, by the roots of germinating weeds (Tomlin, 1994).

Janardhan and Muniyappa (1994) reported that the highest grain yield of rice (6.29 t ha^{-1}) was obtained from a weed free treatment followed by 2.0 kg Pendimethalin, 1.0 kg Pretilachlor and 0.6 kg Anilophos ha^{-1} where the yield recorded to be 6.10 t ha^{-1}.

Hike of labour costs was also responsible for such popularity of the herbicides; furthermore, weeding in rice caused a problem as the rice seedling could not be differentiated with the associated grassy weeds at the early stage of growth of the crop. Thus it had been a common observation that in recent years the farmers on their own have started to adopt chemical weed control themselves (Mukhopadhyay, 1995).

Chun *et al.* (1995) conducted a trial in Korea Republic on the shoot and root growth of rice and barnyard grass (*Echinochloa crus-galli*). Results showed that shoot growth of rice was more reduced when azimsulfuron was applied with the annual herbicides than when applied alone. Application of azimsulfuron with the annual herbicides resulted in greater reduction of root and shoot growth of *E. crus-galli,* as compared to azimsulfuron applied alone.

In greenhouse studies application of azimsulfuron + BSM did not cause rice injury and reduced the total quantity of chemicals used. This combination controlled the tested weeds even under environmental factors such as water leaching, overflow of paddy water and low temperature. The results also suggested that azimsulfuron was a promising rice herbicide especially in combination with BSM (Shirakura *et al.,* 1995).

Phogat and Pandey (1998) reported that Pretilachlor @ 1.0 kg ha^{-1} applied as pre-emergence showed significant control of grasses but was less effective against broadleaf weeds. The maximum yield increase was recorded under the weed-free treatment and Pretilachlor alongwith Anilophos, Butachlor, Pendimethalin significantly produced higher grain yield and proved to be statistically superior to control and metsulfuron.

In southern Europe, Marquez *et al.*(1995) stated that azimsulfuron, a new selective post-emergence sulfonylurea herbicide, was effective for the control of *Echinochloa* sp. and most of the annual and perennial broadleaf and sedge weeds found in fields of rice (*Oryza sativa*). Studies showed that azimsulfuron had favourable toxicological and environmental fate characteristics. Azimsulfuron inhibited the activity of the enzyme acetolactate synthatase (ALS) in sensitive weeds. It was safe to japonica and indica rice cultivars at the recommended rates.

Results of greenhouse pot tests indicated that azimsulfuron at a rate as low as 6 g/ha gave excellent control of sedges and perennial weeds, whereas a higher rate was required to give excellent control on annual broad-leaved weeds. Activity of azimsulfuron, especially against Cyperus and Eleochalis was significantly higher than that of bensulfuron-methyl (BSM). Azimsulfuron at rates up to 12 g/ha afforded a comparable rice safety to that of BSM at 75 g/ha under the tested conditions (Shirakura *et al.,* 1995).

The mechanism of selectivity of azimsulfuron was studied by comparing the behaviour of that herbicide in rice with the sensitive weed: flat sedge (*Cyperus serotinus).* Azimsulfuron showed high selectivity between rice and *C. serotinus* on growth response studies conducted in hydroponic solutions. In metabolism studies, rice metabolized azimsulfuron very rapidly in its shoots and roots, while *C. serotinus* metabolized it very slowly in its shoots, roots and tubers. The metabolism of azimsulfuron in rice within the first 24 hours after application involved mostly O-demethylation of the pyrimidine ring (Shirakura *et al.,* 1996).

Bhattacharya *et al.*(1996) reported that although hand weeding, given twice at 21 and at 42 DAT, recorded the highest grain yield of transplanted boro rice, So, the laborious, time consuming and costly hand weeding could be replaced by butachlor 50 EC at 0.5 – 1.0 kg a.i. ha^{-1} at 3 DAT.

Shirakura (1997) stated that a mixture of BSM [bensulfuron-methyl] and azimsulfuron was as effective in the control of some paddy field weeds as higher rates of BSM or azimsulfuron alone. Residual activity of BSM and azimsulfuron varied with weed species. Leaching decreased the activity of azimsulfuron except when applied at high rates but had little effect on the activity of BSM

Singh and Bhan (1998) reported that Metsulfuron methyl @ 3 to 5 g ha^{-1}, Chlorimuron ethyl @ 15 to 25 g ha^{-1} and tribenuron methyl @ 10 to 30 g ha^{-1} applied 15 days after transplanting of rice, significantly reduced broadleaf weed problem and increased grain yield.

Ghosh (1998) reported that by adopting Integrated Weed Management (Cultural + Chemical) in transplanted paddy, 34-40% higher grain yield could be obtained with unweeded control

Sulfonylurea herbicides had high herbicidal activity at low application rates. Among the sulfonylurea products, metsulfuron-methyl [methyl 2-(4-methoxy-6-methyl-1,3,5-triazine- 2-ylcarbamoylsulfamoyl) benzoate] was widely used due to selectivity against a wide range of weeds in cereal, pasture, and plantation crops (Beyer *et al.*, 1988; Brown, 1990; Pons and Barriuso, 1998).

Halder (2000) reported that, Pretilachlor @ 750 g ha^{-1} when applied as pre-emergence was effective in controlling dominant weed flora of summer rice and proved alternative to hand weeding where availability of labour was scarce.

Lee *et al.*(2001) reported from pot experiments that some major perennial paddy weeds, *Cyperus* sp. *Eleocharis kuroguwai, Sagittaria trifolia,* and *Potamogeton distinctus*, could efficiently be controlled by few sulfonylurea herbicides such as azimsulfuron, imazosulfuron and ethoxysulfuron .Effective herbicidal efficacy to the tested perennial weeds was in the order: azimsulfuron > imazosulfuron > ethoxysulfuron in that experiment. Weed control value of sulfonylurea herbicides to the tested perennial rice weed species was highest at 30°C, followed by 20-25°C, but was lowered at 10-15°C.

Mahadevappa (2001) stated that labour had become non-available and costly due to intensification/diversification of agriculture and urbanization; the alternative for that was the use of herbicides particularly under irrigated agriculture and that too for high valued crop.

The use of ALS inhibitors for more than 4-5 years as the sole means of weed control should be avoided. They should instead be rotated or mixed with other herbicides with different modes of action. From a resistance management perspective, it was also important that each herbicide in a mixture controlled the same weed spectrum (Shaner and Heap, 2002).

Fuentes and Ferrucho (2002) opined that azimsulfuron at 14.0 g a.i. ha^{-1} + metsulfuron methyl at 4.0 g a.i. ha^{-1} herbicide mixture in foliar and soil treatments could effectively control purple nutsedge (C. rotundus) and other dominant weed flora in all types of rice culture.

The efficacy of sulfonylurea herbicides, such as azimsulfuron, imazosulfuron and cyclosulfamuron were the most effective against annual and perennial weeds in the rice field and these were controlled by inhibiting acetolactate synthase (Lee *et al.*,2003).

Taylor (2004) from the 11 field experiments conducted in Australia during 3 seasons (2002-03) to investigate the efficacy of rotational weed control practices on rice and observed that the mixture of molinate and benzofenap as wel as azimsulfuron along with metsulfuron methyl were consistently efficient in controlling weeds.

Pusino *et al.* (2004) reported that azimsulfuron was very useful while controlling all categories of weeds in paddy fields. The sorption and desorption of the herbicide azimsulfuron, N-[[(4-dimethoxypyrimidin-2-yl)amino]carbonyl]1-methyl-4-(2-methyl-2 H-tetrazole-5-yl)1H-pyrazole-5-sulfonamide, were studied using five soils and it was found that pH was the main factor influencing the sorption and that the sorption on soils was negatively correlated with pH.

At Pantnagar, Singh *et al.* (2004) observed that Pretilachlor @ 0. 75 and 1.0 kg ha^{-1} was found to be effective in controlling *Echinochloa colona* and also sedges in *kharif* transplanted rice.

The efficacy of some potent micro-herbicides in conjunction with other herbicide for the control of various weed flora in transplanted rice (Oryza sativa cv. Sarju 52) was studied during the rainy season of 2001 and 2002 at Varanasi, Uttar Pradesh, India. metsulfuron-methyl [metsulfuron] (MSM; 4, 6 and 8 g ha^{-1}) and Almix+2,4-DEE applied 8 days after transplanting was the most effective in controlling broadleaf weeds and maximizing rice grain yield (Mukherjee and Singh, 2005).

Pal *et a.,* (2006) reported in the new alluvial zone that Butachlor @ 0.95 kg ha^{-1} at 5 DAT followed by Almix @ 0.004 kg ha^{-1} at 25 DAT, could profitably replace the tedious , time consuming and expensive hand weeding practice for controlling weeds in transplanted paddy.

In the coastal flood plain of West Bengal, Ghosh *et al.*(2007) reported from an experiment in transplanted paddy that the highest grain yield was obtained from twice HW (42.58%) followed by Imazosulfuron 10 SC (32.25 %) which was more cost effective.

In direct seeded rice, application of azimsulfuron at 50 g a.i. ha^{-1} combining with metsulfuron methyl at 4 g a.i. ha^{-1} recoreded at par grain yield of rice with twice hand weeding due to the efficient control of weed flora (Ghosh *et al.*, 2007).

Vidotto *et al.*(2007) reported that *Echinochloa* sps. were listed among the major weeds in rice worldwide. A greenhouse study was carried out on 80 accessions of *Echinochloa*, collected from Italian rice fields, to assess differences in response due to the application of azimsulfuron, bensulfuron-methyl, cyhalofop-butyl, molinate and propanil.

Barui *et al.* (2007) reported that pretilachlor 400 EW at 1500 and 1875 ml ha^{-1} were most effective to control the annual grasses and sedges when sprayed at 3 DAT than that of splash application in transplanted *kharif* rice.

Maximum grain yield of direct seeded rice in IGKV, Raipur, was recorded with post-emergence application of azimsulfuron 50 DF 40 g ha^{-1} + 0.5 % surfactant , which was comparable to azimsulfuron 50 DF 35 g ha^{-1} + 0.5 % surfactant. The yield reduction due to weeds ranged between 5.33 to 72.00 % (AICRP-WC Annual Report, 2007-08).

An experiment conducted at Bidhan Chandra Krishi Viswavidyalaya it was reported that Azimsulfuron 50 DF alongwith metsulfuron methyl 20 WDG could effectively control all types of weed flora under aerobic paddy culture in inceptisol of West Bengal (AICRP-WC Annual Report 2007-08).

In IGKV, Raipur, among the different herbicidal treatments chlorimuron + metsulfuron 4 g ha^{-1} + fenoxaprop 56.25 g ha^{-1} recorded the lowest dry matter of weeds; the highest grain yield was comparable with azimsulfuron 50 DF + metsulfuron 20 SG (4.0 + 2.0 g ha^{-1}). The losses in yield from the infestation of weeds ranged between 35.71 to 87.55 % (AICRP-WC Annual Report 2007-08).

From a field experiments, conducted in Gangetic Inceptosol at the Viswavidyalaya Farm, Kalyani, during *Kharif* season, revealed that Almix 20WP @ 4 g ha^{-1} or the higher two doses of Ethoxysulfuron60 WG as post emergence application can profitably and safely be replaced the tedious time consuming and expensive hand weeding practice in transplanted paddy,(Ghosh *et al.*, 2008).

Mukherjee *et al.* (2008) from an experiment conducted at Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal, India, on IWM in unpuddled Direct seeded rice and reported that brown manuring + butachlor + 2,4-D registered the highest weed control efficiency (89%) resulting in higher grain yield to the extent of 3.0 t ha^{-1} and 3.9 t ha^{-1} in two succeeding years with net profit to the tune of Rs 22,476 ha^{-1} and benefit cost ratio of 1.49.

2.1.2. 3 Use of surfactant in chemical method of weed control

McWhorter (1982) reported that incorporation of surfactants with herbicide spray solution reduced surface tension (ST) - a force which was required to increase one area of surface by one square cm and contact angle (CA) – the angle formed by a droplet in contact with a solid surface; there by altering droplet size, spray distribution, wettability, cuticle retention and penetration of pesticide.

Several surfactants which be used in herbicide spray to enhance foliar retention, Penetration, absorption, and consequently translocation of post emergence herbicide and increase efficiency (Sharma *et al.* 1989).

Adding an appropriate surfactant could decrease the amount of herbicide applied and lowered the cost for weed control (Green, 2001).

Ghosh *et al.* (2004) stated that attrazine with surfactant Active 80 @ 220 ml ha^{-1} showed 53 % higher yield than control and was also significantly higher than attrazine without surfactant.

Tank mix adjuvants could improve the performance of herbicides and adjuvants could overcome adverse conditions caused by the parameters like humidity, rain and application technique (Kudsk and Mathiassen, 2004).

The surfactants not only exerted their effects on plant surfaces but also they could penetrate through the waxy cuticle in to the underlying tissue, thereby assisting the uptake of glyphosate and the herbicidal activity could be produced slightly higher (Sharma *et al.*, 2005)

Mousavi *et al.*(2008) conducted an experiment in a greenhouse in Tehran – Iran, and reported that the best adjuvant on different herbicidal activities in ryegrass, were Volk, Edigor, Cytogate and Cytohef and they could improve the weed control 86%, 71%, 68% and 46%, respectively. The best herbicide was Axial 700 that controlled weed 100% and the weak herbicide was Axial 300 with 49% control.

2.1.3 Impact of different paddy cultures on yield components, grain yield of rice and on economics

Saha *et al.* (1990) observed while working at Himachal Pradesh, reduction in yield was on an average 38 % in unpuddled rice as compared with puddled and 44 %

in yield loss was due to weeds in direct sown rice (puddled condition) as compared to transplanted one. However, by hand weeding twice at 20 DAS and 40 DAS the yield loss reduced to 25 %.

Transplanting of rice recorded 14 % higher grain yield, significantly higher numbers of panicle m^{-2}, higher numbers of grains $panicle^{-1}$ as compared to dry seedling of rice in *kharif* season (Tripathi *et al.* 1999). Dhiman *et al.*(1998) also noticed similar results from Kaul, Haryana

Studying the performance of upland rice under different establishment methods in *kharif* season, Prasad *et al.* (2001) observed that transplanting increased all the growth attributes and yield compoments of rice significantly over dry seeding and puddled sowing of sprouted seeds and recorded the highest grain and straw yields, net monetary return and benefit : cost ratio. Puddle sowing of sprouted seeds was superior to dry seeding in respect of all those characters. Jaiswal and Singh (2001) also opined alike.

Study conducted during *kharif* season at Raipur, revealed that broadcasting with *biasi* recorded the highest grain yield, plant height, number of tillers m^{-2}, dry matter accumulation, leaf area index and also net realization $rupee^{-1}$ invested followed by line sowing, broadcasting without *biasi*, transplanting 24 days old seedling and lehi method, respectively (Kumar *et al.*, 2002).

Singh *et al.* (2002) obtained maximum grain yield in transplanted rice, which was 14.78 and 18.65 % higher than wet seeded and dry seeded rice, respectively. Straw and biological yields followed the similar trend. However, the difference between wet seeded and dry seeded rice for all these characters were found to be not significant. Quite similar results were obtained by Tiwari and Tomar (2002) at Jabalpur and Subhulakshmi and Pandian (2002) from Tamil Nadu Agriculture University, Coimbatore.

Parihar (2004) at Bilaspur, observed the transplanted rice culture registered highest number of effective tillers m^{-2}, highest number of filled grains $panicle^{-1}$, grain yield which were significantly higher over unpuddled line sown rice, but at par with the puddled direct seeded rice.

Singh *et al.* (2005) from Pantnagar, observed that the number of panicles $unit^{-1}$ area was higher in wet seeded rice than in direct seeded rice and transplanted rice. But the number of grains $panicle^{-1}$ was significantly higher in transplanted rice than direct seeded and wet seeded rices. In spite of less number of panicles unit^{-1} area in transplanted rice, the grain yield was similar to direct seeded and wet seeded rice. However, at the same location, several trials indicated significantly higher grain yield in transplanted rice over wet seeding, zero tillage and direct seeded rice (Singh *et al.*, 2005, Dheer Singh *et al.*, 2005). Taller plants, higher panicle length and higher grain yield and better harvest index were observed in puddled than directly sown rice (Tomar *et al.*, 2005).

2.1.4 Economics of chemical weed control in rice culture

Among the several herbicides (0.5, 0.75 and 1.0 kg ha^{-1} Pretilachlor, 1.5, 2.0 and 2.5 kg 2,4-DEE, 0.4, 0.5, 0.6 kg Anilophos 1.5, 1.75 and 2.0 kg Pendimethalin) tested for controlling weeds in transplanted rice, the highest profits were reported with the Anilophos treatment (additional return Re^{-1} invested were Rs 17.17, 14.07 and 15.49 in the 0.4, 0.5 and 0.6 kg Anilophos treatments, respectively) (Janardhan and Muniyappa, 1994).

Prasad *et al.*(1994) reported that pre-emergence application of Oxadiazon @ 0.5 kg ha^{-1}, Butachlor @ 1.25 kg ha^{-1}, Pendimethalin @ 2.0 kg ha^{-1} and Thiobencarb @ 2.0 kg ha^{-1} gave yields comparable to hand weeding and were cheaper (R. 200-300 ha^{-1} for herbicides) as compared to (Rs 450-600 ha^{-1}) the hand weeding.

Out of the different weed control treatments, namely Anilophos, Butachlor, 2,4-D-Na salt and hand weeding (twice), the highest benefit: cost ratio was found in 2, 4-D Na salt treated plots, probably due to the low cost of that herbicide (Thakur *et al.*, 1995).

Pretilachlor @ 1.0 kg ha^{-1} was found to give higher B:C ratio (6.62) over weed free (5.05), Butachlor @2.50 kg ha^{-1}(5.96) and Butachlor + 2, 4 –DEE @1.75 kg ha^{-1} (6.50) in *kharif* transplanted rice (Nagaraju and Kumar, 2005). Similarly, Kandasamy and Chinnuasamy (2005) reported higher B:C ratio with Pretilachlor @ 450 g ha^{-1} (3.37) as against 3.05 with hand weeding twice.

Application of 1.0 kg ha^{-1} of 2, 4-D Na salt at 24 DAT to control weeds in wetland rice gave the highest return of Rs. 66.31 Re^{-1} investment (George *et al.*, 1993).

Gogoi (1997) reported that the highest net return (Rs 2442 ha^{-1}) was achieved with the rotary weeding treatment followed by Anilophos (@ 0.4 kg ha^{-1} as sand mix treatment, but the highest gross return was associated with the handweeding treatment.

Joy *et al.* (1991) reported that Butachlor 50 EC @ 1 kg ha^{-1} resulted in the greatest benefit: cost ratio (28: 1) compared with Anilophos 30 EC @ 0.6 kg ha^{-1},

2.2 Rice-rapeseed cropping system

Das (1991) reported that under rainfed condition rapeseed or mustard can be grown as paira crop, after transplanted *kharif* paddy with the available moisture present in soil.

Das and Das (1994) opined that cultivation of mustard could be possible as "no tillage relay crops" because of short and mild winter alongwith residual moisture after transplanted paddy.

Prasad *et al.* (2002) at IARI, New Delhi, India, reported that among the four rice-based cropping systems (rice-wheat, rice-lentil, rice-chickpea, and rice-rapeseed/ mustard), rice-rapeseed cropping system produced 8.6 4.9 to 5.4 t ha^{-1} of grain but rice-wheat cropping systems was more profitable and was therefore, preferred by the farmers.

From an experiment conducted in West Bengal, India, during the rabi season Bag *et al.* (2004) opined that application of 75% recommended rate of NPK through inorganic sources + remaining N by addition of pelleted form of organic manure (0.4 t ha^{-1} Biomax), the productivity and quality improvement of rape (cv. Sarat) on rice (cv. IET 4786)-rape cropping system was observed on sandy clay loam soil and i.e. significantly higher seed (1.42 t/ha) and stover yields of rape (3.53 t/ha).

Singh (2004) from Manipur in rice-rapeseed cropping system using blue green algae (BGA) and *Azolla pinnata* in integration with graded levels of N fertilizer in rice followed by rapeseed when the rice-rapeseed sequence was considered as a whole, reported that the application of 80 kg N ha^{-1} + A. pinnata or 80 kg N ha-1 + A. pinnata + BGA gave the highest return Re^{-1} invested (Rs 2.33).

Samui *et al.* (2005) reported that in West Bengal rice is grown in rainy season and rapeseed is grown in winter season often in aerated soil and there was no residual effect of the herbicide applied to rice on the growth of succeeding rapeseed crop

2.2 .1 Dynamics of weed flora in rapeseed

2.2.1.1 Under conventional tillage

Study on diversity of weed flora in the major raya (Indian mustard) producing districts of Haryana by Malik and Singh (1994) revealed that *Chenopodiun album, Asphodelus tenuifolius, Euphorbia dracunculoides* and *Trigonella polycerata* were the dominant weeds. They also opined that soil type appeared to influence the spectrum of weeds present.

The most problematic weed species in mustard *Chenopodium album, Melilotus indica, Avena fatua* and *Phalaris minor* on sandy loam at Bulandshahar, Uttar Pradesh (Singh *et al.*, 1993). Similarly, Madhavilatha *et al.*(1997) found that in Rajendra Nagar, Hydearabad that *Cyperus rotundus, Cynodon dactylon, Parthenium hysterophorus, Amaranthus viridis, Digera arvensis, Euphorbia hirta, Cleome viscosa, Portulaca oleracea* and *Melilotus indica* were the dominant species in mustard.

Singh et al. (2001) havd reported that in sandy loam soil of Hissar, *Chenopodium album, Anagallis arvensis, Furamia parviflora, Vicia sativa, Lathyrus aphaca, Melilotus alba, Coronopus didymus, Cynodon dactylon* and *Circium arvense* were most dominant in *Brassica* fields. Whereas, working at same location Banga *et al.* (2004) reported that the experimental field of mustard was predominantly infested with *Asphodelus tenuifolius* (34 %), *Chenopodium album* (18 %), *Avena ludoviciana* (31 %) and *Phalaris minor* (17 %).

Field experiment conducted by Nepalia and Jain (1998) during winter under clay loam soil of Udaipur, Rajasthan, observed that *Melilotus indica, Chenopodium album, Spergula arvensis, Coronopus didymus* and *Phalaris minor* were the most dominant weed flora of the experimental site and the dicot weeds were more dominating in the field. Similar type of findings was also reported by Sharma *et al.* (2001).

Ghosh *et al.* (2005) reported that winter crops like rapeseed / mustard following transplanted rice had fewer weeds when those crops were sown after direct seeded rice in rice-rapeseed cropping system in inceptisol soils. Population of *Cyperus rotundus* was minimal after transplanted rice because the growth of that weed was hampered by the presence of stagnant water which prevented rhizome growth and development.

Under new alluvial zone of West Bengal, *Chenopodium album, Cyperus rotundus, Melilotus alba, Circium arvense, Vicia hirsuta, Cynodon dactylon* and *Cleome viscosa* were the most dominant weed species in mustard (Pal *et al.*, 2000).

2.2.1.2 Under zero tillage

Studying on the influence of four tillage systems, varying from intensive to zero tillage, on weed population in Alberta, Canada, O'Donovan and McAndrew (2000) observed that the weeds like *Thalapsi arvense*, *Capsella bursa-pastoris*, *Polygonum convolvulus* and *Chenopodium album* increased in the soil seed bank as tillage was reduced, but the higher populations in the soil seed bank did not always result in higher spring seedling populations under zero tillage.

In contrast to seed bank, populations of *Chenopodium album* and *Thalapsi arvense* were lowest in zero-till system, however, *Capsella bursa-pastoris* was highest in the same system. Working on the same line, Blackshaw *et al.*(2001) observed that the total weed densities were often greater in zero tillage than minimum or conventional one. Weeds like *Amaranthus retroflexus*, *Salsola iberica, Bromus tectorum, Kochia scoparia* were associated with zero tillage while *Polygonum convolvulus, Chenopodium album, Descurainia sophia* and *Circium arvense* were associated with conventional tillage.

Singh *et al.* (2001) while working in clay loam soil at Pantnagar observed that the zero-till wheat was infested with *Phalaris minor, Avena ludoviciana, Cynodon dactylon, Chenopodium album. Anagallis arvensis, Fumaria parviflora, Lathyrus aphaca, Melilotus indica, Vicia sativa, Eclipta alba, Cyperus rotundus* and *Ageratum conyzoides*. The relative density of grassy weeds increased with the advancement of crop growth while that of non-grassy weeds decreased in zero tillage system. Again higher proportions of grassy weeds were noticed in conventional tillage than in reduced tillage and zero tillage plots. The weed dry matter increased with the advancement of crop growth under all tillage systems. At 30 days stage under weedy check more weeds emerged in conventional and reduced tillage systems. Densities of *Phalaris minor, Chenopodium album* and *Melilotus indica* were lower under zero tillage as compared to other two systems.

On the contrary, from Samastipur, Bihar, Pandey *et al.* (2001) reported that tillage operations in wheat significantly recorded lower weed population and dry weight than under zero tillage.

Sharma *et al.* (2004) found lower population and dry weight of dominant weed flora *P. minor* was recorded under zero tillage than conventional tillage of wheat cultivation might be due to less soil disturbance which helping in keeping the weed seeds at depth from where it could not germinate.

Even conventional tilled wheat had more weed population than zero tilled wheat after any rice establishment method (Singh *et al.*, 2004 and Yadav and Singh, 2005).

Similarly, while working at National Research Centre for Weed Control (NRCWS), Jabalpur, Mishra *et al.* (2005) found reduced population of *Chenopodium album* and *Phalaris minor* and lower total dry weight of weeds in zero tilled condition as compared to conventional tillage condition.

Zero-till rapeseed grown after DS-puddled rice perform better in expressing higher growth and yield attributes than other paddy culture (Khuntia, 2006).

2.2.2 Advantages of zero tillage management

Tillage with regards to weed control results in (a) burying weed seeds and delaying growth of perennial weeds, (b) leaving a clean soil surface for efficient herbicide action, (c) providing enough loose soil to allow effective cultivation and (d) incorporating herbicides when necessary (Richeyel *et al.*,1977).

Mandal *et al.* (1994) from Bidhan Chandra Krishi Viswavidyalaya, reported that hardy crops like safflower and linseed endowed with deep root system can successfully be grown without any land preparation in years of very low winter rainfall.

Brecke and Shilling (1996) reported that no-till system to reduce weed impact, while on the other hand, no-till crops produce lower yield.

Tillage influenced the vertical distribution of weed seeds in soil layer and weed diversity. Tillage affected emergence and seed survival of weeds through changes in soil conditions independently of the effects from the redistribution of seeds in the soil profile (Mohler and Galford, 1997).

Hetz, and Barrios (1997) stated that the energy cost reached values of 2657, 1867 and 1479 m t ha^{-1} for the traditional (100%), reduced (70%) and no-till (56%) systems respectively, showing the potential to save energy by using reduced and zero tillage systems in case of production of wheat, oat, rapeseed and barley.

Rathore *et al.* (1998) reported that minimum tillage, with or without straw, enhanced soil moisture conservation and moisture availability during crop growth as a consequence, the root mass, yield components (plant stand, number of siliqua per plant and plant height) and seed yield increased and Availability of soil moisture during the crops growth period, maintained better plant water status.

No till or Zero till production strategy might reduce weed emergence in Australia as soil disturbances stimulated germination of some hard-seeded weed species (Teasdale and Mollar, 2000).

Yaduraju and Mishra (2002) reported that the problem of weeds in wheat *viz,. Phalaris minor, Chenopodium album* and *Medicago hispida* was reduced whereas *Avena sterilis* sp. *ludoviciana* increased under zero tilled condition as compared to conventional ones.

Similarly, while working at National Research Centre for Weed Control (NRCWS), Jabalpur, Mishra *et al.* (2002) found reduced population of *Chenopodium album* and Phalaris *minor* and lower total dry weight of weeds in zero tilled condition as compared to conventional tillage condition.

Khan *et al,* (2005) reported that zero tillage relatively showed lesser weed infestation than conventional tillage.

Zero tillage technology offered many advantages in the spheres of economic efficiency, effective weed management and resistance management and formed an important component in Integrated Weed Management to ensure profit, productivity and sustainability (Thanh 2005).

Studying on the influence of four tillage systems, varying from intensive to zero tillage, on weed population in Alberta, Canada, O'Donovan and McAndrew (2000) observed that the weeds like *Thalapsi arvense*, *Capsella bursa-pastoris*, *Polygonum convolvulus* and *Chenopodium album* increased in the soil seed bank as tillage was reduced, but the higher populations in the soil seed bank did not always result in higher spring seedling populations under zero tillage. In contrast to seed bank, populations of *Chenopodium album* and *Thalapsi arvense* were lowest in zero till system; however, *Capsella bursa-pastoris* was highest in the same system. But as the tillage was reduced, both seed bank and seedling populations of *Setaria viridis* were decreased indicating that the weed should become less problematic under reduced tillage.

Ahuja *et al.* (2005) from an experiment during *kharif* and rabi seasòns in Karnataka, India, reported that among the three tillage treatments [zero tillage (ZT), minimum tillage (MT) and conventional tillage] and three herbicide treatments (paraquat at 0.6 kg ha^{-1}, glyphosate at 2.0 kg ha^{-1}, control , MT+glyphosate (rice)-MT+glyphosate (green gram) sequence resulted significantly in highest rice equivalent yield (63.1 q ha^{-1}) among all the treatment combinations, except MT+paraquat (rice)-MT+paraquat (green gram) sequence which was at par with ZT+ paraquat (rice)-ZT+ paraquat (green gram).

2.3 Effect of herbicides on soil environment

2.3.1 Effect of herbicides on soil micro - flora

Lozano-calle (1970) and Schreven *et al.* (1970) reported that herbicides applied at recommended field rates generally had no harmful effect upon the growth and activity of the soil-microflora. Baklivanov and Nicolova (1971), on the other hand Blieve (1973) observed that some of the herbicides had stimulatory effect on the soil microflora.

Deshmukh and Shrikhande (1974) who observed an inhibitory effect of pre-emergence as well as post-emergence herbicides on the soil microflora.

Normally, the quantities of common herbicides applied at recommended doses to soils or which reached the soil from above-ground spraying operations were not sufficient to appreciably depress the growth and activity of specific soil microbes (Randhawa and Bhalla, 1976; Atlas *et al.,* 1978; Lewis *et al.,* 1978; Olsen *et al.,* 1984), instead some of them exerted a stimulatory effect on them (Dey and Ganguly, 1984). In general, herbicides had no effect on the total number of bacteria when applied at normal field rate (Cullimore, 1969). However, few herbicides had great or prolonged adverse effects on the total bacterial component of soil (Deshmukh and Shrikhande, 1974).

Application of herbicides at normal rates had no effect on nitrogen fixation (Singh *et al.,* 1981). But some herbicides exerted stimulation on nitrogen fixing power of soil (Nelson and Hedrick., 1976).

Normally, the quantities of common herbicides applied at recommended rates to soils or which reached the soil from above ground spraying operations were not sufficient to appreciably depress the growth and activity of specific soil microbes (Randhawa and Bhalla, 1976; Atlas *et al.,* 1978; Lewis *et al.,* 1978; Olson *et al.,* 1984; Cullimore, 1969), instead some of them exerted stimulatory effect on them (Blieva, 1973; Dey and Ganguly, 1984).

Application of herbicides with organic matter maintained higher population of soil microflora at all the stages of rice and wheat. Butachlor in rice and Isoproturon in wheat also stimulated the soil microflora population as compared to weedy check

(Chopra and Mogu, 1985). This happened due to the fact that degradation of herbicides might have surved as carbon source for microbes (Paul and Clark, 1989).

Working with seven different herbicides like Metolachlor, Fluometuron, Fluometuron + Metolachlor, Trifluralin, Pendimethalin, Dinitramine and Butralin, Youssef *et al.,* (1987) found significantly higher populations of bacteria, fungi and actinomycetes in the rhizosphere of cotton treated with these herbicides.

In direct seeded rice, Mandal *et al.* (1987) found that Butachlor applied during pre-kharif season caused short term fluctuations in the actinomycetes population and initially depressed bacterial population but no prolonged effects on soil microflora were noticed.

Zelles *et al.* (1989) found that in soils of low organic matter content, residue loss of pentachlorophenol and its damage to soil microflora was higher and the reversibility of the damage was lower than in soil with high organic matter content.

Katayama and Kuwatsuka (1992) reported decreased microbial population in paddy soils with the increasing concentration of Paraquat dichloride and the decrease was more pronounced for bacteria and actinomycetes than in case of fungi.

Chauhan *et al.* (1993) also reported that low concentration of Butachlor and Pendimethalin did not alter the activity of microorganisms but at higher concentration, most of the bacterial and fungal species were affected.

Working at Jorhat, Assam, Pathak *et al.* (1996) revealed that 2,4-D pre and post emergence application at concentration of 10,000, 1,000 and 100 ppm reduced fungal activity. The higher the concentration of herbicide, the greater was the inhibition.

Shukla (1997) reported that in submerged rice fields of Meghalaya, India, initially fungal population increased with the application of butachlor and 2,4-D but decreased during the later part of the study. They also found that bacterial population also increased on application of Butachlor and 2,4-D.

Experiment conduced in China, Liu Qing *et al.* (1997) revealed that the number of Actinomycetes was inhibited significantly after the application of Butachlor @ 2.7 kg ha^{-1}.

Gigliotti *et al.* (1998) while working on the Bensulfuron methyl, found that the higher dose of the chemical substantially inhibited nitrification possibly because of greater herbicide persistence and the persistence was greater in soil with pH 5.5

while lower in alkaline soils containing more microflora.

Nowak *et al.* (1999) observed that Paraquat and Diquat mostly reduced the number of fungi alongwith bacteria in the soil but the population of actinomycetes and total microbial biomass were more viable in heavy soil than sandy soil.

In direct seeded rice, Tiwari and Kolhe (2002) observed that Pretilacholor + safener, Butachlor, Oxadiargyl, Pendimethalin and Chlorimuron + Metsulfuron suppressed the soil microflora upto 15 DAT. However, microflora started increasing after 30 DAA till harvest. The suppression of microflora was more evident under higher rate than under lower rate of herbicides. Application of Pretilachor and Glyphosphate in transplanted rice caused initial retardation of microfloral growth, but it gained its growth slowly and reached at the peak about 40-60 days after application of the herbicide (Mitra and Khan, 2005).Working on different herbicides similar findings were also reported by Barman *et al.* (2002) and Bhan and Kolhe (2002).

Donkova and Perkova (2003) studying the behaviour of Acetachlor on three soils (leaching chernozem, alluvial meadow and light grey forest soils) noticed that the herbicide had high negative effects on soil microflora, but its degradation occurred within 30 days after application. Ammonifying bacteria were mostly affected while actinomycetes were least affected. Results indicated that Acetachlor exhibited moderate resistance and short time effects on soil microflora, hence it was safe to apply on all soils studied.

Ghosh *et al.* (2004) reported that none of the herbicide IR 5790 10 EC, Pretilachlor 30 Ec, Butachlor 50 EC, Oxydiargyl 80 WP was found to be toxic to the crop and it also found that all the herbicides reduced the population of NSNF and PSB bacteria at 2 DAA of the chemical but recovery took place gradually.

The proliferation of micro-organism particularly the aerobic non-symbiotic nitrogen fixing bacteria and PSB, upto a certain period could be attributed to the utilization of those micro-organisms of the herbicides and their degraded products as their sources of energy, carbon and other nutrients of growth and development (Mitra and Khan, 2005).

While experimenting with five different herbicides like Pretilachlor, Butachlor, 2, 4 DEE, Isoproturon and Clodinafop in rice-wheat cropping sequence, Singh and Mishra (2005) observed numerically higher population of soil microflora due to the use of these herbicides with and without organic matter upto 7 DAA and decreased thereafter.

Working on Gangetic alluvial soil, Ghosh *et al.*(2005) observed that Pyrazosulfuron ethyl remarkably reduced the population of total bacteria and non-symbiotic nitrogen fixing bacteria upto 10 DAA followed by their rapid proliferation from 15 DAA onwards, but the reduction was more pronounced in Carfentrazone ethyl as compared to PSE and 2,4-DEE. However, the hand weeded and weedy check treatments didn't show any adverse effect on microbial population and their growth remained at a steady state.

Moreno *et al.* (2006) reported that atrazine had direct influence on microbial biomass, microbial respiration, ATP content and dehydrogenase and urease activity in a semiarid soil and the influence of time on the response of soil microbial activity.

Valle *et al.* (2006) reported that Azimsulfuron, a recently introduced sulfonylurea herbicide, was useful in controlling weeds in paddy fields. Azimsulfuron treatment seemed to have the ability to cause changes in the bacterial community structure.

Mukherjee *et al.* (2007) informed that high levels of pyrazosulfuron ethyl caused a significant enhancement in the proliferation of both non symbiotic N-fixing bacteria and PSB in the soil rhizosphere over that of the soils in unweeded plots in summer rice.

Ghosh *et al.* (2008) reported from an experiment in Kharif rice with 9 treatments, viz, Ethoxysulfuron 60 WG @ 15,17.50, 20 & 40 g/ha, Ethoxysulfuron 15 WP @ 18.75 g/ha, Almix 20 WP @ 4g/ha and 2,4- DEE 38 EC and reported no detrimental effect on soil micro organism after 30DAA with none of the herbicides though population in the initial stage showed slight decrease in all fungi, actinomycetes and total bacteria.

2.3.2 Effect of herbicides on soil enzyme activity

Frankenberger and Dick (1983) observed the relationship between soil enzyme and microbial biomass. They reported that same enzyme activities like urease, alkaline phosphatase and amidase were highly correlated ($P < 0.01$)) with microbial biomass as determined by CO_2 evolution.

Nannipieri *et al.* (1983) stated that enzyme activity and microbial biomass increased after the addition of energy source mainly due to increase in bacterial biomass and rapid immobilization of N.

Urease and dehydrogenase activity in flooded rice soil were higher than the upland rice soil and urease activity was more durig plant growth than at or harvest (Baruah and Mishra,1984)

Baruah and Mishra (1986) reported that the three herbicides 2,4-D, butachlor and oxyfluorfen could significantly stimulate the dehydrogenase activity but did not affect the urease activity and the activity remained almost unchanged.

Perucci (1990) reported that there was a signicicant positive and negative correlation with the changes in microbial biomass value and different enzyme activity. The negative correlations were due to the delay in enzymatic activity compared with the changes in microbial biomass.

Kirchner *et al.* (1993) investigated the effect of green manuring on microbial biomass and different enzyme activities and reported that enzyme activity was greater under green manuring as compared to N fertilizer conventionally filled soil.

Sathi *et al.*(1993) reported that salt and pH stress decreased urease activity by 24-50 and 10-49 and azotobacter numbers by 50(at EC >5 ds $m^{-1)}$ and pH > 8.0.

Naseby *et al.* (1997) reported that microbial biomass as well as urease enzyme decreased with the increase in depth of soil.

Klose and Tabatabai (1999) reported that separation of the different pools of enzyme activity in soils (intra- and extracellular) was needed to assess the contribution of the microbial community to specific enzyme reactions. The activities of total urease was significantly correlated with microbial biomass C.. The urease activity of the microbial biomass, expressed as a percentage of total urease activity, ranged from 37.1 to 73.1% (avg=54.0).

Ismail *et al.* (1998) reported that in loamy sand (Sungai Buluh series) and clay loam soil (Lating series) metsulfuron-methyl at 5· 0 $\mu g\ g^{-1}$ caused a reduction in amylase and urease activities for the entire period of study, especially at 28 days of incubation. A similar trend was observed in Lating series soil where the lowest activities of amylase and urease were attained at Day 28 in the presence of 5 ·0 $\mu g\ g^{-1}$ of metsulfuron-methyl.

The inhibitory effects of herbicides on soil enzyme activities decreased in the order: urea group>dinoseb>propanil>diphenyl ether group>acid amide group for urease, and dinoseb>urea group>diphenyl ether group>acid amide group. Herbicides inhibited the activities of soil enzymes in the early stage of treatment but increased the activities of urease, L-glutaminase and protease later (Kim and Hong,1988).

Sannino and Gianfreda (2001) reported from 22 samples reported that glyphosate, paraquat, atrazine, and carbaryl, on the activities of invertase, urease and phosphatase had some direct or indirect influence on soil enzyme. The addition of glyphosate and paraquat activated invertase and urease activities in several soils. A general inhibitory effect (from 5% to 98%) was observed for phosphatase in the presence of glyphosate.

The combined effects of cadmium (Cd, 10 mg kg^{-1} of soil) and butachlor (5, 10 and 50 mg kg^{-1} of soil) on enzyme activities and microbial community structure were assessed. Urease and phosphatase activities were significantly reduced by high butachlor concentration (50 mg kg^{-1} of soil). When Cd and butachlor concentrations in soils were added at milligram ratio of 2:1 or 1:2, urease and phosphatase activities were decreased, while enzyme activities were greatly improved at the ratio of 1:5. This study indicated that the combined effects of Cd and butachlor on soil urease and phosphatase activities depended largely on the addition concentration ratios to soils (Wang *et. al*. 2007)

Zheng *et al.* (2007) showed that after application of bispyribac-sodium with concentrations of 1.5, 15, 30, 60 and 120 mg kg^{-1} dried soil, compared with the control, soil respiration was also stimulated at the beginning but reduced slightly at 13d, and after the third week, the soil respiration was strongly depressed by higher concentration. The catalase activity in soil was slightly depressed during the early period and recovered after 21days. The activity of urease was stimulated after the application of bispyribac-sodium, and the lower concentration of bispyribac-sodium had more effects and lasted for a longer time.

2.4 Critical stage for crop-weed competition

The Critical period of crop-weed competition is the shortest time span in the ontogeny of crop when weeding will result in the highest economic return.

2.4.1 Critical stages of crop-weed competition in direct seeded rice

Tiwari and Singh (1991) reported that the highest rice yield occurred when the crop was kept weed-free throughout the season (926 kg ha^{-1}, compared to 510 kg ha^{-1}in unweeded plots) or upto 4 weeks after sowing (833 kg ha^{-1}), revealing that crop-weed competition began at that point. While Fischer *et al.* (1993) found that weeds emerging with the crop were the most damaging ones. Rice yields increased with longer weed-free periods upto 70 days after emergence (DAE), weed emergence and growth after 70 DAE was suppressed by the crop.

Alam *et al.* (1995) found that the first 25-55 days after sowing (DAS) in direct-seeded upland rice cv. BR 14, was found to be critical for crop-weed competition in that rice cultivar. The highest grain yield (3.33 t ha^{-1}) was obtained when the crop was kept weed free for first 65 DAS, whereas the lowest grain yield (0.19 t ha^{-1}) was obtained in the absence of any weeding.

In direct-sown rice, both in dry and wet sown condition, Huh et al. (1995) observed that weeds started to grow above the plant height of rice from 45 days after sowing (DAS), and there was a great difference in plant height between rice and weeds from 75 DAS. The dry weight of weeds drastically increased from 30 DAS in both dry- and wet sown rice, and the increase of dry weight was faster in dry than in water-sown rice with time. A weed-free period for the first 30-45 DAS was required in order to avoid any yield loss.

The critical period, the span of time between the time period after seeding or emergence when weed competition did not reduce crop yield and the time period after which competition would no longer reduce crop yield (Balasubramaniam and Ravichandran, 1996). Often that period was approximately the first one fourth to one third of crop life (Kandasamy, 1996).

Desoki (2003) observed that crop weed competition 20 days after sowing caused drastic reduction in the number of panicles m^{-2} and grain yield. Grain yield of rice significantly increased with the increasing duration of weed-free period. Weed density emerging between 20 and 40 days after sowing was high and the weeds competed with the crop resulting in reduced grain yield. Hand weeding three times (20, 40 and 60 days after sowing) gave results equal to hand weeding upto harvest (4.437 and 4.532 t ha^{-1}). The period within 20 to 60 days after sowing was an important factor in crop weed competition.

2.4.2 Critical stages of crop-weed competition in transplanted rice

Pande and Rao (1965) stated that severe weed infestation at the early stage of crop growth reduced significantly the grain yield. They also reported that reduction of 4 to 9 % rice yield occurred when grasses were not controlled upto 25 days after emergence and the loss increased to over 40 % if grasses were not controlled upto 63 to 73 days after emergence. A weed-free period of 20 days after transplanting (Var. IR 8) was sufficient to obtain optimum yield. Longer weed free period did not increase grain yield significantly while shorter period gave very poor yield. Likewise, De Datta *et al.* (1969) suggested that early weed-control was more important for the achievement of higher rice yield.

Gill and Kolar (1980) viewed that the most critical period of crop weed competition in rice noted to be between four to six weeks after transplanting during which weed competition resulted in yield reduction. The tillering phase was the most critical phase affected due to weed-crop competition.

Zimdahl (1980) reported that the period between 3 and 6 weeks after transplanting was the most critical time for low land rice. He also reported that barnyard grass (*Echinochloa crus-galli*) caused the maximum damage and competed at the maximum tillering stage (approximately at 40 DAT) or just after heading (approximately at 60 DAT) of rice crop.

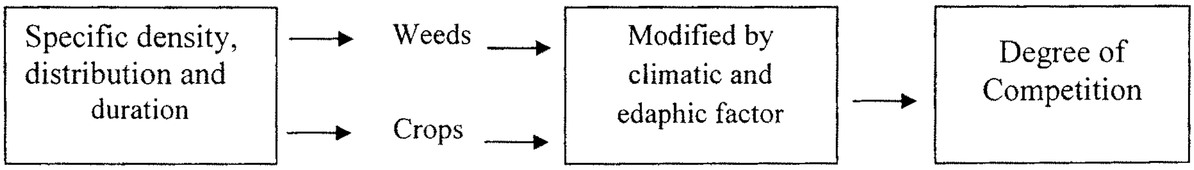
The presence of weeds after 9 weeks of transplanting had little or no effect on grain yield. A weed-free period of 45 DAT increased grain yield significantly (Mukhopadhyay, 1980). While Locket (1983) reported that weed-crop competition during the first 15 to 30 days from germination caused the highest yield reduction.

De Datta and Herdt (1983) reported that in high yielding, fertilizer responsive dwarf variety, timely and early weed control measure washighly critical for obtaining a good yield. A weed free period of 45 days was enough to control the weeds in transplanted rice (Singh and Bhan ,1989).

Rahman (1992) reported that the rice yield obtained through weeding upto 30 DAT was significantly greater than those plots weeded upto 10 DAT and 20 DAT and identical yield was produced when the field was kept weed free upto 30 to 40 DAT. From this observation, he concluded that hand weeding once between 21 and 41 DAT was as effective as hand weeding twice at the other stages.

2.4.3 Nature of competition between weeds and rice

According to Balasubramanian and Ravichandran (1996), crop-weed-competition was a function of:



Application of fertilizer without adequate weed control measure was uneconomic and unchecked weeds depleted 22.91 kg N ha^{-1}, when nutrient was applied at the rate of 90 kg ha^{-1} (Kakati and Pradhani, 1980). Ali and Sankaran (1981) reported that *Echinochloa crus-galli* and *Echinochloa colona* were the predominant grassy weeds under puddled and non puddled condition, respectively, which competed with rice at all the growth stages.

Among the irrigated rice cultures, transplanted rice had the lowest potential loss to weeds, because of the head start rice seedlings, which won over the weeds and because of flooded water itself acted as weed control measure. Despite these advantages, uncontrolled weeds reduced rice yields on an average 48 %, through competition for light and nutrients (Ampong-Nyarko and De Datta, 1991).

2.5 Biology of some important weeds

2.5.1 Dynamics of important Phenotype mimicry (*Echinochloa crus-galli*) and Pernicious weed (*Cyperus rotundus*)

Chang (1973) noted the heaviest loss in rice yield under the infestation of barnyard grass than monochoria and the yield loss due to barnyard grass at low and high soil fertility levels were 81% and 88.8%.

Ali and Sankaran (1981) reported that *Echinochloa crus-galli* and *Echinochloa colona* were the predominant weeds in the *kharif* and *boro* seasons of 1975-77 under puddled and non-puddled condition. Among the sedges, *Cyperus difformis* was the predominant weed offering severe competition at the early stage under puddled condition unlike *Cyprus iria* in non-puddled rice.

Senanayake *et al.* (1986) reported that rice was sensitive to the presence of *Echinochloa crus-galli*, causing depression of panicle and spikelet numbers in particular. A highly significant negative correlation was established between weed dry weight and grain yield. The threshold density of *Echinochloa crus-galli* for season long competition was 5 m^{-2} at which level grain yield losses were 8 to 17 %. Devendra *et al.* (1987) reported that *Echinochloa* sp. was the most competitive than rice in terms of light, moisture and CO_2 utilization.

Tripathi *et al.* (1993) in eastern Uttar Pradesh, during rainy season revealed that *Echinochloa crus-galli* and *Echinochloa colona* were the predominant grassy weeds under puddled and non-puddled conditions, respectively and they competed with rice at all stages.

Studying on the competitive ability of major weeds in transplanted rice like *Echinochloa sp., Paspalum distichum, Cyperus difformis, Marsilea minuta and Eclipta prostrata,* Srinivasan and Palaniappan (1994) observed that *Echinochloa* sp. was found to be the most competitive weed in reducing the growth and yield of rice, followed by *Marsilea minuta*, with the nature of competition being for light and nutrients, respectively. The light-transmission ratio was the lowest under *Echinochloa sp.*, whereas the nutrient removal was greatest under *Marsilea minuta*.

At Karnal, Haryana, *Echinochloa colona, Echinochloa crus-galli* and *Cyperus iria* were reported to be the dominant weed floras in *kharif* season (Singh *et al.*, 1996).

Conducting experiment to find out the threshold level of the problem, weed umbrella sedge or flat sedge (*Cyperus iria*) in rainfed direct-seeded rice, Moorty and Das (1998) observed that different densities of this weed varied from 40 to 400 plants m^{-2}, produced a dry matter of 0.3-2.34 t $ha^{-1}$and reduced rice grain yield by 11-40 %. Thus, they concluded that a density of 40 plants of *Cyperus iria* m^{-2} with a dry-matter accumulation of 0.3 t ha^{-1} was considered as the threshold level in upland rice.

Under upland direct-seeded conditions, yield reduction due to sedges varied from 23-48% depending on the conditions of the cultivar, yield reduction due to sedges varied from 23-48% depending on cultivar related response (Ramprasad *et al.*, 1999).

Various reports on yield reductions in rice by individual sedge species and sedges as a group indicated the differences in competitive abilites among the sedge species and the influence of cultivation type as well as competitiveness of the cultivar on the aggressive nature of the sedge species. Sedges were observed to be more competitive causing higher yield reduction than broadleaved weeds in rice-rice cropping systems of Tamilnadu (Umapathi and Sivakumar, 2000). In wet seeded rice, the yield reduction due to *C. rotundus* ranged between 60-70% (Singh and Govindrasingh 2001).

At Pantnagar, Singh *et al.*(2003) observed *Echinochloa colona* covering 82.1 % of total weed population followed by *Fimbristylis miliacea* (3.6 %), *Caesulia axillaris* (3.6 %) in transplanted *kharif* rice in clay loam soil during the rainy season.

Weeds and particularly grasses such as *Echinochloa* sp. were highly competitive in tropical direct seeded wet-sown rice and could reduce yield by 45-75 % when not controlled (Jhonson *et al.* 2003).

Desoki (2003) from Domielta, Egypt reported that *Echinochloa crus-galli*, *Echinochloa colona* and *Cyperus difformis* were major weeds in direct seeded rice fields. However, Sardana et al. (2004) found, in Punjab, that during *Kharif* season, *Cyperus* sp., *Echinochloa* sp., *Trianthema* sp. and *Eclipta* sp. were most prominent in direct seeded rice.

Yield loss due to *C. iria* at densities 10-200 plants m^{-2} was less with semi-tall varieties (4.8 to 20%) while the same was higher to the tune of 6.8 to 40% in short stature varieties (NRCWS, 2004b).

Working in Indo-gangetic plains, Tewari *et al.* (2005) identified *Echinochloa colona* and *Cyperus rotundus* as the major weeds in direct seeded rice culture. The other associated weeds were *Dactyloctenium aegyptium, Digitaria sanguinalis, Eleusine indica, Phyllanthus niruri, Trianthema monogyna, Digera arvensis* and *Cyperus iria.*

At Pantnagar, Dheer Singh *et al.*(2005) noticed *Cyperus rotundus and Fimbristylis dichotoma* were the major sedges in non-puddled rice plots, whereas, population of *Cyperus iria* was higher in puddled plots than unpuddled plots during all the years of experimentation.

2.5.2 Biology of *Echinochloa crus-galli*

Smith (1968) reported that barnyard grass competed more with thin rice stands compared with the thick rice stands. Rice panicles m^{-2}, height of matured plants, weight of rice straw, number of filled grains panicle^{-1} and weight of 1000 grains (Test weight) decreased as the grass (*E. crus-galli*) population increased in a fixed rice stand.

According to Norris (1992), the inflorescence length of barnyard grass (*Echinochloa crus-galli*) varied from < 2 cm to 20 cm >. Floral number increased from about 15 for the smallest inflorescence to over 2000.

From the study on biology of jungle rice (*Echinochloa colona*) and barnyard grass (*Echinochloa crus-galli*), Dhawn and Malik (2003) reported that under different dates of sowing, barnyard grass plants attained a height of 110 cm on 1st June and 1st July sowings and 75 cm on 15th July sowing. Biomass accumulation of *Echinochloa crus-galli* was more as compared to *Echinochloa colona.* Time taken for flowering in *E. colona* was half than the time taken by *E. crus-galli* at all the dates of sowing.

In Czech Republic, Jursik *et al.* (2004) found that the duration of primary dormancy of *Echinochloa crus-galli* was influenced by photoperiod during ripening. The minimum and optimum seed germination temperatures were 10-15 ^{0}C and 20-25 ^{0}C, respectively.At high temperature seed germination was not affected by light intensity.

Ghosh (2006) reported that spike and spikelet length alongwith height and duration of *Echinochloa colona* were less in comparison with *Echinochloa crus-galli* might be better competitive ability of *E. crus-galli* with rice than that of *E. colona* with the same crop.

2.5.3 Biology of *Cyperus rotundus*

Hauser (1962) reported that under identical conditions, purple nut sedge produced larger and greater number of tubers and it produced 5700 kg ha^{-1} of rhizomes after 20 weeks of planting tubers

Shoots of purple nut sedge emerged under suitable conditions 4 to 7 days after planting tubers. Tuber formations began from 4 to 6 weeks after seedling emergence and more tubers developed in the upper 15 cm of soil (Bell *et al.*, 1962 and Tripathi, 1969).

Horowitz (1992) stated that in case of *Cyperus rotundus* (purple nutsedge or nutgrass) both basal bulbs and tubers stored food reserves.

In Delhi, during 1994-95, Inder *et al.* (1998) stated that shoot length, leaf area plant^{-1}, number of shoots m^{-2} and dry matter accumulation of shoots of *Cyperus rotundus* increased substantially upto 60 days after emergence and a steady decline was observed thereafter. The number of tubers also increased substantially upto 75 days after emergence and decreased thereafter. There was a substantial increase in *C. rotundus* infestation during the second year.

Purple nut sedge (*Cyperus rotundus* L.) was considered as one of the worst weeds of the World, widely distributed through outthe tropics and subtropics in 52 different crops and in 92 countries (Rao, 2000) and is very common throughout South East Asia (Merita and Moody, 1999).

Nishimoto (2001) reported that purple nutsedge (*Cyperus rotundus*) tubers remained viable for several years and served as its principal means of survival. Apical dominance influenced bud dormancy within a tuber and in a chain of tubers, and dormancy increased with tuber age. Several growth inhibitors were identified in tubers, but their role in tuber dormancy was not established.

Neese and Varshney (2001) reported that purple nutsedge (*Cyperus rotundus*) was one of the most trouble some weeds in tropical and subtropical regions of the world. It was particularly a challenging weed for small farmers who did not have any access to effective herbicides as purple nutsedge populations could increase very rapidly and would cause significant yield loss. In developing countries, the use of effective herbicides to manage this weed was seldom cost effective on one hand and on the other, caused pollution hazards besides affecting quality of the produce.

Adekunle and Badejo (2002) informed that oil from *Cyperus* nut has antifungul activity on some dermophytes and storage fungi, edible and non-edible with free fatty acid.

In contrast, the perennial species of *C. rotundus* aggressive perennation through tubers was seen with a biomass of 151.6 g from 10 tubers and with a higher tuber germinability of 81% (Prabukumar *et al.* 2005).

Cyperus rotundus and *C. esculentus* (purple and yellow nutsedges, respectively) were some of the most serious problematic weeds in several cropping systems at Florida and in some other parts of the world. They had been reported to cause yield losses to the extent of 20-89% in various horticultural crops (Shabana *et al.* 2008).

The oil from *Cyperus* content 18 % saturated (pamitic and stearic acid) and 81 % unsaturated (oleic & linoleic acid) fatty acid (Anonymus 2008a)

Anonymus (2008b) reported oil from nut of *Cyperus* is being used in perfumery compound and in the manufacture of soaps, medicine, cosmetics & incense sticks (agarbati).

2.6 Management of *Cyperus rotundus*

2.6.1 Management through physical method

Hand weeding twice had been observed to be ineffective in suppressing perennial purple nut sedge *C. rotundus*, permitting the preponderance of the weed over a period of three years when practiced repeatedly in rice – mungbean sequence (Kathiresan, 2002).

The traditionally practiced method of control by farmers, in India, was hand weeding. Hand weeding in rice was normally by hand pulling of weeds or through hand hoeing. Hand weeding had been effective for all the types of annual sedges under almost all types of rice cultivation, viz, upland direct seeded rice, lowland puddled sown and transplanted rice. Hand wedding had been reported to be effective against *C. iria, F. miliacea* and *C. rotundus* (Chaubey *et al.,* 2005; Dubey *et al.,* 2005; Ghosh *et al.,* 2005; Mohan *et al.,* 2005).

2.6.2 Management through cultural method

Gogoi,(1996) of Eastern India stated another approach that helped in reducing sedge infestation involving similar principle of interruption of light and oxygen supply for the seeds and seedlings was the application of mulch materials like rice husk, rice straw and saw dust under direct-seeded upland rice in heavy rainfall region.

Among the methods of cultivation, transplanting in puddled condition had been effective in reducing the infestation of *C. rotundus* in Uttar Pradesh (Singh, 1999) and sedges, in general, in Uttaranchal (Singh *et al.,* 2001).

Cultivar tolerance and competitive superiority of rice varieties also suppressed sedges (Singh & Singh 2001; Singh *et al.* 2004a).

Higher crop density of rice reduced infestation by the sedges under transplanted condition (Brar and Walia, 2001) and in wet seeded rice (Singh *et al.,* 2004b).

Continuous submergence of rice field compared with rotational water supply inhibited emergence and establishment of sedges in transplanted rice (Subbulakshmi *et al.,* 2001). Likewise, stagnant water upto 7.5 cm interrupted sedge emergence in transplanted rice as compared to saturation (Mishra *et al.,* 2001).

Regarding the tillage practices, conventional tillage (dry ploughing once followed by three puddling and levelling) was effective while controlling *C. difformis* and *C. iria;* in rainfed lowland, transplanting of rice (Moorthy *et al.,* 2002).

Off-season land management through raising of green manure *Sesbania aculeata* and ploughing if *in situ* before raising the transplanted rice offered the advantage of reduced sedge density of *F. miliacea, C. difformis* and *C. rotundus* in Tamilnadu (Gnanavel and Kathiresan 2002).

Impaired soil structure due to puddling and stagnant water in transplanted rice helped inhibiting germination of sedge seeds. Similarly, drum seeding of rice reduced sedge infestation in direct wet seeded rice in Tamilnadu (Kandasamy and Chinnusamy 2005).

Intercropping dhaincha (*Sesbania aculeate*) in wet seeded rice reduced sedge infestation (Kandasamy and Chinnusamy, 2005).

2.6.3 Management through soil solarization

Solarization gave a highly significant reduction of the weed population of *C. rotundus* at Brazil and increased carrot yield. Soil treatment was less effective in green beans and yield was not influenced despite weed numbers being decreased. In the solarized plots, no weeding was needed during the vegetable crops cycle whereas the untreated plots required hand weeding within the first month from sowing. Soil solarization significantly reduced numbers of ant and earthworm but had no effect on millipede population (Ricci *et al.*, 1999).

Esfahani *et al.*, (1999) reported that solarization effectively reduced the populations of almost all weeds by around 100% save at *Cyperus rotundus* and *Sonchus asper* which were reduced by 59 and 44%, respectively, during summer month.

Nishimoto (2001) reported that, temperature regulates sprouting of *Cyperus* rotundus and no sprouting occurred below 10°C and above 45°C and daily alternating temperatures greatly stimulated the sprouting, further fluctuation of soil temperature daily may be a major signal for purple nutsedge emergence such as when the plant canopy is removed, or when soils were solarized.

Sumachandrika *et al.*,(2003) in Andhra Pradesh, India, during the kharif season of 2000 from an experimental field infested with *Cynodon dactylon, Digitaria sanguinalis, Eragrostis minor, Cyperus rotundus, C. difformis, Trianthema portulacastrum, Euphorbia hirta* and *Commelina benghalensis*, reported that weeding 20 ad 40 DAS resulted in the lowest number of weeds (6.36 m^{-2}) and weed dry weight (15.6 g m^{-2}), and highest number of pods per plant (15.6) seed yield (3.9 g $plant^{-1}$) and grain yield (1222 kg ha^{-1}). No significant differences in weed dry matter due to solarization and two hand weeding 20 and 40 DAS were observed.

Chopra and Chopra, (2004) from a field experiment, conducted in Karnal, Haryana, during the 2000 and 2001 summer seasons to study on the effect of soil solarization on weeds in nurseries of aubergine (cv. Pusa Kranti) and chilli (cv. Pusa Sadabahar) and reported soil solarization reduced *Cyperus rotundus* population by 63-65%, whereas *Eleusine indica, Echinochloa colona* and *Cenchrus ciliaris* were reduced by 80%. The dry weight of weeds at harvest was reduced by 96 and 95% for aubergine and chilli, respectively.

Patel *et al.*,(2005) reported that soil solarization was a novel technique of controlling soil borne pests including weeds. It involved covering the wet soil with a thin transparent polyethylene sheet during the summer months. The process would raise the surface soil temperature by 8 to 12^0 as compared to non-solarized soils. Transparent polyethylene was found highly effective for heating the soil than black polyethylene. Thinner (19-25 micro m) transparent polyethylene sheets were more effective for solar heating than thicker (50-100 micro m) ones. Duration of 4 to 6 weeks was sufficient to give satisfactory control of most of the weeds.

2.6.4 Management through biological method

Extracts of different plant parts, viz, root, stem, leaf and stem+leaf of *Calotropis* sp. affected germination and seedling vigor of many agricultural crop have been reported (Oudhia and Tripathi 1997). They found that stem+leaf inhibited the germination of *Paspalum scrobiculatum* (kodo) to the minimum upto 11 DAS but failed to produce any detrimental effects on weeds such as *Chenopodium album, Melilotus alba, Melilotus indica, Sphaeranthus indicus* and *Phalaris minor.*

Babu and Kandasamy (1997) have reported that aqueous leachates of fresh leaves of *Eucalyptus* significantly suppressed the establishment of vegetative propagules and early seedling growth of the *Cyperus rotundus* and *Cynodon dactylon*. Leachate of fresh leaf cuttings had a growth inhibitory effect on bermuda grass but showed growth promotion with purple nutsedge. In addition to that the leachate of dried leaves of *Eucalyptus* had a differential influence on the growth of the two weeds

Field experiment coducted by Mandal and De (2001), at Sriniketan under red and lateritic soil of west Bengal, found that green leaves of *Calotropis gigantea* at 150 kg ha^{-1} was able to produce considerably minimum dry weight of weeds with above 80% WCE, equivalent with butachlor. The yield reduction due to weeds under *Calotropis gigantea* treated plots was only 5.98% as compared to weed free check when the value in butachlor was about 8%.

Parthiban and Kathiresan (2002) found that *Calotropis* leaf leachates at 3% concentration were highly inhibitory on seed germination of *Echinochloa crus-galli* (46.7%) and least for rice (11.8%). *Calotropis* leaf at 5 t ha^{-1} caused significant reduction in weed density and biomass in rice nursery and main rice field with 38.9 and 29.6% weed controlling efficiency.

Allelopathic control of sedge weeds both in nursery and in main fields of lowland transplanted rice under South Indian conditions was reported (Parthiban & Kathiresan 2002). Fresh leaves of *Eucalyptus globulus* and *Leucaena leucocephala* at the rate of 5 t ha^{-1} in rice nurseries reduced the population of *C. rotundus* whereas in the main field those treatments reduced the infestation of *C. difformis, C. rotundus* and *F. miliacea* better than standard weed control practice of pre-emergence butachlor herbicide + one hand weeding.

Kayode (2004) had studied that the effects of 24 and 48 hours *Calotropis procera* leaf extracts on the radicle and plumule growth of maize cultivars Oba Super I, II, III and IV revealed that both the extracts showed considerable inhibitory effects on radicle and plumule growth of the cultivars. The severity of inhibition increased with an increase in the duration of the extraction.

Allelopathic inhibition of shoot length, shoot weight and tuber dry weight of *C. rotundus* was found with the use of leaves of *Mangifera indica, Parthenium hyserophorus*, a social noxious weed, *Cynodon dactylon* and *Physalis minima.* (Swain *et al.* 2005).

At Jabalpur, Swain *et al.* (2005) found that *Calotropis gigantea* (100 g fresh bio-matter kg^{-1} of soil) plant residue was able to reduce relative shoot length, shoot dry weight $tuber^{-1}$ (0.54 and 0.93, respectively) of *Cyperus rotundus* but was not able to reduce the relative dry weight $tuber^{-1}$ (1.58) at 20 days after sowing.

Ghosh (2006) reported from BCKV, West Bengal that PE application od aqueous leaf extract of *Calotropis gigantea* (5%) inhibited the seed germination and physiological metabolism of grassy weed category and to some extent on sedge but not on the broadleaf weeds.

Sorgaab (Sorghum water extract) in combination with reduced rates of herbicide S. metalachlor by one half to one third was quite effective in suppressing the density and dry weight of purple nut sedge in cotton and was at per with labelled rates of herbicide (Iqbal and Cheema, 2007).

Schroeder *et al.* (2008) reported that in irrigated systems, *Cyperus rotundus and C. esculentus* were effectively controlled with *Meloidogyne incognita*.

2.6.5 Management through chemical method

Integrating pre-emergence herbicides with cultural practices also rendered the herbicides more ecologically safe by virtue of reducing their residue levels (Arulchezian and Kathiresan, 1990).

Six herbicides namely, 2,4,D, glufosinate, glyphosate, bentazone, bensulfuron, MCPA, were studied under green house condition to find at their efficacies against purple nut sedge and out of these 2,4-D, glufosinate and glyphosate completely killed plants and completely suppressed tuber sprouting (Blatazar *et al.,* 1997).

Use of butachlor as a component of integrated management with hand weeding also conserved the floristic composition of weeds, preventing shift towards any particular group over prolonged cropping periods and herbicide use (Kathiresan, 2002).

Fuentes and Ferrucho (2002) opined that azimsulfuron at 14.0 g a.i. ha^{-1} + metsulfuron methyl at 4.0 g a.i. ha^{-1} herbicide mixture in foliar and soil treatments could effectively control purple nutsedge (C. rotundus) and other dominant weed flora in all types of rice culture.

The efficacy of the commercial glyphosate [(N-phosphonomethyl) glycine] formulations Roundup Ultra, Touchdown and Engame were compared for the control of purple nutsedge (*Cyperus rotundus*); application of glyphosate above 1120 g ha^{-1} at 7 days after treatment gave rise to more than 80% control was achieved (Molin and Hirase, 2004).

Devendra *et al.,* (2005) from an experiments conducted at Bangalore, on *C. rotundus* control using glyphosate (at 0, 20, 40, 80, 160, 320, 640, 1200 and 2400 g ha^{-1}) with or without co-penetrating surfactant Triton X 100 (0.01%) reported that the best results of fresh weight reduction bioassay obtained where glyphosate was applied in December and the addition of surfactant reduced the dose of glyphosate by 10 folds.

Following routine pre-tillage spraying of glyphosate or gluphosinate alluminium at the respective rates of 2-3 kg a.i. ha^{-1} or 0.5-1.5 kg a.i. ha^{-1} with the knapsack sprayer was promising for controlling *Cyperus* sp. at Malaysia (Baki, 2005).

Foliar-treated herbicides such as bentazone, 2,4-D and pyrazosulfuron ethyl were effective to control *Cyperus* sp. till 7 - 8 leaf stage (Known *et al.,* 2005).

From an experiment in TNA Centre, Coimbatore, it was reported that directed application of glyphosate 41 % SL (Roundup) 15 ml l^{-1} of water could reduce the density of *Cyperus rotundus* effectively (AICRP-WC Annual Report 07-08).

CHAPTER III

Materials and Methods

3.1 Experimental site

The field experiment was conducted at the 'C' Block (Incheck) Farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India during 2006-07 and 2007-08. The experimental site is situated at $22^0 5'$N latitude and 89 ^{0}E longitudes with an altitude of 9.75 m above mean sea level and topographically medium land.

3.2 Experimental soil

The experimental field was medium land with good irrigation and drainage facilities and the soil was typical Gangetic alluvium (*Inceptisol*) and sandy loam in texture. Composite soil samples from 0-15 cm depth of the experimental field were collected and the physico-chemical properties of the soil sample was determined (Table 3.1).

Table 3.1 Physico-chemical properties of the experimental soil (0-15 cm depth)

Particulars	Results	Analytical method employed
A) Mechanical composition of the soil		
Sand ((%)	53.2	
Silt (%)	23.7	International Pipette Method (Piper, 1950)
Clay (%)	23.1	
B) Chemical composition of the soil		
pH	6.95	pH meter in 1:2.5 soil water suspension (Jackson, 1973)
Organic carbon (%)	0.586	Volumetric Redox Titration (Walkley and Black) Method (Jackson, 1973)
Total N (%)	0.057	Modified Macrokjeldahl Distillation Method (Jackson, 1973)
Available P_2O_5 (kg ha^{-1})	19.4	Olsen's method (Jackson, 1973)
Available K_2O (kg ha^{-1})	124.6	Flame Photometer Method (Jackson, 1973)

3.3 Climatic condition

The experimental area comes under sub-tropical humid climate and situated just south of the Tropic of Cancer. The climate is characterized with short summer and winter and is not subjected to extreme weather conditions. The crop seasons of this region are broadly classified as: (i) Pre-*kharif* or summer-dry and warm (February to May) (ii) *Kharif* or rainy- wet and warm (June to September) and (iii) *Rabi* or winter- dry and cool (October to January).

The annual rainfall is around 1700 mm, of which approximately 70% is received during the rainy season, i.e., June to September and more than 50% during July and August only. The details of the weather conditions during the period of experimentation were recorded at the Meteorological observatory, Agricultural Research Complex, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal.

3.3.1 Air temperature

The data related to air temperature during both the years of experimentation have been presented in Table 3.2. The mean maximum temperature was recorded in the month of June during both the year of experimentation whereas the maximum temperature of 35.95 $^{\circ}$ C and 35.57 $^{\circ}$ C was recorded during the second and first fortnight of June 2006 and 2007, respectively. The minimum temperature falls to 9.75 $^{\circ}$C and 10.42 $^{\circ}$C in the first fortnight of January and second fortnight of December during the experimental year 2006 and 2007, respectively.

3.3.2 Relative humidity (%)

The meteorological data related to relative humidity during the period of experimentation presented in Table 3.2 depicted that the monthly maximum relative humidity varied from 99.44 % in second fortnight of December to 96.13 % in first fortnight of July during 2006 and the corresponding figure in 2007 were 97.13 % in first fortnight of December to 91.13 % in first fortnight of November. The monthly mean minimum relative humidity varied from 41.00 % in first fortnight of January to 86.13 % in second fortnight of August during 2006 and the corresponding figure during the experimental year 2007 were 40.77 % in first fortnight of January and 80.46 % during first fortnight of July.

3.3.3 Rainfall

The details of rainfall received during the experimental period have been presented in Table 3.2. The rainfall received during 1st fortnight of June' 2006 to 2nd fortnight of October' 2006 was 11.73 cm more than that of the rainfall of 2007.

Table 3.2 Meteorological data during the experimental period

Month	Fortnight	Temperature (^0C)				Relative humidity (%)				Rainfall (cm)	
		maximum		minimum		maximum		minimum			
		2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
June	First	34.65	35.57	26.25	25.75	94.40	93.42	71.00	65.13	55.20	12.70
	Second	35.95	31.51	26.05	25.63	96.87	93.53	69.93	77.86	27.30	17.51
July	First	33.61	32.62	26.47	26.55	96.13	95.33	81.20	80.46	144.50	14.89
	Second	32.63	31.39	25.89	25.72	98.19	95.43	82.25	79.31	265.30	10.93
August	First	32.96	33.51	25.69	27.26	96.13	92.41	78.47	69.25	56.30	02.66
	Second	31.92	32.21	25.74	26.12	99.06	95.69	86.13	78.06	196.50	13.08
September	First	34.0	32.55	25.5	26.55	96.90	94.90	73.90	78.40	78.5	02.91
	Second	32.3	31.73	25.1	25.62	99.20	95.53	81.50	81.00	343.3	30.05
October	First	34.46	33.21	24.95	25.60	98.53	93.40	74.33	70.00	4.43	05.83
	Second	32.11	31.12	21.46	22.23	98.25	92.13	69.46	61.63	1.95	00.46
November	First	30.36	32.42	20.08	22.36	97.40	91.69	65.06	61.13	1.60	0.46
	Second	30.63	29.48	15.97	17.01	96.70	94.27	44.33	55.60	0.00	0.41
December	First	28.30	27.35	12.53	14.03	99.40	97.13	45.20	52.00	0.00	0.00
	Second	27.41	25.25	12.65	10.42	99.44	95.50	52.16	45.63	0.00	0.41
January	First	24.93	27.09	9.75	10.92	99.30	95.53	41.00	40.77	0.00	0.00
	Second	27.24	23.93	11.71	13.63	99.18	95.19	49.06	59.25	0.00	3.78

3.4 Cropping history

The cropping history of the experimental field for last three years has been presented in Table 3.3.

Table 3.3 Cropping history of the field under experimentation

Year	Season	Crop grown
2003	Pre-*kharif*	Green gram
	Kharif	Rice
	Rabi	Rapeseed
2004	Pre-*kharif*	Sesame
	Kharif	Rice
	Rabi	Rice
2005	Pre-*kharif*	Black gram
	Kharif	Rice
	Rabi	Rice

3.5 Experimental details

3.5.1 Experiment 1 A: Bio-efficacy and phytotoxicity of azimsulfuron on the weed dynamics of transplanted rice and the following zero-till rapeseed

Season: *Kharif* - Crop: Transplanted rice, Variety IET 4094 (Khitish)

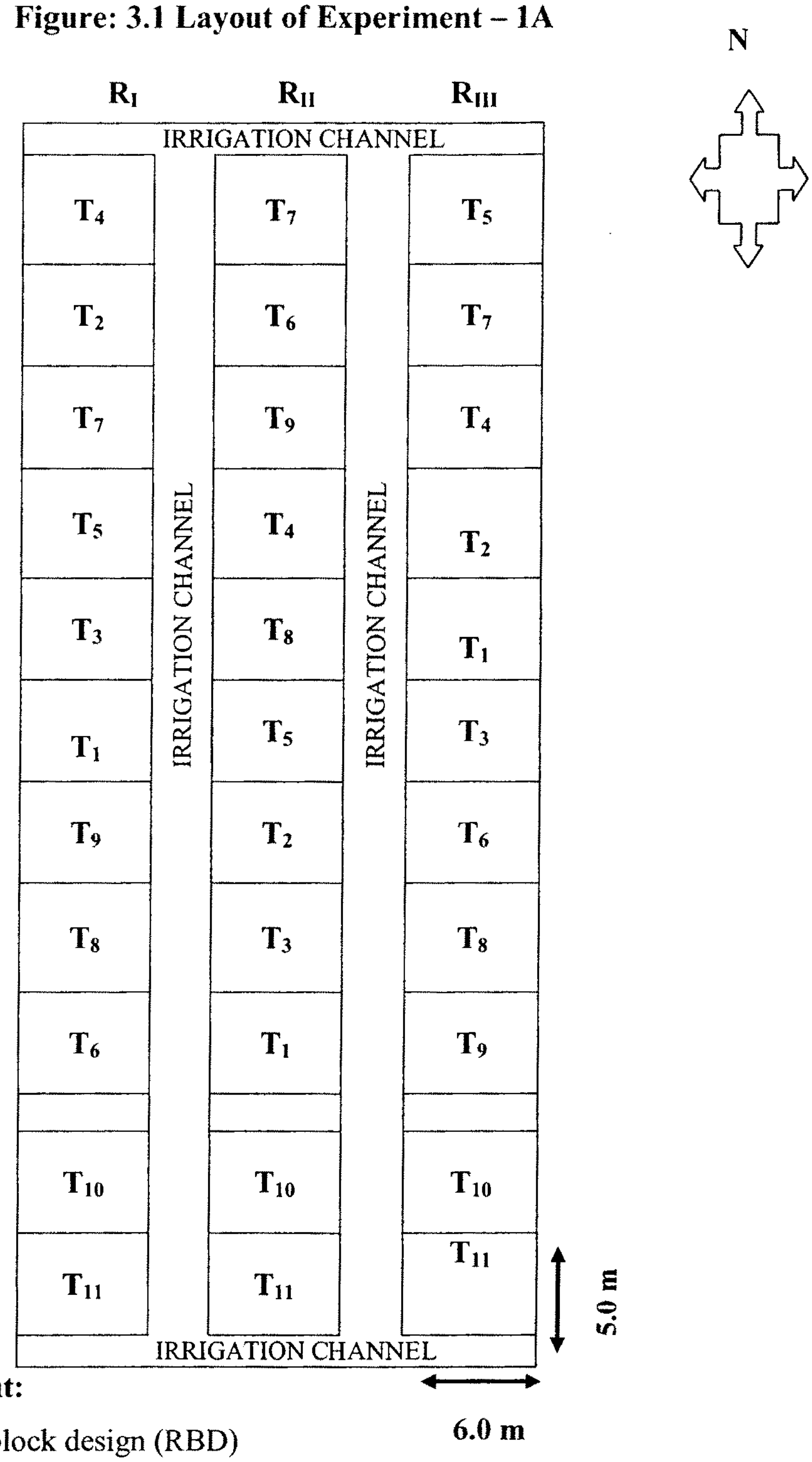
Spacing: 20 cm X 15 cm

Season: Rabi - Crop: rapeseed, Variety B 9 (Binoy)

Spacing: 30 cm X 10 cm

The Experiment 1A was carried out in a randomized block design (RBD) with eleven treatments (nine for bio-efficacy and two for phytotoxocity) replicated thrice with a net plot size of 6 m × 5 m .The follow-up zero till rapeseed was sown after harvesting of the transplanted paddy in between the two paired cross wise rows (plant to plant) without disturbing the layout. The plan of layout of those experiments was given in Figure 3.1

Figure: 3.1 Layout of Experiment – 1A



Specification of layout:

Design: Randomized block design (RBD)

Replication: 3 (Three)

Net plot size: 6.0 m x 5.0 m

Bund around the experimental field: 0.5 m

Bund: 0.25 m

Irrigation Channel: 1.0 m

Total Number of plots: (3 x 11) = 33 (Separated 6 for phytotoxicity)

3.5.1.1 Treatment details

Treatments : 11

T_1 – Azimsulfuron 50 DF @ 35.0 g a. i. ha^{-1}+Metsulfuron methyl 20 WG @ 2 g a. i. ha^{-1}+0.2 % Surfactant at 14 DAT
T_2 – Azimsulfuron 50 DF @ 40.0 g a. i. ha^{-1} + Metsulfuron methyl 20 WG @2 g a. i. ha^{-1} + 0.2 % Surfactant at 14DAT
T_3 – Azimsulfuron 50 DF @ 35.0 g a. i. ha^{-1} + Metsulfuron methyl 20 WG 2 g a. i. ha^{-1} at 14 DAT
T_4 – Azimsulfuron 50 DF @ 40.0 g a. i. ha^{-1} + Metsulfuron methyl 20 WG 2 g a. i. ha^{-1} at 14 DAT
T_5 – Azimsulfuron 50 DF @ 35 g a. i. ha^{-1} + 0.2 % Surfactant at 14 DAT
T_6 – Azimsulfuron 50 DF @ 40 g a. i. ha^{-1} + 0.2 % Surfactant at 14 DAT
T_7 – Metsulfuron methyl 20 WG 2 g a. i. ha^{-1} + 0.2 % Surfactant at 14 DAT
T_8 – Pretilachlor 30.7 EC @ 500 g a. i. ha^{-1} at 1 DAT (Standard Check)
T_9 - Untreated Check
*T_{10} – Azimsulfuron50 DF @ 80.0 g a. i. ha^{-1}+Metsulfuron methyl 20 WG @ 4 g a. i. ha^{-1}+0.2 % Surfactant at 14 DAT
*T_{11} –Azimsulfuron 50 DF @ 80.0 g a. i. ha^{-1} + Metsulfuron methyl 20 WG @ 4 g a. i. ha^{-1} at 14 DAT

* Treatments T_{10} and T_{11} were only for phytotoxicity studies

Surfactant : PROCOMBO, a universal spreader, sticker and activator

3.5.2 Experiment 1B : Bio-efficacy and phytotoxicity of azimsulfuron on the weed dynamics of direct seeded paddy and the following zero-till rapeseed

Season: *Kharif* - Crop: Direct seeded rice, Variety IET 4786 (Satabdi)

Season: Rabi - Crop: rapeseed, Variety B 9 (Binoy)

The direct seeded paddy was grown under irrigated condition with eleven treatments replicated thrice in a randomized block design with plot size of 5 m x 4 m. The seeds were sown in puddled condition and the follow-up rapeseed was also grown as similar as mentioned earlier (Experiment – 1 A) condition.

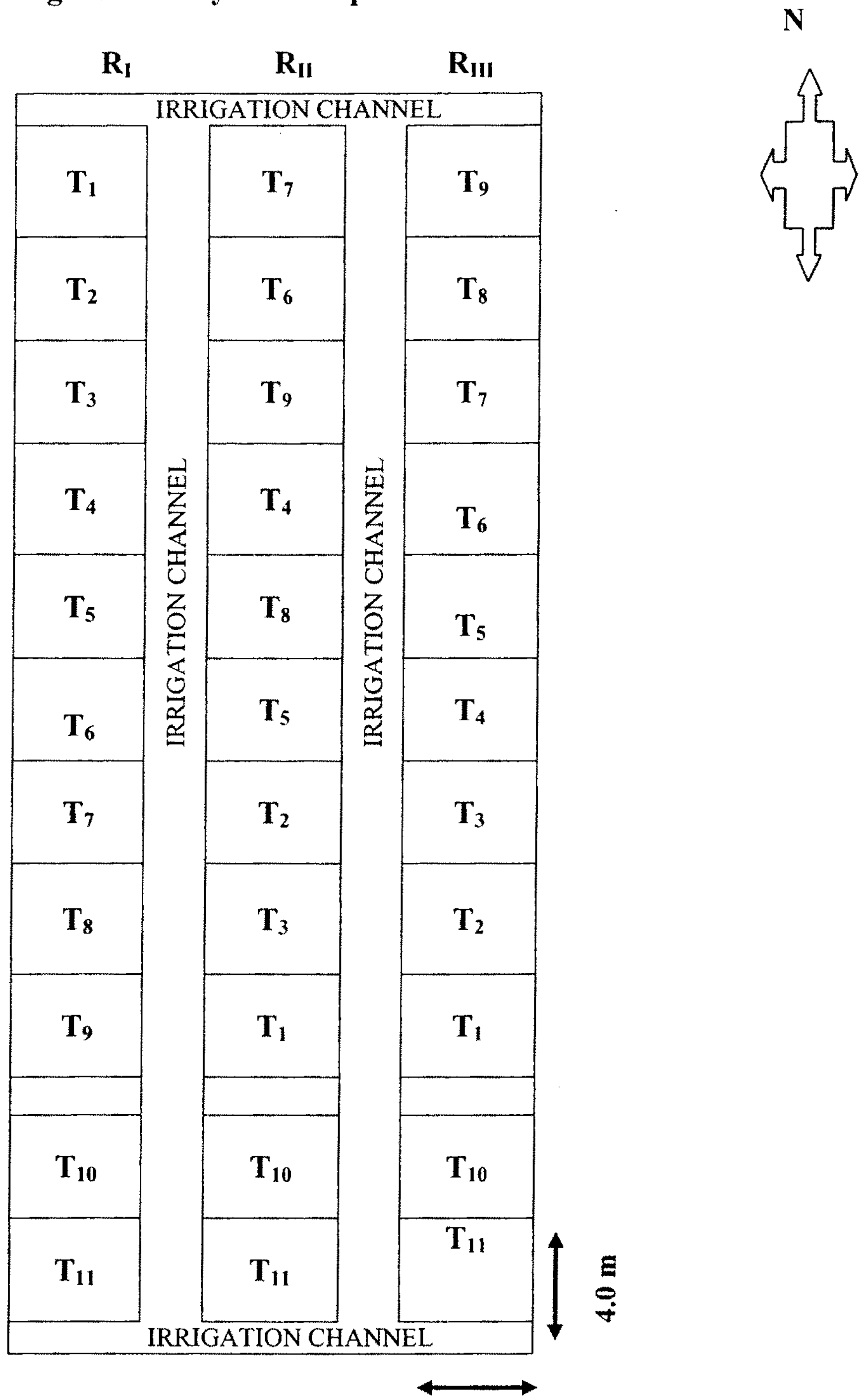
3.5.2.1 Treatment details

Treatments : 11

T_1 – Azimsulfuron 50 DF @ 35.0 g a. i. ha^{-1}+Metsulfuron methyl 20 WG @ 2 g a. i. ha^{-1}+0.2 % Surfactant at 25 DAS
T_2 – Azimsulfuron 50 DF @ 40.0 g a. i. ha^{-1} + Metsulfuron methyl 20 WG @2 g a. i. ha^{-1} + 0.2 % Surfactant at 25 DAS
T_3 – Azimsulfuron 50 DF @ 35.0 g a. i. ha^{-1} + Metsulfuron methyl 20 WG 2 g a. i. ha^{-1} at 25 DAS
T_4 – Azimsulfuron 50 DF @ 40.0 g a. i. ha^{-1} + Metsulfuron methyl 20 WG 2 g a. i. ha^{-1} at 25 DAS
T_5 – Azimsulfuron 50 DF @ 35 g a. i. ha^{-1} + 0.2 % Surfactant at 25 DAS
T_6 – Azimsulfuron 50 DF @ 40 g a. i. ha^{-1} + 0.2 % Surfactant at 25 DAS
T_7 – Metsulfuron methyl 20 WG 2 g a. i. ha^{-1} + 0.2 % Surfactant at 25 DAS
T_8 – Pretilachlor 30.7 EC @ 500 g a. i. ha^{-1} at 1 DAS (Standard)
T_9 - Untreated Check
*T_{10} –Azimsulfuron 50 DF @ 80.0 g a. i. ha^{-1}+Metsulfuron methyl 20 WG @ 4 g a. i. ha^{-1}+0.2 % Surfactant at 25 DAS
*T_{11} –Azimsulfuron 50 DF @ 80.0 g a. i. ha^{-1} + Metsulfuron methyl 20 WG @ 4 g a. i. ha^{-1} at 25 DAS

* Treatments T_{10} and T_{11} are only for phytotoxicity studies
Surfactant : PROCOMBO, a universal spreader, sticker and activator

Figure: 3.2 Layout of Experiment – 1B



Specification of layout:

Design: Randomized block design (RBD)

Replication: 3 (Three)

Net plot size: 5.0 m x 4.0 m

Bund around the experimental field: 0.5 m

Bund: 0.25 m

Irrigation Channel: 1.0 m

Total Number of plots: (3 x 11) = 33 (Separated 6 for phytotoxicity)

3.5.3 Experiment 2 Effect of azimsulfuron on soil enzyme (urease) activity and soil micro flora in transplanted paddy

3.5.3.1 Study on the soil-microflora

3.5.3.1.1 Collection of soil sample

Soil samples were collected from the rhizosphere of transplanted rice under Experiment-1 A at 5, 15, 30, 45 and 60 days after application of the applied herbicides. The samples were properly tagged, sealed and carried out from the field to the laboratory for isolation of soil microflora.

3.5.3.1.2 Methods of analyses

The enumeration of the microbial population was done on agar plates containing appropriate media following serial dilution technique and pour plate method (Pramer and Schmidt, 1965), plates were incubated at 30^0C. The counts were taken from 3^{rd} day to 5^{th} day of incubation. The results were reported as number of CFU (Colony Forming Unit) g^{-1} of soil multiplied with the dilution factor. The media were prepared as per following composition.

3.5.3.1.2.1 Total bacteria

For counting total number of viable bacteria, Thornton's agar medium (Thornton, 1922) was used. The pH of the medium was adjusted at 7.4 and sterilized at 15 lbs pressure for 20 minutes.

Table 3.4 Thornton's agar medium

Dipotassium hydrogen phosphate	K_2HPO_4	1.0 g
Calcium chloride	$CaCl_2$	0.1 g
Magnesium sulphate	$MgSO_4.7H_2O$	0.2 g
Sodium chloride	NaCl	0.1 g
Ferric chloride	$FeCl_3.6H_2O$	0.002 g
Potassium nitrate	KNO_3	0.5 g
Asparagine	$C_4H_8N_2O_3$	0.5 g
Mannitol	$C_6H_8(OH)_6$	1.0 g
Agar		15.0 g
Distilled water		1000 ml

3.5.3.1.2.2 Actinomycetes

Jensen's agar medium (Jensen, 1930) was used for counting the total number of actinomycetes. The pH of the medium was maintained at 6.5-6.6 and the medium was sterilized at 15 lbs steam pressure for 20 minutes.

Table 3.5 Jensen's agar medium for Actinomycetes		
Dextrose	$C_6H_{12}O_6$	2.0 g
Casein [dissolved in 10ml of 0.1N(N) NaOH]		0.2g
Dipotassium hydrogen phosphate	K_2HPO_4	0.5 g
Magnesium sulphate	$MgSO_4.7H_2O$	0.2 g
Ferric chloride	$FeCl_3.6H_2O$	Trace
Agar		15.0 g
Distilled water		1000 ml

3.5.3.1.2.3 Fungi

Martin's rose Bengal streptomycin agar medium (Martin, 1950) of the following composition was used for counting total fungi.

Table 3.6 Martin's rose Bengal streptomycin agar medium		
Potassium di hydrogen phosphate	KH_2PO_4	1.0 g
Magnesium sulphate	$MgSO_4.7H_2O$	0.5 g
Dextrose	$C_6H_{12}O_6$	10.0 g
Peptone		5.0 g
Agar		10.0 g
Rose Bengal (1:350 aq)		10.0 ml
Distilled water		1000 ml
Streptomycin		$30\mu gml^{-1}$

Sterile streptomycin was added to the medium just prior to plating. A stock solution was prepared by dissolving 10.0 mg of streptomycin in 2.0 ml distilled water. Approximately 0.1 ml of this stock solution was added to each plate containing about 15 ml of the medium. Medium containing all ingredients except streptomycin was sterilized at 15 lbs steam pressure for 20 minutes.

3.5.3.2 Determination of urease activity in soil (Tabatabai and Bremner, 1972)

This method was based on determination of ammonia released after incubation of soil samples with urea solution 2 h at 37^0 C.

$$H_2NCONH_2 + H_2O \longrightarrow 2NH_3 + CO_2$$

Procedure:

The estimation was made by taking 5 g of moist soil in duplicate in 50 ml volumetric flask .0.2 ml toluene and 9 ml of THAM buffer (pH 9.0, 0.5 M) were than added to the flasks. The flasks were swirled for few seconds to mix the contents. Subsequently, 1 ml of 0.2 M urea solution was added and swirled again for a few second. The flasks were stopped and placed in an incubator for 2 hrs. at 37 ^{0}C. The stopper was removed after incubation and approximately 35 ml of KCl- Ag_2SO_4 solution made by dissolving 100 mg of reagent grade Ag_2SO_4 and 188 g of reagent geade KCl in 700 ml water and diluted to 1 lit. The flasks were swirrled again for few seconds and were allowed to stand until the contents had cooled to room temperature (about 5 minutes). The content was brought up to 50 ml / 1 g addition of KCl- Ag_2SO_4 solution. The flasks were stopped and were inverted several times to mix the contents. The same procedure was followed for the two replicated control with the addition of 35 ml KCl- Ag_2SO_4 solution followed by 1 ml of 0.2 M urea solution.

The estimation of NH_4-N was performed by pouring the 50 ml suspension of soil samples in each replicate into the 250 ml distillation flask followed by the addition of few pinches of MgO to it. The content of the flask was then distilled for 15 mins and distilled was collected in a 250 ml conical flask containing 20 ml boric acis mix indicator solution. The distillate was titrated with 0.005 M H_2SO_4. One ml of 0.005 M H_2SO_4 is equivalent 70 µg NH_4-N,

Calculations:

$$\text{Urease activity } (\mu g\ NH_4\text{-N } g^{-1} \text{ dwy } 2\ h^{-1} \text{ at } 37\ ^0C) = \frac{C \times 50}{Dwt \times 5}$$

Where,

C is the measured NH_4-N concentration (µg NH_4-N ml $^{-1}$ soil suspension)

Dwt is the dry weight of 1 g moist soil material

5 is the weight of soil used

50 is the total volume of the soil material suspension

2 is the period of incubation in hr

3.5.4 Experiment 3 Weed biology of *Echinochloa crus-galli* and *Cyperus rotundus* in *kharif* season

Methods of growing the weed plants:

A) *Echinochloa crus-galli*

At first, fresh seeds of the entire weed species were collected. The seeds were dried in shade for five days after which the seeds were sown on 1st July during both the years @ 50 seeds pot^{-1}. The size of the earthen pot was 10 cm diameter at the top, contain fine sand. To avoid the germination of other weed seeds in the earthen pot, weed seed free fine sand was used. The emergence of weed seeds was recorded in that small 10 cm top diameter plot. The seedling at two leaf stage were transplanted into another earthen pot of 30 cm top diameter @ 20 seedlings pot^{-1} where the plants were grown upto maturity with proper care.

B) *Cyperus rotundus*

The nuts of *Cyperus rotundus* were collected at first and thereafter were cleaned and dried at first. Then the nuts were placed in a small earthen pot on 1st July during both the years @ 20 nuts pot^{-1}. The average weight of nuts was 0.30 – 0.70 g with small roots.The emergences of weeds were recorded and after 15 days of emergence these weeds are transplanted into another bigger earthen pot.

3.5.5 Experiment 4 Management of *Cyperus rotundus* during pre-*kharif* season

The experimental field was ploughed twice with power tiller and then levelling was done to get good surface. All the weeds, stubbles and plant residues are removed out from the plot and then seeds of *Cyperus rotundus* were allow to grow naturally plot size of 3 m X 2 m having three replications.

Treatments: 11

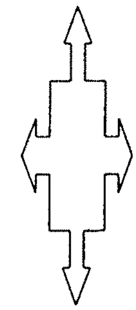
T_1	Untreated control
T_2	Twice hand pulling 15 & 30DAE)
T_3	Soil solarization
T_4	Extract of *Calotropis gigantea* @ 10 ml l^{-1} of water
T_5	Extract of *Parthenium hysterophorus* @ 10 ml l^{-1} of water
T_6	Extract of *Pistia stratiotes* @ 12 ml l^{-1} of water
T_7	XL-COMBI-SG (35 % Ammonium salt of Glyphosate + 35 % 2,4–D ammonium salt) @ 5 g l^{-1} of water
T_8	Glyphosate 41 % SL @ 10 ml l^{-1} of water
T_9	Azimsulfuron 50 DF @ 40 g a.i. ha^{-1} + 0.2 % surfactant
T_{10}	Almix (MSM + CME) @ 4 g a.i. ha^{-1}
T_{11}	Azimsulfuron @ 40 g a.i. ha^{-1} + Metsulfuron methyl @ 2 g a.i. ha^{-1} + 0.2 % surfactant

Figure: 3.3 Layout of Experiment – 4

R_{III}	R_{II}	R_{I}
T_{11}	T_8	T_1
T_{10}	T_7	T_2
T_9	T_6	T_3
T_8	T_2	T_4
T_7	T_1	T_5
T_6	T_{10}	T_6
T_5	T_{11}	T_7
T_4	T_9	T_8
T_3	T_5	T_9
T_2	T_4	T_{10}
T_1	T_3	T_{11}

2.0 m

2.0 m



Specification of layout:

Design: Randomized block design (RBD)

Replication: 3 (Three)

Net plot size: 3.0 m x 2.0 m

Bund around the experimental field: 0.5 m

Total Number of plots: (3 x 11) = 33

Gross plot area: 6.0 m^2

3.5.6 Chemical nature of the herbicide used

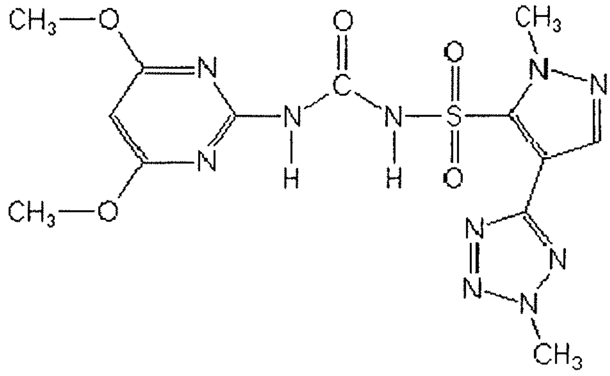
3.5.6.1 Azimsulfuron (New molecule)

Chemical Name: 1- (4, 6-dimethoxypyrimidin-2-yl) -3- [1-methyl-4- (2-methyl- *2H* -tetrazol-5-yl) pyrazol-5-ylsulfonyl] urea

Empirical Formula: $C_{13}H_{16}N_{10}O_5S$

Molecular weight: 424.40

Structure:



Mode of action: Post-emergent foliar uptake. Like other sulfonylurea, Azimsulfuron inhibits the plant enzyme acetolactate synthetase which is also known as aceto hydroxyl acid synthase (ALS / AHAS). This enzyme inhibition blocks branched – chain amino acid bio synthesis of valine (VA), leucine (LE) and isoleucine (ILE). Azimsulfuron is applied as PoE, it is taken up mainly by leaves, shoots and to a lesser extent, by roots and translocated by xylem and phloem.

Selectivity: Azimsulfuron has broad application selectivity and window. The compound can be applied to fields with moist or water saturated soil. It can be applied to rice from 3-leaf stage to tillering.

Solubility in water: 72.3 mg l^{-1} at 20^0C at pH 5.

1050 mg l^{-1} at 20^0C at pH 7.

6536 mg l^{-1} at 20^0C at pH 9.

Melting point: 170 ^{0}C

Vapour pressure at 25°C (mPa) : 4.00 X 10^{-06}

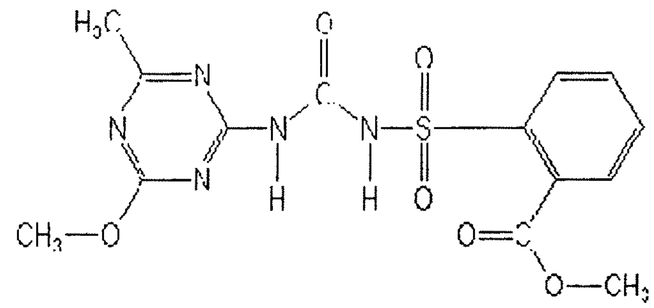
Persistency: It has les to moderately persistent in soil with a half-life of 20 days.

3.5.6.2 Metsulfuron methyl

Chemical Name: Methyl 2-(4-methoxy -6-methyl-1, 3,5 triazin-2 carbamoysulfomyl) benzoate (Algrip)

Empirical Formula: $C_{17}H_{26}ClNO_2$

Structural Formula:



Time of application: It is generally applied as post emergence

Mode of action:. Metsulfuron methyl like other sulfonylurea inhibits the plant enzyme acetolactate synthase which is also known as aceto hydroxyl acid synthase (ALS / AHAS). This enzyme inhibition blocks branched –chain amino acid bio synthesis of valine (VA), leucine (LE) and isoleucine (ILE).

Persistency: It is moderately persistent in soil with a half-life of 35 days with a range of 1-6 weeks

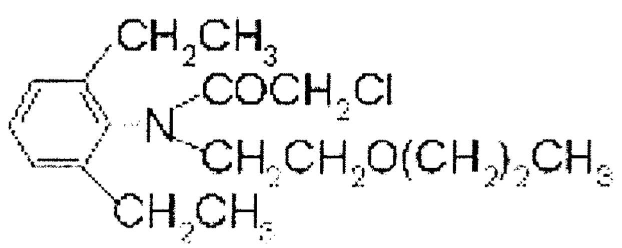
3.5.6.3 Pretilachlor

Chemical Name: 2-chloro-N-(2,6-diethylphenyl)-N-(2-propoxyethyl) acetamide (Rifit)

Empirical Formula: $C_{17}H_{26}ClNO_2$

Molecular Weight: 311.9

Structural Formula:



Boiling point: 135°C /0.001mmHg

Solubility: In water, 50 mg l^{-1} (20°C), very soluble in benzene, hexane, methanol and dichloromethane

Vapour pressure: 0.133mPa (20°C)

Density: 1.076(20°C)

Formulations: 300 g l^{-1}, 500 g l^{-1} EC; 50%EW

Application: Biochemistry: cell division inhibitor.

Mode of action: selective herbicide. It is taken up readily by the hypocotyls, mesocotyls and coleoptiles, and to a less extent by the roots of germinating weeds.

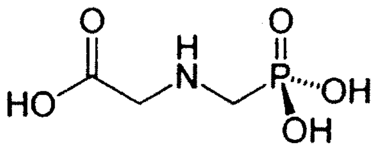
Uses: Herbicide effective against main annual grasses, broad-leaf weeds and sedges in transplanted and direct seeded rice.

Phytotoxicity: Applied alone, Pretilachlor will cause injury to direct seeded rice.

3.5.6.4 Glyphosate

Chemical name: N- (phosphonomethyl) glycine (Roundup)

Structure:



Formulations: Glyphosate is supplied in several formulations for different uses:

- Ammonium salt.
- Isopropyl amine salt.
- Glyphosate acid – stand alone, as ammonium salt or as isopropyl salt.

Products are supplied most commonly in formulations of 120, 240, 360, 480 and 680g active ingredient l^{-1}. The most common formulation in agriculture is 360g, either alone or with added cationic surfactants.

Mode of action : Glyphosate kills plants by inhibiting the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), which catalyzes the reaction of shikimate-3-phosphate (S3P) and phosphoenolpyruvate to form 5-enolpyruvyl-shikimate-3-phosphate (ESP).

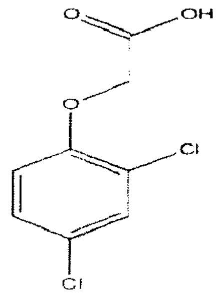
Use: Glyphosate is effective in killing a wide varieties of plants, including grasses, broadleaf, and woody plants. It has a relatively small effect on some clover species. By volume, it is one of the most widely used herbicides. It is commonly used for agriculture, horticulture, and silviculture purposes, as well as garden maintenance (including home use).

Persistency: It has Moderate persistency in soil, with a half-life of 47 days.

3.5.6.5 2,4-D Ammonium salt

Chemical name: 2, 4-dichlorophenoxy acetic acid

Structure:



Mode of action: 2, 4 –D is a systemic PoE herbicide but is also effective as PE.

Formulation: It is available in ester formulation (ethyl ester, butoxyethyl ester, isopropyl ester, isooctyl ester, etc.) and salt formulation (sodium and amine).

Persistency: The persistency of 2, 4 –D phytotoxicity is 1- 4 week in worm, moist soil. Field half-life is 10 days.

Use: This herbicide is generally used to control many annual weeds in cereal crops,sugarcane , plantation crops and in non-cropped areas.

3.5.6.6 XL-COMBI-SG (mixture of 35 % Glyphosate ammonium salt and 35 % 2,4 –D ammonium salt)

3.5.7 Herbicide application

The required quantity of herbicide was calculated by using the formula

$$Q = \frac{\text{Dose} \times 100}{\text{a.i.}}$$

Where, Q = Quality of chemical in g or ml per ha

Dose = Rate (kg a.i. ha^{-1})

a.i. = Percentage of the chemical in herbicide (active ingredient)

3.5.8 Particulars of crop cultivars

Rice (*Oryza sativa* L.)

Variety: IET 4094 (Khitish)

A derivative of the cross between BU-l and CR-115, released in 1981 in West Bengal. Plant height 80-100 cm, good plant type with erect flag leaf and high tillering ability. Grains long slender (LS), (21g 1000^{-1} grains). Moderately resistant to blast and BLB and average yield 4.5 t ha^{-1} during *Kharif* season. The average seed to seed duration during *Kharif* season is 120 days and 25 days more during summer season.

Variety: IET 4786 (Satabdi)

This is a semi dwarf, high yielding variety, developed at CRRI, Cuttack, from a cross between CR10-114 and CR-115, in the year 1977 and is recommended for medium land situation. The seed to seed duration of the variety being 120 days in *kharif* season to 145 days in *boro* season. It has good cooking and milling qualities and grains are of long-slender (LS) type (average length 6.5-7.0 mm and L : B ratio around 3.0). The average yield potential is 4.5 t ha^{-1}.

Rapeseed (*Brassica campestris* L. var Yellow sarson)

Variety: B-9 (Binoy)

This variety, popularly known as Binoy, was released from Pulse and Oilseeds Research Station, Berhampur, West Bengal during 1980. Height of the plant is 80-120 cm., branching is very limited. The round and smooth seeds are light yellow in colour and large in size. It matures between 90 and 95 days. Fruits are two chambered. Yield potential of the variety is 1.3 t ha^{-1}. Oil content of the seeds is 46%. However, it is moderately susceptible to aphids.

3.6 Calendar of field operation

Table 3.7 Calendar of agronomic field operations for Experiment 1A (Transplanted paddy – zero-tilled rapeseed)

Transplanted paddy

Operation	Date		Details of operations
	2006	2007	
1) Nursery sowing	29.06.06	24.06.07	Seedlings were raised by wet bed method. After treating with Trichoderma @ 4 g kg^{-1}. Seeds were kept for 36 hours for incubation and sown on the well prepared 5 cm raised wet bed each with 1.5 m width and 10 m length
2) Land preparation			
a) Preparatory tillage			
i) Initial	21.07.06	14.07.07	The experimental field was ploughed crosswise in standing water thrice with power tiller to make the land well puddled and then laddering was done to get a uniform surface.
ii) Final	22.07.06	16.07.07	
b) Lay out	23.07.06	17.07.07	The experimental field was divided into 4 blocks of which 3 blocks each contained 9 plots and last one contained 6 plots (for phytotoxicity). Each of the total 33 plots having size of 5 m X 4 m, was demarcated with the help of bunds.
3. Transplanting	26.07.06	18.07.06	27 days old seedlings during 2006 and 24 days during 2007 were used for straight row planting at 3-4 cm depth at a spacing of 20 cm x 15 cm with 2-3 seedlings $hill^{-1}$. The North-South direction of planting was followed. Gap filling was made seven days after transplanting.
4. Fertilizers management			
a) Basal (1/4th N, full P_2O_5 and full K_2O)	21.07.06	16.07.07	A general recommended dose of 60 kg N, 30 kg each of P_2O_5 and K_2O ha^{-1} was applied. Out of that 15 kg N ha^{-1}, 30 kg each of P_2O_5 and K_2O were applied as basal during final land preparation, ½ of the total N (30 kg ha^{-1}) was applied at active tillering stage and rest ¼ N (15 kg ha^{-1}) was applied at panicle initiation stage. The sources of N, P_2O_5 and K_2O were Urea , SSP and MOP, respectively.
b) 1st top dressing (1/2 N)	13.08.06	08.08.07	
c) 2nd top dressing (1/4th N)	3.09.06	29.08.07	
5. Water management	Whenever needed	Whenever needed	

Contd. ... Table 3.7

Contd. ... Table 3.7

6. Plant protection measures	24.08.06	21.08.07	Polytrin C (mixture of 40 % profenomus and 4 % cypermethrin) @ 750 ml ha^{-1} were applied.
7. Herbicide application			The required quantity of commercial formulation was accurately measured and was applied with high volume Knapsack sprayer fitted with flat jet deflector nozzle with 500 l water ha^{-1} spray volume. Proper care was taken to ensure uniform application.
Azimsulfuron and metsulfuron methyl	15.08.06	3.08.07	
Pretilachlor	27.07.06	20.07.07	
8. Harvesting	16.10.07	23.10.06	The crop was harvested from the net plot when 80% grains in each panicle were matured. Harvesting was done excluding the two border rows from each side of a plot. Subsequently, the harvested crop was threshed, cleaned and sun dried.

Follow up zero-tilled rapeseed

Particulars	Date of operation	
	2006-07	**2007-08**
1. Layout	Remain unchanged as the preceding transplanted rice for both the seasons	
2. Basal fertilizer application	25.10. 06	18.10.07
3. Sowing of seeds	25.10.06	18.10.07
5. Thinning	14.11.06	9.11.07
6. Top-dressing of N-fertilizer (urea)	28.11.06	19.11.07
7. Irrigation	26.11.06 25.12.06	19.11.07 20.12.07
8. Hand weeding (once at 30 DAS)	25.11.06	18.11.07
9. Harvesting	23.01.07	17.01.08
10. Drying	18.01.07 and 19.01.07	21.01.08 and 22.01.08
11. Threshing	20.01.07	23.01.08

Table 3.8 Calendar of agronomic field operations for Experiment 1 B (Direct seeded puddle paddy – zero-tilled rapeseed)

Direct seeded puddled paddy

Operation	Date		Details of operations
	2006	2007	
1) Land preparation			
a) Preparatory tillage			
i) Initial	15.06.06	20.06.07	The experimental field was ploughed in standing water thrice with power tiller to make the land well puddled crosswise and then laddering was done for uniform surface.
ii) Final	22.06.06	26.06.07	After laddering the water was drained out from the field.
b) Lay out	23.07.06	27.06.07	The whole experimental field was divided into 4 blocks of which 3 blocks each contained 9 plots and last one contained 6 plots (for phytotoxicity). Each of the total 33 plots having size 5 m X 4 m, was demarcated with the help of bunds. Three irrigation cum drainage channels were provided.
2 Sowing of seeds	24.06.06	29.06.07	Wet seeds after treating with Trichoderma @ 4 g kg $^{-1}$ were kept for 36 hours for incubation and sown on the well prepared main field.
4.Fertilizers management			
a) Basal (1/4th N, full dose of P_2O_5 and K_2O)	24.06.06	28.06.07	A general recommended dose of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} was applied. Out of this 15 kg N ha^{-1} and full of P_2O_5 and K_2O were applied as basal during final land preparation. ½ of total N (30 kg ha^{-1}) was applied at active tillering stage and rest ¼ N (15 kg ha^{-1}) was applied at panicle initiation stage. The sources of N, P_2O_5 and K_2O were Urea, SSP and MOP, respectively.
b) 1st top dressing (1/2 N)	24.07.06	28.07.07	
c) 2nd top dressing (1/4th N)	25.09.06	29.08.07	
5. Water management	24.06.06 to 03.10.06 (need based)	29.06.07 to 05.10.07 (need based)	

Contd. ... Table 3.8

Contd. ... Table 3.8

6. Plant protection measures	19.08.06	22.08.07	Polytrin C (mixture of 40 % profenomus and 4 % cypermethrin) @ 750 ml ha^{-1} was applied.
7. Herbicide application			The required quantity of commercial formulation was accurately measured and was applied with high volume Knapsack sprayer fitted with flat fan nozzle with 500 l water ha^{-1} volume of spray. Proper care was taken to ensure uniform application.
Azimsulfuron and metsulfuron methyl	14.07.06	19.07.07	
Pretilachlor	25.07.06	30.06.07	
8. Harvesting	21.10.06	28.10.07	The crop was harvested from the net plot when 80% grains in each panicle were matured. Harvesting was done excluding the two border rows from each side of a plot. Subsequently, the harvested crop was threshed, cleaned and sun dried.

Follow up zero-tilled rapeseed

Particulars	Date of operation	
	2006-07	2007-08
1. Layout	Remain unchanged as the preceding transplanted rice for both the seasons	
2. Basal fertilizer application	21.10.06	27.10.07
3. Sowing of seeds	22.10.06	29.10.07
5. Thinning	17.11.06	19.11.07
6. Top-dressing of N-fertilizer (urea)	24.11.06	26.11.07
7. Irrigation	As and when required	As and when required
8. Hand weeding	16.11.06	20.11.07
9. Harvesting	19.01.07	28.01.08
10. Drying	20.01.07 and 21..01.07	29.01.08 and 30.01.08
11. Threshing	22.01.07	31.01.08

3.7 Methods of recording observations

3.7.1 Observations on weeds

3.7.1.1 Weed flora present in the experimental plots

Regular and timely observations were undertaken to identify different weed species prevalent in the experimental plots right from the initiation of the experiment up to the period of harvest. The data on different weed species found in the experimental field were recorded at regular intervals for both rice and rapeseed.

Table 3.9 Time of recording observations on weeds

Experiment no.	Crop	Time of observation
1A (*Kharif*)	Transplanted rice	15 and 45 days after the application of herbicide (DAA)
(Rabi)	Zero tilled rapeseed	Total weed data along with visual observation, on10 and 25 DAS
1 B (*Kharif*)	Direct seeded rice	15 and 45 days after application of herbicide (DAA)
(Rabi)	Zero tilled rapeseed	Total weed data along with visual observation, on10 and 25 DAS

3.7.1.2 Visual Observation

Observations on visual rating of the weed density as against, the applied herbicides were taken on 10, 25 and 40 DAA from all the plots according to the efficacy of controlling weeds.

3.7.1.3 Weed density

To count the weed population m^{-2} for each treatment, a quadrat of size 0.5m x 0.5m was thrown randomly at two places in each plot. Different categories of weeds (grass, sedge and broadleaf) and some dominant individual species (rice crop only) were counted separately for each plot in rice for both Experiment-1A and Experiment-1B as per schedule mentioned in the Table. The weed data as per the category of weeds (grass, sedge and broadleaf) were counted in rapeseed crop. The average value thus obtained from two spots in each plot was converted into weed density m^{-2}.

3.7.1.4 Weed dry weight

Weeds belonging to three different categories, obtained in the population count at 30 and 45 DAA were pulled out from the fields individually, washed thoroughly with clean water, labelled properly and dried in hot-air oven at a temperature of 60^0C till constant weights of the samples were obtained, after which the dry weight of the weeds or weed biomass was recorded separately.

3.7.1.5 Weed control efficiency (WCE %)

It denotes the efficiency of the applied weed management treatments, for comparison purpose. As per schedule mentioned in the Table in experiment 1 A and 1 B (rice), the WCE of different weed management treatments were calculated using the following formula:

$$\text{WCE} = \frac{\text{Dry weight of weeds in control plot} - \text{Dry weight of weeds in treated plot}}{\text{Dry matter of weeds in control plot}} \times 100$$

3.7.2 Crop studies

3.7.2.1 Crop phytotoxicity rating

Visual assessment of response of herbicide on rice (at 3, 10 and 30 DAA) and rapeseed plants (at 5 and 20 DAS) was rated by following the European Weed Research Council Rating System in Form No. 'B' with a 1-9 scale as shown in Table No 3.10 to record herbicide toxicity on crop stand and growth.

Table 3.10 Qualitative description of treatment effects on crop in the visual scoring scale of 1 to 9

FORM No. B		
Rating	**Crop response**	**Verbal description**
1	0-1.0	No reduction or injury
2	1.0-3.5	Very slight discolouration
3	3.5-7.0	More severe but not lasting
4	7.0-12.5	Moderate and more lasting
5	12.5-20.0	Medium and lasting
6	20.0-30.0	Heavy injury
7	30.0-50.0	Very heavy injury
8	50.0-90.0	Nearly destroyed
9	100.0	Completely destroyed

3.7.2.2 Rice

The effect of different treatments on the various characters and yield components were studied as follows.

3.7.2.2.1 Plant population

The observation on plant population in experiment-1 was recorded by using a quadrat of size 0.5 m x 0.5 m and was taken converted to number m^{-2}.

3.7.2.2.2 Plant height

Ten plants were selected at random in each individual plot under experiment 1A and 1 B and plant heights in centimeter were measured from their base to the tip of the top leaf.

3.7.2.2.3 Number of panicle

The number of panicle m^{-2} was recorded during harvest stage of the crop under experiment 1A & 1B was made.

3.7.2.2.4 Length of panicle

Ten panicles were taken at random from each plot. Then the panicle length was measured from basal node to the tip of the top most grain and finally the average length for each treatment was calculated and recorded.

3.7.2.2.5 Filled grain panicle^{-1}

The number of filled grains was counted separately from ten randomly selected panicles and the mean was worked out.

3.7.2.2.6 Test weight

One thousand filled grains were taken at random from the harvested bulk samples of each treatment, dried in sun and their weights were recorded separately from each plot.

3.7.2.2.7 Grain yield

Plants from net plot area from each plot were harvested at ground level, were then threshed, winnowed and were separately dried in the sun for each treatment and the grain yields were computed on the basis of t ha^{-1}.

3.7.2.2.8 Straw yield

After threshing, the straw bundles were allowed to dry for about two to three days in direct sun and then the yield of straw was recorded for each plot. The plot wise yield of straw was converted in t ha^{-1}.

3.7.2.3 Rapeseed

The effect of different treatments on the various characters and yield components were studied as follows.

3.7.2.3.1 Height of the plants

The height of ten plants selected randomly from each plot was recoded from the ground level to the tip of the plant and average was made at harvest stage of the rapeseed crop.

3.7.2.3.2 Number of branches plant^{-1}

Number of branches of ten plants of rapeseed was counted at 50 DAS, 70 DAS and at harvest stage and average number of branches plant^{-1} were calculated.

3.7.2.3.3 Number of siliqua plant^{-1}

Ten plants were selected at random from each plot and all the siliquae (rapeseed) were stripped off and counted at the time of harvesting and the average number of siliquae plant^{-1} was calculated.

3.7.2.3.4 Number of seeds siliqua^{-1}

Twenty siliquae were selected from previously stripped siliquae. Their seed number was counted and average number of seeds siliquae^{-1} was calculated.

3.7.2.3.5 Test weight

After threshing and cleaning, one thousand seeds were counted randomly for each treatment. The seeds were sun dried and their respective weights were recorded.

3.7.2.3.6 Seed yield

Plants were cut at their base from net plot area, were dried in the sun and subsequently threshed. The seeds were cleaned, sun dried, weighed and then converted into tonne ha^{-1}.

3.7.2.3.7 Stover yield

The rest portion of the produce of crop after separating the seeds, were sun dried and weighed and then yield was converted into t ha^{-1}.

3.7.3 Observations on the weed species for weed biology

3.7.3.1 Times of emergence

When the coleoptiles of the weed species came above the surface of the sand in the earthen pot, the date was noted and the number of days taken for emergence was recorded.

3.7.3.2 Time of the flowering

When 50 % weed plants of a species bore flowers, the day was taken as the time of flowering and the number of days was counted to indicate the time of flowering.

3.7.3.3Time of maturity

After flowering, when the leaves of the plant turned yellow as found in case of *Echinochloa crus-galli* were considered mature. In *Cyperus rotundus*, the leaves were dried up and become straw coloured at maturity.

3.7.3.4 Dry matter accumulation at different stage

The life span of the plant was divided into their different stages (30 DAS, 60 DAS and at maturity). For every species, at each stage, one seedling from one pot was uprooted from all the pots in such a way that the roots were not damaged. Thereafter, the plant of a species were packed together, lebelled and dried in a hot air oven drier at 60 ^{0}C . The dry weight was then recorded individually to get the dry matter accumulation of single weed species.

3.7.3.5 Length of the root

The plant was uprooted by core sampler and the length of roots was measured with the help of a scale at maturity for each species.

3.7.3.6 Period of dormancy

At maturity, seeds of every weed species were collected separately which was then dried in shade for three days. Later on, 50 seeds of each species were kept on moist cotton in a Petridis in the laboratory for germination. The number of days to germinate was noted to determine the dormancy of every weed species.

3.7.3.7 Number of seeds per plant

Numbers of seeds from five plants were counted separately for each species and then the average data were recorded.

3.7.3.8 Oil content in *Cyperus rotundus* nut

The oil content of the nut of *Cyperus rotundus* was estimated by adopting Soxhlet Ether Extraction Method (Sadasivam and Manickam, 1996). For that purpose, 5.0 g seed sample of each treatment was used and the oil content was then calculated in percent.

3.7.4 Bio-efficacy observation

3.7.4.1 Visual scoring

Observations on visual rating of the weed density as against the applied herbicides were taken on 10, 20 and 40 DAA on the basis of 1-10 Scale.

3.7.4.2 Weed density

To count the weed population m^{-2} for each treatment, a quadrat of size 0.25 m x 0.25 m was thrown randomly at two places in each plot at 10, 20 and 40 DAA.

3.7.4.3 Weed dry weight

For dry weight, the weeds were collected through a quadrate of size 0.25 m x 0.25 m and thereafter dried in a hot air oven drier at 60 ^{0}C . The dry weight was then recorded at 10, 20 and 40 at DAA.

3.7.4.4 Resurgence of weed growth

The dates and intensity of regrowth of weeds were observed.

3.8 Economic analyses

Cost of various inputs and crop management practices in producing the crops including the treatment cost and the price of the produce were estimated as per available market price. Cost of cultivation, gross and net returns of the crop for various treatments were then calculated.

3.9 Mechanical analysis of soil

Composite samples were taken from the experimental field at a depth of 0-15 cm before land preparation for analysis.

Mechanical analysis of soil particularly the contents of fine sand, coarse sand, silt and clay was done by International Pipette Method (Piper, 1950).

3.10 Statistical analyses

The statistical analysis of the recorded data was done by the analysis of variance method (Gomez and Gomez, 1984). The significance of different sources of variation was tested by Error Mean Square by Fisher and Snedecor's 'F' test at probability level of 0.05. for the determination of critical difference (CD) at 5% level of significance, Fisher and Yates (1979) tables were consulted.

CHAPTER IV

Results

The present investigation was carried out at 'C' Block farm, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, during 2006-07 and 2007-08 to study the bio-efficacy of weed flora with the phytotoxicity in paddy-rapeseed crop sequence under chemical weed management. Observations on weed density, weed biomass, different growth parameters, yield and yield attributing characters of both transplanted and direct seeded paddy along with the effect of chemical weed management on the population of the soil microflora and soil urease enzymatic study of herbicide were recorded during the course of investigation. Besides, observation on the weed biology of *Echinocloa crus-galli* and *Cyperus rotundus* along with the management practices for controlling *Cyperus rotundus* were also recorded and analysed statistically. The results thus obtained have been presented in this chapter.

4.1 Experiment 1

The results of different weed management practices on transplanted as well as direct seeded paddy and following zero-till rapeseed in addition to phytotoxicity effect of herbicides on paddy and rapeseed plants are highlighted.

4.1.1 Impact of treatments on weed status, growth and yield of transplanted paddy and follow up zero-till rapeseed crop and economics

4.1.1.1 Visual observation of efficacy on weed flora

Bio-efficacy study was done by taking the visual observations on 10, 25 and 40 DAA of herbicide. Table 4.1 represents the visual observation of efficacy on weed control. The data recorded on visual rating of herbicides revealed that at 10 DAA the maximum efficacy of 7.8 and 7.9 were obtained in 2006-07 & 2007-08, respectively where the combination of Azim + MSM along with 0.2% surf was applied @ 40+2 g a.i. ha^{-1} closely followed by Azim + MSM with 0.2% surf @ 35+2 g a.i. ha^{-1}. Same kind of efficacy was obtained in the other dates of observation in both the year.

Table 4.1 Visual scoring on efficacy of weed flora at 10, 25, 40 DAA in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	10 DAA		25 DAA		40 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	7.4	7.5	7.7	7.9	8.6	8.7
T_2 - Azim +MSM+0.2%surf	40+2	7.8	7.9	8.1	8.3	8.8	9.0
T_3 - Azim +MSM	35+2	7.0	7.2	7.2	7.5	8.1	8.3
T_4 - Azim +MSM	40+2	7.0	7.3	7.6	7.6	8.3	8.4
T_5 - Azim +0.2%surf	35	6.5	6.8	7.0	7.1	7.8	8.2
T_6 - Azim +0.2%surf	40	6.9	7.3	7.3	7.4	8.1	8.3
T_7 - MSM+0.2%surf	2	6.3	6.6	6.8	6.7	7.5	7.7
T_8 - Pretilachlor 30.7 EC	500	6.4	7.0	6.9	7.0	7.1	7.3
T_9 - Untreated Control	-	-	-	-	-	-	-

4.1.1.2 Effect of treatments on weed density

Grass weeds

The most dominated grassy weeds intercepted in the experimental field of transplanted paddy were *Echinoclhloa crus-galli, Echinochloa formosensis, Leersia hexendra* and other weeds like, *Paspalum conjugatum*, *Paspalum distichum, Brachiaria platyphylla, Leptochloa chinensis* .

Data on effect of chemical weed management on grass weeds population were recorded at 30 and 45 DAA and have been presented in Table 4.2 – 4.5. It is evident from the pooled data that the density of *Echinoclhloa crus-galli* was significantly lower in all the chemical treatments during both the years and all the dates of observation i.e. 30 and 45 DAA .The pool data revealed that the minimum weed density of *E. crus-galli* (3.95) were obtained from the plot where Azim + MSM + 0.2% surf was applied @ 40+2 g a.i. ha^{-1} which is significantly superior than the treatment of same dose of herbicide without surf (6.28) but statistically at par with by Azim + MSM + 0.2% surf @ 35+2 g a.i. ha^{-1}(4.62).The maximum density was recorded in weedy check (T_9). Same kind of observations was recorded in 45 DAA in both the year (Table 4.2).

The density of another weed species *E. formosensis* was highest in untreated control in both the year (Table 4.3). The lowest population of this weed in all the dates was recorded from Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} (2.69 and 2.09 respectively) treatment followed by Azim + MSM + 0.2% surf @ 35 +2 g a.i.

Table 4.2 Population of *Echinoclhloa crus-galli* in transplanted paddy

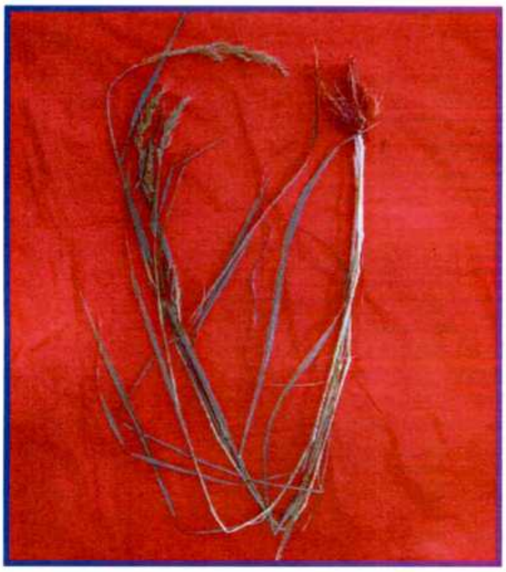
Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	4.67	4.33	4.62	4.26	2.33	3.23
T_2 - Azim +MSM+0.2%surf	40+2	4.00	3.93	3.95	3.93	1.67	2.80
T_3 - Azim +MSM	35+2	6.33	6.22	6.28	5.90	4.67	5.29
T_4 - Azim +MSM	40+2	5.67	5.37	5.61	5.57	4.33	4.96
T_5 - Azim +0.2%surf	35	6.67	6.55	6.61	6.88	5.33	6.10
T_6 - Azim +0.2%surf	40	5.33	5.24	5.28	6.56	5.00	5.78
T_7 - MSM+0.2%surf	2	7.67	7.53	7.60	8.33	8.20	8.26
T_8 - Pretilachlor 30.7 EC	500	7.33	7.00	7.18	7.67	7.54	7.60
T_9 - Untreated Control	-	12.33	12.12	12.12	19.67	14.17	16.92
S.Em (±)		**0.472**	**0.332**	**0.460**	**0.204**	**0.231**	**0.217**
C.D. (P=0.05)		**1.416**	**0.994**	**1.324**	**0.611**	**0.693**	**0.624**

Table 4.3 Population of *Echinochloa formosensis* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	3.49	2.67	3.08	3.21	2.33	2.64
T_2 - Azim +MSM+0.2%surf	40+2	3.06	2.33	2.69	2.34	1.67	2.09
T_3 - Azim +MSM	35+2	5.68	4.33	5.00	6.43	4.67	5.98
T_4 - Azim +MSM	40+2	4.80	3.67	4.24	5.97	4.33	4.77
T_5 - Azim +0.2%surf	35	6.38	4.88	5.62	6.31	4.58	5.86
T_6 - Azim +0.2%surf	40	6.01	4.58	5.30	5.92	4.30	5.44
T_7 - MSM+0.2%surf	2	7.89	6.02	6.95	9.86	7.16	8.22
T_8 - Pretilachlor 30.7 EC	500	7.14	5.44	6.29	9.08	6.60	7.07
T_9 - Untreated Control	-	14.85	11.33	13.09	23.51	19.67	21.75
S.Em (±)		**0.345**	**0.290**	**0.325**	**0.296**	**0.406**	**0.348**
C.D. (P=0.05)		**1.035**	**0.870**	**0.975**	**0.886**	**1.216**	**1.002**

Table 4.4 Population of *Leersia hexendra* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	3.06	2.33	2.69	4.69	3.67	4.17
T_2 - Azim +MSM+0.2%surf	40+2	2.62	2.00	2.31	2.98	2.33	2.65
T_3 - Azim +MSM	35+2	4.50	3.67	4.23	5.97	4.67	5.31
T_4 - Azim +MSM	40+2	4.37	3.33	3.85	5.11	4.00	4.55
T_5 - Azim +0.2%surf	35	4.83	4.20	4.85	6.82	5.33	6.07
T_6 - Azim +0.2%surf	40	4.60	3.67	4.23	6.39	5.00	5.69
T_7 - MSM+0.2%surf	2	6.55	5.00	5.77	9.38	7.33	8.35
T_8 - Pretilachlor 30.7 EC	500	5.68	4.33	5.00	8.52	6.37	7.59
T_9 - Untreated Control	-	13.10	10.33	11.55	19.18	15.00	17.08
S.Em (±)		**0.255**	**0.329**	**0.294**	**0.419**	**0.329**	**0.377**
C.D. (P=0.05)		**0.764**	**0.987**	**0.846**	**1.258**	**0.988**	**1.085**



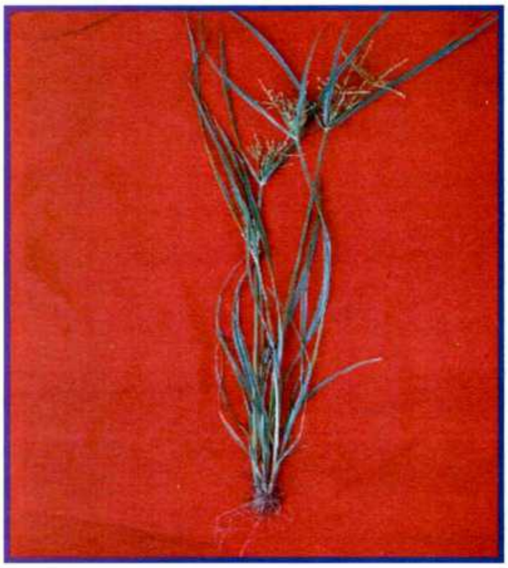
Echinochloa crusgalli

Grass

Echinochloa formosensis

Cyperus difformis

Sedge



Cyperus iria

Alternanthera philoxeroides

Broadleaf

Marselia quadrifolia

Marsilea

Plate 1 Dominant weed flora in transplanted paddy field

ha^{-1} (3.08 and 2.64) which were significantly higher than that of other treatments. The sole application of Azim with surf showed at par results with the combination of Azim + MSM without surf in all the doses.

At 30 DAA all chemical weed control treatments, significantly reduced the density of *L. hexendra* as compared to weedy check (Table 4.4). Both year wise and pool data revealed that Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} treatment recorded the minimum density (2.31). Pretilachlor (5.00) and MSM (5.77) recorded at par result but both were less effective than the other treatments. This trend was also similar at 45 DAA.

The density of other grasses was highest in untreated control plot at all dates of observation during 2006-07 & 2007-08 (Table 4.5). All chemical treatments recorded significantly lower density than the control plot, but the lowest (5.00) was observed in T_2 which showed at par with T_1 at 30 DAA (5.39). Same was observed at 45 DAA.

Sedge weeds

During the period of experimentation, *Cyperus difformis, Cyperus iria, Fimbristylis littoralis, Scirpus juncoides* were found in the field of which *Cyperus difformis* and *Cyperus iria* were dominated.

The data presented in Table 4.6 indicated that all chemical weed control treatments significantly reduced the density of *Cyperus iria* at all the stages of crop growth during both the years of experimentation over untreated control. From the pooled data it was observed that T_2 recorded the lowest population (4.11) , which was at par with T_1 (4.58). At 30 DAA MSM (7.93) and Pretilachlor (7.44) were less effective in controlling *C. iria.* But pooled data showed that at 45 DAA, except the two standards all the treatments showed at par result in controlling the *C. iria.*

The density of *Cyperus difformis* was significantly influenced with the chemical treatment and recorded lower value over to untreated control (Table 4.7). From the pooled data it was clear that in both 30 and 45 DAA, T_2 recorded the lowest population (3.84), which was significantly superior than all the treatments excepting T_1.Combination or sole application of Azimsulfuron recorded significantly better efficacy in controlling the population of *C. difformis* than the standard Pretilachlor and MSM used in this experiment.

Table 4.5 Population of other grassy weeds in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	6.11	4.33	5.39	8.10	6.33	7.27
T_2 - Azim +MSM+0.2%surf	40+2	6.33	5.68	5.00	7.25	5.67	6.45
T_3 - Azim +MSM	35+2	8.30	5.67	7.31	9.80	7.67	8.73
T_4 - Azim +MSM	40+2	7.42	7.00	6.54	8.52	6.67	7.59
T_5 - Azim +0.2%surf	35	9.17	6.67	8.08	10.65	8.33	9.49
T_6 - Azim +0.2%surf	40	8.73	8.00	7.70	9.80	7.67	8.73
T_7 - MSM+0.2%surf	2	10.48	7.33	9.24	11.08	8.67	9.87
T_8 - Pretilachlor 30.7 EC	500	12.67	9.61	8.47	10.78	8.67	9.72
T_9 - Untreated Control	-	16.59	14.67	14.63	23.44	18.33	20.88
S.Em (±)		**0.297**	**0.414**	**0.387**	**0.474**	**0.410**	**0.443**
C.D. (P=0.05)		**0.891**	**1.240**	**1.114**	**1.423**	**1.231**	**1.274**

Table 4.6 Population of *Cyperus iria* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	5.50	3.67	4.58	6.43	4.00	5.21
T_2 - Azim +MSM+0.2%surf	40+2	4.89	3.33	4.11	6.22	3.67	4.94
T_3 - Azim +MSM	35+2	6.42	4.67	5.54	7.34	5.67	6.50
T_4 - Azim +MSM	40+2	5.81	4.00	4.90	6.88	5.33	6.10
T_5 - Azim +0.2%surf	35	7.64	5.67	6.65	8.26	6.67	7.46
T_6 - Azim +0.2%surf	40	6.72	4.67	5.69	7.80	6.00	6.90
T_7 - MSM+0.2%surf	2	8.86	7.00	7.93	14.23	8.33	11.28
T_8 - Pretilachlor 30.7 EC	500	8.56	6.33	7.44	16.98	9.33	13.15
T_9 - Untreated Control	-	14.37	12.67	13.52	35.34	18.00	26.6
S.Em (±)		**0.243**	**0.226**	**0.234**	**0.470**	**0.441**	**0.443**
C.D. (P=0.05)		**0.730**	**0.677**	**0.673**	**1.410**	**1.322**	**1.275**

Table 4.7 Population of *Cyperus difformis* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	4.80	3.67	4.23	5.98	4.00	4.99
T_2 - Azim +MSM+0.2%surf	40+2	4.37	3.33	3.84	5.48	3.67	4.57
T_3 - Azim +MSM	35+2	6.11	4.67	5.39	7.17	5.67	6.47
T_4 - Azim +MSM	40+2	5.24	4.00	4.62	6.47	5.33	6.15
T_5 - Azim +0.2%surf	35	6.42	5.67	6.14	7.97	6.67	7.31
T_6 - Azim +0.2%surf	40	6.11	4.67	5.39	6.97	6.00	6.48
T_7 - MSM+0.2%surf	2	9.17	7.00	8.08	12.46	8.33	10.39
T_8 - Pretilachlor 30.7 EC	500	8.30	6.33	7.31	13.95	9.33	11.64
T_9 - Untreated Control	-	16.59	12.67	14.63	26.91	18.00	22.45
S.Em (±)		**0.459**	**0.408**	**0.362**	**0.448**	**0.441**	**0.427**
C.D. (P=0.05)		**1.376**	**1.224**	**1.042**	**1.343**	**1.322**	**1.229**

Broadleaf weeds

The experimental field was infested with broad leaf weeds viz. *Alternanthera philoxeroides, Eclipta alba, Marsilea quadrifolia, Sphenoclea zeylanica, Ammania baccifera Lemna minor, Ludwigia octovallis, Stellaria media, Oldenlandia corymbosa, Lindernia ciliata* ,among which the first three were most dominated and the rest were clubbed together as 'other broadleaf weeds'.

It is clear from the Table 4.8 that at 30 DAA the density of *Alternanthera philoxeroides* was highest (13.28) in untreated control plot followed by Pretilachlor. Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} recorded the minimum population (2.69), which was at par with their lower doses. T_3 and T_4, were also statically at par with their same combination excepting the surfs. MSM @ 2 g a.i. ha^{-1} + 0.2% surf recorded significantly lower density than the sole application of Azimsulfuron and the standard Pretilachlor.

The study on density of *Marsilea quadrifolia* (Table 4.9) revealed that same kind of variations was found at 45 DAA where all the treatments having Metsulfuron methyl (MSM) lower the value than it was at 30 DAA. The maximum weed population was observed in untreated control plot during both the year at all the dates of observation.

The density of *Eclipta alba* was significantly influenced with the chemical treatment and recorded lower value than untreated control (Table 4.10). From the pooled data it was clear that T_2 recorded the minimum population of *E. alba* and performed significantly superior to all the herbicides used in this experiment. MSM + 0.2% surf @ 35 +2 g a.i. ha^{-1} recorded significantly better efficacy than sole application of Azim + 0.2% surf @ 35 and 40 g a.i. ha^{-1}.

The density of other broad leaf weeds was always lowest in T_2 followed by T_1 and T_4 (Table 4.11).Weedy check (10.49 and 14.93 respectively) recorded the highest weed density at all stages of crop growth. Application of MSM @ 2 g a.i. ha^{-1} along with 0.2 % surf recorded significantly minimum population than all the dose of Azim + 0.2% surf and Pretilachlor in both the year.

Azim + MSM + 0.2% S @ 40 + 2 g a.i. ha^{-1}

Azim + 0.2% S @ 40 g a.i. ha^{-1}

Azim + MSM + 0.2% S @ 35 + 2 g a.i. ha^{-1}

Azim + MSM @ 40 + 2 g a.i. ha^{-1}

Azim + MSM @ 35 + 2 g a.i. ha^{-1}

Plate 2 Effect of weed management in transplanted paddy field

Table 4.8 Population of *Alternanthera philoxeroides* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	3.49	2.67	3.08	4.59	2.33	3.46
T_2 - Azim +MSM+0.2%surf	40+2	3.06	2.33	2.69	3.93	2.00	2.96
T_3 - Azim +MSM	35+2	5.46	4.17	4.81	4.59	3.33	4.64
T_4 - Azim +MSM	40+2	5.24	4.00	4.62	3.68	2.67	2.95
T_5 - Azim +0.2%surf	35	6.55	5.20	5.77	6.43	4.67	5.92
T_6 - Azim +0.2%surf	40	5.68	4.73	5.20	5.96	4.33	5.32
T_7 - MSM+0.2%surf	2	5.33	4.30	4.76	5.05	3.67	4.44
T_8 - Pretilachlor 30.7 EC	500	6.99	5.33	6.16	7.81	5.67	6.40
T_9 - Untreated Control	-	9.07	11.50	10.28	19.31	17.00	18.22
S.Em (±)		**0.227**	**0.230**	**0.278**	**0.367**	**0.309**	**0.335**
C.D. (P=0.05)		**0.680**	**0.690**	**0.801**	**1.100**	**0.927**	**1.080**

Table 4.9 Population of *Marsilea quadrifolia* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	3.49	2.67	3.08	2.95	1.67	2.47
T_2 - Azim +MSM+0.2%surf	40+2	2.62	2.00	2.31	2.35	1.33	1.97
T_3 - Azim +MSM	35+2	4.37	3.33	3.85	3.65	2.33	3.46
T_4 - Azim +MSM	40+2	3.49	2.67	3.08	3.23	2.00	2.97
T_5 - Azim +0.2%surf	35	7.42	5.67	6.54	8.79	6.67	9.89
T_6 - Azim +0.2%surf	40	5.68	4.33	5.00	7.44	5.33	7.91
T_7 - MSM+0.2%surf	2	3.93	3.00	3.46	4.90	3.33	4.94
T_8 - Pretilachlor 30.7 EC	500	6.55	5.00	5.77	8.21	6.33	9.39
T_9 - Untreated Control	-	14.85	11.33	13.09	18.32	16.00	23.73
S.Em (±)		**0.174**	**0.281**	**0.233**	**0.400**	**0.366**	**0.406**
C.D. (P=0.05)		**0.520**	**0.841**	**0.671**	**1.121**	**1.098**	**1.169**

Table 4.10 Population of *Eclipta alba* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	1.75	1.33	1.54	1.33	1.00	1.16
T_2 - Azim +MSM+0.2%surf	40+2	1.31	1.00	1.16	1.00	0.67	0.83
T_3 - Azim +MSM	35+2	3.06	2.33	2.69	2.62	1.33	1.97
T_4 - Azim +MSM	40+2	2.53	1.93	2.23	1.97	1.00	1.48
T_5 - Azim +0.2%surf	35	4.37	3.33	3.85	4.21	3.67	3.44
T_6 - Azim +0.2%surf	40	3.93	3.00	3.46	3.90	3.00	3.45
T_7 - MSM+0.2%surf	2	3.76	2.87	3.12	4.25	2.67	3.97
T_8 - Pretilachlor 30.7 EC	500	5.68	4.43	5.00	7.15	5.67	6.40
T_9 - Untreated Control	-	10.92	8.33	9.63	15.57	13.00	14.28
S.Em (±)		**0.231**	**0.251**	**0.241**	**0.277**	**0.255**	**0.311**
C.D. (P=0.05)		**0.693**	**0.752**	**0.694**	**0.830**	**0.763**	**0.895**

Table 4.11 Population of other broadleaf weed in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	2.33	1.33	1.79	1.31	1.00	1.15
T_2 - Azim +MSM+0.2%surf	40+2	2.00	1.00	1.500	0.98	0.67	0.82
T_3 - Azim +MSM	35+2	3.49	2.33	3.08	3.90	1.33	3.61
T_4 - Azim +MSM	40+2	3.06	1.93	2.69	3.25	1.00	3.12
T_5 - Azim +0.2%surf	35	5.68	3.33	5.00	5.15	3.67	4.40
T_6 - Azim +0.2%surf	40	5.24	3.00	4.62	4.18	3.00	3.89
T_7 - MSM+0.2%surf	2	4.37	2.87	3.85	3.56	2.67	3.61
T_8 - Pretilachlor 30.7 EC	500	6.55	4.43	5.77	7.77	5.67	6.72
T_9 - Untreated Control	-	12.66	8.33	10.49	16.47	13.00	14.93
S.Em (±)		**0.218**	**0.324**	**0.259**	**0.418**	**0.412**	**0.388**
C.D. (P=0.05)		**0.655**	**0.971**	**0.746**	**1.253**	**1.235**	**1.117**

4.1.1.3 Effect of treatments on weed biomass

The biomass accumulation of different categories of weed under different treatments was significantly varied throughout the growth period during both the years of experimentation.

Grass weeds

Data on effect of chemical weed management on dry weight of grass weeds were recorded at 30 and 45 DAA and have been presented from Table 4.12 – 4.15.

The pool data revealed that the minimum weed dry weight of *E. crusgalli* (0.62 gm^{-2}) were obtained from T_2 treated plot which is statistically at par with all the treatment having mixture Application of Azim and MSM, and significantly superior than all the other treatments at 30 DAA. The maximum (2.07 g m^{-2}) weed dry weight of *E. crus-galli* was recorded from the untreated control plot through out the growth stages. Similar trend was noted in 45 DAA in both the year (Table 4.12).

The biomass accumulation of *E. formosensis* was maximum (2.27 g m^{-2} in first year and 3.77 g m^{-2} in second year) in untreated control (Table 4.13). All the chemical treatments excepting the standard Pretilachlor (0.75 g m^{-2}) and MSM (0.91 g m^{-2}), showed at par result regarding the dry weight of *E. formosensis* at 30 & 45 DAA in both the years.

Table 4.12 Dry weight of *Echinochloa crus-galli* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.81	0.67	0.74	0.87	0.60	0.79
T_2 - Azim +MSM+0.2%surf	40+2	0.69	0.57	0.62	0.81	0.56	0.74
T_3 - Azim +MSM	35+2	0.96	0.77	0.81	1.07	0.73	0.96
T_4 - Azim +MSM	40+2	0.85	0.70	0.77	1.01	0.70	0.92
T_5 - Azim +0.2%surf	35	1.12	1.00	1.07	1.21	0.83	1.10
T_6 - Azim +0.2%surf	40	1.02	0.83	0.92	1.07	0.73	0.96
T_7 - MSM+0.2%surf	2	1.38	1.23	1.25	1.79	1.23	1.62
T_8 - Pretilachlor 30.7 EC	500	1.01	1.13	1.06	1.69	1.17	1.54
T_9 - Untreated Control	-	2.28	1.87	2.07	4.69	3.23	4.27
S.Em (±)		**0.080**	**0.051**	**0.066**	**0.056**	**0.040**	**0.054**
C.D. (P=0.05)		**0.240**	**0.152**	**0.190**	**0.169**	**0.120**	**0.155**

Table 4.13 Dry weight of *Echinochloa formosensis* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.66	0.36	0.51	0.71	0.43	0.63
T_2 - Azim +MSM+0.2%surf	40+2	0.56	0.30	0.42	0.54	0.33	0.48
T_3 - Azim +MSM	35+2	0.78	0.47	0.66	0.98	0.63	0.82
T_4 - Azim +MSM	40+2	0.67	0.40	0.57	0.82	0.53	0.68
T_5 - Azim +0.2%surf	35	0.95	0.57	0.81	1.14	0.73	0.97
T_6 - Azim +0.2%surf	40	0.76	0.45	0.64	1.03	0.67	0.85
T_7 - MSM+0.2%surf	2	1.07	0.64	0.91	1.60	1.03	1.31
T_8 - Pretilachlor 30.7 EC	500	0.89	0.53	0.75	1.34	0.87	1.17
T_9 - Untreated Control	-	2.66	1.59	2.27	3.97	3.60	3.77
S.Em (±)		**0.064**	**0.030**	**0.052**	**0.065**	**0.043**	**0.062**
C.D. (P=0.05)		**0.192**	**0.090**	**0.149**	**0.194**	**0.128**	**0.168**

Table 4.14 Dry weight of *Leersia hexendra* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.65	0.43	0.58	0.91	0.57	0.75
T_2 - Azim +MSM+0.2%surf	40+2	0.57	0.38	0.50	0.81	0.50	0.66
T_3 - Azim +MSM	35+2	0.90	0.60	0.79	1.17	0.73	0.96
T_4 - Azim +MSM	40+2	0.78	0.53	0.70	1.07	0.67	0.88
T_5 - Azim +0.2%surf	35	0.94	0.63	0.84	1.44	0.90	1.17
T_6 - Azim +0.2%surf	40	0.84	0.57	0.75	1.20	0.75	0.98
T_7 - MSM+0.2%surf	2	1.09	0.73	0.97	1.39	0.87	1.14
T_8 - Pretilachlor 30.7 EC	500	0.90	0.60	0.79	1.29	0.80	1.05
T_9 - Untreated Control	-	2.58	1.73	2.30	5.24	3.27	4.30
S.Em (±)		**0.058**	**0.049**	**0.057**	**0.067**	**0.053**	**0.061**
C.D. (P=0.05)		**0.174**	**0.146**	**0.163**	**0.201**	**0.158**	**0.142**

The maximum (2.30 g m^{-2}) dry weight of *L. hexendra* was obtained from untreated control plot (Table 4.14). Both individual year and pooled data revealed that all the combination treatment of Azim and MSM applied with 0.2 % surf performed at par result and recorded lower value than that of without surf. Azim with 0.2% surf at both 35 & 40 g a.i. ha^{-1} recorded significantly better efficacy than the standard pretilachlor. Similar trend was observed at 45 DAA.

The weed biomass of other grass was also influenced with the application of herbicide at all dates of observation in both the years (Table 4.15). From the pooled data in first year, T_2 recorded significantly lower density of other grass weed (0.66 g m^{-2}) than the others. Same kind of observation was obtained in the next second year also. The highest dry weight was observed in untreated control plot.

Sedge weeds

Data on effects of chemical weed management treatments on dry weight of *Cyperus iria* presented in Table 4.16 indicated that minimum dry weight was observed in Azim + MSM along with 0.2% surf at both the doses recorded at par result but significantly higher than the same herbicide combination without surf at 30 DAA. Application of Azim with surf also showed better efficacy in reducing weed biomass than pretilachlor and MSM in both the year. At 45 DAA though the biomass of *C. iria* showed higher value (3.56 g m^{-2}) than 30 DAA but followed the similar trends. During both the years of experimentation the maximum dry weight was obtained from untreated control.

The dry weight of *Cyperus difformis* was significantly influenced with the chemical treatment and recorded lower value over to untreated control (Table 4.17). Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} recorded the lowest value (0.55 g m^{-2}). Azim + 0.2% surf @ 35 & 40 DAA recorded at par result with the Azim + MSM without surf and significantly better than the standards at all the dates of observation in both the year of experimentation. In this case also the maximum weed dry weight was recorded from untreated control plot.

Table 4.15 Dry weight of other grassy weeds in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.76	0.57	0.81	1.04	0.70	1.02
T_2 - Azim +MSM+0.2%surf	40+2	0.63	0.47	0.66	0.94	0.63	0.92
T_3 - Azim +MSM	35+2	1.03	0.77	1.09	1.24	0.83	1.22
T_4 - Azim +MSM	40+2	0.89	0.67	0.95	1.13	0.76	1.11
T_5 - Azim +0.2%surf	35	1.07	0.80	1.14	1.29	0.79	1.27
T_6 - Azim +0.2%surf	40	1.04	0.77	1.10	1.24	0.83	1.22
T_7 - MSM+0.2%surf	2	1.20	0.90	1.28	1.83	1.23	1.80
T_8 - Pretilachlor 30.7 EC	500	1.13	0.84	1.20	1.73	1.70	1.71
T_9 - Untreated Control	-	2.11	1.57	2.25	4.36	2.93	4.29
S.Em (±)		**0.071**	**0.058**	**0.068**	**0.078**	**0.047**	**0.066**
C.D. (P=0.05)		**0.214**	**0.173**	**0.196**	**0.225**	**0.140**	**0.190**

Table 4.16 Dry weight of *Cyperus iria* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.93	0.63	0.77	1.02	0.80	0.92
T_2 - Azim +MSM+0.2%surf	40+2	0.83	0.57	0.70	0.84	0.65	0.76
T_3 - Azim +MSM	35+2	1.03	0.90	0.99	1.45	1.13	1.32
T_4 - Azim +MSM	40+2	0.98	0.87	0.95	1.26	0.98	1.14
T_5 - Azim +0.2%surf	35	1.37	1.13	1.29	1.70	1.80	1.76
T_6 - Azim +0.2%surf	40	1.22	0.93	1.15	1.52	1.93	1.81
T_7 - MSM+0.2%surf	2	1.86	1.24	1.56	3.61	2.81	3.28
T_8 - Pretilachlor 30.7 EC	500	1.82	1.24	1.52	3.31	3.50	3.40
T_9 - Untreated Control	-	4.26	2.90	3.56	8.71	6.77	7.92
S.Em (±)		**0.076**	**0.041**	**0.058**	**0.086**	**0.05**	**0.064**
C.D. (P=0.05)		**0.226**	**0.122**	**0.166**	**0.260**	**0.151**	**0.184**

Table 4.17 Dry weight of *Cyperus difformis* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.69	0.53	0.63	1.04	0.60	0.88
T_2 - Azim +MSM+0.2%surf	40+2	0.61	0.47	0.55	0.87	0.50	0.73
T_3 - Azim +MSM	35+2	0.80	0.61	0.72	1.45	0.83	1.22
T_4 - Azim +MSM	40+2	0.73	0.56	0.66	1.21	0.69	1.01
T_5 - Azim +0.2%surf	35	0.87	0.67	0.79	1.40	0.80	1.17
T_6 - Azim +0.2%surf	40	0.79	0.61	0.71	1.28	0.73	1.07
T_7 - MSM+0.2%surf	2	1.09	0.83	0.99	2.49	1.43	2.10
T_8 - Pretilachlor 30.7 EC	500	0.93	0.71	0.85	3.07	1.77	2.59
T_9 - Untreated Control	-	2.98	2.28	2.71	9.45	5.43	7.96
S.Em (±)		**0.050**	**0.034**	**0.046**	**0.095**	**0.048**	**0.105**
C.D. (P=0.05)		**0.151**	**0.101**	**0.134**	**0.284**	**0.144**	**0.191**

Dry weight of broadleaf weeds

It is evident from Table 4.18 that the minimum dry weight of *Alternanthera philoxeroides* was highest with Azim + MSM + 0.2% surf @ 40 +2 g a.i. ha^{-1}. The maximum was obtained at all the growing stage in untreated control plot. All the combination approaches with or without surf reported at par results among them and MSM + 0.2% surf Azim and pretilachlor recorded lower efficiency in reducing the weed dry weight at 30 DAA.

Dry weight of *Marsilea quadrifolia* is directly influenced with the application of herbicide (Table 4.19).The lowest population was obtained from Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} which was significantly better than all the treatments and the maximum (1.84 g m^{-2}) was obtained from untreated control plot at 30 DAA. Application of MSM + 0.2% surf showed significantly better performance than pretilachlor and Azim for controlling weed dry weight. At 45 DAA the dry weight *Marsilea* reported higher value in Azim and Pretilachlor treated plot. The maximum weed population was observed in untreated control plot during both the year at all the dates of observation.

The pooled data in Table 4.20 revealed that the dry weight of *Eclipta alba* was significantly influenced with the herbicide and recorded lower value than untreated control (2.28 g m^{-2}). Azim + MSM + 0.2% surf at all the doses recorded significantly lower population of *E. alba* than Azim + MSM. The maximum dry weight was recorded from untreated control plot.

Table 4.18 Dry weight of *Alternanthera philoxeroides* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.31	0.23	0.29	0.32	0.20	0.29
T_2 - Azim +MSM+0.2%surf	40+2	0.25	0.19	0.22	0.27	0.17	0.24
T_3 - Azim +MSM	35+2	0.49	0.37	0.42	0.43	0.33	0.41
T_4 - Azim +MSM	40+2	0.45	0.33	0.37	0.38	0.30	0.35
T_5 - Azim +0.2%surf	35	0.70	0.52	0.64	0.85	0.53	0.78
T_6 - Azim +0.2%surf	40	0.59	0.44	0.53	0.70	0.43	0.63
T_7 - MSM+0.2%surf	2	0.53	0.40	0.47	0.64	0.40	0.58
T_8 - Pretilachlor 30.7 EC	500	0.76	0.57	0.71	1.34	0.83	1.22
T_9 - Untreated Control	-	2.10	1.57	1.84	3.85	2.40	3.51
S.Em (±)		**0.066**	**0.021**	**0.049**	**0.076**	**0.044**	**0.062**
C.D. (P=0.05)		**0.197**	**0.064**	**0.141**	**0.229**	**0.131**	**0.179**

Table 4.19 Dry weight of *Marsilea quadrifolia* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.62	0.38	0.47	0.45	0.23	0.34
T_2 - Azim +MSM+0.2%surf	40+2	0.50	0.30	0.38	0.39	0.20	0.29
T_3 - Azim +MSM	35+2	0.81	0.50	0.62	0.71	0.37	0.53
T_4 - Azim +MSM	40+2	0.67	0.46	0.53	0.58	0.30	0.44
T_5 - Azim +0.2%surf	35	1.18	0.66	0.90	1.35	0.70	1.02
T_6 - Azim +0.2%surf	40	0.99	0.53	0.76	1.26	0.65	0.95
T_7 - MSM+0.2%surf	2	0.81	0.43	0.62	0.88	0.45	0.66
T_8 - Pretilachlor 30.7 EC	500	1.24	0.67	0.95	1.67	0.86	1.26
T_9 - Untreated Control	-	2.29	1.23	1.76	3.38	2.27	3.32
S.Em (±)		**0.064**	**0.031**	**0.051**	**0.071**	**0.021**	**0.052**
C.D. (P=0.05)		**0.193**	**0.093**	**0.146**	**0.213**	**0.064**	**0.149**

Table 4.20 Dry weight of *Eclipta alba* in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.62	0.56	0.47	0.51	0.27	0.40
T_2 - Azim +MSM+0.2%surf	40+2	0.43	0.40	0.33	0.37	0.18	0.27
T_3 - Azim +MSM	35+2	0.87	0.51	0.66	0.52	0.33	0.47
T_4 - Azim +MSM	40+2	0.71	0.41	0.54	0.43	0.27	0.39
T_5 - Azim +0.2%surf	35	1.12	0.83	0.85	1.18	0.73	1.07
T_6 - Azim +0.2%surf	40	0.96	0.64	0.73	0.90	0.57	0.83
T_7 - MSM+0.2%surf	2	0.89	0.73	0.68	0.59	0.37	0.53
T_8 - Pretilachlor 30.7 EC	500	1.15	0.71	0.88	1.34	0.83	1.22
T_9 - Untreated Control	-	2.98	1.65	2.28	3.44	2.67	3.91
S.Em (±)		**0.068**	**0.035**	**0.054**	**0.086**	**0.032**	**0.067**
C.D. (P=0.05)		**0.203**	**0.105**	**0.155**	**0.258**	**0.097**	**0.192**

Table 4.21 Dry weight of other broadleaf weed in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.39	0.33	0.36	0.35	0.43	0.31
T_2 - Azim +MSM+0.2%surf	40+2	0.33	0.23	0.28	0.30	0.30	0.23
T_3 - Azim +MSM	35+2	0.43	0.47	0.45	0.68	0.52	0.50
T_4 - Azim +MSM	40+2	0.37	0.38	0.37	0.59	0.49	0.43
T_5 - Azim +0.2%surf	35	0.78	0.60	0.69	1.31	0.71	1.01
T_6 - Azim +0.2%surf	40	0.66	0.52	0.58	1.16	0.68	0.86
T_7 - MSM+0.2%surf	2	0.43	0.48	0.45	0.84	0.43	0.60
T_8 - Pretilachlor 30.7 EC	500	0.87	0.62	0.74	2.52	0.96	1.67
T_9 - Untreated Control	-	2.52	1.60	2.06	7.86	2.89	5.26
S.Em (±)		**0.069**	**0.030**	**0.056**	**0.116**	**0.037**	**0.086**
C.D. (P=0.05)		**0.206**	**0.090**	**0.161**	**0.348**	**0.098**	**0.247**

Untreated control

MSM + 0.2% S @ 2 g a.i. ha^{-1}

General view

Azim + 0.2% surf @ 35 g a.i. ha^{-1}

Pretilachlor @ 500 g a.i. ha^{-1}

Plate 3 : Effect of weed management in transplanted paddy field

At 30 DAA the other broad leaf weed biomass of herbicide treated plot was always lower than the untreated control plot. Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} gave best result followed by Azim + MSM + 0.2% surf @ 35+2 g a.i. ha^{-1} in both dates (Table 4.21).Weedy check recorded the highest weed density at all stages of crop growth. Application of MSM registered at par result with the higher dose of Azim. Untreated control recorded highest biomass of other broad leaf weed.

4.1.1.4 Weed Control Efficiency (WCE) on 30 and 45 DAA in transplanted paddy

The weed control efficiency (WCE) of different weed management treatments during both the years are presented in Table 4.22.

From the mean data of both the year it is recorded that highest weed control efficiency (79.08 %) is observed from T_2 at 30 DAA which is closely followed (75.25 %) by T_1. The WCE of Azim was quite higher than MSM and the standard Pretilachlor 30.7 EC. Same trends were also observed at 45 DAA. In all the herbicide the WCE was more at 45 DAA than the concern values of the same treatments at 30 DAA.

Table 4.22 Weed Control Efficiency of herbicide on 30 and 45 DAA in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	Weed Control Efficiency (%)					
		30 DAA			45 DAA		
		2006	2007	Mean	2006	2007	Mean
T_1 - Azim +MSM+0.2%surf	35+2	74.32	76.17	75.25	86.27	87.11	86.69
T_2 - Azim +MSM+0.2%surf	40+2	78.19	79.96	79.08	88.55	89.01	88.78
T_3 - Azim +MSM	35+2	66.74	69.40	68.07	81.78	82.86	82.32
T_4 - Azim +MSM	40+2	70.96	73.50	72.23	83.86	84.92	84.39
T_5 - Azim +0.2%surf	35	58.07	61.11	59.59	75.54	76.20	75.87
T_6 - Azim +0.2%surf	40	64.39	66.44	65.42	78.19	79.13	78.66
T_7 - MSM+0.2%surf	2	58.67	60.98	59.83	71.96	72.88	72.42
T_8 - Pretilachlor 30.7 EC	500	57.82	60.16	58.99	63.49	65.29	64.39
T_9 - Untreated Control	-	-	-	-	-	-	-

4.1.1.5 Effect of treatments on the phytotoxicity of transplanted paddy crops

The observations taken in the experimental field on the basis of Phytotoxicity Rating Scale (PRS) was prepared by visual scoring scale of 0 – 10 are presented in Table 4.23 to 4.27. The results indicated that there was no phytotoxocity symptom was epinasty, hyponasty, leaf tip yellowing, wilting or surface injury and chlorotic or necrotic symptoms as well as stunting growth of the paddy plant, observed in transplanted paddy plant due to the application of Azim applied sole or mixing with MSM with or without surf even with its double dose. All the crop plants looked healthy in the experimental field during both the years

Table 4.23 Phytotoxicity on leaf epinasty or hyponasty in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	7 DAA		14 DAA		21 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	0	0	0	0	0	0
T_2 - Azim +MSM+0.2%surf	40+2	0	0	0	0	0	0
T_3 - Azim +MSM	35+2	0	0	0	0	0	0
T_4 - Azim +MSM	40+2	0	0	0	0	0	0
T_5 - Azim +0.2%surf	35	0	0	0	0	0	0
T_6 - Azim +0.2%surf	40	0	0	0	0	0	0
T_{10} - Azim +MSM+0.2%surf	80+4	0	0	0	0	0	0
T_{11}- Azim +MSM	80+4	0	0	0	0	0	0

Table 4.24 Phytotoxicity on leaf yellowing in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	7 DAA		14 DAA		21 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	0	0	0	0	0	0
T_2 - Azim +MSM+0.2%surf	40+2	0	0	0	0	0	0
T_3 - Azim +MSM	35+2	0	0	0	0	0	0
T_4 - Azim +MSM	40+2	0	0	0	0	0	0
T_5 - Azim +0.2%surf	35	0	0	0	0	0	0
T_6 - Azim +0.2%surf	40	0	0	0	0	0	0
T_{10} - Azim +MSM+0.2%surf	80+4	0	0	0	0	0	0
T_{11}- Azim +MSM	80+4	0	0	0	0	0	0

Table 4.25 Phytotoxicity on necrosis or chlorosis in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	7 DAA		14 DAA		21 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	0	0	0	0	0	0
T_2 - Azim +MSM+0.2%surf	40+2	0	0	0	0	0	0
T_3 - Azim +MSM	35+2	0	0	0	0	0	0
T_4 - Azim +MSM	40+2	0	0	0	0	0	0
T_5 - Azim +0.2%surf	35	0	0	0	0	0	0
T_6 - Azim +0.2%surf	40	0	0	0	0	0	0
T_{10} - Azim +MSM+0.2%surf	80+4	0	0	0	0	0	0
T_{11}- Azim +MSM	80+4	0	0	0	0	0	0

Table 4.26 Phytotoxicity on stunting in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	7 DAA		14 DAA		21 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	0	0	0	0	0	0
T_2 - Azim +MSM+0.2%surf	40+2	0	0	0	0	0	0
T_3 - Azim +MSM	35+2	0	0	0	0	0	0
T_4 - Azim +MSM	40+2	0	0	0	0	0	0
T_5 - Azim +0.2%surf	35	0	0	0	0	0	0
T_6 - Azim +0.2%surf	40	0	0	0	0	0	0
T_{10} - Azim +MSM+0.2%surf	80+4	0	0	0	0	0	0
T_{11}- Azim +MSM	80+4	0	0	0	0	0	0

Table 4.27 Phytotoxicity on wilting in transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	7 DAA		14 DAA		21 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	0	0	0	0	0	0
T_2 - Azim +MSM+0.2%surf	40+2	0	0	0	0	0	0
T_3 - Azim +MSM	35+2	0	0	0	0	0	0
T_4 - Azim +MSM	40+2	0	0	0	0	0	0
T_5 - Azim +0.2%surf	35	0	0	0	0	0	0
T_6 - Azim +0.2%surf	40	0	0	0	0	0	0
T_{10} - Azim +MSM+0.2%surf	80+4	0	0	0	0	0	0
T_{11}- Azim +MSM	80+4	0	0	0	0	0	0

4.1.1.6 Effect of treatments on growth and yield of transplanted paddy

4.1.1.6.1 Plant height at harvest

Data on plant height at harvest have been presented in Table 4.28 .In both the 2006 & 2007 the height of paddy plants were varied significantly with the treatments. The maximum plant height (104.30 cm) was found in T_2 and it was closely followed by the same combination applied without surf (102.70 cm). The minimum plant height 96.60 cm & 97.20 cm were observed from the untreated control (T_9) in both the years respectively.

4.1.1.6.2 Number of effective tiller m^{-2}

The number of effective tillers m^{-2} in rice during both the year (Table 4.28), differed significantly with various weed management practices. Pooled data revealed, the maximum number of effective tillers m^{-2} (350.6) was recorded in Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} (T_2) which statistically at par with T_1 (344.6) and T_4 (332.0 m^{-2}), respectively. Azim + 0.2% surf in both the dose registered higher effective tiller m^{-2} than the standard. The minimum number of effective tillers m^{-2} (256.6 m^{-2}) was recorded in the crop having no weed management practices.

4.1.1.6.3 Panicle length

The data as presented in Table 4.28 indicated that in both the years, maximum panicle length (22.52 cm) of transplanted rice was recorded from the combination of highest doses of Azim with MSM in addition to surf (T_2) and the minimum was observed from untreated control plot (T_9). It is evident from the pooled result that all the chemical treatments excepting the mix application of Azim and MSM in both combination of, with or without surf, having no significant variation among themselves but showed significantly higher panicle length over to untreated control (19.81 cm).

4.1.1.6.4 Filled grains panicle^{-1}

Treatment T_9 recorded the minimum number of filled grains panicle^{-1} (65.53) which was significantly lower than all the chemical treatments. T_2 recorded the maximum filled grains panicle^{-1} (71.96) which was at par with all the combinations of Azim + MSM. Application of Azim + 0.2% surf also recorded higher numbers filled grains panicle^{-1} than standard (Table 4.28).

Table 4.28 Growth and yield attributes of transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	Plant height (cm) at harvest			Effective tiller (m^{-2})			Panicle length (cm)			Filled grain $panicle^{-1}$		
		2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	102.20	104.00	103.60	340.7	345.0	344.6	22.23	22.54	22.38	70.08	69.23	69.65
T_2 - Azim +MSM+0.2%surf	40+2	104.30	107.10	104.70	348.3	353.9	350.6	22.39	22.65	22.52	70.88	73.04	71.96
T_3 - Azim +MSM	35+2	101.30	102.30	101.80	319.9	327.1	323.2	22.04	22.29	22.16	67.17	67.28	67.22
T_4 - Azim +MSM	40+2	102.70	105.50	102.60	326.0	339.5	332.0	22.16	22.47	22.31	68.59	70.06	69.32
T_5 - Azim +0.2%surf	35	100.00	101.30	100.60	317.8	319.7	318.8	21.69	21.84	21.76	65.31	67.37	67.34
T_6 - Azim +0.2%surf	40	102.30	102.70	102.50	324.6	328.2	327.2	21.83	22.00	21.91	67.25	69.09	68.17
T_7 - MSM+0.2%surf	2	99.00	100.40	99.70	269.7	279.4	274.4	20.80	21.56	21.48	65.10	67.14	66.51
T_8 - Pretilachlor 30.7 EC	500	99.30	101.40	100.40	305.5	306.0	301.0	21.45	21.67	21.56	66.44	68.40	66.92
T_9 - Untreated Control	-	96.60	97.20	96.90	260.9	273.4	257.6	19.70	19.92	19.81	62.32	64.75	63.53
S.Em (±)		**1.304**	**1.474**	**1.445**	**7.668**	**8.804**	**7.331**	**0.622**	**0.644**	**0.633**	**0.946**	**1.151**	**1.053**
C.D. (P=0.05)		**3.908**	**4.682**	**4.461**	**22.987**	**26.391**	**21.113**	**1.864**	**1.930**	**1.823**	**2.836**	**3.450**	**3.032**

4.1.1.6.5 Test weight of grain

Different weed management practices had no significant influence on 1000 grain weight of rice during 2006 and 2007 (Table 4.29), though the maximum pooled value was recorded with the treatment Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} and the minimum pooled value was observed from untreated control.

4.1.1.6.6 Grain and straw yield

The grain yield of rice varied significantly with different herbicidal treatments used in the experiment (Table 4.29). The pooled data revealed that the lowest grain yield (2.64 t ha^{-1}) was obtained from T_9 (untreated control), was significantly lower than any other treatments tried in this investigation. The maximum grain yield (4.76 t ha^{-1}) was recorded from the treatment Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} applied at 14 DAT and it was statistically at par with treatment T_1 (4.63 t ha^{-1}) and significantly superior than the treatments having same combination but without surf. The sole application Azim @ 40 g a.i. ha^{-1} along with 0.2% surf also recorded significantly higher yield (4.50 t ha^{-1}) than the standard used Pretilachlor (4.18 t ha^{-1}). Application of MSM + 0.2% surf recorded statistically at par with Pretilachlor. Both the year same trends were observed regarding grain yield.

Significant increases in straw yield by employing different herbicidal treatments were also observed during 2006 & 2007 (Table 4.29). The maximum pooled straw yield (5.76 t ha^{-1}) was recorded from T_2. This was statistically at par with its lower dose keeping the treatment combination same (5.50 t ha^{-1}) or with same higher dose without surf (5.43 t ha^{-1}). Sole Azim @ 40 g a.i. ha^{-1} along with 0.2% surf recorded statistically at par result with its lower dose but significantly higher than that of MSM. The minimum straw yield was obtained from the control plot (3.94 t ha^{-1}).

Table 4.29 Test weight, grain and straw yield of transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	1000-grain weight (g)			Grain yield (t ha^{-1})			Straw yield (t ha^{-1})		
		2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	22.10	22.32	22.21	4.53	4.67	4.63	5.42	5.68	5.50
T_2 - Azim +MSM+0.2%surf	40+2	22.27	22.41	22.34	4.69	4.83	4.76	5.61	5.83	5.76
T_3 - Azim +MSM	35+2	21.69	22.08	21.88	4.42	4.57	4.49	5.13	5.53	5.26
T_4 - Azim +MSM	40+2	21.84	22.18	22.01	4.54	4.62	4.58	5.26	5.57	5.43
T_5 - Azim +0.2%surf	35	21.54	21.69	21.62	4.40	4.49	4.42	4.89	5.37	5.01
T_6 - Azim +0.2%surf	40	21.73	21.80	21.76	4.48	4.63	4.50	5.00	5.49	5.12
T_7 - MSM+0.2%surf	2	21.23	21.66	21.44	3.78	4.27	3.98	4.67	4.83	4.76
T_8 - Pretilachlor 30.7 EC	500	21.42	21.81	21.61	4.08	4.37	4.18	4.83	5.08	4.94
T_9 - Untreated Control	-	20.53	21.10	20.81	2.59	2.68	2.64	3.64	3.82	3.77
S.Em (±)		**0.725**	**0.865**	**0.798**	**0.060**	**0.041**	**0.043**	**0.092**	**0.080**	**0.085**
C.D. (P=0.05)		**NS**	**NS**	**NS**	**0.179**	**0.120**	**0.125**	**0.270**	**0.242**	**0.243**

Table 4.30 Economics of transplanted paddy cultivation

Treatment	Dose (g a.i. ha^{-1})	Cost of cultivation (Rs. ha^{-1})			Gross return (Rs. ha^{-1})			Net return (Rs. ha^{-1})			Return per rupee invested (Rs.)		
		2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
T_1 - Azim +MSM+0.2%surf	35+2	15105	15105	15105	28313	29188	28750	13208	14083	13645	1.87	1.93	1.90
T_2 - Azim +MSM+0.2%surf	40+2	15155	15155	15155	29313	30188	29750	14158	15033	14595	1.93	1.99	1.96
T_3 - Azim +MSM	35+2	14830	14830	14830	27625	28563	28094	12795	13733	13264	1.86	1.93	1.89
T_4 - Azim +MSM	40+2	14880	14880	14880	28375	28875	28625	13495	13995	13745	1.91	1.94	1.92
T_5 - Azim +0.2%surf	35	14805	14805	14805	27500	28063	27781	12695	13258	12976	1.86	1.90	1.88
T_6 - Azim +0.2%surf	40	14855	14855	14855	28000	28938	28469	13145	14083	13614	1.88	1.95	1.92
T_7 - MSM+0.2%surf	2	14755	14755	14755	23625	26688	25156	8870	11933	10401	1.60	1.81	1.70
T_8 - Pretilachlor 30.7 EC	500	14505	14505	14505	25500	27313	26406	10995	12808	11901	1.76	1.88	1.82
T_9 - Untreated Control	-	14000	14000	14000	16188	16750	16468	2188	2750	2469	1.16	1.20	1.18

4.1.1.7 Economics of different treatments

The pooled data presented in Table 4.30 showed that among all the treatments Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} recorded maximum net return (Rs 14595.00) and also highest return per rupee investment (Rs 1.96). The corresponding figures for control were Rs 1.41. T_4 recorded net return of Rs 13745.00 and whereas only Azim @ 40 g a.i. ha^{-1} + 0.2% surf, the same was Rs 13614.00.

4.1.1.8 Impact of different treatments on weed dynamics, growth and yield of zero-till rapeseed

4.1.1.8.1 Visual scoring of weeds on rapeseed

The effect of applied herbicide treatments in the *Kharif* transplanted paddy on to the succeeding rapeseed was not significantly varied through out the growth period. The visual observations on 10 and 25 DAS stated that at 10 DAS, there was a variation amongst the treated plots but at 25 DAS all the treatments represented almost same population of total weed flora in the follow up zero-till rapeseed (Table 4.31).

Table 4.31 Visual observation on weed flora of succeeding zero till rapeseed

Treatment	Dose (g a.i. ha^{-1})	Weed population (1-10 scale)			
		10 DAS		25 DAS	
		2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	7.6	7.4	9.4	9.5
T_2 - Azim +MSM+0.2%surf	40+2	6.5	6.4	9.2	9.2
T_3 - Azim +MSM	35+2	8.2	8.1	9.2	9.3
T_4 - Azim +MSM	40+2	8.0	8.0	9.5	9.5
T_5 - Azim +0.2%surf	35	7.9	7.8	9.6	9.4
T_6 - Azim +0.2%surf	40	7.8	7.7	9.2	9.3
T_7 - MSM+0.2%surf	2	9.2	9.2	9.8	9.7
T_8 - Pretilachlor 30.7 EC	500	8.9	8.8	9.5	9.7
T_9 - Untreated Control	-	-	-	-	-

4.1.1.8.2 Weed population and biomass

Grass weed density

The dominant weed floras present in the zero-till rapeseed were *Echinochloa colona, Digitaria sanguinalis, Eleusine indica, Dactyloctaneun aegyptium.*

From the pooled that at 10 DAS, Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} treatment showed minimum weed population (2.92) and this was significantly lower than all other treatments. The maximum grassy weed population (8.20) was obtained from the control plot where no herbicide was applied earlier. At 25 DAS pooled data revealed that no significant variation was there in the total grassy weed population in the follow up zero-till rapeseed (Table 4.32).

Sedge weed density

The most important sedge in the rapeseed field was *Cyperus rotundus* throughout the crop growth. The pooled data presented in the Table 4.33 clearly indicated that at initial stage of crop the sedge weed population was significantly lower at 10 DAS with the four treatments where the combination of Azim + MSM were applied to the transplanted paddy. The minimum sedge weed density (6.44) was obtained in T_2 and the maximum from the control plot (10.63). At 25 DAS all the treatments applied to the preceding paddy showed statistically at par sedge weed population in the follow up rapeseed.

Broadleaf weed density

The most dominant broadleaf weeds present in the experimental plots were *Argemone mexicana, Digera arvensis, Melilotus alba, Chenopodium album, Cleome viscosa, Physalis minima, Alternanthera sessilis, Blumea lacera, Capsella bursa-pastoris, Anagallis arvensis* etc.

The populations of broadleaf weeds (Table 3.34) were significantly lower in all the plots where the combination of Azim and MSM was applied at 10 DAS. The highest weed population (10.34) was found in untreated control plot. In both the year more or less similar trends were found. At 25 DAS no significant variation was found among the treatments during 2006-07 and 2007-08.

Density of total weeds

The data on total weed population were presented in Table 4.35. The total weed density showed maximum weed population (30.91) in the control plot and the minimum (12.24) was obtained from Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} followed by T_1 and T_4. At 25 DAS this variation among treatments was not found.

Biomass of grassy weed

The grassy weed biomass was minimum (1.07 g m^{-2}) with Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} which is significantly higher than all other treatments and the maximum (1.76 g m^{-2}) dry weight was recorded in control plot. As like the density the grassy weed biomass also not varied significantly at later stage.

Biomass of sedge weed

At 10 DAS, the minimum sedge weed biomass (1.54 g m^{-2}) was observed by the higher dose of Azim combining with MSM @ 2 g a.i. ha^{-1} along with 0.2% surf. It was at par with the same treatments excepting the surf and Azim + MSM + 0.2% surf @ 35+2 g a.i. ha^{-1}. Maximum dry weight (2.49 g m^{-2}) was obtained from

Biomass of broadleaf weed

Different weed management treatments exhibited significant influence on broadleaf weed biomass during both the years of experimentation and pooled data at 10 DAS recorded such variations (Table 4.38). Similar trend of weed biomass was observed as it was found as like broadleaf weed population.

Total weed biomass

The total weed biomass was significantly affected by different weed management treatments at 10 DAS (Table 4.39). The mixture of Azim and MSM @ 40+2 g a.i. ha^{-1} with all the combinations showed significantly lower weed biomass (3.48 g m^{-2}) and the control plot registered the maximum value (6.07 g m^{-2}). However, at 25 DAS all treatments showed at par results. At 25 DAS all the treatments showed no significant variation amongst the treatment.

Table 4.32 Population of total grass weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	3.77	3.00	3.42	7.63	6.36	6.77
T_2 - Azim +MSM+0.2%surf	40+2	3.10	2.66	2.92	6.94	5.66	6.33
T_3 - Azim +MSM	35+2	4.61	3.68	4.04	8.32	6.93	7.88
T_4 - Azim +MSM	40+2	4.20	3.56	3.94	7.67	6.39	7.22
T_5 - Azim +0.2%surf	35	5.04	4.27	4.80	8.52	7.28	8.01
T_6 - Azim +0.2%surf	40	4.75	4.02	4.41	8.24	6.86	7.65
T_7 - MSM+0.2%surf	2	7.34	707	7.14	9.62	8.02	8.56
T_8 - Pretilachlor 30.7 EC	500	5.44	4.33	5.00	8.50	7.60	7.99
T_9 - Untreated Control	-	8.16	8.22	8.20	10.08	8.59	9.75
S.Em (±)		**0.804**	**0.687**	**0.726**	**1.445**	**1.298**	**1.327**
C.D. (P=0.05)		**2.401**	**2.189**	**2.170**	**NS**	**NS**	**NS**

Table 4.33 Population of total sedge weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	7.29	7.64	7.44	14.22	12.83	13.34
T_2 - Azim +MSM+0.2%surf	40+2	6.57	6.77	6.44	11.03	10.77	10.99
T_3 - Azim +MSM	35+2	8.61	6.88	7.76	14.77	14.12	13.87
T_4 - Azim +MSM	40+2	7.85	7.28	7.52	12.19	13.93	13.06
T_5 - Azim +0.2%surf	35	9.42	8.72	8.97	13.54	11.57	12.73
T_6 - Azim +0.2%surf	40	8.88	7.70	8.24	13.09	10.91	12.16
T_7 - MSM+0.2%surf	2	10.26	9.27	9.48	15.29	17.89	17.28
T_8 - Pretilachlor 30.7 EC	500	9.65	9.88	9.75	13.51	12.08	12.69
T_9 - Untreated Control	-	10.94	10.26	10.63	14.43	13.65	13.90
S.Em (±)		**0.796**	**0.883**	**0.803**	**0.968**	**1.078**	**0.992**
C.D. (P=0.05)		**2.377**	**2.637**	**2.398**	**NS**	**NS**	**NS**

Table 4.34 Population of total broadleaf weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	3.87	3.00	3.40	11.97	10.80	11.23
T_2 - Azim +MSM+0.2%surf	40+2	3.40	2.68	2.90	10.28	9.07	9.26
T_3 - Azim +MSM	35+2	4.59	3.74	4.12	12.12	11.56	11.75
T_4 - Azim +MSM	40+2	4.18	3.94	4.00	10.27	11.74	11.00
T_5 - Azim +0.2%surf	35	8.11	7.85	7.97	11.20	9.57	11.14
T_6 - Azim +0.2%surf	40	7.86	7.24	7.40	10.83	9.02	10.06
T_7 - MSM+0.2%surf	2	4.33	4.08	4.24	10.80	9.45	10.09
T_8 - Pretilachlor 30.7 EC	500	8.26	9.26	8.31	12.89	11.53	12.11
T_9 - Untreated Control	-	10.44	9.79	10.14	13.77	13.03	13.27
S.Em (±)		**0.770**	**0.642**	**0.711**	**0.986**	**1.447**	**1.338**
C.D. (P=0.05)		**2.298**	**1.917**	**2.124**	**NS**	**NS**	**NS**

Table 4.35 Population of total weed flora of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	15.03	13.64	14.24	33.82	29.99	31.34
T_2 - Azim +MSM+0.2%surf	40+2	13.37	12.13	12.24	28.25	25.5	26.58
T_3 - Azim +MSM	35+2	17.79	14.36	16.00	35.21	32.61	33.5
T_4 - Azim +MSM	40+2	16.21	15.16	15.52	30.13	32.06	31.28
T_5 - Azim +0.2%surf	35	25.64	24.42	24.91	33.26	28.42	31.88
T_6 - Azim +0.2%surf	40	24.6	22.18	23.04	32.16	26.79	29.87
T_7 - MSM+0.2%surf	2	18.92	17.43	17.96	35.71	35.36	35.93
T_8 - Pretilachlor 30.7 EC	500	26.17	28.4	26.37	34.9	31.21	32.79
T_9 - Untreated Control	-	31.82	29.84	30.91	38.28	35.27	36.92
S.Em (±)		**2.748**	**2.358**	**2.523**	**2.157**	**1.587**	**1.796**
C.D. (P=0.05)		**8.206**	**7.041**	**7.534**	**NS**	**NS**	**NS**

Table 4.36 Dry weight of total grass weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	1.23	1.18	1.20	1.99	1.90	1.94
T_2 - Azim +MSM+0.2%surf	40+2	1.11	0.98	1.07	1.86	1.81	1.83
T_3 - Azim +MSM	35+2	1.32	1.10	1.20	1.96	1.41	1.91
T_4 - Azim +MSM	40+2	1.11	1.21	1.14	1.46	1.30	1.87
T_5 - Azim +0.2%surf	35	1.73	1.25	1.41	1.63	1.48	2.08
T_6 - Azim +0.2%surf	40	1.26	1.17	1.24	1.57	1.39	2.00
T_7 - MSM+0.2%surf	2	1.72	1.63	1.68	2.03	2.14	2.09
T_8 - Pretilachlor 30.7 EC	500	1.59	1.07	1.38	1.62	1.54	2.12
T_9 - Untreated Control	-	1.83	1.69	1.76	2.09	2.16	2.15
S.Em (±)		**0.206**	**0.158**	**0.182**	**0.128**	**0.264**	**0.219**
C.D. (P=0.05)		**0.616**	**0.473**	**0.543**	**NS**	**NS**	**NS**

Table 4.37 Dry weight of total sedge weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	1.71	1.63	1.69	3.28	3.55	3.41
T_2 - Azim +MSM+0.2%surf	40+2	1.55	1.45	1.54	3.24	3.37	3.30
T_3 - Azim +MSM	35+2	1.69	1.48	1.58	3.76	3.67	3.56
T_4 - Azim +MSM	40+2	1.59	1.67	1.63	3.15	3.30	3.25
T_5 - Azim +0.2%surf	35	1.78	1.91	1.85	3.03	2.75	2.82
T_6 - Azim +0.2%surf	40	1.75	1.81	1.78	2.93	3.42	3.24
T_7 - MSM+0.2%surf	2	2.23	2.04	2.18	3.78	3.98	3.90
T_8 - Pretilachlor 30.7 EC	500	2.21	2.04	2.13	3.86	3.99	3.89
T_9 - Untreated Control	-	2.54	2.34	2.49	3.90	3.74	4.01
S.Em (±)		**0.150**	**0.124**	**0.134**	**0.215**	**0.198**	**0.207**
C.D. (P=0.05)		**0.449**	**0.371**	**0.400**	**NS**	**NS**	**NS**

Table 4.38 Dry weight of total broadleaf weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	1.06	0.97	1.01	2.05	1.95	2.01
T_2 - Azim +MSM+0.2%surf	40+2	0.94	0.85	0.87	1.89	1.97	1.93
T_3 - Azim +MSM	35+2	1.02	0.96	1.00	2.20	2.06	2.08
T_4 - Azim +MSM	40+2	0.96	1.07	0.99	1.97	1.86	1.90
T_5 - Azim +0.2%surf	35	1.58	1.40	1.49	1.88	1.71	1.75
T_6 - Azim +0.2%surf	40	1.39	1.33	1.38	2.09	2.20	2.13
T_7 - MSM+0.2%surf	2	1.15	1.03	1.10	1.93	2.02	1.93
T_8 - Pretilachlor 30.7 EC	500	1.67	1.49	1.59	2.27	2.07	2.18
T_9 - Untreated Control	-	1.92	1.87	1.82	2.32	2.15	2.25
S.Em (±)		**0.165**	**0.185**	**0.177**	**0.321**	**0.298**	**0.307**
C.D. (P=0.05)		**0.492**	**0.551**	**0.528**	**NS**	**NS**	**NS**

Table 4.39 Dry weight of total weed flora of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	4.00	3.78	3.90	7.52	7.53	7.54
T_2 - Azim +MSM+0.2%surf	40+2	3.60	3.28	3.48	7.00	7.15	7.06
T_3 - Azim +MSM	35+2	4.03	3.54	3.78	7.92	7.14	7.55
T_4 - Azim +MSM	40+2	3.66	3.95	3.76	6.58	6.45	7.02
T_5 - Azim +0.2%surf	35	5.09	4.56	5.45	6.54	5.94	6.65
T_6 - Azim +0.2%surf	40	4.40	4.31	5.39	6.59	7.01	7.37
T_7 - MSM+0.2%surf	2	5.10	4.70	4.08	7.73	8.15	7.92
T_8 - Pretilachlor 30.7 EC	500	5.47	4.60	5.31	7.75	7.60	8.19
T_9 - Untreated Control	-	6.29	5.90	6.07	8.32	8.05	8.41
S.Em (±)		0.378	0.334	0.369	**0.558**	**0.787**	**0.654**
C.D. (P=0.05)		1.114	0.998	1.101	**NS**	**NS**	**NS**

4.1.1.8.3 Visual crop toxicity

Crop response was rated in the scale of 0 to 9, as presented in Table 4.40 to record herbicide toxicity on crop stand and growth (Reference Table 3.10 of 'Materials and Methods',). During both the years of experimentation all the treatments showed no phytotoxicity, so rated as one (1) under crop toxicity rating, symptom of toxicity on rapeseed plants and its germination.

Table 4.40 Crop Toxicity Rating in follow up zero- till rapeseed

Treatment	Dose (g a.i. ha^{-1})	Crop Toxicity Rating (1-9 scale)*			
		10 DAS		25 DAS	
		2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	1	1	1	1
T_2 - Azim +MSM+0.2%surf	40+2	1	1	1	1
T_3 - Azim +MSM	35+2	1	1	1	1
T_4 - Azim +MSM	40+2	1	1	1	1
T_5 - Azim +0.2%surf	35	1	1	1	1
T_6 - Azim +0.2%surf	40	1	1	1	1
T_7 - MSM+0.2%surf	2	1	1	1	1
T_8 - Pretilachlor 30.7 EC	500	1	1	1	1
T_9 - Untreated Control	-	-	-	-	-
T_{10} - Azim +MSM+0.2%surf	80+4	1	1	1	1
T_{11} - Azim +MSM	80+4	1	1	1	1

*European Weed Research Council Rating System in Form No. 'B' with a 1-9 scale

4.1.1.8.4 Plant height

The data on plant height of zero-till rapeseed presented in Table 4.41 revealed that in the first year there was no significant variation among all the treatments under consideration. In each year of experimentation control plot showed the minimum plant height viz.73.54 cm in first year and 75.25 cm in second year. During the 2007-08 the combine application of herbicide reported significantly more height than the others.

4.1.1.8.5 Number of primary branch plant $^{-1}$

Data presented in the Table 4.41 stated that in both the year of experimentation all the treatments were statistically at par and gave significantly higher number of primary branch plant $^{-1}$. The maximum (3.42) was obtained from Azim + MSM @ 40+2 g a.i. ha^{-1} + 0.2% surf and the minimum (2.46) from the control plot.

4.1.1.8.6 Siliqua plant^{-1}

Different herbicide applied to transplanted paddy showed significant effect on producing number of siliqua plant^{-1} during both the years of investigation as well as in pooled data (Table 4.41). The pooled data revealed that all the treatments as mixture or sole application of Azimsulfuron 50 DF with or without surf gave significant higher number of siliqua plant^{-1}. Minimum was reported from untreated control plot (58.60).

Table 4.41 Growth and yield attributes of rapeseed followed by transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	Plant height (cm)			Number of primary branch $plant^{-1}$			Number of siliqua $plant^{-1}$			Siliqua length (cm)		
		2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	78.88	80.23	79.55	3.35	3.41	3.38	61.78	62.35	62.06	3.62	3.67	3.64
T_2 - Azim +MSM+0.2%surf	40+2	79.35	80.85	80.10	3.40	3.45	3.42	62.38	63.22	62.80	3.71	3.75	3.73
T_3 - Azim +MSM	35+2	77.65	79.22	78.43	3.29	3.24	3.26	60.32	61.33	60.82	3.64	3.61	3.60
T_4 - Azim +MSM	40+2	76.89	80.11	78.50	3.31	3.37	3.34	61.11	61.84	61.47	3.62	3.64	3.62
T_5 - Azim +0.2%surf	35	76.35	77.25	76.80	3.20	3.31	3.25	59.64	60.54	60.09	3.54	3.60	3.57
T_6 - Azim +0.2%surf	40	80.27	81.22	80.74	3.24	3.34	3.29	60.57	61.08	60.82	3.57	3.61	3.59
T_7 - MSM+0.2%surf	2	75.33	78.14	76.73	3.06	3.18	3.12	58.65	60.11	59.38	3.54	3.58	3.56
T_8 - Pretilachlor 30.7 EC	500	76.68	79.17	77.92	3.06	3.20	3.13	59.34	60.22	59.78	3.58	3.61	3.59
T_9 - Untreated Control	-	73.54	75.25	74.93	3.05	3.12	3.09	60.85	58.36	58.60	3.50	3.41	3.45
S.Em (±)		**1.795**	**1.506**	**1.671**	**0.161**	**0.120**	**0.149**	**0.753**	**0.766**	**0.759**	**0.095**	**0.073**	**0.084**
C.D. (P=0.05)		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**2.257**	**2.296**	**2.185**	**NS**	**NS**	**NS**

Rapeseed at 30 DAS

Rapeseed at 60 DAS

Rapeseed at 75 DAS

Rapeseed at flowering stage

Rapeseed at ripening stage

General view

Plate 4 Follow-up zero tilled rapeseed after transplanted paddy

4.1.1.8.7 Siliqua length

No significant variation was obtained regarding the length of siliqua in the follow up rapeseed after transplanted paddy. Table 4.41 stated that in both the year though the control plot recorded the smallest size of siliqua but in other case no concrete pattern was found.

4.1.1.8.8 Seeds siliqua^{-1}

Among the different treatments only T_2, applied to the preceding paddy crops reported significantly highest seeds siliqua^{-1} (18.83) in follow up zero-till rapeseed (Table 4.42). During both the season the minimum was obtained from untreated control plot (17.21).

4.1.1.8.9 Test weight

The variation of 1000' grain weight among different weed management treatments was not significant during both the years of experimentation as well as pooled data (Table 4.42). The pooled data showed that Azim + MSM + 0.2 % surf treatments recorded 2.92 g whereas untreated control recorded 2.80g.

4.1.1.8.10 Seed and Stover yield

Different herbicides applied to the preceding transplanted paddy exerted significant influence on seed yield of rapeseed during both the years of experimentation as well as in pooled data (Table 4.42). The pool data revealed that the highest Seed yield (0.760 t ha^{-1}) was obtained from T_2 treated plot which was statistically at par with all treatments excepting the two standard Pretrilachlor (0.688 t ha^{-1}) and MSM (0.693 t ha^{-1}). However, the untreated plot recorded minimum seed yield (0.664t ha^{-1}).Similar trend was observed during both 2006-07 and 2007-08.

As like the Seed yield Stover yield also showed same trend of observation in both the year of experimentation. Data presented in Table 4.42 stated that highest stover yield (1.593 t ha^{-1}) was obtained from the plot where T_2 were applied to the *Kharif* transplanted paddy closely followed by T_1 (1.560 t ha^{-1}). The minimum stover yield (14.04 t ha^{-1}) was collected from the plot where no herbicides were applied to the preceding rice crop.

Table 4.42 Yield attributes and yields of rapeseed followed by transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	Seeds $siliqua^{-1}$			Test weight (g)			Seed yield (t ha^{-1})			Stover yield (t ha^{-1})		
		2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	18.33	18.67	18.45	2.88	2.92	2.89	0.719	0.764	0.745	1.529	1.591	1.560
T_2 - Azim +MSM+0.2%surf	40+2	18.69	18.95	18.83	2.90	2.95	2.92	0.744	0.776	0.760	1.581	1.615	1.593
T_3 - Azim +MSM	35+2	17.99	18.22	18.05	2.79	2.82	2.80	0.705	0.746	0.729	1.446	1.477	1.466
T_4 - Azim +MSM	40+2	18.05	18.55	18.27	2.81	2.88	2.83	0.713	0.769	0.742	1.477	1.560	1.518
T_5 - Azim +0.2%surf	35	17.60	18.08	17.65	2.78	2.82	2.80	0.702	0.748	0.727	1.404	1.550	1.477
T_6 - Azim +0.2%surf	40	17.65	18.32	18.17	2.83	2.86	2.83	0.716	0.770	0.733	1.556	1.525	1.546
T_7 - MSM+0.2%surf	2	17.12	17.42	17.36	2.76	2.80	2.77	0.662	0.679	0.673	1.373	1.450	1.386
T_8 - Pretilachlor 30.7 EC	500	17.44	17.55	17.42	2.86	2.91	2.87	0.662	0.719	0.688	1.456	1.381	1.418
T_9 - Untreated Control	-	17.25	17.22	17.21	2.75	2.81	2.80	0.656	0.686	0.664	1.385	1.589	1.404
S.Em (±)		**0.514**	**0.615**	**0.563**	**0.123**	**0.071**	**0.103**	**0.015**	**0.029**	**0.023**	**0.034**	**0.029**	**0.031**
C.D. (P=0.05)		**1.540**	**1.843**	**1.517**	**NS**	**NS**	**NS**	**0.047**	**0.088**	**0.065**	**0.103**	**0.088**	**0.089**

4.1.1.9 Economics of zero-till rapeseed after transplanted paddy

It is evident from the table 4.43 that zero-till rapeseed grown after transplanted paddy that the maximum net return (Rs 3815.00) and Return per rupee invested (1.56) was obtained from the plot where the higher dose of Azim combining with MSM @ 2 g a.i. ha^{-1} along with 0.2% surf was applied to the *kharif* paddy followed by Azim + MSM + 0.2% surf @ 35+2 g a.i. ha^{-1} (Rs 3556.00).The minimum net profit (Rs 2569.00) was recorded from untreated control plot.

4.1.1.10 Economics of transplanted paddy and follow up zero-till rapeseed crop sequence

Table 4.44 clearly indicate that the maximum net return (Rs 18,410.00) and best Return per rupee invested (Rs 1.84) was recorded in transplanted paddy – zero till rapeseed crop sequence when Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} was applied to the earlier crop and the minimum total return (Rs 29,082.00) from this sequence was obtained when no herbicide was applied to the previous rice crop.

Table 4.43 Economics of zero - till rapeseed after transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	Cost of cultivation (Rs. ha^{-1})			Gross return (Rs. ha^{-1})			Net return (Rs. ha^{-1})			Return per rupee invested (Rs.)		
		2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
T_1 - Azim +MSM+0.2%surf	35+2	6825	6825	6825	10066	10696	10381	3241	3871	3556	1.47	1.57	1.52
T_2 - Azim +MSM+0.2%surf	40+2	6825	6825	6825	10416	10864	10640	3591	4039	3815	1.53	1.59	1.56
T_3 - Azim +MSM	35+2	6825	6825	6825	9870	10444	10157	3045	3619	3332	1.45	1.53	1.49
T_4 - Azim +MSM	40+2	6825	6825	6825	9982	10766	10374	3157	3941	3549	1.46	1.58	1.52
T_5 - Azim +0.2%surf	35	6825	6825	6825	9828	10472	10150	3003	3647	3325	1.44	1.53	1.49
T_6 - Azim +0.2%surf	40	6825	6825	6825	10024	10780	10402	3199	3955	3577	1.47	1.58	1.52
T_7 - MSM+0.2%surf	2	6825	6825	6825	9408	9926	9667	2583	3101	2842	1.38	1.45	1.42
T_8 - Pretilachlor 30.7 EC	500	6825	6825	6825	9268	10066	9667	2443	3241	2842	1.36	1.47	1.42
T_9 - Untreated Control	-	6825	6825	6825	9184	9604	9394	2359	2779	2569	1.35	1.41	1.38

Table 4.44 Economics of transplanted paddy and follow up zero -till rapeseed crop sequence

Treatment	Dose (g a.i. ha^{-1})	Cost of cultivation (Rs. ha^{-1})			Value of produce (Rs. ha^{-1})			Net return (Rs. ha^{-1})	Return per rupee investment
		Rice	Rapeseed	Total	Rice	Rapeseed	Total		
T_1 - Azim +MSM+0.2%surf	35+2	15105	6825	21930	28750	10381	39131	17201	1.78
T_2 - Azim +MSM+0.2%surf	40+2	15155	6825	21980	29750	10640	40390	18410	1.84
T_3 - Azim +MSM	35+2	14830	6825	21655	28094	10157	38251	16596	1.77
T_4 - Azim +MSM	40+2	14880	6825	21705	28625	10374	38999	17294	1.80
T_5 - Azim +0.2%surf	35	14805	6825	21630	27781	10150	37931	16301	1.75
T_6 - Azim +0.2%surf	40	14855	6825	21680	28469	10402	38871	17191	1.79
T_7 - MSM+0.2%surf	2	14755	6825	21580	25156	9667	34823	13243	1.61
T_8 - Pretilachlor 30.7 EC	500	14505	6825	21330	26406	9667	36073	14743	1.69
T_9 - Untreated Control	-	14000	6825	20825	16469	9394	25863	5038	1.24

4.1.2 Impact of treatments on weed status, growth and yield of direct seeded paddy and follow up zero-till rapeseed crop and economics

4.1.2.1 Visual observation of efficacy on weed flora of direct seeded paddy

Visual observations on bio-efficacy was done on 10, 25 and 40 DAA of herbicide and presented in Table 4.45. The data recorded on visual rating of herbicides revealed that at 10 DAA the maximum efficacy (7.2 and 7.4) was obtained in both the year respectively from T_2 closely followed by the same combination of the lower doses. In all the other dates of observation same trend of efficacy was obtained from the different treatment in both the season. At 40 DAA better efficacy on weed flora of DS paddy was found over to 10 DAA and 25 DAA.

Table 4.45 Visual observation of efficacy on weed flora at 10, 25, 40 DAA in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	10 DAA		25 DAA		40 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	6.8	7.0	7.0	7.3	7.7	7.9
T_2 - Azim +MSM+0.2%surf	40+2	7.2	7.4	7.5	7.8	8.0	8.2
T_3 - Azim +MSM	35+2	6.4	6.6	6.3	6.4	7.2	7.5
T_4 - Azim +MSM	40+2	6.5	6.8	6.9	7.1	7.4	7.7
T_5 - Azim +0.2%surf	35	6.2	6.3	6.5	6.7	6.8	7.0
T_6 - Azim +0.2%surf	40	6.3	6.7	6.8	7.0	7.2	7.5
T_7 - MSM+0.2%surf	2	6.0	6.2	5.4	5.8	6.3	6.7
T_8 - Pretilachlor 30.7 EC	500	6.2	6.3	5.9	6.2	6.0	6.5
T_9 - Untreated Control	-	-	-	-	-	-	-

4.1.2.2 Effect of treatments on weed density

Grass weeds

The most dominated grassy weeds intercepted in the experimental field of direct seeded paddy were *Cynodon dactylon, Leersia hexendra, Echinochloa colona, Paspalum conjugatum, Brachiaria mutica, Eleusine indica, Digitaria sanguinalis, Dactyloctanium aegyptium.* Data on effect of chemical weed management on grass weeds population were recorded at 30 and 45 DAA and have been presented in Table 4.46 – 4.49.

Population of *Echinochloa colona* was significantly influenced with the herbicide applied to the direct seeded paddy. The pool data presented in the Table 4.48 revealed that the minimum weed density of *E. formosensis* (2.20 g m^{-2}) were obtained

Table 4.46 Population of *Echinochloa colona* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	3.03	2.33	2.68	5.63	4.33	4.98
T_2 - Azim +MSM+0.2%surf	40+2	2.74	1.67	2.20	4.20	3.00	3.60
T_3 - Azim +MSM	35+2	6.07	4.00	5.03	7.18	5.67	6.42
T_4 - Azim +MSM	40+2	5.36	4.67	5.01	6.93	5.33	6.13
T_5 - Azim +0.2%surf	35	7.37	5.67	6.51	9.85	8.67	9.25
T_6 - Azim +0.2%surf	40	6.93	5.33	6.13	9.34	7.67	8.50
T_7 - MSM+0.2%surf	2	8.00	7.67	7.83	12.42	10.33	11.37
T_8 - Pretilachlor 30.7 EC	500	6.50	5.00	5.75	9.97	7.67	8.81
T_9 - Untreated Control	-	17.26	15.33	16.29	30.25	26.67	28.46
S.Em (±)		**0.374**	**0.642**	**0.531**	**0.383**	**0.465**	**0.391**
C.D. (P=0.05)		**1.121**	**1.924**	**1.529**	**1.147**	**1.393**	**1.126**

Table 4.47 Population of *Leersia hexendra* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	6.11	4.33	5.22	9.60	7.33	8.47
T_2 - Azim +MSM+0.2%surf	40+2	5.64	4.00	4.82	8.74	6.67	7.70
T_3 - Azim +MSM	35+2	8.07	6.67	7.36	11.08	9.00	10.04
T_4 - Azim +MSM	40+2	7.26	6.00	6.63	11.49	9.33	10.41
T_5 - Azim +0.2%surf	35	8.47	7.00	7.73	12.72	10.33	11.52
T_6 - Azim +0.2%surf	40	7.89	6.33	7.11	11.49	9.33	9.53
T_7 - MSM+0.2%surf	2	11.29	9.33	10.31	15.99	13.00	14.49
T_8 - Pretilachlor 30.7 EC	500	8.87	7.33	8.10	13.94	11.33	12.63
T_9 - Untreated Control	-	20.25	16.67	18.45	30.85	27.67	29.63
S.Em (±)		**0.256**	**0.534**	**0.419**	**0.319**	**0.597**	**0.478**
C.D. (P=0.05)		**0.767**	**1.602**	**1.207**	**0.957**	**1.790**	**1.376**

Table 4.48 Population of *Eleusine indica* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	5.04	3.67	4.36	8.64	6.67	7.65
T_2 - Azim +MSM+0.2%surf	40+2	3.77	2.67	3.21	5.58	4.00	4.79
T_3 - Azim +MSM	35+2	6.88	5.33	6.10	10.53	8.33	9.43
T_4 - Azim +MSM	40+2	6.35	4.50	5.42	9.60	7.33	8.46
T_5 - Azim +0.2%surf	35	8.45	6.67	7.55	11.18	8.67	9.92
T_6 - Azim +0.2%surf	40	7.92	5.67	6.79	9.31	7.33	8.32
T_7 - MSM+0.2%surf	2	9.88	7.00	8.74	13.12	10.33	11.72
T_8 - Pretilachlor 30.7 EC	500	8.47	6.00	7.23	11.68	7.67	9.67
T_9 - Untreated Control	-	19.74	16.00	17.87	27.68	24.33	26.00
S.Em (±)		**0.393**	**0.524**	**0.466**	**0.600**	**0.475**	**0.687**
C.D. (P=0.05)		**1.179**	**1.570**	**1.342**	**1.798**	**1.423**	**1.978**

from the plot where T_2 was applied which is statistically at par with T_1but significantly superior with the same dose of herbicide combination without surf at 30 DAA.The maximum density of weed was recorded from weedy check. Similar trends were also recorded at 45 DAA in both the year.

The density of *L. hexendra* significantly reduced as compared to weedy check all chemical treatments for weed control (Table 4.47). Pooled data revealed that T_2 recorded the minimum density at 30 DAA as well as 45 DAA. The maximum population was observed in untreated control plot (T_9). The standard, Pretilachlor 30.7 EC (T_8) recorded the highest population among the all herbicide used during the experimentation. Ready mix application of Azim + MSM without surf and sole application of Azim with surf recorded at per result for controlling particularly this weed. At 45 DAA same variations were there found in the next dates of observation.

The most dominating weed, *Eleusine indica* was highest in untreated control in both the years (Table 4.48). The lowest population of this weed in all the dates was recorded from T_2 closely followed by T_1, both of which were significantly higher than the other treatments. The sole application of Azim with surf showed at par result with the combination of Azim + MSM without surf in all the doses but significantly higher with the two standards.

The population of *Dactyloctanium aegyptium* was highest in untreated control plot at all dates of observation during 2006-07 & 2007-08 (Table 4.49). All chemical treatments recorded significantly lower density than the control plot, but the lowest was observed in T_2. Application of T_1 (Azim 35+ MSM 2+ 0.2% surf) recorded at par results with the Azim + MSM @ 40 +2 g a.i. ha^{-1} and Azim 40+ 0.2 % surf.

Sedge weeds

During the period of experimentation, *Cyperus rotundus, Cyperus difformis, Cyperus esculentus* were found in the field most dominantly. The data presented in Table 4.50 indicated that the density of *Cyperus rotundus* was significantly reduced, at all the stages of crop growth with the application of chemical weed control treatments during both the years of experimentation over untreated control.

Table 4.49 Population of *Dactylactonium aegyptium* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	9.38	7.33	8.40	9.68	8.33	9.00
T_2 - Azim +MSM+0.2%surf	40+2	8.00	6.67	7.02	8.77	6.33	7.55
T_3 - Azim +MSM	35+2	11.58	9.57	10.68	12.38	10.67	11.52
T_4 - Azim +MSM	40+2	10.04	8.30	8.86	10.82	9.33	10.07
T_5 - Azim +0.2%surf	35	12.69	10.66	11.62	13.50	11.00	12.25
T_6 - Azim +0.2%surf	40	9.52	8.00	8.81	10.42	9.57	9.99
T_7 - MSM+0.2%surf	2	14.28	13.33	13.57	18.00	16.33	17.16
T_8 - Pretilachlor 30.7 EC	500	11.07	9.30	10.07	17.62	13.00	15.31
T_9 - Untreated Control	-	24.19	20.33	21.50	41.20	36.00	38.60
S.Em (±)		**0.442**	**0.394**	**0.418**	**0.456**	**0.746**	**0.618**
C.D. (P=0.05)		**1.326**	**1.180**	**1.203**	**1.366**	**2.237**	**1.779**

Table 4.50 Population of *Cyperus rotundus* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	13.27	11.33	12.30	19.56	16.33	17.94
T_2 - Azim +MSM+0.2%surf	40+2	12.91	10.00	11.45	17.96	15.00	16.48
T_3 - Azim +MSM	35+2	14.58	13.67	14.12	23.15	19.33	21.24
T_4 - Azim +MSM	40+2	13.00	12.33	12.66	21.95	18.33	20.14
T_5 - Azim +0.2%surf	35	17.00	15.67	16.33	26.35	22.00	24.17
T_6 - Azim +0.2%surf	40	15.98	14.33	15.15	24.35	20.33	22.34
T_7 - MSM+0.2%surf	2	20.22	17.67	18.94	31.12	29.33	31.22
T_8 - Pretilachlor 30.7 EC	500	19.54	21.69	19.93	35.72	32.33	35.52
T_9 - Untreated Control	-	31.27	27.33	29.30	51.50	44.67	49.08
S.Em (±)		**0.621**	**0.530**	**0.577**	**0.645**	**0.673**	**0.658**
C.D. (P=0.05)		**1.862**	**1.589**	**1.661**	**1.934**	**2.019**	**1.893**

Table 4.51 Population of *Cyperus difformis* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	7.34	6.33	6.83	8.33	7.33	7.83
T_2 - Azim +MSM+0.2%surf	40+2	6.58	5.67	6.12	7.74	6.67	7.20
T_3 - Azim +MSM	35+2	9.28	8.00	8.64	10.82	9.33	10.08
T_4 - Azim +MSM	40+2	8.90	7.67	8.28	10.06	8.67	9.36
T_5 - Azim +0.2%surf	35	10.82	9.33	10.07	12.76	11.00	11.88
T_6 - Azim +0.2%surf	40	9.71	8.37	9.03	11.98	10.33	11.15
T_7 - MSM+0.2%surf	2	14.98	10.33	12.15	16.28	14.67	15.47
T_8 - Pretilachlor 30.7 EC	500	13.11	12.00	12.05	20.35	18.33	19.34
T_9 - Untreated Control	-	21.71	18.00	19.85	33.30	30.00	31.65
S.Em (±)		**0.423**	**0.404**	**0.451**	**0.452**	**0.775**	**0.634**
C.D. (P=0.05)		**1.267**	**1.211**	**1.298**	**1.356**	**2.323**	**1.826**

From the pooled data it was observed that in both the dates of observation all the chemical treatments excepting MSM and Pretilachlor recorded statistically at par performances for controlling this pernicious weed. Untreated control plot showed maximum weed population.

The density of *Cyperus difformis* was significantly influenced with the chemical treatment and recorded lower value over to untreated control (Table 4.51). From the pooled data it was clear that in all the dates of observation T_2 recorded the minimum population, which was significantly superior than all the treatments and at par with T_1. The Combination product without surf or sole application of Azimsulfuron recorded significantly better efficacy in controlling the sedges than the standard used in this experiment. Here also the highest density was observed from control plot.

Broadleaf weeds

The experimental field was infested with broad leaf weeds viz., *Ammania baccifera, Stellaria media, Phyllanthus niruri, Scoparia dulcis, Digera arvens, Blainvillea latifolia, Physalis minima, Oldenlandia corymbosa, Ludwigia parviflora, Oldenlandia diffusa, Eclipta alba.*, among which the first three were most dominated and the rest were clubbed together as 'other broadleaf weeds'.

It is clear from the Table 4.52 that the density of *Ammania baccifera* was highest in untreated control plot followed by Pretilachlor. Azim 40 + MSM 2+ 0.2% surf (T_2) recorded the minimum population, which was at par with the lower doses. Azim + MSM @ 40+2 g a.i. ha^{-1} and Azim + MSM @ 35 +2 g a.i. ha^{-1}, these two treatments were also statiscally at par with their same combination excepting the surfs. MSM @ 2 g a.i. ha^{-1} + 0.2% surf recorded significantly lower density than that of Azim and the standard Pretilachlor.

The study on density of *Stellaria media* (Table 4.53) revealed that same kind of variations was found at 45 DAA where all the treatments having MSM lower the value than at 30 DAA. The maximum weed population was observed in untreated control plot during both the year at all the dates of observation. Here also Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} (T_2) recorded best performances.

Table 4.52 Population of *Ammania baccifera* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	4.38	2.50	3.44	3.50	2.33	2.91
T_2 - Azim +MSM+0.2%surf	40+2	4.08	2.33	3.20	2.89	1.67	2.78
T_3 - Azim +MSM	35+2	6.20	4.00	5.10	5.63	4.33	4.98
T_4 - Azim +MSM	40+2	5.69	3.67	4.68	4.77	3.67	4.21
T_5 - Azim +0.2%surf	35	9.49	7.33	8.41	8.99	7.67	8.32
T_6 - Azim +0.2%surf	40	9.07	7.00	8.03	8.35	6.67	7.50
T_7 - MSM+0.2%surf	2	7.77	5.67	6.72	5.63	4.33	4.98
T_8 - Pretilachlor 30.7 EC	500	8.67	7.33	8.50	12.69	10.67	11.67
T_9 - Untreated Control	-	17.33	14.33	15.83	28.97	25.20	27.08
S.Em (±)		**0.456**	**0.429**	**0.463**	**0.416**	**0.660**	**0.489**
C.D. (P=0.05)		**1.368**	**1.285**	**1.334**	**1.248**	**1.978**	**1.408**

Table 4.53 Population of *Stellaria media* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	3.90	2.67	3.28	2.38	1.33	1.85
T_2 - Azim +MSM+0.2%surf	40+2	3.52	2.33	2.93	1.87	0.67	1.26
T_3 - Azim +MSM	35+2	6.54	4.33	5.43	4.17	2.33	3.25
T_4 - Azim +MSM	40+2	5.78	3.83	4.80	3.28	1.83	2.55
T_5 - Azim +0.2%surf	35	8.99	6.67	7.82	9.98	8.00	8.99
T_6 - Azim +0.2%surf	40	7.85	5.67	6.75	8.79	7.67	8.22
T_7 - MSM+0.2%surf	2	6.54	4.33	5.43	7.65	3.67	5.65
T_8 - Pretilachlor 30.7 EC	500	14.09	9.33	11.71	14.58	11.67	13.12
T_9 - Untreated Control	-	16.69	13.67	15.17	24.74	21.67	26.03
S.Em (±)		**0.546**	**0.465**	**0.529**	**0.359**	**0.363**	**0.458**
C.D. (P=0.05)		**1.636**	**1.393**	**1.522**	**1.075**	**1.089**	**1.319**

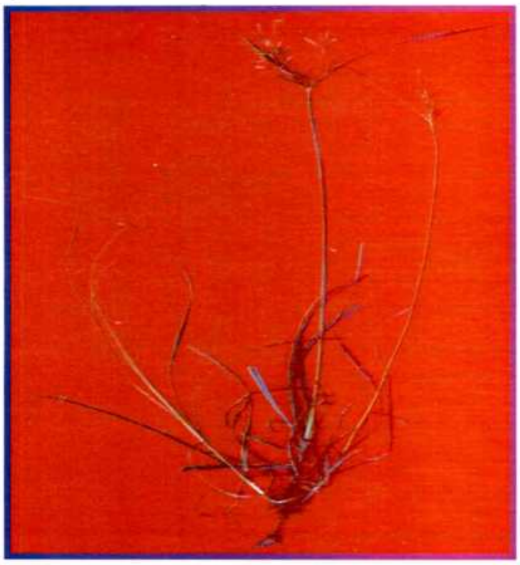
Table 4.54 Population of *Phyllanthus niruri* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	2.15	1.33	1.74	2.02	1.33	2.00
T_2 - Azim +MSM+0.2%surf	40+2	1.62	1.00	1.31	1.17	0.83	1.27
T_3 - Azim +MSM	35+2	4.33	2.67	3.49	3.92	2.00	2.79
T_4 - Azim +MSM	40+2	3.77	2.33	3.05	3.33	1.70	2.51
T_5 - Azim +0.2%surf	35	7.57	4.67	6.11	7.94	4.67	6.30
T_6 - Azim +0.2%surf	40	5.39	3.33	4.36	6.24	3.67	4.95
T_7 - MSM+0.2%surf	2	2.71	1.67	2.18	4.68	1.67	6.17
T_8 - Pretilachlor 30.7 EC	500	8.10	5.00	6.55	7.66	5.33	6.49
T_9 - Untreated Control	-	15.40	11.67	13.53	23.33	19.67	21.49
S.Em (±)		**0.444**	**0.358**	**0.395**	**0.415**	**0.263**	**0.347**
C.D. (P=0.05)		**1.329**	**1.073**	**1.137**	**1.245**	**0.790**	**0.999**

Echinochloa colona

Grass

Eleusine indica



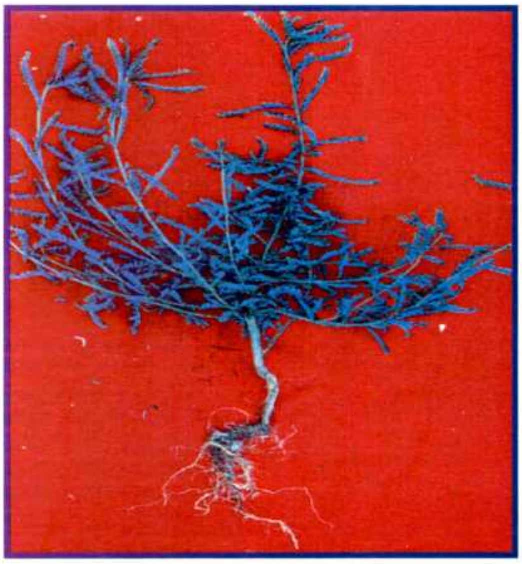
Cyperus rotundus

Sedge

Fimbristylis littolaris

Physalis minima

Broadleaf



Phyllanthus niruri

Plate 5 Dominant weed flora in direct seeded paddy field

The density of *Phyllanthus niruri* was significantly influenced with the chemical treatment and recorded lower value over to untreated control (Table 4.54). From the pooled data it was clear that T_2 recorded the minimum population and significantly better controlling efficiency than all other treatments. MSM + 0.2% surf @ 35 +2 g a.i. ha^{-1} recorded significantly better performances than Azimsulfuron and the other standard Pretilachlor.

The density of other broad leaf weeds were found to be always lowest in T_2 followed by T_1.Application of MSM showed at par result with Azim + MSM @ 35+2 g a.i. ha^{-1} (Table 4.56) and significantly superior to Azim + 0.2% surf and Pretilachlor in both the year. Untreated control (T_9) recorded the highest weed density at all stages of crop growth.

4.1.2.3 Effect of treatments on weed biomass

The biomass accumulation of different categories of weed under different treatments was significantly varied throughout the growth period during both the years of experimentation.

Grass weeds

Data on effect of chemical weed management on dry weight of grass weeds were recorded at 30 and 45 DAA and have been presented from Table 4.57 – 4.60.

The pool data revealed that as like the population the maximum weed dry weight of *E. colona* was recorded from the untreated control plot. The minimum weed biomass of *E. colona* was obtained from T_2 treated plot which is statistically at par with T_1. At 30 DAA combine application of Azim + MSM and Azim + 0.2% surf recorded statistically at par result but significantly varied at 40 DAA. All the tested herbicide recorded significantly better performances than both the standards (Table 4.57).

Table 4.55 Population of other broadleaf weed in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	4.53	3.33	3.93	4.53	3.33	3.97
T_2 - Azim +MSM+0.2%surf	40+2	3.63	2.67	3.14	3.63	2.67	3.32
T_3 - Azim +MSM	35+2	6.65	4.00	5.32	6.35	4.67	5.60
T_4 - Azim +MSM	40+2	5.55	3.67	4.60	5.44	4.00	4.80
T_5 - Azim +0.2%surf	35	8.43	7.67	9.04	13.35	10.33	10.51
T_6 - Azim +0.2%surf	40	7.52	7.00	8.26	12.00	11.67	10.49
T_7 - MSM+0.2%surf	2	7.89	5.00	5.44	7.25	5.33	6.45
T_8 - Pretilachlor 30.7 EC	500	13.15	9.67	11.40	18.84	16.67	15.66
T_9 - Untreated Control	-	19.51	15.33	17.42	31.79	28.33	25.81
S.Em (±)		**0.388**	**0.324**	**0.357**	**0.670**	**0.373**	**0.302**
C.D. (P=0.05)		**1.162**	**0.971**	**1.028**	**2.007**	**1.117**	**0.869**

Table 4.56 Dry weight of *Echinochloa colona* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.46	0.33	0.39	1.02	0.77	0.89
T_2 - Azim +MSM+0.2%surf	40+2	0.37	0.26	0.31	0.89	0.57	0.73
T_3 - Azim +MSM	35+2	0.78	0.56	0.66	1.32	1.05	1.18
T_4 - Azim +MSM	40+2	0.71	0.51	0.60	1.19	0.94	1.06
T_5 - Azim +0.2%surf	35	0.85	0.61	0.73	1.60	1.15	1.37
T_6 - Azim +0.2%surf	40	0.81	0.65	0.72	1.45	1.04	1.24
T_7 - MSM+0.2%surf	2	0.89	0.77	0.83	2.12	1.78	1.95
T_8 - Pretilachlor 30.7 EC	500	0.85	0.64	0.74	1.78	1.21	1.49
T_9 - Untreated Control	-	3.01	2.16	2.58	7.00	5.43	6.21
S.Em (±)		**0.128**	**0.069**	**0.099**	**0.076**	**0.045**	**0.062**
C.D. (P=0.05)		**0.383**	**0.206**	**0.285**	**0.228**	**0.136**	**0.178**

Table 4.57 Dry weight of *Leersia hexendra* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.70	0.51	0.69	1.19	0.88	1.09
T_2 - Azim +MSM+0.2%surf	40+2	0.61	0.44	0.53	1.08	0.80	1.00
T_3 - Azim +MSM	35+2	0.90	0.78	0.85	1.60	1.36	1.47
T_4 - Azim +MSM	40+2	0.78	0.68	0.72	1.40	1.07	1.31
T_5 - Azim +0.2%surf	35	1.09	0.70	1.03	1.60	1.43	1.50
T_6 - Azim +0.2%surf	40	1.02	0.78	0.92	1.29	0.95	1.18
T_7 - MSM+0.2%surf	2	1.36	0.99	1.24	1.82	1.67	1.74
T_8 - Pretilachlor 30.7 EC	500	1.06	0.83	1.07	1.75	1.58	1.65
T_9 - Untreated Control	-	1.86	1.55	1.74	4.67	3.97	4.33
S.Em (±)		**0.063**	**0.072**	**0.073**	**0.073**	**0.124**	**0.115**
C.D. (P=0.05)		**0.187**	**0.216**	**0.198**	**0.198**	**0.372**	**0.331**

The biomass of *L. hexendra* was maximum in untreated control plot in both the years (Table 4.58). All the chemical treatments excepting MSM and standard Pretilachlor, showed at par result regarding the dry weight of *E. formosensis* at both 30 & 45 DAA. Here also the minimum weed biomass of *E. formosensis* was obtained from Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1}.Same trend was also found at 45 DAA.

The maximum dry weight of *Eleusine indica* was obtained from untreated control plot (Table 4.59). Both individual year and pooled data revealed that all the combination treatment of Azim and MSM applied with 0.2 % surf performed at par result and recorded higher efficiency than that of without surf. Application of Azim with 0.2% surf at both 35 & 40 g a.i. ha^{-1} recorded significantly better efficacy than that of standards. At 45 DAA similar trend was also observed.

The weed biomass of *Dactyloctanium aegyptium* was also influenced with the application of herbicide at all dates of observation in both the years (Table 4.60). From the pooled data in first year, T_2 recorded significantly lower density of this weed than the others. Similar kind of observations were observed in the next second year. Pretilachlor 30.7 EC recorded significantly better results that MSM + 0.2 % surf @ 2 g a.i. ha^{-1}.The highest weed biomass was recorded from untreated control (T_9).

Dry weight of sedge weeds

Data on biomass of *Cyperus rotundus* presented in Table 4.61 indicated that minimum dry weight was observed in T_2, which was significantly higher than the same herbicide combination without surf at 30 DAA. Application of Azim + 0.2 % surf also showed better efficacy in reducing weed biomass than Pretilachlor and MSM in both the year. But at 45 DAA the biomass of *C. rotundus* recorded at par result with all the testing herbicide but significantly better than the two standard and control during both the years of experimentation.

The dry weight of *Cyperus difformis* was significantly influenced with the chemical treatment and recorded lower value over to untreated control (Table 4.62). T_2 recorded the lowest value. The single application Azim + 0.2% surf recorded at par result with the Azim + MSM without surf but significantly better than the two standards at all the dates of observation in both the year of experimentation. The maximum weed dry weight was recorded from untreated control plot (T_9).

Pretilachlor @ 500 g a. i. ha^{-1} at 1 DAS

Azim 40 +MSM 2 at 25 DAS

MSM 2 + 0.2 % Surfactant at 25 DAS

Azim 40 +MSM 2 + 0.2 % Surfactant at 25 DAS

Plate 6 Effect of weed management in direct seeded paddy field

Table 4.58 Dry weight of *Eleusine indica* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.67	0.47	0.57	1.49	1.12	1.30
T_2 - Azim +MSM+0.2%surf	40+2	0.52	0.34	0.42	1.25	0.88	1.06
T_3 - Azim +MSM	35+2	1.00	0.70	0.84	1.68	1.35	1.51
T_4 - Azim +MSM	40+2	0.89	0.55	0.72	1.54	1.17	1.35
T_5 - Azim +0.2%surf	35	1.01	0.71	0.86	1.78	1.40	1.59
T_6 - Azim +0.2%surf	40	0.95	0.67	0.81	1.74	1.22	1.47
T_7 - MSM+0.2%surf	2	1.21	0.90	1.05	2.40	1.94	2.16
T_8 - Pretilachlor 30.7 EC	500	1.08	0.77	0.92	1.74	1.61	1.67
T_9 - Untreated Control	-	4.12	3.50	3.81	6.66	5.54	6.09
S.Em (±)		**0.056**	**0.066**	**0.053**	**0.081**	**0.105**	**0.098**
C.D. (P=0.05)		**0.165**	**0.199**	**0.152**	**0.243**	**0.316**	**0.283**

Table 4.59 Dry weight of *Dactyloctanium aegyptium* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	1.00	0.76	0.88	1.54	1.21	1.37
T_2 - Azim +MSM+0.2%surf	40+2	0.85	0.62	0.73	1.19	0.90	1.16
T_3 - Azim +MSM	35+2	1.19	0.90	1.04	1.90	1.63	1.81
T_4 - Azim +MSM	40+2	1.02	0.76	0.88	1.85	1.48	1.71
T_5 - Azim +0.2%surf	35	1.40	1.06	1.23	2.31	1.75	1.02
T_6 - Azim +0.2%surf	40	1.23	0.88	1.05	2.00	1.65	1.90
T_7 - MSM+0.2%surf	2	1.56	1.26	1.41	2.36	1.97	2.21
T_8 - Pretilachlor 30.7 EC	500	1.31	1.07	1.18	2.09	1.67	1.93
T_9 - Untreated Control	-	2.66	2.32	2.49	6.85	5.45	6.14
S.Em (±)		**0.046**	**0.035**	**0.041**	**0.078**	**0.074**	**0.075**
C.D. (P=0.05)		**0.136**	**0.105**	**0.116**	**0.233**	**0.221**	**0.216**

Table 4.60 Dry weight of *Cyperus rotundus* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	3.37	2.26	2.81	5.58	3.47	4.52
T_2 - Azim +MSM+0.2%surf	40+2	3.10	1.93	2.51	5.00	3.27	4.13
T_3 - Azim +MSM	35+2	4.67	2.56	3.61	6.67	4.20	5.43
T_4 - Azim +MSM	40+2	4.16	2.28	3.21	6.19	3.73	4.96
T_5 - Azim +0.2%surf	35	5.27	2.89	4.08	7.08	4.43	5.75
T_6 - Azim +0.2%surf	40	5.00	2.65	3.82	6.79	4.27	5.53
T_7 - MSM+0.2%surf	2	5.71	3.13	4.42	7.55	4.87	6.20
T_8 - Pretilachlor 30.7 EC	500	5.46	2.83	4.14	7.89	5.37	6.62
T_9 - Untreated Control	-	887	6.07	7.96	13.79	10.65	11.22
S.Em (±)		**0.115**	**0.082**	**0.094**	**0.694**	**0.640**	**0.714**
C.D. (P=0.05)		**0.345**	**0.245**	**0.271**	**2.083**	**1.917**	**2.054**

Dry weight of broadleaf weeds

It is evident from Table 4.63 that the minimum dry weight of *Ammania baccifera* was found with T_2. The maximum was obtained at all the growing stage from untreated control plot. All the combination approaches with or without surf reported at par results in controlling this weed. MSM + 0.2% surf recorded better performances than Azim and Pretilachlor recorded at 30 DAA.

Weed biomass of *Stellaria media* is also directly influenced with the application of herbicide (Table 4.64).The lowest population was obtained from T_2 which was significantly better than all the treatments excepting T_1. The maximum was obtained from untreated control plot in all the dates of observation in both the years. Application of MSM + 0.2% surf showed significantly better performance than azimsulfuron for controlling this broadleaf weeds. At 45 DAA same kind of observation was found.

The pooled data in Table 4.65 revealed that the dry weight of *Phylanthus niruri* was significantly influenced with the herbicidal treatment and recorded lower value than untreated control. Azim + MSM + 0.2% surf at all the doses recorded significantly lower population of *P. niruri* than Azim + MSM .for reducing broad leaf weed dry weight MSM performed significantly better than Azimsulfuron. The maximum dry weight at 30 DAA (1.02 g m^{-2}) and 45 DAA (1.67 g m^{-2} were recorded from untreated control plot. The minimum, 0.08 and 0.10 g m^{-2} were recorded from T_2 (Azim 40 + MSM 2+ 0.2% surf) in both the 30 DAA and 45 DAA, respectively.

The other broad leaf weed biomass recorded always lower value than the untreated control plot (Table 4.66). In the fist year 2006, T_2 gave best results offered minimum values (0.63 g m^{-2}) followed by T_1 (0.76 g m^{-2}). Untreated control (T_9) recorded the highest weed population at all stages of crop growth. Application of MSM+ 0.2 5surf registered at par result with the higher dose of Azim. Untreated control recorded highest biomass of other broad leaf weed. Same kind of variation was recorded at 45 DAA also.

Table 4.61 Dry weight of *Cyperus difformis* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	1.10	0.72	0.91	1.31	1.10	1.20
T_2 - Azim +MSM+0.2%surf	40+2	0.89	0.65	0.77	1.23	0.93	1.07
T_3 - Azim +MSM	35+2	1.11	0.88	1.09	1.44	1.29	1.36
T_4 - Azim +MSM	40+2	1.06	0.84	1.00	1.29	1.17	1.13
T_5 - Azim +0.2%surf	35	1.25	1.13	1.18	1.65	1.45	1.60
T_6 - Azim +0.2%surf	40	1.19	1.03	1.15	1.51	1.26	1.43
T_7 - MSM+0.2%surf	2	1.65	1.33	1.49	2.08	1.63	1.85
T_8 - Pretilachlor 30.7 EC	500	1.77	1.50	1.63	2.38	1.87	2.12
T_9 - Untreated Control	-	4.08	2.97	3.52	6.83	4.97	5.90
S.Em (±)		**0.063**	**0.063**	**0.062**	**0.350**	**0.307**	**0.329**
C.D. (P=0.05)		**0.190**	**0.187**	**0.178**	**1.044**	**0.928**	**0.943**

Table 4.62 Dry weight of *Ammania baccifera* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.62	0.47	0.54	0.42	0.32	0.37
T_2 - Azim +MSM+0.2%surf	40+2	0.52	0.39	0.45	0.38	0.27	0.32
T_3 - Azim +MSM	35+2	0.86	0.64	0.74	0.74	0.56	0.65
T_4 - Azim +MSM	40+2	0.78	0.55	0.66	0.85	0.51	0.67
T_5 - Azim +0.2%surf	35	1.20	1.06	1.13	1.49	1.23	1.36
T_6 - Azim +0.2%surf	40	1.28	0.93	1.10	1.33	1.11	1.21
T_7 - MSM+0.2%surf	2	1.09	0.82	0.95	1.22	0.73	0.97
T_8 - Pretilachlor 30.7 EC	500	1.27	0.96	1.12	1.72	1.30	1.51
T_9 - Untreated Control	-	2.13	1.77	1.94	4.28	3.23	3.75
S.Em (±)		**0.032**	**0.052**	**0.038**	**0.030**	**0.052**	**0.042**
C.D. (P=0.05)		**0.095**	**0.154**	**0.109**	**0.089**	**0.155**	**0.120**

Table 4.63 Dry weight of *Stellaria media* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.73	0.47	0.59	0.76	0.42	0.59
T_2 - Azim +MSM+0.2%surf	40+2	0.67	0.39	0.52	0.66	0.30	0.48
T_3 - Azim +MSM	35+2	1.08	0.73	0.90	1.37	0.91	1.14
T_4 - Azim +MSM	40+2	0.92	0.62	0.77	1.22	0.71	0.96
T_5 - Azim +0.2%surf	35	1.13	0.87	1.09	1.89	1.30	1.54
T_6 - Azim +0.2%surf	40	1.00	0.77	0.96	1.45	1.21	1.37
T_7 - MSM+0.2%surf	2	0.61	0.47	0.54	0.94	0.62	0.76
T_8 - Pretilachlor 30.7 EC	500	1.27	0.91	1.14	2.75	1.60	2.17
T_9 - Untreated Control	-	2.40	1.57	2.13	6.99	4.83	5.91
S.Em (±)		**0.061**	**0.074**	**0.068**	**0.083**	**0.091**	**0.091**
C.D. (P=0.05)		**0.184**	**0.222**	**0.195**	**0.246**	**0.274**	**0.261**

Table 4.64 Dry weight of *Phylanthus niruri* in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.12	0.07	0.09	0.16	0.09	0.12
T_2 - Azim +MSM+0.2%surf	40+2	0.11	0.06	0.08	0.13	0.07	0.10
T_3 - Azim +MSM	35+2	0.19	0.11	0.15	0.25	0.14	0.19
T_4 - Azim +MSM	40+2	0.15	0.10	0.12	0.19	0.08	0.13
T_5 - Azim +0.2%surf	35	0.31	0.19	0.25	0.52	0.37	0.44
T_6 - Azim +0.2%surf	40	0.27	0.17	0.21	0.43	0.35	0.38
T_7 - MSM+0.2%surf	2	0.14	0.08	0.11	0.41	0.24	0.32
T_8 - Pretilachlor 30.7 EC	500	0.22	0.15	0.18	0.77	0.43	0.60
T_9 - Untreated Control	-	1.23	0.82	1.02	2.11	1.23	1.67
S.Em (±)		**0.018**	**0.023**	**0.020**	**0.047**	**0.011**	**0.034**
C.D. (P=0.05)		**0.053**	**0.070**	**0.057**	**0.142**	**0.032**	**0.097**

Table 4.65 Dry weight of other broadleaf weed in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	30 DAA			45 DAA		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	0.81	0.51	0.76	1.29	0.81	1.04
T_2 - Azim +MSM+0.2%surf	40+2	0.72	0.45	0.63	1.19	0.75	0.97
T_3 - Azim +MSM	35+2	0.98	0.69	0.91	1.67	1.05	1.36
T_4 - Azim +MSM	40+2	0.86	0.72	0.81	1.47	0.93	1.20
T_5 - Azim +0.2%surf	35	1.13	0.87	1.10	2.16	1.59	2.07
T_6 - Azim +0.2%surf	40	1.00	0.71	0.89	2.04	1.41	1.82
T_7 - MSM+0.2%surf	2	0.97	0.61	0.76	1.73	1.09	1.41
T_8 - Pretilachlor 30.7 EC	500	1.22	0.76	1.14	3.78	2.47	3.12
T_9 - Untreated Control	-	2.73	1.69	2.27	6.89	4.39	5.63
S.Em (±)		**0.051**	**0.021**	**0.043**	**0.062**	**0.049**	**0.056**
C.D. (P=0.05)		**0.152**	**0.064**	**0.123**	**0.187**	**0.148**	**0.161**

4.1.2.4 Weed Control Efficiency (WCE) on 30 and 45 DAA in DS paddy

The weed control efficiency (WCE) of different weed management treatments during both the years are presented in Table 4.66.

From the mean data of both the year it was recorded that highest weed control efficiency (76.47 %) was observed from T_2 at 30 DAA which is closely followed by Azim + MSM + 0.2% surf @ 35+2 g a.i. ha^{-1} (72.55 %). The WCE of Azim was quite higher than the standard Pretilachlor. Similar trends were observed at 45 DAA also. At 45 DAA all the herbicide showed lower WCE in comparison to 30 DAA and the concern values for the same treatments were 74.28 & 71.45 %.

Table 4.66 Weed Control Efficiency of herbicide at 30 and 45 DAA in DS paddy

Treatment	Dose (g a.i. ha^{-1})	Weed Control Efficiency (%)					
		30 DAA			45 DAA		
		2006	2007	Mean	2006	2007	Mean
T_1 - Azim +MSM+0.2%surf	35+2	75.37	73.18	74.28	70.38	72.31	71.45
T_2 - Azim +MSM+0.2%surf	40+2	75.59	77.35	76.47	72.00	73.10	72.55
T_3 - Azim +MSM	35+2	69.65	71.00	70.33	62.19	64.99	63.59
T_4 - Azim +MSM	40+2	71.98	74.75	73.37	66.38	69.66	68.02
T_5 - Azim +0.2%surf	35	63.40	65.52	64.46	55.22	58.68	56.95
T_6 - Azim +0.2%surf	40	66.79	69.01	67.90	58.78	62.16	60.47
T_7 - MSM+0.2%surf	2	62.84	64.57	63.71	54.88	57.58	56.23
T_8 - Pretilachlor 30.7 EC	500	57.22	59.07	58.15	53.90	57.33	55.62
T_9 - Untreated Control	-				-	-	-

4.1.2.5 Effect of treatments on the phytotoxicity of direct seeded paddy

The observations regarding the phytotoxic effect of herbicede to the DS rice was taken on the basis prepared by visual scoring scale of 0 – 10 on Phytotoxicity Rating Scale (PRS) are presented in Table 4.67 to 4.71. The results clearly registered that no phytotoxocity symptom was observed in paddy plant due to the application of Azimsulfuron sole or mixing with MSM with or without surf even with its double dose for any parameters viz. epinasty, hyponasty, leaf tip yellowing or surface injury and chlorotic or necrotic symptoms as well as stunting growth of the paddy plant. All the crop plants looked healthy in the experimental field during both the years.

Table 4.67 Phytotoxicity on leaf epinasty or hyponasty in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	7 DAA		14 DAA		21 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	0	0	0	0	0	0
T_2 - Azim +MSM+0.2%surf	40+2	0	0	0	0	0	0
T_3 - Azim +MSM	35+2	0	0	0	0	0	0
T_4 - Azim +MSM	40+2	0	0	0	0	0	0
T_5 - Azim +0.2%surf	35	0	0	0	0	0	0
T_6 - Azim +0.2%surf	40	0	0	0	0	0	0
T_{10} - Azim +MSM+0.2%surf	80+4	0	0	0	0	0	0
T_{11}- Azim +MSM	80+4	0	0	0	0	0	0

Table 4.68 Phytotoxicity on leaf yellowing in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	7 DAA		14 DAA		21 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	0	0	0	0	0	0
T_2 - Azim +MSM+0.2%surf	40+2	0	0	0	0	0	0
T_3 - Azim +MSM	35+2	0	0	0	0	0	0
T_4 - Azim +MSM	40+2	0	0	0	0	0	0
T_5 - Azim +0.2%surf	35	0	0	0	0	0	0
T_6 - Azim +0.2%surf	40	0	0	0	0	0	0
T_{10} - Azim +MSM+0.2%surf	80+4	0	0	0	0	0	0
T_{11}- Azim +MSM	80+4	0	0	0	0	0	0

Table 4.69 Phytotoxicity on necrosis or chlorosis in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	7 DAA		14 DAA		21 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	0	0	0	0	0	0
T_2 - Azim +MSM+0.2%surf	40+2	0	0	0	0	0	0
T_3 - Azim +MSM	35+2	0	0	0	0	0	0
T_4 - Azim +MSM	40+2	0	0	0	0	0	0
T_5 - Azim +0.2%surf	35	0	0	0	0	0	0
T_6 - Azim +0.2%surf	40	0	0	0	0	0	0
T_{10} - Azim +MSM+0.2%surf	80+4	0	0	0	0	0	0
T_{11}- Azim +MSM	80+4	0	0	0	0	0	0

Table 4.70 Phytotoxicity on stunting growth in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	7 DAA		14 DAA		21 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	0	0	0	0	0	0
T_2 - Azim +MSM+0.2%surf	40+2	0	0	0	0	0	0
T_3 - Azim +MSM	35+2	0	0	0	0	0	0
T_4 - Azim +MSM	40+2	0	0	0	0	0	0
T_5 - Azim +0.2%surf	35	0	0	0	0	0	0
T_6 - Azim +0.2%surf	40	0	0	0	0	0	0
T_{10} - Azim +MSM+0.2%surf	80+4	0	0	0	0	0	0
T_{11}- Azim +MSM	80+4	0	0	0	0	0	0

Azim 35 +MSM 2 + 0.2 % Surfactant at 25 DAS

Azim 35 + 0.2 % Surfactant at 25 DAS

Azim 30 +MSM 2 at 25 DAS

Untreated Control

Plate 7 Effect of weed management in direct seeded paddy field

Table 4.71 Phytotoxicity on wilting in direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	7 DAA		14 DAA		21 DAA	
		2006	2007	2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	0	0	0	0	0	0
T_2 - Azim +MSM+0.2%surf	40+2	0	0	0	0	0	0
T_3 - Azim +MSM	35+2	0	0	0	0	0	0
T_4 - Azim +MSM	40+2	0	0	0	0	0	0
T_5 - Azim +0.2%surf	35	0	0	0	0	0	0
T_6 - Azim +0.2%surf	40	0	0	0	0	0	0
T_{10} - Azim +MSM+0.2%surf	80+4	0	0	0	0	0	0
T_{11}- Azim +MSM	80+4	0	0	0	0	0	0

4.1.2.6 Effect of treatments on growth and yield of direct seeded paddy

4.1.2.6.1 Plant height at harvest

Data on weed control treatments on plant height have been presented in Table 4.72. In both the year the plant height of paddy plants varied significantly with the chemical treatments. The pooled data revealed that the maximum plant height (102.10 cm) was found in Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} and at par with the same combination of its lower dose (101.60 cm) and also having same dose but without surf. The minimum plant height 93.84 cm was observed from the untreated control plot (T_9).

4.1.2.6.2 Number of effective tiller m^{-2}

The number of effective tillers m^{-2} in direct seeded rice influenced significantly with various weed management practices during 2006 and 2007(Table 4.72),. Pooled data revealed, the maximum number of effective tillers m^{-2} (299.0) was recorded in Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} which statistically at par with Azim 35+ MSM 2+ 0.2% surf (294.5) and that of the same dose without surf (290.5). Both the doses of Azim alongwith 0.2% surf recorded higher effective tiller m^{-2} than the two standards Pretilachlor (267.3). The minimum number of effective tillers m^{-2} (190.5) was recorded in the crop having no weed management practices.

Table 4.72 Growth and yield attributes of direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	Plant height (cm) at harvest			Effective tiller (m^{-2})			Panicle length (cm)			Filled grain $panicle^{-1}$		
		2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	100.20	102.00	101.60	289.5	299.5	294.5	21.25	21.40	21.32	58.10	59.76	59.39
T_2 - Azim +MSM+0.2%surf	40+2	101.80	102.30	102.10	293.9	305.0	299.0	21.45	21.53	21.49	60.03	60.46	60.24
T_3 - Azim +MSM	35+2	99.30	100.00	99.65	280.4	284.0	281.6	20.28	20.66	20.47	56.35	58.56	58.28
T_4 - Azim +MSM	40+2	100.00	101.40	100.73	283.0	298.2	290.5	21.00	21.19	21.09	57.44	59.12	58.72
T_5 - Azim +0.2%surf	35	97.60	97.80	97.70	276.0	288.8	280.0	20.00	20.37	20.18	56.86	57.58	57.22
T_6 - Azim +0.2%surf	40	99.50	100.20	99.83	279.5	289.0	286.0	20.35	20.85	20.60	57.27	58.27	57.77
T_7 - MSM+0.2%surf	2	96.30	96.60	96.55	258.0	267.5	263.2	19.20	19.39	19.29	54.22	55.69	54.95
T_8 - Pretilachlor 30.7 EC	500	97.00	97.80	97.43	264.4	272.5	267.3	19.75	20.00	19.87	55.98	56.66	56.32
T_9 - Untreated Control	-	93.50	94.10	93.84	184.5	196.3	190.5	18.20	18.57	18.38	48.41	49.25	48.83
S.Em (±)		**0.963**	**1.291**	**1.155**	**3.586**	**3.979**	**3.787**	**0.375**	**1.313**	**0.482**	**0.723**	**0.734**	**0.728**
C.D. (P=0.05)		**2.886**	**3.871**	**3.312**	**10.750**	**11.926**	**9.754**	**1.123**	**NS**	**1.388**	**2.166**	**2.201**	**2.096**

4.1.2.6.3 Panicle length

The data as presented in Table 4.72 indicated that in the first year the length of panicle varied significantly with the treatments but remain ay par in the next season, Pooled data revealed that maximum panicle length (21.49 cm) was recorded from the combination of highest doses Azim + MSM with surf and the minimum (18.38 cm) was observed from control plot. It is also evident from the table that rest of treatments did not showed any significant variation among themselves but recorded significantly higher panicle length than untreated control (18.38 cm).

4.1.2.6.4 Filled grains panicle^{-1}

Untreated control (T_9) recorded the minimum number of filled grains panicle^{-1} (48.83) which was significantly lower than any other treatments. Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} recorded the maximum number of filled grains panicle^{-1} (60.24) which was at par with all the combination treatments. Application of Azim + 0.2% surf recorded higher numbers filled grains panicle^{-1} than the standard Pretilachlor (Table 4.72).

4.1.2.6.5 Test weight of grain

Different weed management practices applied to the direct seeded paddy had no significant influence on 1000 grain weight during both the year (Table 4.73), though the maximum pooled value was recorded with the treatment Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} .The minimum pooled value (20.44 g) was observed in untreated control.

Table 4.73 Test weight, grain and straw yield of direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	1000-grain weight (g)			Grain yield (t ha^{-1})			Straw yield (t ha^{-1})		
		2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	21.44	21.75	21.59	3.22	3.43	3.32	4.10	4.25	4.17
T_2 - Azim +MSM+0.2%surf	40+2	21.76	21.89	21.82	3.46	3.67	3.56	4.20	4.37	4.28
T_3 - Azim +MSM	35+2	21.27	21.40	21.33	3.07	3.27	3.17	3.88	4.04	3.96
T_4 - Azim +MSM	40+2	21.36	21.43	21.39	3.2	3.37	3.28	4.03	4.16	4.09
T_5 - Azim +0.2%surf	35	21.00	21.22	21.11	2.94	3.00	2.92	3.67	3.82	3.74
T_6 - Azim +0.2%surf	40	21.18	21.35	21.26	2.88	3.08	2.99	3.69	3.84	3.76
T_7 - MSM+0.2%surf	2	20.64	20.88	20.76	2.71	2.54	2.52	3.10	3.23	3.16
T_8 - Pretilachlor 30.7 EC	500	20.75	21.00	20.87	2.44	2.82	2.42	3.03	3.15	3.08
T_9 - Untreated Control	-	20.18	20.53	20.44	2.03	2.14	2.08	2.90	3.02	2.96
S.Em (±)		**0.511**	**0.599**	**0.556**	**0.085**	**0.088**	**0.082**	**0.083**	**0.065**	**0.068**
C.D. (P=0.05)		**NS**	**NS**	**NS**	**0.254**	**0.267**	**0.235**	**0.252**	**0.195**	**0.192**

Table 4.74 Economics of direct seeded paddy cultivation

Treatment	Dose (g a.i. ha^{-1})	Cost of cultivation (Rs. ha^{-1})			Gross return (Rs. ha^{-1})			Net return (Rs. ha^{-1})			Return per rupee invested (Rs.)		
		2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
T_1 - Azim +MSM+0.2%surf	35+2	13105	13105	13105	20125	21438	20781	7020	8333	7676	1.54	1.64	1.59
T_2 - Azim +MSM+0.2%surf	40+2	13155	13155	13155	21625	22938	22281	8470	9783	9126	1.64	1.74	1.69
T_3 - Azim +MSM	35+2	12830	12830	12830	19188	20438	19813	6358	7608	6983	1.50	1.59	1.54
T_4 - Azim +MSM	40+2	12880	12880	12880	20000	21063	20531	7120	8183	7651	1.55	1.64	1.59
T_5 - Azim +0.2%surf	35	12805	12805	12805	18375	18750	18563	5520	5895	5708	1.43	1.46	1.44
T_6 - Azim +0.2%surf	40	12855	12855	12855	18000	19250	18625	5195	6445	5820	1.41	1.50	1.45
T_7 - MSM+0.2%surf	2	12755	12755	12755	16938	15875	16406	4183	3120	3651	1.33	1.24	1.29
T_8 - Pretilachlor 30.7 EC	500	12505	12505	12505	15250	17625	16438	2745	5120	3933	1.22	1.41	1.31
T_9 - Untreated Control	-	12000	12000	12000	12688	13375	13031	688	1375	1031	1.06	1.11	1.08

4.1.2.6.6 Grain and straw yield

The grain yield of direct seeded rice varied significantly with different herbicidal treatments (Table 4.73). The pooled data revealed that the lowest grain yield (2.08 t ha^{-1}) was observed in control treatment which was significantly lower than any other treatments tried in this experiment. The maximum grain yield (3.56 t ha^{-1}) was obtained from T_2 applied at 14 DAT followed T_1 (3.32 t ha^{-1}) .Treatments with surf recorded significantly superior yield than the treatments having same combination without surf. The sole application Azim 40 (2.99 t ha^{-1}) and Azim 35 (2.92 t ha^{-1}) g a.i. ha^{-1} along with 0.2% surf also recorded significantly higher yield than the standard used Pretilachlor (2.42 t ha^{-1}) and MSM + 0.2% surf (2.52 t ha^{-1}).

Significant increases in straw yield by employing different herbicidal treatments were observed during both 2006 & 2007 (Table 4.73). The maximum pooled straw yield (4.28 t ha^{-1}) was recorded where highest doses of Azim were applied in combination with MSM alongwith 0.2% surf. This was statistically at par with its lower dose keeping the treatment combination same (4.17 t ha^{-1}) or with same higher dose without surf (4.09 t ha^{-1}). Sole application Azim along with 0.2% surf recorded statistically superior result than the standard Pretilachlor (3.08t ha^{-1}). The minimum straw yield was obtained from the control plot (2.96 t ha^{-1}).

4.1.2.7 Economics of different treatments

The pooled data presented in Table 4.74 showed that among all the treatments adopted for controlling weeds in direct seeded rice Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} recorded maximum net return (Rs 9126.00) with highest return per rupee investment (Rs 1.69). The lowest net profit was obtained from the untreated control plot (Rs 1031.00) and the return per rupee investment was Rs 1.17. Application of Azim + MSM @ 35+2 g a.i. ha^{-1} recorded net return of Rs 7676.00.

4.1.2.8 Impact of different treatments on weed dynamics, growth and yield of zero-till rapeseed

4.1.2.8.1 Visual scoring of weeds on rapeseed

The effect of applied herbicide applied to the previous *kharif* direct seeded paddy to the succeeding rapeseed was not significantly varied through out the growth period. From the Table 4.75 it was clearly observed that among the two dates of visual observations taken on 10 and 25 DAS, only at 10 DAS though there was some variation amongst the earlier treated plots but at 25 DAS all the treatments represented almost same population of total weed flora in the follow up zero-till rapeseed followed by puddle direct seeded paddy.

Table 4.75 Visual observation on weed flora of zero till rapeseed

Treatment	Dose (g a.i. ha^{-1})	Weed population (1-10 scale)			
		5 DAS		25 DAS	
		2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	8.9	9.0	9.9	9.8
T_2 - Azim +MSM+0.2%surf	40+2	8.8	8.8	9.9	9.9
T_3 - Azim +MSM	35+2	9.3	9.4	9.9	9.8
T_4 - Azim +MSM	40+2	9.2	9.3	9.8	9.7
T_5 - Azim +0.2%surf	35	9.0	8.9	9.	9.4
T_6 - Azim +0.2%surf	40	9.0	9.1	9.2	9.9
T_7 - MSM+0.2%surf	2	9.3	9.4	9.8	9.8
T_8 - Pretilachlor 30.7 EC	500	9.5	9.4	9.9	9.9
T_9 - Untreated Control	-	-	-	-	-

4.1.2.8.2 Weed population and biomass

Grass weed density

The dominant grass weeds present in the zero-till rapeseed field were *Echinochloa colona, Cynodon dactylon, Leersia hexendra, Digitaria sanguinalis, Eleusine indica, Dactyloctaniun aegyptium.*

From the pooled data (Table 4.76) revealed that at 10 DAS Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} showed minimum weed population (4.17) of grassy weeds was significantly lower value than the standard Pretilachlor (9.44) and untreated control (11.66) but showed statistically at par results with the other herbicides. But at 25 DAS pooled data revealed that no significant variation was found in total grass weed population due to the application of herbicide in the preceding rice to the follow up zero-till rapeseed.

Sedge weed density

Cyperus rotundus, the most important sedge in the rapeseed field throughout the crop period. The pooled data presented in the Table 4.77 clearly indicated that initially up to 10 DAS the sedge weed population was significantly lower with all the treatments having mixture or sole application of Azim to the rice than that of

Pretilachlor and control. The minimum sedge weed density (7.65) was obtained in Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} and the maximum from the control plot (19.13). But after 25 DAS no significant variation was found.

Broadleaf weed density

Cleome viscose, Ammania baccifera, Argemone Mexicana, Blumea lacera, Gnaphalium luetoalbum, Eclipta alba, Melilotus alba, Chenopodium album, Stellaria media, Anagallis arvensis were the most dominant broadleaf weeds present in the experimental field.

The populations of broadleaf weeds were presented in Table 4.78. It is evident from the table that in all the plots where Azim + MSM were applied showed significantly lower broadleaf weeds at 10 DAS. The highest weed population (19.16) was found from untreated control plot (T_9). In both the year more or less similar trends were found. No significant difference in broad leaf weed population was found during 2006-07 and 2007-08 at 25 DAS.

Density of total weeds

The data on total weed population were presented in Table 4.79. The total weed density showed maximum weed population (49.80) in control plot and the minimum (18.48) was obtained from Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1}. At 25 DAS no variation was observed in the total weed population.

Biomass of grassy weed

The grassy weed biomass was minimum (1.44 g m^{-2}) with Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} which is significantly higher than all other treatments and the maximum (2.38 g m^{-2}) was recorded from control plot. As like the density the grassy weed biomass also not varied significantly at later stage (Table 4.80).

Biomass of sedge weed

It is evident from the Table 4.81 that at 10 DAS, the minimum sedge weed biomass (1.94 g m^{-2}) was observed by the highest dose of Azim combining with MSM @ 2 g a.i. ha^{-1} along with 0.2% surf. It was at par with the same treatments excepting the surf and. Maximum dry weight (2.92 g m^{-2}) was obtained from untreated control. During 25 DAS all the treatments showed at par sedge weed dry weight.

Table 4.76 Population of total grass weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	5.41	4.68	4.89	13.73	11.45	12.19
T_2 - Azim +MSM+0.2%surf	40+2	4.44	3.81	4.17	12.49	10.19	11.39
T_3 - Azim +MSM	35+2	6.60	5.55	5.97	14.98	12.47	14.18
T_4 - Azim +MSM	40+2	6.01	5.10	5.65	13.81	11.50	13.00
T_5 - Azim +0.2%surf	35	7.22	6.11	6.87	15.34	13.10	14.42
T_6 - Azim +0.2%surf	40	6.80	5.76	6.32	14.83	12.35	13.77
T_7 - MSM+0.2%surf	2	9.14	8.68	9.10	17.32	14.44	15.41
T_8 - Pretilachlor 30.7 EC	500	8.49	10.23	9.44	15.30	13.68	14.38
T_9 - Untreated Control	-	12.32	10.44	11.66	18.16	17.18	17.50
S.Em (±)		**0.623**	**0.559**	**0.604**	**1.345**	**1.275**	**1.296**
C.D. (P=0.05)		**1.861**	**1.668**	**1.804**	**NS**	**NS**	**NS**

Table 4.77 Population of total sedge weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	10.05	8.62	8.99	19.20	17.32	18.01
T_2 - Azim +MSM+0.2%surf	40+2	8.20	6.60	7.65	18.20	17.77	18.13
T_3 - Azim +MSM	35+2	14.85	11.48	12.98	21.42	20.47	20.11
T_4 - Azim +MSM	40+2	12.56	10.48	10.83	17.68	20.20	18.94
T_5 - Azim +0.2%surf	35	13.48	12.56	12.92	19.63	16.78	18.46
T_6 - Azim +0.2%surf	40	11.62	11.09	11.87	18.98	15.82	17.63
T_7 - MSM+0.2%surf	2	20.52	16.69	17.06	25.23	29.52	28.51
T_8 - Pretilachlor 30.7 EC	500	17.30	17.56	17.32	22.29	19.93	20.94
T_9 - Untreated Control	-	21.88	18.47	19.13	23.81	22.52	22.94
S.Em (±)		**0.896**	**0.762**	**0.894**	**1.536**	**1.347**	**1.429**
C.D. (P=0.05)		**2.677**	**2.429**	**2.669**	**NS**	**NS**	**NS**

Table 4.78 Population of total broadleaf weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	7.31	5.67	6.43	20.23	18.25	18.98
T_2 - Azim +MSM+0.2%surf	40+2	6.43	5.07	5.48	17.37	13.25	15.65
T_3 - Azim +MSM	35+2	8.68	7.07	7.79	20.48	24.85	22.74
T_4 - Azim +MSM	40+2	7.90	7.42	7.56	17.36	19.84	18.59
T_5 - Azim +0.2%surf	35	13.82	12.95	13.17	21.17	18.09	21.05
T_6 - Azim +0.2%surf	40	12.97	11.79	12.10	21.12	17.59	19.62
T_7 - MSM+0.2%surf	2	8.19	8.05	8.10	20.41	17.86	19.07
T_8 - Pretilachlor 30.7 EC	500	15.61	17.50	15.71	24.36	21.79	22.89
T_9 - Untreated Control	-	19.73	18.50	19.16	26.03	23.78	25.08
S.Em (±)		**1.106**	**1.217**	**1.142**	**1.423**	**1.285**	**1.375**
C.D. (P=0.05)		**3.304**	**3.634**	**3.409**	**NS**	**NS**	**NS**

Biomass of broadleaf weed

Different weed management treatments exhibited significant influence on broadleaf weed biomass during both the years at earlier crop stage up to 10 DAS and the maximum value was recorded from untreated control (2.77 g m^{-2}) but the difference in between the treatments was not clear at 25 DAS (Table 4.82).

Total weed biomass

The total weed biomass was significantly affected by different weed management treatments at 10 DAS (Table 4.83). The mixture of Azim and MSM @ 40+2 g a.i. ha^{-1} with all the combinations showed significantly lower total weed biomass (4.47g m^{-2}) and the control plot registered the maximum value (8.07 g m^{-2}). However, at 25 DAS all treatments showed at par results.

Table 4.79 Population of total weed flora of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	22.77	18.97	20.31	53.16	49.17	49.18
T_2 - Azim +MSM+0.2%surf	40+2	19.07	15.48	17.30	48.06	45.18	45.17
T_3 - Azim +MSM	35+2	30.13	24.10	26.74	56.88	57.04	57.03
T_4 - Azim +MSM	40+2	26.47	23.00	24.04	48.85	50.52	50.53
T_5 - Azim +0.2%surf	35	34.52	31.62	32.96	56.14	53.93	53.93
T_6 - Azim +0.2%surf	40	31.39	28.64	30.29	54.93	51.02	51.02
T_7 - MSM+0.2%surf	2	37.85	33.42	34.26	62.96	62.99	62.99
T_8 - Pretilachlor 30.7 EC	500	41.40	45.29	42.47	61.95	58.21	58.21
T_9 - Untreated Control	-	53.93	47.41	49.95	68.00	65.52	65.52
S.Em (±)		**2.657**	**3.060**	**2.852**	**3.157**	**3.759**	**3.533**
C.D. (P=0.05)		**7.933**	**9.137**	**8.515**	**9.427**	**11.224**	**10.55**

Table 4.80 Dry weight of total grass weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	1.66	1.38	1.62	3.70	3.53	3.61
T_2 - Azim +MSM+0.2%surf	40+2	1.48	1.32	1.44	3.46	3.37	3.40
T_3 - Azim +MSM	35+2	1.78	1.49	1.62	3.65	2.62	3.55
T_4 - Azim +MSM	40+2	1.50	1.63	1.54	2.72	2.42	3.48
T_5 - Azim +0.2%surf	35	1.70	1.58	1.62	3.03	2.75	3.87
T_6 - Azim +0.2%surf	40	1.66	1.29	1.59	2.92	2.59	3.72
T_7 - MSM+0.2%surf	2	2.34	1.69	2.17	3.98	3.52	3.89
T_8 - Pretilachlor 30.7 EC	500	2.15	1.44	2.13	3.01	2.86	3.94
T_9 - Untreated Control	-	2.47	2.28	2.38	3.89	4.02	4.00
S.Em (±)		**0.231**	**0.248**	**0.234**	**0.348**	**0.378**	**0.359**
C.D. (P=0.05)		**0.714**	**0.766**	**0.722**	**NS**	**NS**	**NS**

Table 4.81 Dry weight of total sedge weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	2.15	2.05	2.13	5.13	4.86	4.95
T_2 - Azim +MSM+0.2%surf	40+2	1.95	1.83	1.94	4.44	4.62	4.52
T_3 - Azim +MSM	35+2	2.13	1.86	1.99	5.15	5.03	5.10
T_4 - Azim +MSM	40+2	2.00	1.92	1.95	4.32	4.52	4.45
T_5 - Azim +0.2%surf	35	2.29	2.20	2.23	4.15	3.77	3.86
T_6 - Azim +0.2%surf	40	2.21	2.16	2.19	4.01	4.69	4.44
T_7 - MSM+0.2%surf	2	2.92	2.65	2.79	5.18	5.45	5.34
T_8 - Pretilachlor 30.7 EC	500	2.69	2.53	2.62	5.29	5.47	5.33
T_9 - Untreated Control	-	3.03	2.79	2.92	5.34	5.12	5.49
S.Em (±)		0.189	0.234	0.218	0.258	0.347	0.310
C.D. (P=0.05)		0.584	0.723	0.673	NS	NS	NS

Table 4.82 Dry weight of total broadleaf weeds of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	1.66	1.52	1.58	3.62	3.44	3.55
T_2 - Azim +MSM+0.2%surf	40+2	1.47	1.33	1.36	4.10	3.28	3.65
T_3 - Azim +MSM	35+2	1.60	1.50	1.57	3.88	3.64	3.67
T_4 - Azim +MSM	40+2	1.50	1.67	1.55	3.48	3.28	3.35
T_5 - Azim +0.2%surf	35	2.30	2.11	2.19	2.37	4.23	3.27
T_6 - Azim +0.2%surf	40	2.10	1.95	1.99	3.05	3.21	3.11
T_7 - MSM+0.2%surf	2	1.45	1.30	1.39	2.62	3.98	3.12
T_8 - Pretilachlor 30.7 EC	500	2.54	2.26	2.42	3.90	3.42	3.75
T_9 - Untreated Control	-	2.92	2.84	2.77	4.32	3.75	3.86
S.Em (±)		0.187	0.211	0.197	0.324	0.287	0.319
C.D. (P=0.05)		0.577	0.651	0.607	NS	NS	NS

Table 4.83 Dry weight of total weed flora of succeeding zero-till rapeseed

Treatment	Dose (g a.i. ha^{-1})	10 DAS			25 DAS		
		2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	5.47	4.95	5.33	12.45	11.84	12.11
T_2 - Azim +MSM+0.2%surf	40+2	4.90	4.48	4.74	12.00	11.26	11.57
T_3 - Azim +MSM	35+2	5.51	4.85	5.18	12.68	11.29	12.32
T_4 - Azim +MSM	40+2	5.00	5.22	5.04	10.51	10.22	11.28
T_5 - Azim +0.2%surf	35	6.29	5.89	6.04	9.55	10.75	11.00
T_6 - Azim +0.2%surf	40	5.97	5.40	5.77	9.99	10.48	11.27
T_7 - MSM+0.2%surf	2	6.71	5.64	6.35	11.78	12.95	12.35
T_8 - Pretilachlor 30.7 EC	500	7.38	6.23	7.17	12.21	11.75	13.02
T_9 - Untreated Control	-	8.42	7.91	8.07	13.55	12.89	13.35
S.Em (±)		0.395	0.367	0.382	0.957	1.206	1.007
C.D. (P=0.05)		1.220	1.133	1.180	NS	NS	NS

Rapeseed at 30 DAS

Rapeseed at 55 DAS

Rapeseed at 70 DAS

Rapeseed at siliqua formation stage

Rapeseed at flowering stage

General view

Plate 8 Follow-up zero tilled rapeseed after direct seeded paddy

4.1.2.8.3 Visual crop toxicity

Crop response was rated in the scale of 0 to 9, as presented in Table 4.40 to record herbicide toxicity on crop stand and growth (Reference Table 3.10 of 'Materials and Methods'). During both the years of experimentation all the treatments showed no phytotoxic effect on rapeseed plants and its germination and thus rated as one (1).

4.84 Crop Toxicity Rating in zero till rapeseed followed by direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	Crop Toxicity Rating (1-9 scale)*			
		30 DAA		45 DAA	
		2006	2007	2006	2007
T_1 - Azim +MSM+0.2%surf	35+2	1	1	1	1
T_2 - Azim +MSM+0.2%surf	40+2	1	1	1	1
T_3 - Azim +MSM	35+2	1	1	1	1
T_4 - Azim +MSM	40+2	1	1	1	1
T_5 - Azim +0.2%surf	35	1	1	1	1
T_6 - Azim +0.2%surf	40	1	1	1	1
T_7 - MSM+0.2%surf	2	1	1	1	1
T_8 - Pretilachlor 30.7 EC	500	1	1	1	1
T_9 - Untreated Control	-	-	-	-	-
T_{10} - Azim +MSM+0.2%surf	80+4	1	1	1	1
T_{11} - Azim +MSM	80+4	2	1	1	1

4.1.2.8.4 Plant height

The pooled data on plant height of zero-till rapeseed presented in Table 4.85 revealed that in there was no significant variation observed duel the treatments applied to preceding *kharif* direct seeded paddy. But the maximum plant height (77.14 cm) was recorded when Azim + MSM @ 40+2 g a.i. ha^{-1} + 0.2 % was applied to the earlier crop of the same sequence.

4.1.2.8.5 Number of primary branch plant $^{-1}$

Data presented in the Table 4.85 stated that in both the year of experimentation all the treatments rather than MSM and Pretilachlor, recorded statistically at par number of primary branch plant $^{-1}$. The maximum (3.27) was obtained from Azim + MSM @ 40+2 g a.i. ha^{-1} +0.2 % surf and the minimum (2.74) from the control plot.

Table 4.85 Growth and yield attributes of rapeseed followed by direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	Plant height (cm)			Number of primary branch $plant^{-1}$			Number of siliqua $plant^{-1}$			Siliqua length (cm)		
		2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	75.65	77.02	76.33	3.22	3.28	3.24	57.52	58.98	58.25	3.50	3.58	3.53
T_2 - Azim +MSM+0.2%surf	40+2	76.18	78.12	77.14	3.23	3.32	3.27	60.15	62.81	61.97	3.54	3.62	3.57
T_3 - Azim +MSM	35+2	74.54	76.38	75.46	3.10	3.25	3.17	55.78	58.02	56.39	3.48	3.50	3.49
T_4 - Azim +MSM	40+2	74.00	76.91	75.45	3.12	3.24	3.18	56.00	58.50	57.25	3.50	3.56	3.53
T_5 - Azim +0.2%surf	35	73.30	75.85	74.57	2.90	3.18	3.04	55.22	57.27	56.74	3.46	3.49	3.47
T_6 - Azim +0.2%surf	40	77.06	77.97	77.51	3.10	3.21	3.15	56.42	57.78	55.60	3.48	3.52	3.50
T_7 - MSM+0.2%surf	2	74.33	76.15	75.24	2.95	2.93	2.94	54.17	56.86	55.51	3.41	3.45	3.43
T_8 - Pretilachlor 30.7 EC	500	74.49	74.96	74.89	3.05	2.99	3.02	55.41	58.97	57.68	3.39	3.43	3.41
T_9 - Untreated Control	-	70.60	74.11	72.35	2.67	2.79	2.72	56.33	58.21	55.77	3.37	3.44	3.40
S.Em (±)		**1.256**	**1.511**	**1.339**	**0.079**	**0.113**	**0.097**	**1.103**	**1.339**	**1.226**	**0.071**	**1.111**	**0.077**
C.D. (P=0.05)		**3.953**	**NS**	**NS**	**0.237**	**0.337**	**0.279**	**3.307**	**4.014**	**3.530**	**0.214**	**3.331**	**NS**

Table 4.86 Yield attributes and yields of rapeseed followed by direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	Seeds per siliqua			Test weight (g)			Seed yield (t ha^{-1})			Stover yield (t ha^{-1})		
		2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled
T_1 - Azim +MSM+0.2%surf	35+2	17.94	18.23	18.08	2.80	2.87	2.83	0.701	0.721	0.713	1.440	1.482	1.461
T_2 - Azim +MSM+0.2%surf	40+2	17.46	18.46	18.22	2.82	2.90	2.86	0.722	0.736	0.729	1.486	1.568	1.520
T_3 - Azim +MSM	35+2	17.69	18.19	17.94	2.75	2.80	2.77	0.677	0.695	0.687	1.354	1.376	1.361
T_4 - Azim +MSM	40+2	17.65	18.25	18.06	2.80	2.83	2.81	0.686	0.710	0.698	1.362	1.448	1.403
T_5 - Azim +0.2%surf	35	17.70	18.00	17.85	2.76	2.77	2.77	0.667	0.700	0.687	1.346	1.446	1.390
T_6 - Azim +0.2%surf	40	17.86	18.12	18.00	2.82	2.81	2.81	0.677	0.731	0.703	1.373	1.476	1.424
T_7 - MSM+0.2%surf	2	17.36	17.89	17.62	2.71	2.80	2.76	0.614	0.674	0.642	1.356	1.440	1.401
T_8 - Pretilachlor 30.7 EC	500	16.60	16.93	16.88	2.78	2.81	2.79	0.625	0.684	0.654	1.372	1.474	1.423
T_9 - Untreated Control	-	16.02	16.32	16.15	2.70	2.76	2.73	0.549	0.628	0.590	1.319	1.421	1.375
S.Em (±)		**0.376**	**0.554**	**0.486**	**0.058**	**0.059**	**0.058**	**0.017**	**0.020**	**0.019**	**0.027**	**0.034**	**0.030**
C.D. (P=0.05)		**1.126**	**1.661**	**1.370**	**NS**	**NS**	**NS**	**0.052**	**0.059**	**0.054**	**0.081**	**0.103**	**0.086**

4.1.2.8.6 Siliqua plant^{-1}

Different herbicide applied to direct seeded paddy showed significant effect on siliqua plant^{-1} during 2006-07 & 2007-08 (Table 4.85).The pooled data revealed that all the treatments as mixture or sole application of Azimsulfuron 50 DF with or without surf gave significant higher number of siliqua plant^{-1} over to control. Minimum was reported from untreated control plot (55.77).

4.1.2.8.7 Siliqua length

No significant variation was obtained in the rapeseed when grown after direct seeded paddy as follow up crop in the length of siliqua due to use of herbicide in preceding crop. Table 4.85 stated that in both the year control plot recorded the smallest size of siliqua.

4.1.2.8.2.8 Seeds siliqua^{-1}

Among the different treatments only when T_2 was applied in preceding direct seeded paddy, reported significantly highest seeds siliqua^{-1} (18.22) in the follow up zero-tilled rapeseed (Table 4.86). During both the season the minimum number of seeds siliqua^{-1} was obtained from untreated control plot (16.93).

4.1.2.8.2.9 Test weight

From the Table 4.86 it is clear that there was no significant variation of 1000' grain weight among different weed management treatments during both the years of experimentation as well as pooled data. The pooled data showed that Azim + MSM + 0.2 % surf treatments recorded 2.86 g whereas untreated control recorded 2.73 g.

4.1.2.8.2.10 Seed and Stover yield

Herbicides applied to the preceding direct seeded paddy exerted significant influence on seed yield of rapeseed during both the years of experimentation as well as in pooled data (Table 4.86). The pool data revealed that the highest seed yield (0.729 t ha^{-1}) was obtained from T_2 treated plot of earlier DS paddy, which was statistically at par with all treatments excepting standard Pretrilachlor (0.654 t ha^{-1})

and MSM (0.642 t ha^{-1}). However, the untreated plot recorded minimum seed yield (0.590 t ha^{-1}).Similar trend was also observed during both 2006-07 and 2007-08.

Stover yield also varied accordingly, showed similar observation in both the year of experimentation as like the seed yield. Data presented in Table 4.86 stated that highest stover yield (1.520 t ha^{-1}) was obtained from the plot where T_2 were applied to the *Kharif* transplanted paddy closely followed by Azim 35+ MSM 2+ 0.2 % surf (1.461 t ha^{-1}). The minimum stover yield (1.375 t ha^{-1}) was collected from the plot where no herbicides were applied to the preceding rice crop.

4.1.2.8.11 Economics of zero-tilled rapeseed after direct seeded paddy

It is evident from the Table 4.87 that zero-till rapeseed grown after direct seeded paddy gave maximum net return (Rs 3381.00) and Return per rupee invested (Rs1.50) was from the plot where the higher doses of Azim + MSM @ 40+2 g a.i. ha^{-1} was applied along with 0.2% surf to the earlier *kharif* paddy of the same sequence followed by Azim + MSM + 0.2% surf @ 35+2 g a.i. ha^{-1} (Rs 3129.00).The minimum net profit (Rs 1414.00) and Return per rupee invested (Rs1.21) was recorded from untreated control plot.

4.1.2.8.12 Economics of transplanted paddy and follow up zero-tilled rapeseed crop sequence

Table 4.88 clearly indicate that the cumulative maximum net return (Rs 12507.00) and best Return per rupee invested (1.63) was recorded in transplanted paddy – zero till rapeseed crop sequence when Azim + MSM + 0.2% surf @ 40+2 g a.i. ha^{-1} was applied to the earlier paddy crop. Minimum total net return of DS paddy – zero tilled rapeseed (Rs 2445.00) was obtained when no herbicide was applied to the previous rice crop of the same sequence.

Table 4.87 Economics of zero - tilled rapeseed after direct seeded paddy

Treatment	Dose (g a.i. ha^{-1})	Cost of cultivation (Rs. ha^{-1})			Gross return (Rs. ha^{-1})			Net return (Rs. ha^{-1})			Return per rupee invested (Rs.)		
		2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
T_1 - Azim +MSM+0.2%surf	35+2	6825	6825	6825	9814	10094	9954	2989	3269	3129	1.44	1.48	1.46
T_2 - Azim +MSM+0.2%surf	40+2	6825	6825	6825	10108	10304	10206	3283	3479	3381	1.48	1.51	1.50
T_3 - Azim +MSM	35+2	6825	6825	6825	9478	9730	9604	2653	2905	2779	1.39	1.43	1.41
T_4 - Azim +MSM	40+2	6825	6825	6825	9604	9940	9772	2779	3115	2947	1.41	1.46	1.43
T_5 - Azim +0.2%surf	35	6825	6825	6825	9338	9800	9569	2513	2975	2744	1.37	1.44	1.40
T_6 - Azim +0.2%surf	40	6825	6825	6825	9478	10234	9856	2653	3409	3031	1.39	1.50	1.44
T_7 - MSM+0.2%surf	2	6825	6825	6825	8596	9436	9016	1771	2611	2191	1.26	1.38	1.32
T_8 - Pretilachlor 30.7 EC	500	6825	6825	6825	8750	9576	9163	1925	2751	2338	1.28	1.40	1.34
T_9 - Untreated Control	-	6825	6825	6825	7686	8792	8239	861	1967	1414	1.13	1.29	1.21

Table 4.88 Economics of direct seeded paddy - zero till rapeseed crop sequence

Treatment	Dose (g a.i. ha^{-1})	Cost of cultivation (Rs. ha^{-1})			Value of produce (Rs. ha^{-1})			Net return (Rs. ha^{-1})	Return per rupee investment
		Rice	Rapeseed	Total	Rice	Rapeseed	Total		
T_1 - Azim +MSM+0.2%surf	35+2	13105	6825	19930	20781	9954	30735	10805	1.54
T_2 - Azim +MSM+0.2%surf	40+2	13155	6825	19980	22281	10206	32487	12507	1.63
T_3 - Azim +MSM	35+2	12830	6825	19655	19813	9604	29417	9762	1.50
T_4 - Azim +MSM	40+2	12880	6825	19705	20531	9772	30303	10598	1.54
T_5 - Azim +0.2%surf	35	12805	6825	19630	18625	9856	28194	8564	1.44
T_6 - Azim +0.2%surf	40	12855	6825	19680	18563	9569	28419	8739	1.44
T_7 - MSM+0.2%surf	2	12755	6825	19580	16406	9016	25422	5842	1.30
T_8 - Pretilachlor 30.7 EC	500	12505	6825	19330	16438	9163	25601	6271	1.32
T_9 - Untreated Control	-	12000	6825	18825	13031	8239	20770	2445	1.13

4.2 Influence of herbicides on soil environment

4.2.1 Microbial population in rhizosphere soil of transplanted paddy

4.2.1.1 Total bacteria

Data presented in the Table 4.89 indicated that the PoE application of Azim at 14 DAT as sole (40 and 35 g a.i. ha^{-1}) or in combination from (Azim+ MSM @ 40+2 or 35+2 g a.i. ha^{-1}) with and without surf and PE application of Pretilachlor showed initial depression of total bacteria population up to 15 DAA over weedy check (48.33 x 10^5 CFU), but a rapid increase was noticed after 3rd week. Mean data from the table stated that among all the treatments and comparing with the untreated control (T_2), Application of MSM @ 2 g a.i. ha^{-1} recorded more inhibitory effect on the population of total bacteria. All the herbicides showed significantly higher total bacteria population at 60 DAA in the rhizosphere of the soil (0-5 cm) over to control plot (45.92 x 10^5 CFU).

4.2.1.2 Actinomycetes

All the chemicals applied in this experiment imposed a marginal depression of the population of actinomycetes up to 15 DAA (4.90) and a continuous rise was revealed up to 45 DAA, but there after a gradual decline in the population was noticed irrespective of herbicides used in this experiment. However, comparing with weedy check, all the tested and standard herbicide registered higher value after 30 DAA to up to 60 DAA. The mean data at 30, 45 and 60 DAA for both of the year showed that irrespective of date of observation application of Azim @ 40 g a.i. ha^{-1} recorded maximum population (39.84, 59.17 and 51.34 x 10^5 CFU) and the minimum was from MSM (24.67 , 15.25, 10.42, x 10^5 CFU) respectively. The corresponding values in weedy check were, 16.42, 10.67 and 16.13 x 10^5 CFU.

4.2.1.3 Fungi

At 5 DAA, all the herbicidal treatments recorded conspicuous decline in fungi population (Table 4.91) over weedy check (21.17 x 10^5 CFU) and the depression was most prominent with MSM up to 5 DAA (16.16 x 10^5 CFU). But this suppression of fungi population was recovered distinctly within 15 DAA and thereafter the population of fungi was increased with a increasing rate excepting the standard Pretilachlor (26.92 x 10^5 CFU) and MSM (32.99 x 10^5 CFU).

Table 4.89 Population of total bacteria (CFU X 10 ^{5}) in the rhizosphere soil of transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	Days After Application (DAA)														
		5			15			30			45			60		
		2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
T_1 - Azim +MSM+0.2%surf	35+2	21.00	24.69	22.85	31.86	35.45	33.66	43.54	45.21	44.38	63.70	66.20	64.95	96.56	100.00	98.28
T_2 - Azim + MSM+0.2%surf	40+2	23.56	27.99	25.78	34.50	40.27	37.39	47.68	49.65	48.67	68.97	70.24	69.61	100.21	106.78	103.50
T_3 - Azim +MSM	35+2	15.00	17.42	16.21	21.35	26.00	23.68	42.85	45.22	44.04	51.53	56.37	53.95	86.58	95.34	90.96
T_4 - Azim +MSM	40+2	17.53	20.60	19.07	24.38	28.54	26.46	44.00	46.74	45.87	56.32	60.40	58.36	90.50	93.25	91.88
T_5 - Azim +0.2%surf	35	19.37	23.64	21.51	27.66	34.69	31.18	40.00	43.42	41.71	59.74	63.33	61.54	95.71	99.00	97.36
T_6 - Azim + 0.2%surf	40	21.50	25.89	23.70	29.64	38.00	33.82	43.85	46.00	44.93	62.44	64.00	63.22	99.32	102.55	100.94
T_7 - MSM+0.2%surf	2	16.70	20.67	18.69	21.35	25.49	23.42	34.52	37.61	36.07	49.66	54.63	52.15	76.49	89.45	82.97
T_8 - Pretilachlor 30.7 EC	500	22.00	28.33	25.17	28.50	34.50	31.50	41.33	46.50	43.92	63.50	67.50	65.50	89.50	96.57	93.04
T_9 - Untreated Control		35.33	41.50	38.42	45.33	51.33	48.33	39.00	41.33	40.17	42.00	48.50	45.25	40.33	51.50	45.92
Mean		21.33	25.64	22.85	29.40	34.92	33.66	42.97	45.30	43.38	56.65	61.35	59.39	86.13	92.72	98.28

Sources	CD at 1 % level		SEm (±)	
	2006	2007	2006	2007
Treatments (T)	1.450	1.514	0.351	0.367
Days (d)	1.962	2.044	0.454	0.473
Treatments x Days (T x d)	3.113	3.218	0.804	0.831

Table 4.90 Population of actinomycetes (CFU X 10^5) in the rhizosphere soil of transplanted paddy

Treatment	Dose (g a.i. ha^{-1})	Days After Application (DAA)														
		5			15			30			45			60		
		2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
T_1 - Azim +MSM+0.2%surf	35+2	10.50	12.00	11.25	16.32	18.33	17.33	30.50	33.56	32.03	49.99	54.33	52.16	38.33	40.22	39.28
T_2 - Azim +MSM+0.2%surf	40+2	11.37	13.25	12.31	18.94	20.33	19.64	37.50	40.25	38.88	56.00	59.70	57.85	41.20	45.12	43.16
T_3 - Azim +MSM	35+2	9.65	11.50	10.58	15.00	17.55	16.28	22.33	26.33	24.33	38.00	41.65	39.83	32.33	34.75	33.54
T_4 - Azim +MSM	40+2	7.00	10.33	8.67	16.80	17.89	17.35	26.44	28.00	27.22	43.55	45.00	44.28	35.50	36.50	36.00
T_5 - Azim +0.2%surf	35	10.69	11.40	11.05	18.56	20.33	19.45	34.66	37.45	36.06	53.22	56.89	55.06	48.00	49.64	48.82
T_6 - Azim +0.2%surf	40	12.30	14.55	13.43	20.50	22.40	21.45	39.45	40.22	39.84	58.33	60.00	59.17	50.30	52.37	51.34
T_7 - MSM+0.2%surf	2	5.33	7.22	6.28	10.80	12.39	11.60	16.67	20.55	18.61	28.55	31.70	30.13	15.33	16.00	15.67
T_8 - Pretilachlor 30.7 EC	500	10.00	12.50	11.25	18.33	20.50	19.42	24.00	25.33	24.67	15.50	15.00	15.25	9.33	11.50	10.42
T_9 - Untreated Control		13.25	14.75	14.00	21.33	23.75	22.54	15.50	17.33	16.42	9.00	12.33	10.67	15.75	16.50	16.13
Mean		10.01	11.94	10.98	17.40	19.27	18.34	27.56	30.22	28.89	39.02	42.07	40.55	30.67	32.51	41.59

Sources	CD at 1 % level		SEm (±)	
	2006	2007	2006	2007
Treatments (T)	2.257	2.366	0.547	0.573
Days (d)	3.053	3.191	0.707	0.739
Treatments x Days (T x d)	3.673	4.588	0.948	1.185

Table 4.91 Population of total fungi (CFU X10 ^{4}) in the rhizosphere soil of transplanted paddy

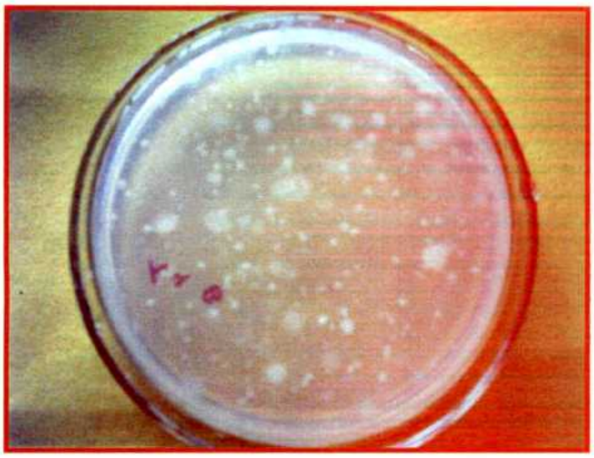
Treatment	Dose (g a.i. ha^{-1})	Days After Application (DAA)														
		5			15			30			45			60		
		2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
T_1 - Azim +MSM+0.2%surf	35+2	18.99	21.38	20.19	35.56	37.60	36.58	58.55	60.22	59.39	88.33	90.33	89.33	123.66	126.33	125.00
T_2 - Azim +MSM+0.2%surf	40+2	19.53	22.50	21.02	37.56	40.55	39.06	63.33	64.88	64.11	94.33	96.44	95.39	130.74	134.74	132.74
T_3 - Azim +MSM	35+2	16.55	19.58	18.07	28.99	30.76	29.88	49.74	51.00	50.37	75.66	77.00	76.33	95.66	97.60	96.63
T_4 - Azim +MSM	40+2	18.00	20.76	19.38	32.00	35.69	33.85	55.44	56.70	56.07	80.50	82.50	81.50	106.33	108.00	107.17
T_5 - Azim +0.2%surf	35	20.33	22.50	21.42	34.56	37.56	36.06	57.60	60.22	58.91	83.55	85.33	84.44	110.33	115.30	112.82
T_6 - Azim +0.2%surf	40	21.56	23.40	22.48	37.44	40.00	38.72	60.25	61.38	60.82	85.00	87.00	86.00	115.70	120.88	118.29
T_7 - MSM+0.2%surf	2	15.33	16.98	16.16	30.74	35.23	32.99	54.88	57.33	56.11	60.00	63.33	61.67	55.33	53.33	54.33
T_8 - Pretilachlor 30.7 EC	500	19.33	21.50	20.42	26.50	27.33	26.92	29.50	32.00	30.75	46.50	48.50	47.50	35.50	36.33	35.92
T_9 - Untreated Control		20.00	22.33	21.17	25.33	30.00	27.67	18.33	24.00	21.17	24.33	25.00	24.67	19.55	21.50	20.53
Mean		19.74	22.10	20.92	32.85	34.97	33.91	49.74	51.97	50.86	70.91	72.83	71.87	88.09	90.45	89.27

Sources	CD at 1 % level		SEm (±)	
	2006	2007	2006	2007
Treatments (T)	6.658	4.725	1.612	1.144
Days (d)	7.831	6.379	1.813	1.477
Treatments x Days (T x d)	9.344	7.675	2.413	1.982

Table 4.92 Urease enzyme activity (µg NH_4^{-N} g^{-1} dry soil 2 h^{-1} at 37^0 C) in the rhizosphere soil of transplanted paddy

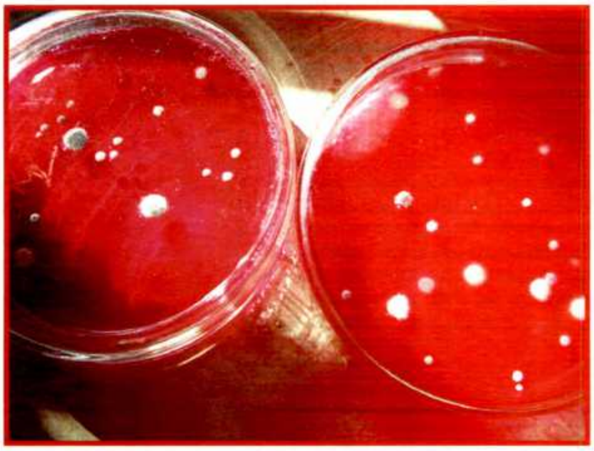
Treatment	Dose (g a.i. ha^{-1})	Days After Application (DAA)								
		15			30			45		
		2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
T_1 - Azim +MSM+0.2%surf	35+2	36.15	39.89	38.02	46.31	47.52	46.92	40.76	41.52	41.14
T_2 - Azim +MSM+0.2%surf	40+2	37.23	43.02	40.13	47.81	48.84	48.33	42.66	44.23	43.45
T_3 - Azim +MSM	35+2	29.73	33.84	31.79	39.11	40.13	39.62	34.42	35.06	34.74
T_4 - Azim +MSM	40+2	34.77	36.33	35.55	40.37	41.25	40.81	36.02	37.35	36.69
T_5 - Azim +0.2%surf	35	37.75	38.00	37.88	58.56	59.37	58.97	49.42	49.97	49.70
T_6 - Azim +0.2%surf	40	39.63	40.50	40.07	60.45	60.89	60.67	50.73	54.12	52.43
T_7 - MSM+0.2%surf	2	24.37	26.48	24.55	30.00	32.37	31.01	33.22	34.00	33.51
T_8 - Pretilachlor 30.7 EC	500	30.86	36.45	33.66	45.30	46.39	45.85	38.55	38.22	38.39
T_9 - Untreated Control	-	33.20	33.68	33.44	32.15	36.53	34.34	33.02	35.26	34.14
Mean		33.74	36.47	35.01	44.45	45.92	45.17	39.87	41.08	40.47

Sources	CD at 1 % level		SEm (±)	
	2006	2007	2006	2007
Treatments (T)	3.5230	2.0591	1.133	0.662
Days (d)	5.2836	3.0882	1.699	0.993
Treatments x Days (T x d)	3.0509	1.7830	0.981	0.573

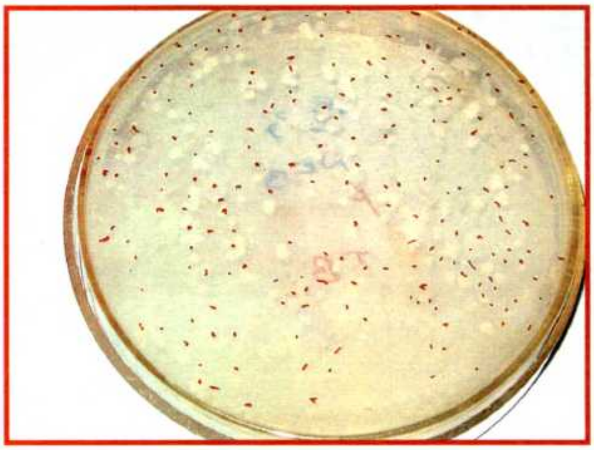


Actinomycetes with Azim 40 + MSM 2

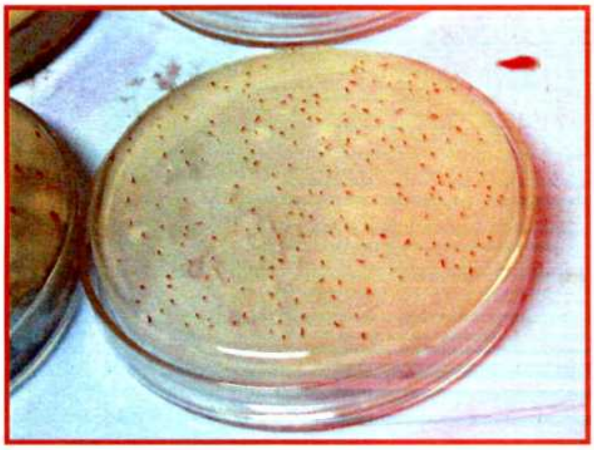
Fungi with Azim 40 + MSM 2 + 0.2% surf



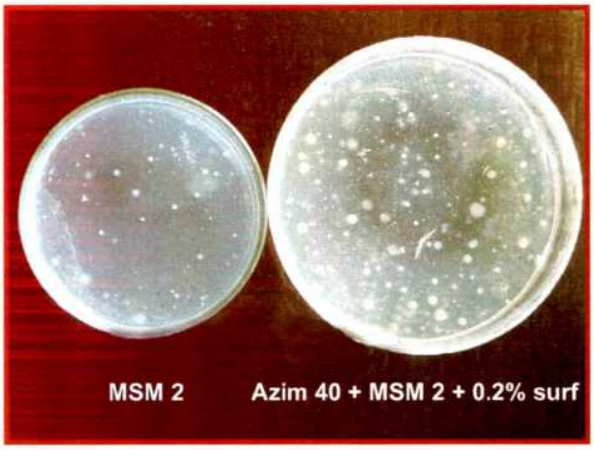
Fungi with Azim 40 + MSM 2



Total Bacteria with Azim 35 + 0.2% surf



Total Bacteria with Azim 40 + 0.2% surf



Actinomycetes

Plate 9 Effect of herbicides on soil microflora of transplanted paddy

In this case also the untreated showed lower population of fungi in comparison to the others at the later crop growth stage. At 60 DAA the minimum population of fungi (20.53 x 10^5 CFU) recorded from control whereas the highest population (132.74 x 10^5 CFU) was obtained from Azim + MSM @ 40 g a.i. ha^{-1} along with surf.

4.2.2 Urease enzyme activity in rhizosphere soil of transplanted paddy

The data related to urease enzyme activity in soil during the experimentation was prsesnted in Table 4.92. Through out the growing period of observation was taken only) the uraese activity was decreased with MSM viz. 24.55, 31.01 and 33.55 µg NH_4^{-N} g^{-1} dry soil at 15, 30 and 45 DAA, respectively over to control (31.79, 34.34 and 34.14 µg NH_4^{-N} g^{-1} dry soil). Application of Azimsulfuron as sole or in combination with MSM with or with surf recorded significantly better urease activity than that of the standard Pretilachlor and untreated control plot. Among the all herbicides Azim as sole showed better performances in urease activity even more from its combination dose.

4.2.3 Correlation between microbial population and Urease enzyme

The relation between the soil microbial population (Total bacteria, actinomycetes and fungi) and the urease enzyme activity in soil rhizosphere of transplanted paddy are presented in the Table 4.93. It is very clear from the data presented in the table that all kind of soil microflora (Total bacteria, actinomycetes and fungi) has a positive relationship with the activity of urease enzyme. But among these three only the total bacterial populations have a significant positive correlation with soil urease activity.

Table 4.93 Correlation between microbial population and Urease enzyme

	Microflora versus urease activity		
	15DAA	30DAA	45DAA
Total Bacteria	0.686*	0.759**	0.685*
Actinomycetes	0.296NS	0.294NS	0.526NS
Fungi	0.594NS	0.330NS	0.487NS

*Significant at 0.05 probability level

** Significant at 0.01 probability level

NS Positive but not significant

4.3Biology of some important weeds

The weed biology studies of *Echinochloa crus-galli* and *Cyperus rotundus* was undertaken during the *Kharif* month of 2006 & 2007 and the results regarding the morphological characters and biology was presented in Table 4.94-4.97.

4.3.1 *Echinochloa crus-galli*

Table 4.94 Morphology of *Echinocihloa crus-galli*

Latin name	:	*Echinochloa crus-galli* (L.) P. Beauv
Family	:	Poaceae (Gramineae)
Common name	:	Common barnyardgrass, Shyama ghash
Synonyms	:	*Panicum crus-galli* L. (basionym) *Milium crus-galli* (L.) Moench, *Pennisetum crus-galli* (L.) Baung
Habitat		This weed is mainly found in the low land rice field. The weed prefers wet soils and can continue to grow when partially submerged. *E crusgalli* is normally found only at low and medium altitudes. It is a common weed in swamps and aquatic places.
Morphology	:	**Plant height:** The plant is an annual, erect and height is around 94-118 cm. **Stem:** Rooting at lower nodes, cylindrical, without hairs, and filled with white spongy pith. **Leaf:** leaves are shiny green in colour & linear with a broad round base and narrow top; blade 10 to 40 cm long, no ligules are found. **Inflorescence:** light green to purplish in colour, 10-25cm long, spikelet more or less pointed, usually slightly hairy; awns are green to purplish and 2.5 to 4.0 mm in length.
Propagation	:	Propagates by seed. It can produce seeds within 60 days.

Echinochloa **infested paddy field**

Seed of ***Echinochloa crus-galli***

Cyperus rotundus **infestation**

Single plant of ***Cyperus rotundus***

Cyperus rotundus **nut**

Plate 10 Biology of major associated weeds (Echinochloa crus-galli and Cyperus rotundus)

Table 4.95 Biology of *Echinochloa crus-galli*

Parameters		2007	2008	Mean
Time of sowing	:	01.07.2007	01.07.2008	-
Time of emergence	:	8 DAS	10 DAS	9 DAS
Time of flowering	:	48 DAS	44 DAS	46 DAS
Time of maturity	:	83 DAS	85 DAS	84 DAS
Number of seeds plant^{-1}	:	1225	1340	1282.5
Dormancy	:	up to 9 DAS	up to 11 DAS	up to 10 DAS
Maximum roots at length maturity	:	28.4 cm	27.66 cm	28.03 cm
Plant height	:	94 cm	118 cm	106 cm
DMA plant^{-1}	:			
At 30 DAS		0.80 g	0.92 g	0.86 g
At 60 DAS		2.43 g	2.54 g	2.48 g
At maturity		4.25 g	4.37 g	4.31 g
000' Seed weight	:	2.20 g	2.05 g	2.13 g

4.3.2 *Cyperus rotundus*

Table 4.96 Morphology of *Cyperus rotundus*

Latin name : *Cyperus rotundus* L.

Family : Poaceae (Cyperaceae)

Common name : Purple Nutsedge, Hognut, Java grass, Nutgrass sedge, Red grass, Water grass

Habitat : This nut sedge generally occurs in disturbed habitats, but can tolerate a wide range of soil types.

Morphology **Plant height:** The plant is a perennial and height is around 20-49 cm and occasionally to 70 cm.

Stem: The erect, simple culms are smooth, solid and triangularin cross section.

Leaf: The leaves of *Cyperus* originate from the base of the plant. They are linear with sharp tips. The length of the leaf is as long as stem and some time much shorter than stem and are usually 2- 5 mm in width. The leaves are smooth, shiny to dark green in colour and having purple colour in the top few layers of leaves at the leaf base.

Inflorescence: The red to purplish brown spikelets are up to 3.5 cm long and 2 mm wide and are clustered at the ends of the stalks. Each spikelet is made up of from 10-40 individual flowers.

Roots: It has a fibrous root system which is extensively branched. The plant spreads by means of slender rhizomes.

Tubers: The tubers are formed at the apical ends of indeterminate rhizomes. The tubers generally produce about one to three sprouts which grow toward the soil surface and form a primary basal bulb just below the surface. Each primary basal bulb produces a vegetative plant. Tuber initiation occurs at 6 to 8 weeks after foliar emergence.

Propagation : Most of the success of this troublesome weed is due to its ability to survive and reproduce from tubers during adverse conditions. The plants also reproduce by seeds but this is negligible since seed germination seldom averages more than 1-5%.

Table 4.97 Biology of *Cyperus rotundus*

Parameters		2007	2008	Mean
Time of planting	:	01.07.2007	01.07.2008	-
Time of emergence	:	12 DAP	16 DAP	14 DAP
Time of flowering	:	42 DAP	47 DAP	45 DAP
Time of maturity	:	74 DAP	83 DAP	78.5
Dormancy	:	up to 8DAP	up to 10 DAP	9 DAP
of Maximum root length at maturity	:	13.7 cm	17.6 cm	15.65 cm
Plant height at maturity	:	37.99 cm	48.55 cm	43.27 cm
Dry matter accumulation plant^{-1}	:	At 30 DAS :0.43 g	0.32 g	0.37 g
		At 60 DAS :1.16 g	1.24 g	1.20 g
		At maturity : 3.56 g	2.98 g	3.27 g
Average nut weight	:	0.37 g	0.42 g	0.39 g

4.3.3 Oil content in *Cyperus rotundus*

The oil content of the nut of *Cyperus rotundus* was estimated by adopting Soxhlet Ether Extraction Method (Sadasivam and Manickam, 1996) and it was found that it content 1.5 % oil in its nut.

4.4 Experiment 4 Management of *Cyperus rotundus* during *pre-kharif* season

4.4.1 Density and Biomass of *Cyperus rotundus*

Different weed management treatments significantly influenced the s population and biomass of *C. rotundu* during both the year of experimentation (Table 4.98- 4.99).

Physical method of control (Hand pulling)

Among the different weed management practices hand pulling twice at 15 & 30 days after emergence (DAE) of *C. rotundus* is very much effective for controlling it. The pooled data (Table 4.98) revealed that at 40 DAA (10 days after second hand pulling) the population of C. *rotundus* reduces to 10.86 to control (35.91) but at 60 DAA (30 days after second hand pulling) no significant variation was observed between hand pulling (44.47) and control (58.03).

As like the population same trend was observed in biomass of C. *rotundus*. Table 4.99 recorded significantly lower dry weight of it and at 20 (3.57 g m^{-2}) and 40 DAA (7.56 g m^{-2}) over to control (10.32 and 18.29 g m^{-2}) respectively .

Ecological method of control

Soil solarization with fair coloured 0.05cm polyethylene sheet also become effective at the initial stage during the pre-kharif season. It is evident from pooled data that at 20 DAA the C. *rotundus* population was reduced to 18.15 over to control (35.91) but at 40 DAA the population was increased up to 32.43 and 53.86 at 60 DAA (Table 4.98).

It is evident from pooled data (Table 4.99) soil solarization can reduces the biomass of C. *rotundus* population to 5.83 g m^{-2} over to control (10.32 g m^{-2}) at 20 DAA . At the later stages this value was increased to the extent of 21.42 g m^{-2} at 60 DAA.


Extract of *Calotropis gigantea*


Extract of *Parthenium hysterophorus*


Extract of *Pistia stratiotes*

Plate 12 Biological management of *Cyperus rotundus*

Biological method of control

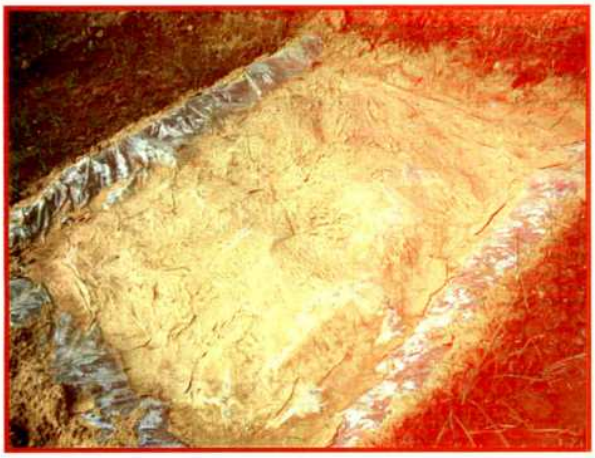
Among the different biological method for controlling *C. rotundus*, application of *Calotropis gigantea* extract @ 10 ml l^{-1} of water was (15.08) at 20 DAA which is significantly superior than the treatment where the extract of *Parthenium hysterophorus* (20.89) and *Pistia stratiotes* (30.47) were used for controlling this pernicious weed. But thereafter this difference was reduced and the population of *C. rotundus* became closer to 40 DAA and at par at 60 DAA with the untreated control (T_1).

Extracts of *Calotropis gigantea* @ 10 ml l^{-1} of water at 20 DAA recorded minimum weed dry weight (6.16 g m^{-2}) among the biological treatment followed by that of *Parthenium hysterophorus* (7.99 g m^{-2}) and *Pistia stratiotes* (8.25 g m^{-2}) and the maximum was observed from untreated control plot (10.32 g m^{-2}).

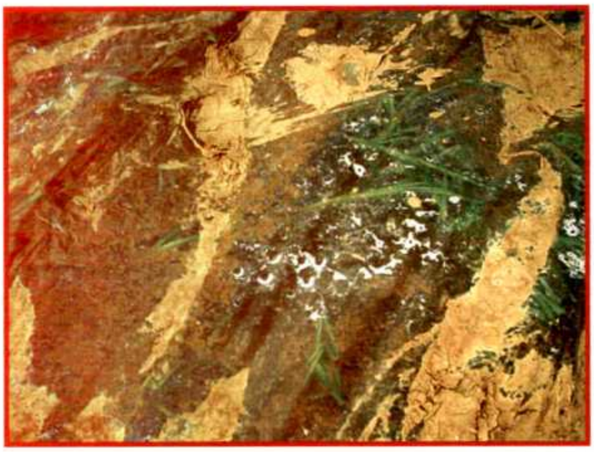
Chemical method of control

It is evident from the Table 4.98 that among the different herbicides used in this experiment, XL-COMBI-SG (35 % ammonium salt of Glyphosate+ 35% of 2,4-D ammonium salt) @ 5 g l^{-1} registered the minimum population (5.38) of *C. rotundus* which was closely followed by T_8 i.e. Glyphosate 41 % SL @ 10 ml (7.03) and T_{11}, application of Azim 50 DF + MSM + 0.2 % surf @ 40 + 2 g a.i. ha^{-1} (8.26) at 20 DAA. Azim + 0.2 % surf also alone can control significantly up to 40 DAA (8.94).Among the herbicides Almix (T_{10}) showed lower efficacy and recorded 30.94 no. of weeds m^{-2}. Untreated control plot recorded the maximum population of C. *rotundus* at all the dates of observation. Throughout the period of experimentation application of XL-COMBI-SG recorded the maximum control of C. *rotundus* than all other treatments used.

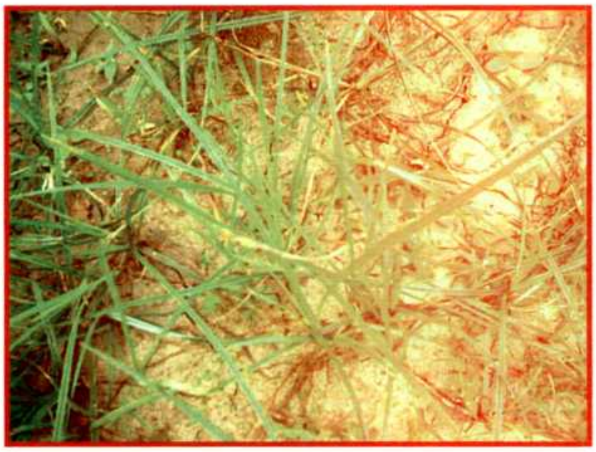
The data regarding the biomass of *C. rotundus* presented in Table 4.98. Here also XL-COMBI-SG @ 5 g l^{-1} recorded minimum dry weight in all the dates of observation (1.50, 0.49 and 2.59 g m $^{-2}$ respectively) which was closely followed by T_8 (Glyphosate 41 % SL @ 10 ml l^{-1}) and T_{11} (Azim 40 + MSM 2 + 0.2 % surf). Combine application of Azim and MSM alongwith surf can reduce weed dry weight very effectively (2.58, 2.94 and 9.18 at 20, 40 and 60 DAA respectively). Untreated control plot recorded maximum weed biomass in all the dates of observation. At 60 DAA XL-COMBI-SG, Glyphosate 41 % SL and Azimsulfuron 50 DF + MSM 20 WG + 0.2 % surf recorded 2.59, 3.25 and 9.18 g m^{-2} respectively which is significantly better than untreated control (19.58 g m^{-2}).



Soil solarization at 10 DAA

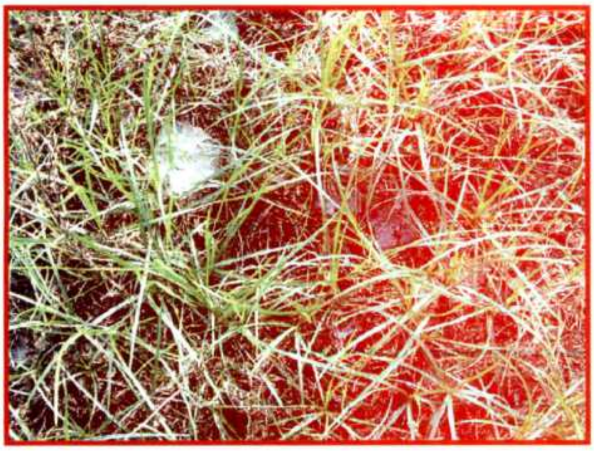


Soil solarization at 60 DAA



Azim @ 40 g a.i. ha^{-1}+ 0.2% surf

Azim + MSM @ 40 + 2 g a.i. ha^{-1} + 0.2% surf



Glyphosate @ 10 ml l^{-1} of water

XL COMBI @ 5 g l^{-1} of water

Plate 13 Management of *Cyperus rotundus* through ecological and chemical means

Table 4.98 Density (no. m $^{-2}$) of *Cyperus rotundus*

Treatment	Dose (ml l^{-1} water/ a.i. ha^{-1})	20 DAA			40 DAA			60 DAA		
		2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled
T1 - Untreated control	-	35.07	36.75	35.91	49.53	42.66	46.09	54.53	63.52	58.03
T_2 - Twice Hand pulling (15 & 30 DAE)	-	11.23	9.50	10.86	10.21	8.77	9.78	47.44	42.50	44.47
T_3 - Soil solarization	-	19.75	16.55	18.15	34.44	30.43	32.43	58.37	56.35	53.86
T_4 - Extracts of *Calotropis gigantea*	10 ml	16.66	14.50	15.08	32.23	28.70	30.75	43.39	47.44	40.25
T_5 - Extracts of *Parthenium hysterophorus*	10 ml	27.50	23.33	25.89	45.37	42.66	43.02	55.10	47.33	52.21
T_6 - Extracts of *Pistia stratiotes*	12 ml	30.22	31.26	30.74	47.99	46.23	47.11	59.92	54.67	57.29
T_7- XL-COMBI-SG (Glyphosate + 2,4-D)	5 g	5.43	5.33	5.38	2.33	2.00	2.16	7.67	6.33	5.50
T_8 - Glyphosate 41 % SL	10 ml	7.37	6.69	7.03	3.66	3.50	3.58	11.76	9.50	10.18
T_9 - Azimsulfuron 50 DF + 0.2 % surf	40 g	10.50	8.97	9.73	9.21	8.67	8.94	14.00	13.50	13.75
T_{10} - Almix (MSM + CME)	2 g	12.92	10.50	11.71	26.18	23.33	24.75	32.2	29.67	30.94
T_{11} - Azimsulfuron 50 DF + MSM 20 WG + 0.2 % surf	40 g + 2g	9.14	7.59	8.26	7.67	7.33	7.50	18.33	16.33	17.86
S.Em (±)		1.114	1.071	1.109	4.857	3.624	4.086	9.616	6.688	7.750
C.D. (P=0.05)		3.311	3.180	3.195	14.436	10.764	11.766	28.571	19.867	22.311

Table 4.99 Dry weight (g m $^{-2}$) of *Cyperus rotundus*

Treatment	Dose (ml l^{-1} water/ g a.i. ha^{-1})	20 DAA			40 DAA			60 DAA		
		2006	2007	Pooled	2006	2007	Pooled	2006	2007	Pooled
T1 - Untreated control	-	9.22	11.43	10.32	15.66	14.93	14.29	20.67	18.50	19.58
T_2 - Twice Hand pulling (15 & 30 DAE)	-	3.75	3.40	3.57	8.33	679	7.56	17.33	14.67	15.50
T_3 - Soil solarization	-	6.67	5.30	5.83	14.66	12.00	13.23	23.50	19.33	21.41
T_4 - Extracts of *Calotropis gigantea*	10 ml	6.33	6.00	6.16	10.89	8.67	9.78	15.08	19.66	17.15
T_5 - Extracts of *Parthenium hysterophorus*	10 ml	8.89	7.23	7.99	14.00	15.40	14.70	20.33	18.85	19.09
T_6 - Extracts of *Pistia stratiotes*	12 ml	7.23	10.42	8.25	15.67	17.43	16.55	20.00	17.45	18.72
T_7- XL-COMBI-SG (Glyphosate + 2,4-D)	5 g	1.67	1.33	1.50	0.56	0.42	0.49	2.63	2.57	2.59
T_8 - Glyphosate 41 % SL	10 ml	2.00	1.85	1.92	0.75	0.63	0.69	3.54	2.96	3.25
T_9 - Azimsulfuron 50 DF + 0.2 % surf	40 g	2.79	3.00	2.86	4.33	3.08	3.67	9.72	7.33	8.52
T_{10} - Almix (MSM + CME)	2 g	3.00	2.67	2.83	1.50	1.33	1.42	13.17	11.24	12.36
T_{11} - Azimsulfuron 50 DF + MSM 20 WG + 0.2 % surf	40 g+2g	2.66	2.50	2.58	3.33	2.56	2.94	10.69	8.67	9.18
S.Em (±)		0.474	0.368	0.388	0.879	0.793	0.742	2.317	2.675	2.268
C.D. (P=0.05)		1.406	1.094	1.115	2.605	2.357	2.134	6.885	7.947	6.530

CHAPTER V

Discussion

In this chapter an attempt has been made for a critical assessment of the result as presented chapter 4.

5.1 Experiment 1 Impact of treatments on weed status, growth and yield of paddy – zero tilled rapeseed cropping systems

5.1.1 Experiment 1 A Impact of treatments on weed status, growth and yield of transplanted paddy and follow up zero tilled rapeseed crop and economics

5.1.1.1 Weed status of transplanted paddy fields

The floristic composition of weed flora observed from the experimental field were *Echinochloa crusgalli, Echinochloa formosensis, Leersia hexendra, Paspalum conjugatum* , *Paspalum distichum* among the grasses, *Cyperus difformis, Cyperus iria ,Fimbristylis littoralis* among the sedge weeds and *Alternanthera philoxeroides, Eclipta alba, Marsilea quadrifolia, Ammania baccifera, Lemna minor, Ludwigia octovalvis, Stellaria media, Oldenlandia corymbosa, a*mong the most dominated broadleaf weeds. Similar kind of observation was made by Bhanurekha *et al.* (2002) at Rajendranagar, Hyderabad, Anadhakrishnan and Jaykumar (2003) and Singh *et al.* (2004).

The results of the weed density (Table 4.2-4.11), weed dry weight (Table 4.12-4.21), WCE (Table 4.22) and Fig.1-10, revealed that all the chemical weed management practices significantly decreased the number and dry weight of grass, sedge and broadleaf weeds over of unwedded control (T_9) during the entire season of crop growth. This may be due to the reason that the chemical herbicides used in this experiment are of sulfonyl urea group which has more activity, low toxicity and also environment safe in nature.

Among the different treatments used in the experiment, minimum weed density and biomass of all types of weed flora recorded by T_2 where Azim @ 40 g a.i. ha^{-1} was applied in combination with MSM @ 2 g a.i. ha^{-1} along with 0.2% surf recorded 75.97 % & 84.72 % lower weed population and 78.76 % & 88.86 % lower dry weight over to unweeded control, at 30 and 45 DAA, respectively (Fig. 11 & 12). This was because of combination of Azim with MSM had the capacity to control all

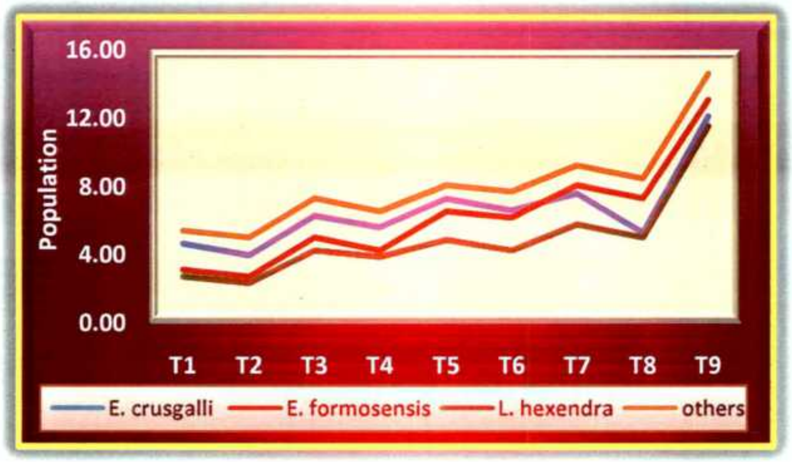


Fig. 1 Population of *grassy weeds* in transplanted paddy at 30 DAA

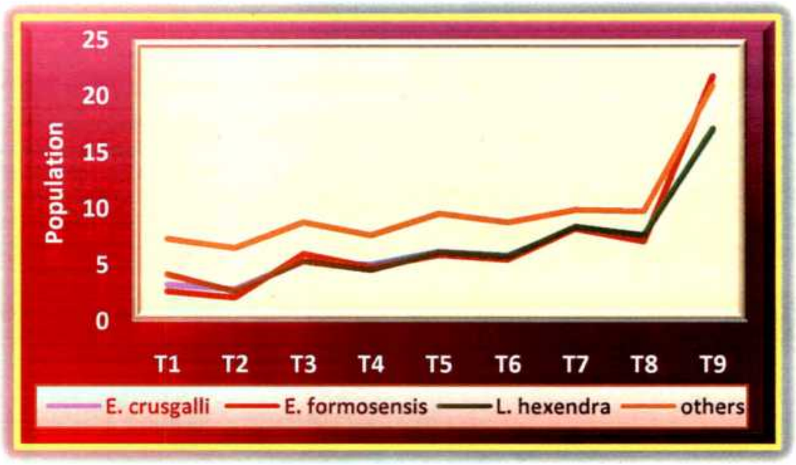


Fig. 2 Population of *grassy weeds* in transplanted paddy at 45DAA

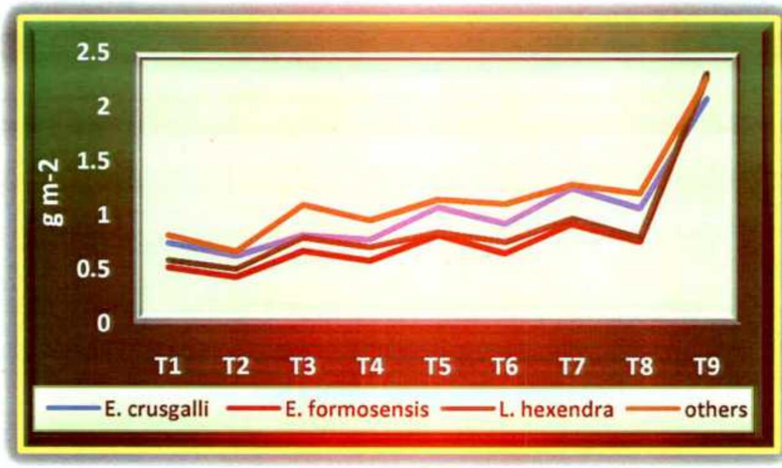


Fig. 3 Dry weight of *grassy weeds* in transplanted paddy at 30DAA

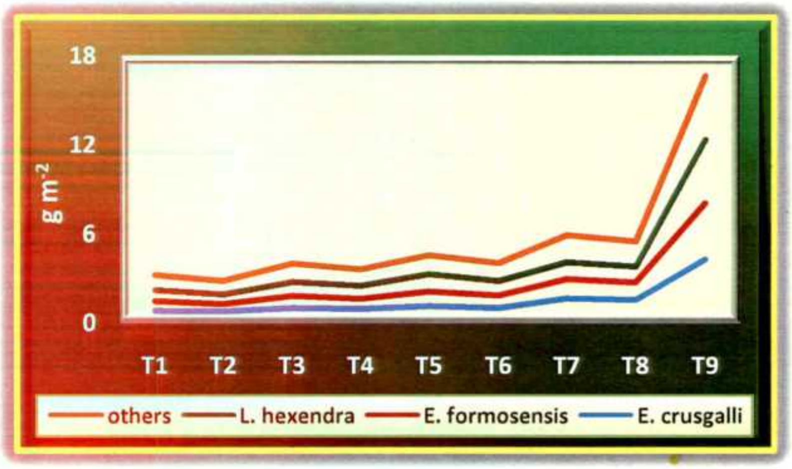


Fig. 4 Dry weight of *grassy weeds* in transplanted paddy at 45DAA

types of weed (grass + sedge + broadleaf). Similar result was opined by Fuentes and Ferrucho (2002).

T_2 also recorded 43.01% & 49.32 % less weed population and 39.72% & 43.39 % dry weight, at 30 and 45 DAA, respectively over T_6 where only Azim + 0.2 % surf were applied @ 40 g a.i. ha^{-1}. This may be due to that Azim (T_6) could able to control only the weed flora belonging to Poaceae (Gramineae & Cyperaceae) family and less effective against broadleaf unlike in T_2 where all types of weeds were controlled. Same kind of observation was also recorded by Chun *et al.* (1995). T_2 also showed 1.65 & 2.64 g m^{-2} less weed dry weight (Fig. 12) at both the dates of observation respectively than that of same combination dose without surf (T_4). This difference was due to the addition of surf enhances the foliar retention, penetration, absorption, and consequently translocation of these early post emergence herbicides and increases the weed controlling efficiency. This result confirmed the earlier findings of Sharma *et al.* (1989) and Ghosh *et al.* (2004) in when surf Active 80 was applied with atrazine in Maize. Azim + MSM +0.2 % surf @ 40 + 2 g a.i. ha^{-1} also gave 13.26 % & 15.86 % lower weed density (Fig. 12) over to its' lower dose of same combination (Azim + MSM +0.2 % surf @ 35 + 2 g a.i. ha^{-1}). This is because of presence of more active ingredient in higher dose (T_2) thereby active in controlling all types of weed flora. The standard herbicide Pretilachlor, an acetamide, was also able to control all the weeds but the annual weeds only & unable to control the perennial grassy weeds. Tomlin (1994) also expressed similar views.

The weed control efficiency (Table 4.22) also exhibited similar trend of variations showing the superiority of Azim 40+ MSM 2 + 0.2% surf (T_2) by exerting 79.08 % and 88.7 % at 30 and 45 DAA over control this was closely followed by T_1. The Sole Azim treatment (T_5 & T_6) recorded 65.42 % & 59.59 % WCE whereas the standard Pretilachlor recorded 58.99 % WCE at 30 DAA. The weed control efficiency data at different dates of observation indicated that all herbicides showed slightly higher WCE at 45 DAA in comparison to 30 DAA, probably due to lesser infestation of second flash of the weed flora because of the more persistency of the used sulfonyl urea herbicides in this experiment.

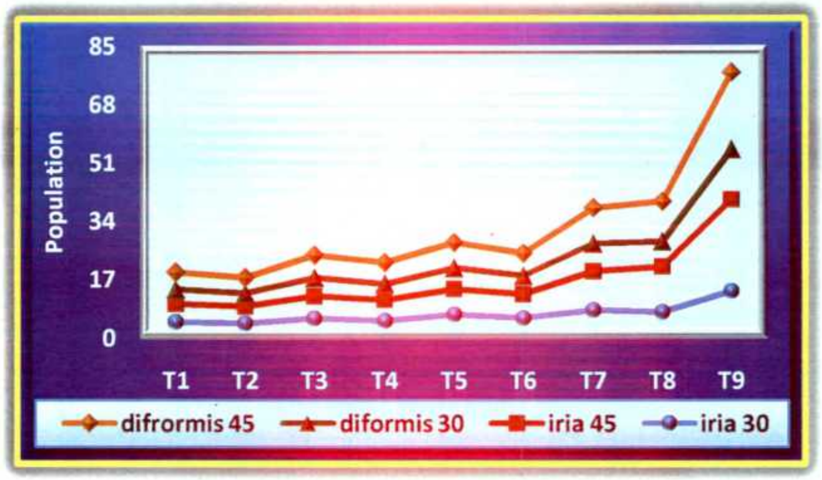
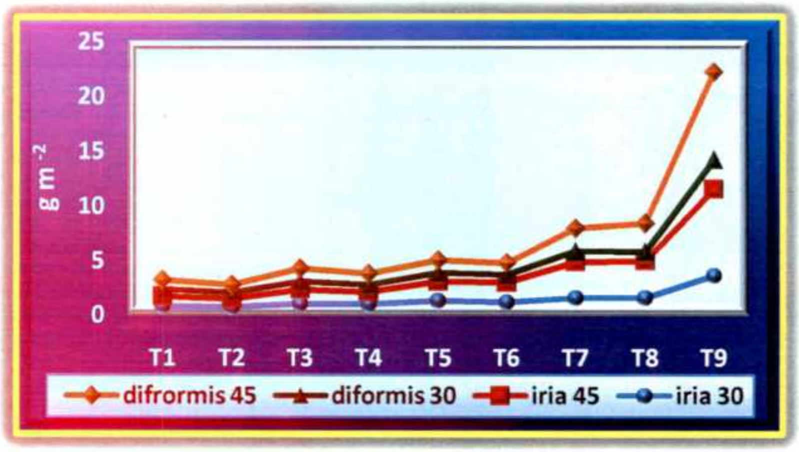


Fig. 5 Population of sedge *weeds* in transplanted paddy at 30 and 45DAA

Fig. 6 Dry weight of sedge *weeds* in transplanted paddy at 30 and 45DAA



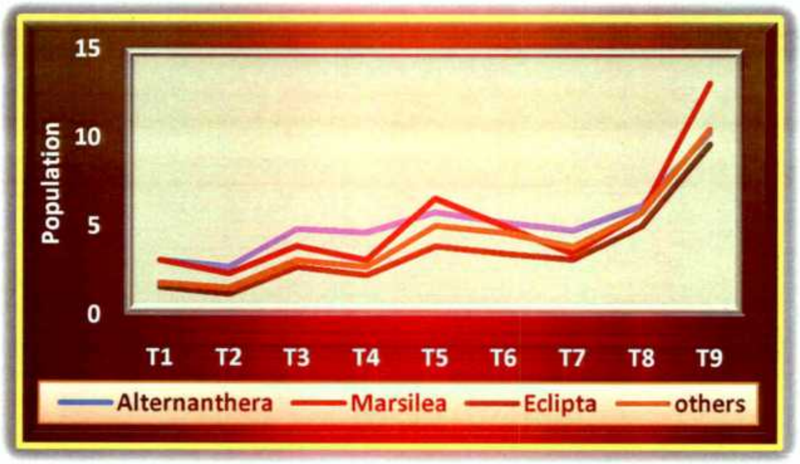
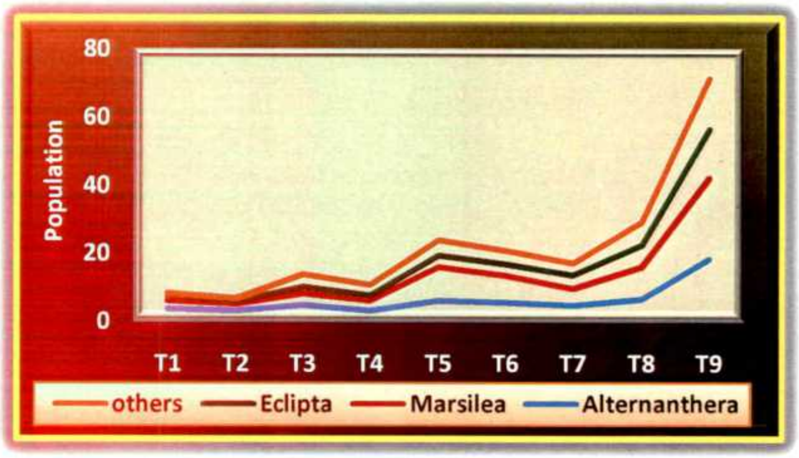


Fig. 7 Population of *BL weed* in transplanted paddy at 30 DAA

Fig. 8 Population of *BL weed* in transplanted paddy at 45 DAA



5.1.1.2 Growth and Yield components of transplanted paddy

Azim @ 40 g a.i.+ MSM @ 2 g a.i. + 0.2 % surf (T_2) recorded the maximum growth and yield attributing characters exhibiting 8.0 % more plant height at harvest, 36.1 % higher effective tillers m^{-2}, 2.71 cm more panicle length, 13.2 % higher filled grain panicle^{-1} and 7.3 % higher test weight over weedy check which is closely followed by T_1 i.e. Azim @ 35+ MSM @ 2 g a.i. + 0.2 % surf (Table 4.28 - 4.29 and Fig. 13). The corresponding figures with the same higher dose without surf were 5.8 %, 28.8 %, 2.5 cm, 9.1% and 5.7%. Over the sole Azim treatment T_2 also recorded 2.14 % more plant height at harvest, 7.15 % effective tillers m^{-2}, 2.78% higher panicle length, 5.55 % more filled grain panicle^{-1} and 2.66 % better test weight. This better results of Azim @ 40 g a.i. +MSM @ 2 g a.i. + 0.2 % surf may because of its' capacity to control the broad spectrum of weed (grass + sedge + broadleaf) and thus reduces the competition for resources to the crop with the weeds. Similar kind of controlling efficiency of herbicide mixture was reported by Taylor (2004) with Azim + MSM and by Shirakura (1997) with Azim + Bensulfuron methyl (BSM).

Treatment T_2 also showed superiority in exhibiting higher growth and yield attributes than that of the same combination of herbicides at same dose but without surf (T_4). Because additions of surf increase the weed control efficiency by increasing the efficacy of it and offered lower crop-weed competition which reflects on the higher growth and yield attributing characters Similarly Ghosh *et. al.* (2004) have also reported the influencing effects of surf applied with herbicide as tank mixture. All the herbicidal treatments recorded better results while untreated weedy check recorded poor performances of all growth and yield attributing parameters of transplanted paddy because of the existence of strong crop-weed competition due to allowing the weed plants to grow.

No phytotoxocity symptom regarding epinasty, hyponasty, leaf tip yellowing, surface injury, wilting and chlorotic or necrotic symptoms as well as stunting growth of the plant and all the crop plants looked healthy in the experimental field during both the years. This was might be due to the reason behind the selectivity of the paddy and rapeseed plants in ALS (Acetolactate synthase) enzymatic process of biosynthesis of branched chain amino acid inhibition mechanism and in case of

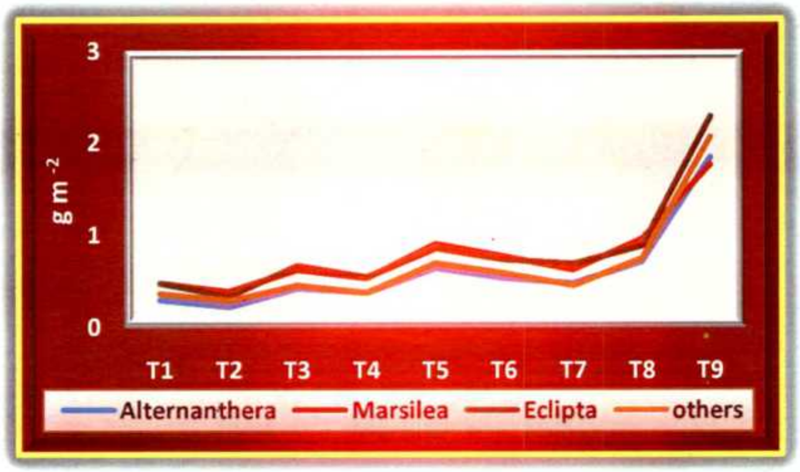
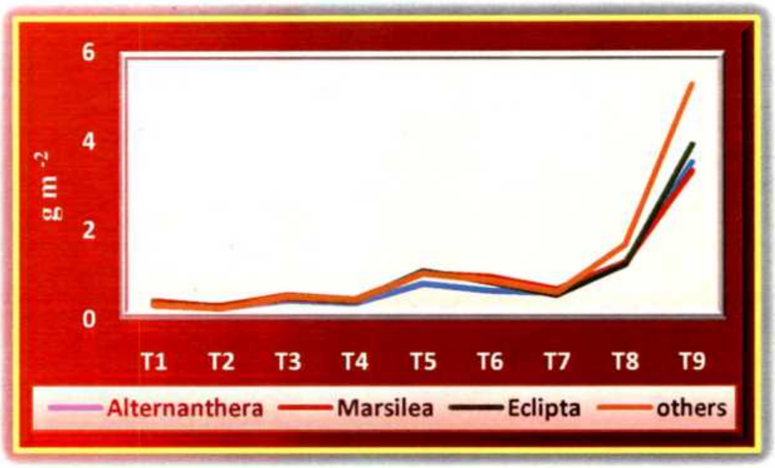


Fig. 9 Dry weight of *BL weed* in transplanted paddy at 30 DAA

Fig. 10 Dry weight of *BL weed* in transplanted paddy at 45 DAA



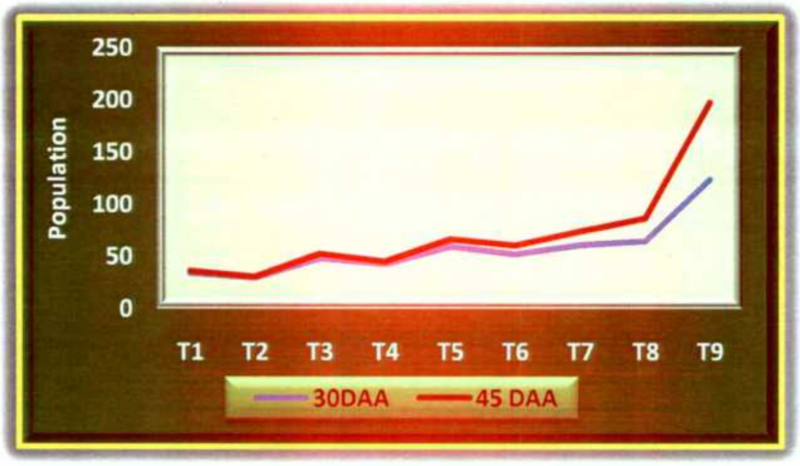
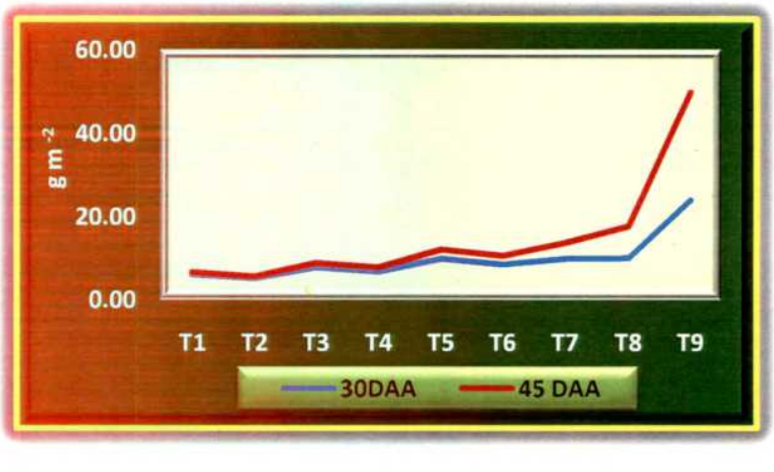


Fig. 11 Total weed population of Transplanted paddy

Fig. 12 Total weed dry weight of Transplanted paddy



Pretilachlor, an acetamide herbicide; this is in microtubule functions tubuline mechanism.

5.1.1.3 Grain and Straw yield of transplanted paddy

From the results (Table 4.29 and Fig. 14) it has been found that higher dose of Azim combining with MSM and surf recorded maximum grain yield (74.33 % over to control). The treatment showed 0.13 t ha^{-1} more grain yield than its' lower dose with same combination and thus is because of the more activity of higher dose than that of its lower dose. The treatment (T_1 & T_2) Azim with MSM @ 2 g a.i. ha^{-1} along with 0.2% surf also recorded 3.9 % and 3.1% higher grain yield over the treatments where only Azim and MSM combination was applied without the surf (T_3 & T_4). The result also showed that treatment T_5 and T_6 recorded 5.74 % & 7.65 % higher paddy grain yield where only Azim + 0.2 % surf was used @ 40 and 35 g a.i. ha^{-1}, respectively over the standard Pretilachlor.

The results presented inTable 4.29 and depicted in Fig. 12 indicated that the maximum straw yield in T_1 (52.78 % and 16.59 % higher than untreated control and the standard Pretilachlor respectively). Use of surf with Azim + MSM @ 40+2 g a.i. ha^{-1} recorded 6.0 % higher straw yield than the same without surf as the nature of surf chemicals is to increase the activity of herbicides. Treatments T_5 and T_6 recorded 27.15 % & 29.94 % more straw than control, respectively where only Azim was used along with surf but without combining with MSM because of same reason as mentioned in paddy grain yield.

The higher grain and straw yield of treatment Azim 40 + MSM 2 + 0.2 % surf over the others was mainly due to the reason that by minimizing the weed competition it could able to increase the growth and yield parameters particularly no. of effective tillers & no. of panicles $plant^{-1}$ of this paddy very effectively. In Azim + MSM without surf (T_3 & T_4) because of less activity due to absence surf competition from weed flora could only minimized and in only Azim treatment (T_5 &T_6) further lower minimisation was due to respectively control of only the grassy weeds effectively, thus competition from BL weeds were existing. Fuentes and Ferrucho (2002) and Ghosh *et al.* (2007) also expressed similar view. Devendra *et al.* (2005) also reported the activity of surf for increasing the efficiency of herbicide.

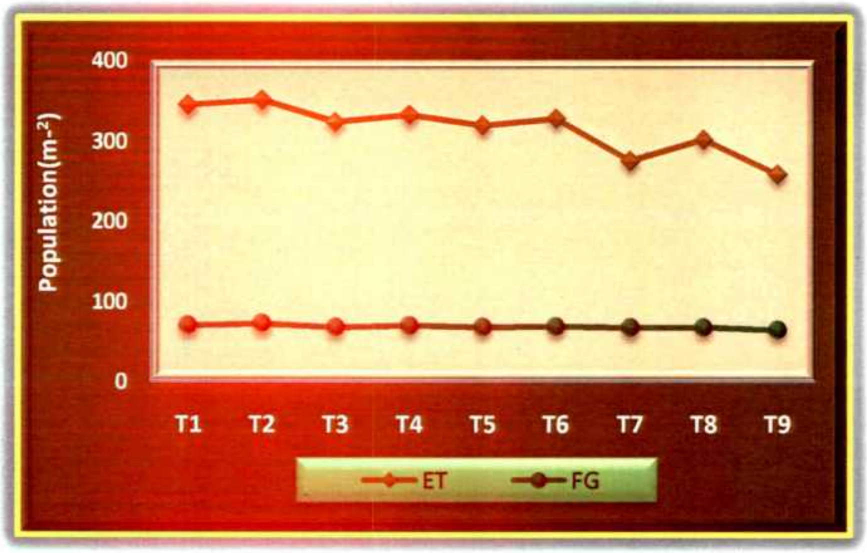


Fig. 13. Effective tiller (m^{-2}) and Field grain per panicle of transplanted paddy

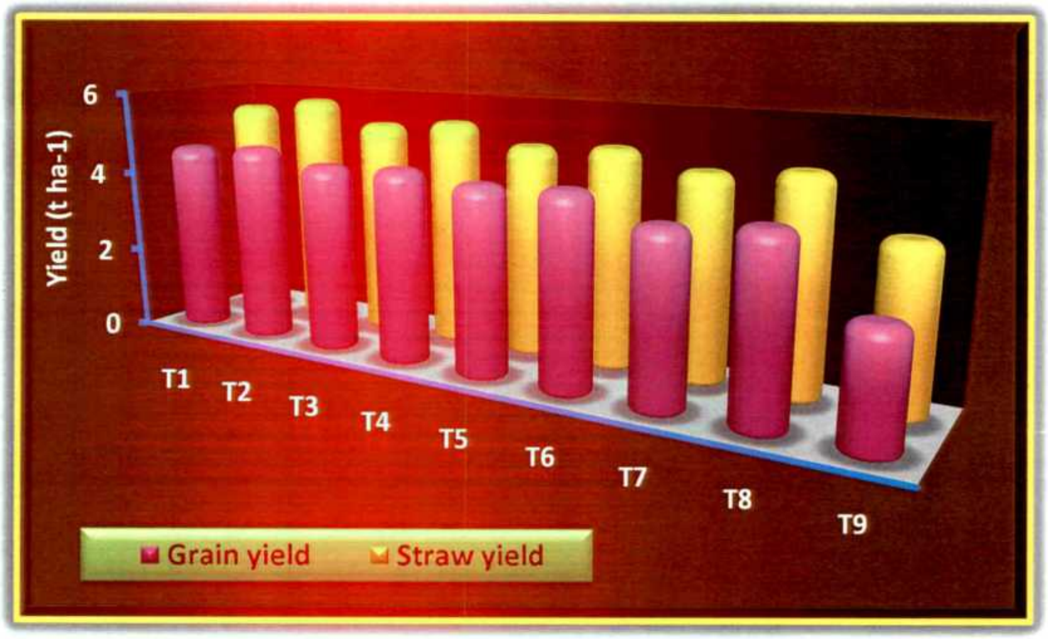


Fig. 14 Grain and Straw yield (t / ha) of transplanted paddy

Pretilachlor on the other hand recorded 58.33 % & 38.03 % more grain & straw yield, respectively over control but 0.58 % 0.82 t ha^{-1} less grain & straw yield respectively compared with T_2. This was because of the existence of the competition from the perennial weeds in Pretilachlor unlike that of T_2.

5.1.1.4 Economics of transplanted paddy cultivation

Any weed control method will be accepted by the farmers only when it becomes economically and environmentally sound. Therefore it needs to evaluate the treatment effects on weed control on the basis of economics is very much essential. Table 4.30 clearly indicates that among the different treatments Azim 40 + MSM 2 + 0.2 % Surf (T_2) gave the maximum net return (Rs 14,595.00) followed by T_4 (Rs 13745.00) and T_1 (Rs 13645.00). Whereas, the treatment T_9 (unweeded control) registered the lowest net return (Rs 2469.00). So far as the return per rupee invest is concerned, the highest value was by T_2 (1.96) which was 66.10 % higher than T_9 and this was Rs 1.18 followed by the treatment T_4 (1.92) and T_1 (1.90). From pooled data it was clear that use of Azim 40 + MSM 2 without surf recorded same return per rupee invested (Rs1.92) alongwith the sole application of Azim + 0.2 % surf @ 40 a.i. ha^{-1} . Similar kind of advantages of chemical weed management in transplanted paddy were reported by Nagaraju and Mohan Kumar (2005) and Kandasamy and Chinnuasamy (2005).

5.1.1.5 Weed status of follow-up rapeseed

The result presented in Table 4.32-4.39 and depicted in Fig. 15 and 16, indicated that there was a clear established initial suppression of total weed flora and decreased in density and biomass of total weed up to 10 DAS and thereafter no significant difference was visualized in follow up rapeseed among the different weed management practices applied to the preceding paddy plants. Initial suppression was might be due to the persistency activity but later at par was might be due emergence of the second flash of weed as the persistency activity of these chemical did not remain more than three weeks.

Pooled data of 2006 & 2007 revealed that adoption Azim + MSM+ 0.2 % surf @ 40 + 2 g a.i. ha^{-1} (T_2) to the earlier transplanted paddy recorded 60.40 % & 42.66

% lower weed population & weed dry weight over to treatment where no herbicides was used and 53.58% & 33.46 % over the standard Pretilachlor, respectively at 10 DAS of rapeseed. It also lowers the weed population and biomass to the tune of 42.88 % & 17.85 % over T_6 and 40.71 % & 25.35 % over T_7, respectively. Combination application of Azim + MSM @ 40+2 g a.i. ha^{-1} with surf reduced the weed population of 28.03 % than without surf and 14.82 % over the same combination having lower dose (T_1). MSM applied in TR paddy significantly reduced the population of BL weeds and showed appreciable lower population of 40.71 % over untreated plot (T_9).

Azim + MSM + 0.2 % surf could able to control the broad spectrum of weeds (grass + sedge + broadleaf) in situ condition in addition to inhibited the viable weed seeds present in the upper soil surface (0-15 cm) very effectively, and probably due to this reason the first flash emergence of weeds in the follow up crop showed lesser in number. The effectiveness of combination of Azim + MSM for controlling all categories of weeds was observed by Taylor (2004) and Shirakura *et al.* (1996). As observed sole Azim could able to control grassy weed flora belonging to family Poaceae (Gramineae & Cyperaceae) in situ but the non-inhibited maximum broadleaf weeds showed their supremacy in follow-up crop. MSM+0.2 % surf again only inhibited the broadleaf weeds both existing and under surfaced seeds in earlier crop but could not reduce the grassy weed population to the follow-up zero tilled rapeseed. Ineffectiveness of Azim to control broadleaf and MSM to control grassy weeds was also reported by Lee *et al.* (2001) and Singh and Bhan (1998). Again additions of surf also increase the effectiveness of herbicide Azim over without of it. Similar result was opined by Ghosh *et al.* (2005).

Further more, adoption of zero tillage management helps to reduce the population of different weeds. Because of shifting from conventional tillage system restricts soil alterations, which directly affects the weed seed bank in under surface rhizosphere soil by not allowing the weed seeds to emerge due to compactness of the upper soil layer. Similar kinds of observation were reported by Mishra *et al.* (2002) at National Research Centre for Weed Control (NRCWS), Singh *et al.*(2001) from Pantnagar in clay loam soil, also observed more weed emergence in conventional and reduced tillage than zero tillage system. Ghosh (2007) also reported observation working on rapeseed-soybean cropping sequence at West Bengal.

5.1.1.6 Growth and yield components of follow-up rapeseed

The growth and yield parameters of follow up zero-tilled rapeseed crop (Table 4.41- 4.42) clearly stated that though all the growth and yield parameters were not influenced with the application of herbicidal treatments in the previous crop excepting the application of Azim @ 40 g a.i. + MSM @ 2 g a.i. + 0.2 % surf (T_2). This treatment recorded the maximum growth and yield attributing characters exhibiting 5.17 cm more height of rapeseed plant at harvest, 10.67 % higher number of primary branch plant^{-1}, 7.16 % more number of siliqua plant $^{-1}$, 0.28 cm higher siliqua length, 9.41 % more seeds siliqua^{-1} and 4.28 % higher test weight over the plot where no chemical was used (T_9) and the corresponding figures with the same dose over the standard Pretilachlor applied to the same crop are 2.18 cm , 9.26 %, 5.05 %, 0.15 cm, 8.0 % and 1.7 %. Application of Azim + 0.2 % surf in *Kharif* transplanted paddy also influence on the yield parameters of follow-up rapeseed by exerting 6.4 % more number of primary branch plant^{-1} and 5.28 % more seeds siliqua^{-1} over to control but showed 3.95 % and 3.63% lower values of the same in compare with T_2.

Probably due to the same reason of lesser competition received by the rapeseed from the weeds by the treatment Azim @ 40 g a.i. +MSM @ 2 g a.i. + 0.2 % surf. The higher growth and yield parameters were observed in compare to all other treatments. Similar kind of controlling efficiency of herbicide mixture was reported by Taylor (2004). Lowest values from the untreated control plot were primarily due to the higher crop weed competition for resources. Growing of rapeseed as zero till also reduced the density of weeds, by suppressing the germination of weed seeds under surface soil favoured and therefore, the better growth of the crops. The results are in agreement with the findings of Teasdale and Mollar, (2000), Ahuja *et al.* in 2005 and Khan *et al,* (2005).

No phytotoxocity symptom was observed in the follow up rapeseed regarding germination and on the plant as the plant had the selectivity of rapeseed plants in ALS (Acetolactate synthase) enzymatic process of biosynthesis of branched chain amino acid inhibition mechanism.

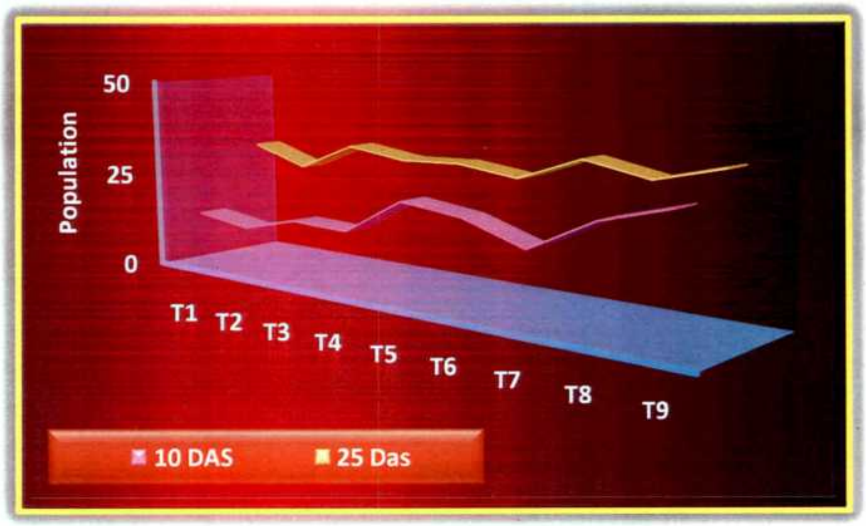


Fig. 15 Population of total weed flora of succeeding zero-till rapeseed

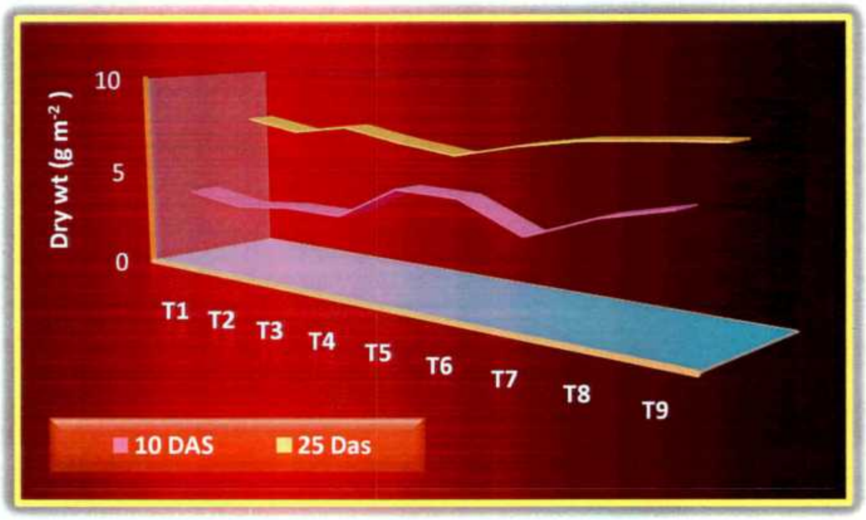


Fig. 16 Dry weight of total weed flora of succeeding zero-till rapeseed

Fig. 17 Seed and Stover yield (t / ha) of follow up zero-till rapeseed after TR paddy

5.1.1.7 Seed and Stover yield components of follow-up rapeseed

The seed and stover yield data as depicted in Fig.17 and Table 4.42 revealed that chemical weed management in the paddy crops also played a vital role in follow-up rapeseed yield. Treatment T_2 (Azim 40 + MSM 2 + 0.2 % surf) applied to preceding crop recorded 14.45 % & 13.46 % and10.46 % & 12.44 % higher seed and stover yield , respectively over untreated and Pretilachlor treated plot. Amongst the other treatment application of Azim @ 40 + 0.2 % surf also registered 10 % more each of seed and stover yield of each than the untreated control plot. T_2 used in paddy showed 0.015t ha^{-1} more rapeseed yield than that of its lower dose with same combination and this might be due to the more activity of higher dose than lower dose. The treatment (T_2) also recorded 2.4 % and 5.0% higher seed & stover yield over the treatments T_4 where no surf was used.

The higher seed and stover yield of Azim 40 + MSM 2 + 0.2 % surf over the others was might be due to the reason that this combination of herbicides could enhanced the target area of control by killing all categories of weeds viz. grass, sedge & broadleaves in soil situ of the experimental field and again addition of surf further enhanced the activity of this treatment while Azim could able to controll grassy weeds and MSM, could only the broadleaf weeds. Ghosh *et al.*(2007) also expressed similar view. This reduction of weed flora in situ condition irrespective of type of weed flora and the decrease the number of viable weed seeds in the upper soil surface (0-15 cm) very effectively and thus minimized in the follow up crop by creating fewer crops weed competitive environment.

Zero tillage management directly affects the weed seed bank by avoiding alteration of soil and in turn reducing the weed number and weed diversity as independent redistribution of seeds in the soil profile was also hampered and also prevent weed seed germination (Sullivan, 2003). Lower weed infestation with zero tilled system was also reported by Mohler and Galford (1997) and Mishra *et al.* (2002). Hence growing of rapeseed as follow up crop paddy through by this tillage management system with the help of conserved soil moisture might have regulated better proliferation of roots and crop establishment (Rathore *et al.* 1998)

5.1.1.8 Economics of follow up rapeseed

Table 4.43 recorded the maximum net return Re^{-1} investment was evolved from T_2 (1.56) which was 13.04 % & 9.85 % more than untreated control (T_9) and standard Pretilachlor (T_8), respectively. Application Azim @ 40 g a.i. ha^{-1} recorded Rs1.52 per rupee investment which is 10.14 % more than the plot where no herbicide was used in the previous crop for controlling weeds.

5.1.1.9 Economics of transplanted paddy – rapeseed crop sequence

Transplanted paddy followed by zero-till rapeseed crop sequence was found to be more remunerative and exhibited highest return per rupee investment (1.84) when Azim 40 + MSM 2 + 0.2 % surf were applied to the TR rice for controlling weeds which was 48.38 % higher over not treated control plot (Table 4.44). This treatment also established the superiority by achieving more return per rupee, 48.18% & 23.48 % over control and standard Pretilachlor, respectively.

5.1.2 Experiment 1 B Impact of treatments on weed status, growth and yield of direct seeded paddy and follow up zero-tilled rapeseed crop and economics

5.1.2.1 Weed status of Direct seeded paddy

The most dominated grassy weeds intercepted in the experimental field of direct seeded paddy were *Cynodon dactylon, Leersia hexendra, Echinochloa colona, Paspalum conjugatum* , *Eleusine indica* , *Digitaria sanguinalis, Dactyloctanium aegyptium.*, and *Cyperus rotundus* & *Cyperus difformis,* were among sedges and among the broad leaf *Ammania baccifera, Physalis minima, Phyllanthus niruri, Scoparia dulcis, Digera arvens, Ludwigia parviflora, Oldenlandia diffusa, Eclipta alba.* Ghosh and Bhowmick (2000), Moorthy and Saha (1999) and Mahajan *et al.* (2003) also reported same kinds of weed flora.

The results of the weed density (Table 4.46 - 4.56) and weed dry weight (Table 4.57- 4.66) of direct seeded paddy at 30 and 45 DAA depicted in Fig 18 - 27 revealed that all the weed management practices applied, significantly reduced the population and biomass of all types of weed over the unweeded control (T_9). This was because of chemical herbicides, used in this experiment.

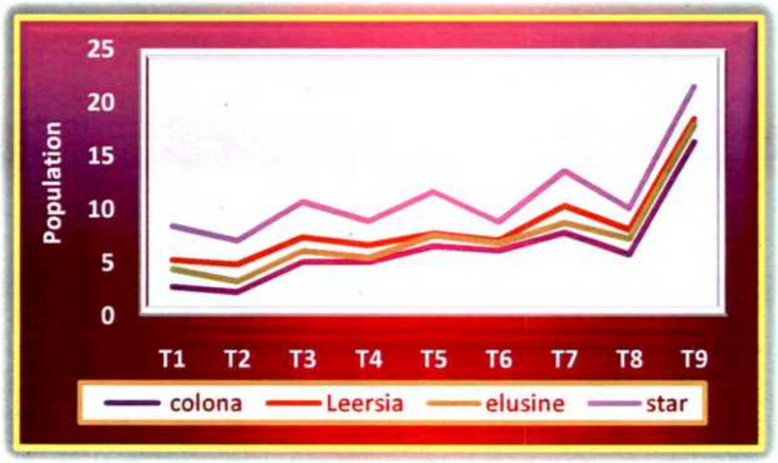
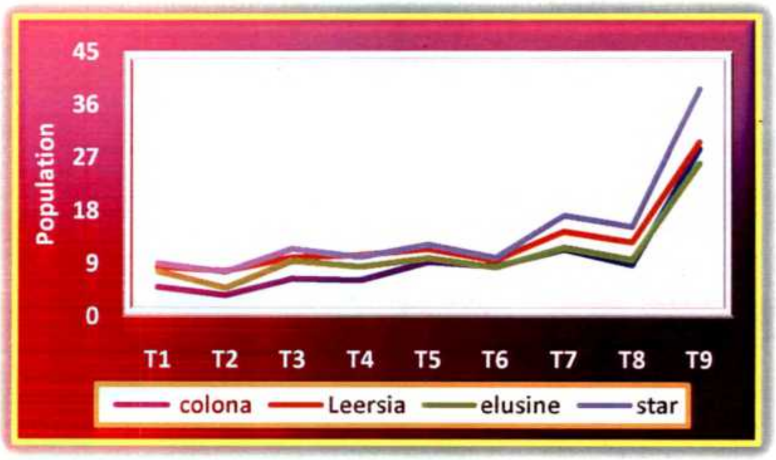


Fig. 18 Population of *grassy weeds* in direct seeded paddy at 30 DAA

Fig. 19 Population of *grassy weeds* in direct seeded paddy at 45DAA



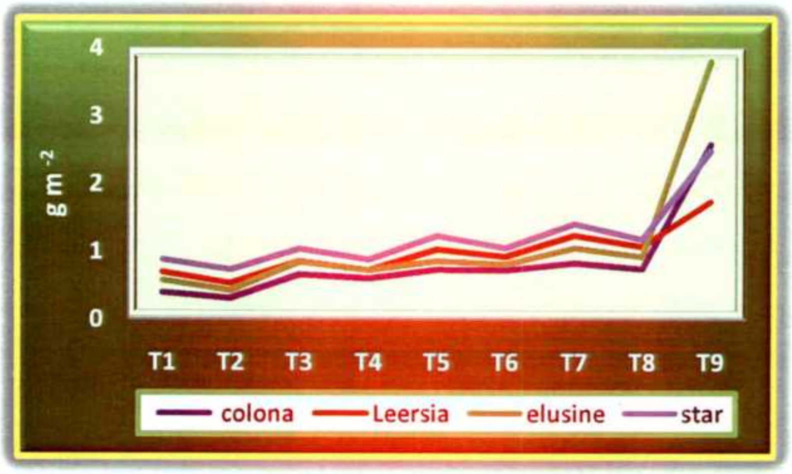
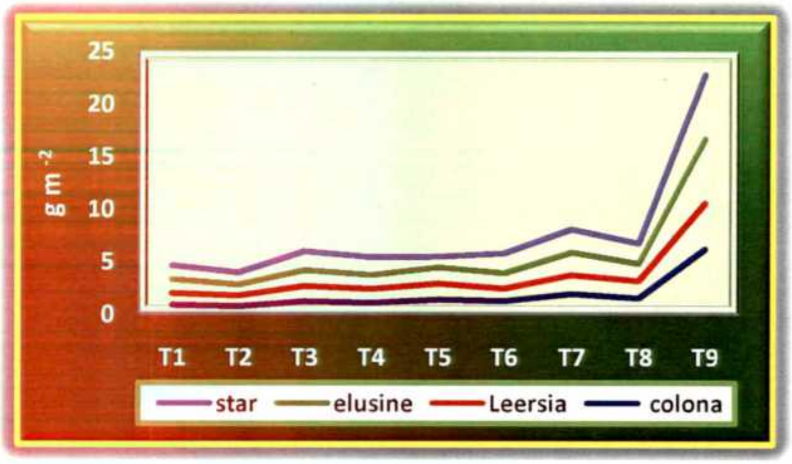


Fig. 20 Dry weight of *grassy weeds* in direct seeded paddy at 30DAA

Fig. 21 Dry weight of *grassy weeds* in direct seeded paddy at 45DAA



Azim + MSM+ 0.2 % surf @ 40 + 2 g a.i. ha^{-1} (T_2) recorded 75.49 % & 81.59 % lower weed population and 76.32 % & 80.08 % lower weed dry weight untreated T_9 and 50.28% & 55.13 % lesser weed density than MSM at 30 and 45 DAA, respectively. As because combination of Azim and MSM increased the area of turget plant (grass + sedge + broadleaf) but MSM only could able to control the broadleaf weeds. Similar result was opined by Shirakura *et al.,* (1995) about the higher efficacy of combination product. In case of the efficacy of MSM, Beyer *et al.* (1988), Brown (1990) and Mukherjee and Singh,(2005) also reported alike.

T_2 recorded 29.05% & 28.85 % lower weed density over without surf (T_4) in both the dates of observation, respectively (Fig. 28). This might be due to the reason that addition of surf increase the controlling efficiency by enhancing the foliar retention, penetration. Similar kind of observation was recorded the earlier findings of Green and Bestman (2004). At 30 and 45 DAA, T_2 also recorded 43.55% & 44.60 % lower weed population and 40.53 % & 38.23 % dry weight over T_6, respectively. This may be due to that Azim could able to control only the weed flora of family Poaceae (Gramineae & Cyperaceae) though was less effective against broadleaf. Chun *et al.* (1995) and Lee *et al.,* (2001) also reported similar views. Treatment T_2 also recorded 1.15 & 1.61g m^{-2} lower weed dry weight (Fig. 28) over to T_1. Because the lower dose of herbicide contain less active ingredient showed lower efficiency. Standard herbicide Pretilachlor also could able to control all the weeds but not the perennials. Singh *et al.* (2004) also expressed similar views.

Weed control efficiency was also recorded similar trend of variation showing the superiority of Azim 40+ MSM 2 + 0.2% surf by exerting 76.47 % and 80.03 % higher WCE over control at 30 and 45 DAA, respectively (Table 4.76).This may be due to the reason that combination of Azim with MSM has the capacity to control the broad spectrum of weed and further addition of surf enhance the efficacy of that treatment. Higher efficiency was observed at 45 DAA than that of 30 DAA because of more persistence of the herbicides. Sane kind of observation was made by Fuentes and Ferrucho (2002) regarding the efficiency of Azim + MSM combination.

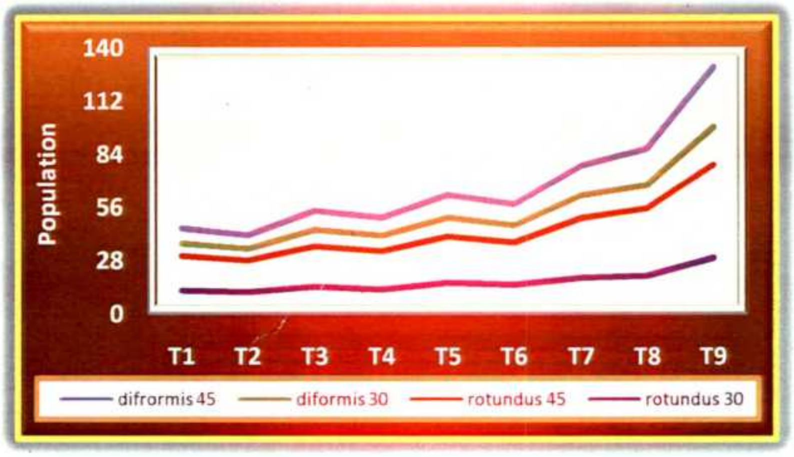


Fig. 22 Population of sedge *weeds* in direct seeded paddy at 30 and 45DAA

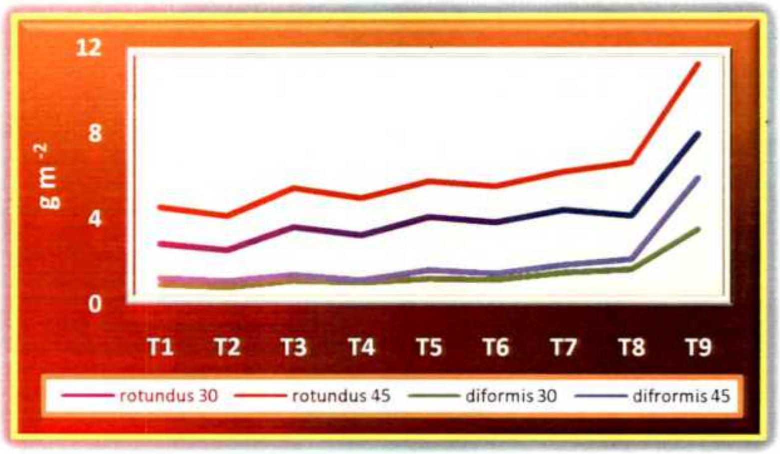


Fig. 23 Dry weight of sedge *weeds* in direct seeded paddy at 30 and 45DAA

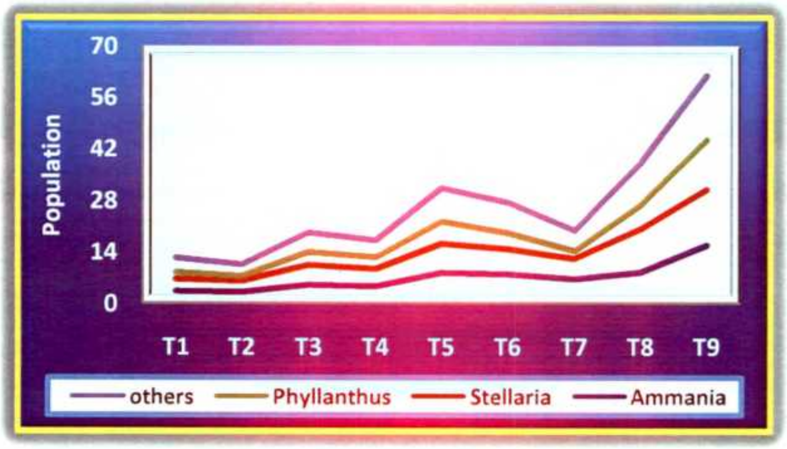


Fig. 24 Population of *BL weed* in direct seeded paddy at 30 DAA

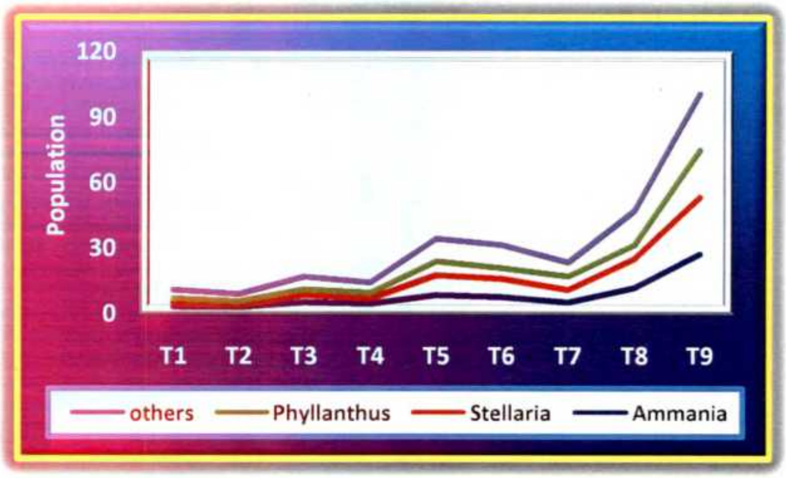


Fig. 25 Population of *BL weed* in direct seeded paddy at 45 DAA

5.1.2.2 Growth and Yield components of direct seeded paddy

All the weed management practices recorded significant better performances in growth and yield attributing components over to weedy check (Table 4.73-4.74). This is because of the chemical used in this experiment having good weed controlling efficiency. Treatment T_2 recorded the highest growth and yield attributing characters by exhibiting 8.26 cm higher plant height at harvest, 56.95 % more effective tillers m^{-2}, 3.11 cm higher panicle length, 23.36 % more filled grain $panicle^{-1}$ and 6.75 % better test weight over T_9. This was might be due to higher capacity to control of all categories of weed by T_2 attributed to lesser crop-weed competition exerted from weeds. Similar kind of observation was reported by Taylor (2004) and by Ghosh *et al.* (2007) in BCKV. This combinations with surf (T_2) also recorded 5.55 cm more plant height at harvest, 4.54 % higher effective tillers m^{-2}, 4.32 % higher panicle length, 4.74 % more filled grain $panicle^{-1}$ and 2.63 % better test weight over sole Azim (T_6). Because, Azim alone only could able to control the grass and sedge weeds rather than more severe broadleaf weeds in direct seeded condition. Vidotto *et al.* (2007) also expressed similar views.

Treatment T_2, also recorded superiority in exhibiting higher growth and yield attributing characters than T_4 (same combination at same dose without surf).Because addition of surf increase WCE by increasing the efficacy of it and offered lower crop-weed competition which reflects on the higher plant growth and better yield components. Similarly Devendra (2005) and Sharma *et al.,* (1982) have also reported the influencing effects of surfactants. All the herbicidal treatments recorded better results while untreated weedy check recorded poor of all growth parameters and yield components. Marquez *et al.* (1995) also reported its inefficiency against BL weeds. Uses of surf also made a significant difference among the treatments as T_2 showed 2.9 % more number of effective tillers m^{-2} and 2.5 % more number of filled grain $panicle^{-1}$ without surf (Fig. 30). Green (2001) and Sharma *et al.* (2005) also stated similar kind of observation with the addition of surf.

In direct seeded paddy plants no phytotoxocity symptom was observed regarding epinasty, hyponasty, leaf tip yellowing, surface injury, wilting and chlorotic or necrotic symptoms as well as stunting growth with the application of

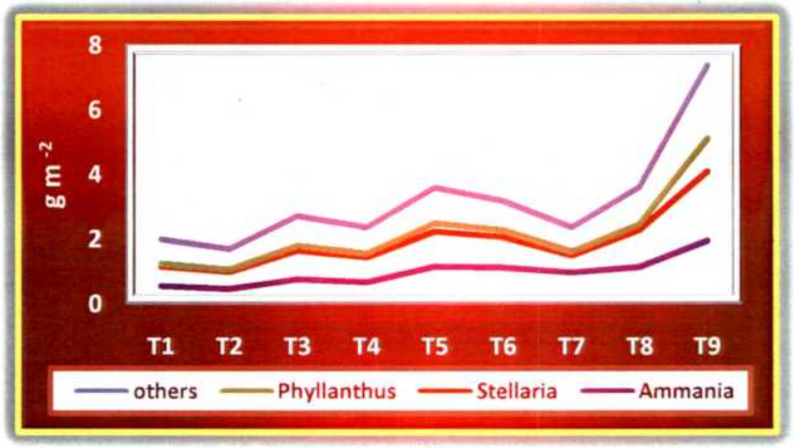
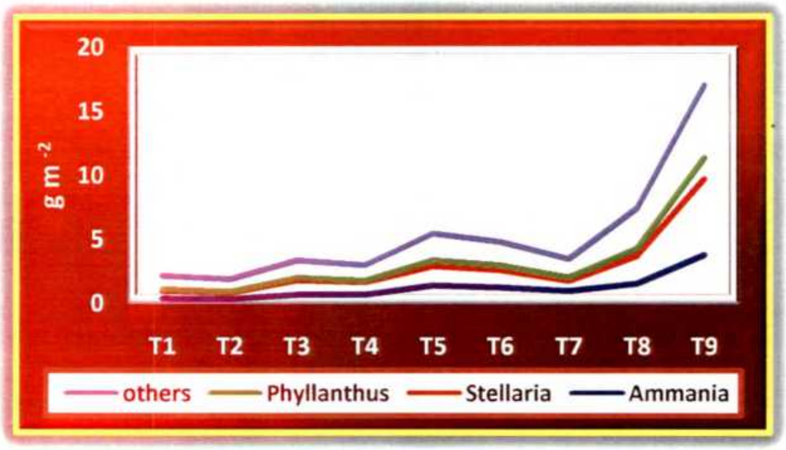


Fig. 26 Dry weight of *BL weed* in direct seeded paddy at 30 DAA

Fig. 27 Dry weight of *BL weed* in direct seeded paddy at 45 DAA



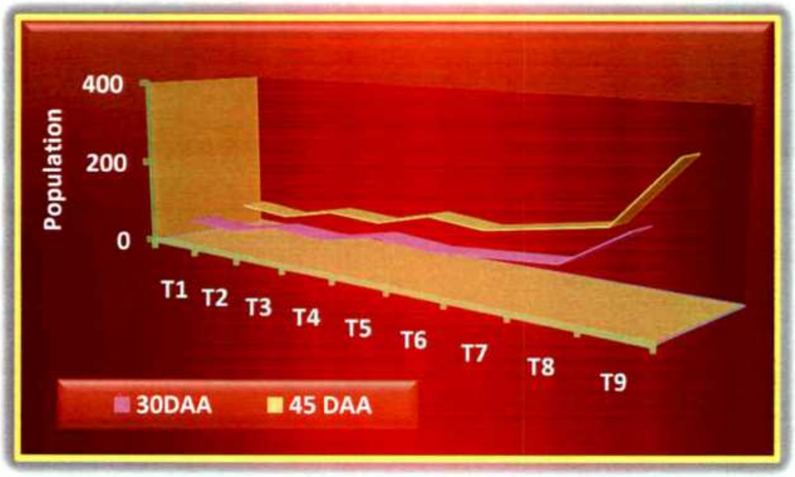
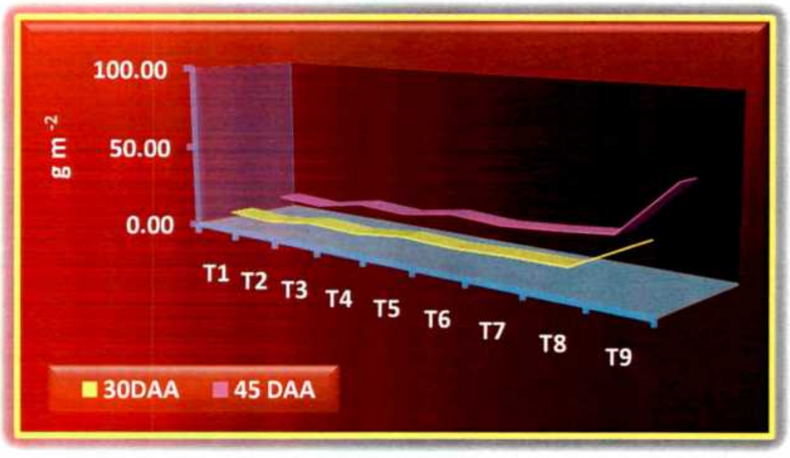


Fig. 28 Total weed population of Direct seeded paddy

Fig. 29 Total weed dry weight of Direct seeded paddy



Azim either as sole or as mixture with MSM with or without surf even with its double dose becsuse of the selectivity of the paddy plants in ALS (Acetolactate synthase) enzymatic process of biosynthesis of branched chain amino acid inhibition mechanism and in case of Pretilachlor, an acetamide herbicide; this is in microtubule functions tubuline mechanism.

5.1.2.3 Grain and Straw yield of direct seeded paddy

Significant variation in the grain and straw yield of direct seeded paddy with the variation of weed management practices was observed from pooled data (Table 4.74 and Fig. 31). All the weed management practices increased the grain yield of rice significantly over unweeded control (T_9). Application of Azim + MSM @ 40+2 g a.i. ha^{-1} + 0.2% surf recorded maximum grain yield which is 71.15 % higher over to T_9 and 7.2 % higher than T_1 because of the presence of more active ingredient. The treatment T_1 & T_2 recorded 4.7 % and 8.5% higher grain yield over the treatments T_3 & T_4, respectively. Use of sole Azim @ 40 g a.i. ha^{-1} + 0.2 % surf (T_6) recorded 23.55% and 43.75 % more grain yield than the standard Pretilachlor (T_8) and untreated control (T_9), respectively.

The straw yield of direct seeded paddy also showed more or less similar trend of variation and the maximum straw yield was also observed from T_2which was 44.59 % higher than T_9. Again between two different modes of combinations treatment with surf recorded higher straw yield than surf. Treatments T_5 and T_6 recorded 26.35 % & 27.02 % more straw than the treatment where no herbicide was used (Table 4.29 and Fig. 31).

This higher production in terms of grain and straw yield of treatment T_2 over the others because of its ability to controlled all types of weeds and thus minimized the competition from all type of weeds and thus could able to increase the growth parameters and yield components namely, higher plant height, greater number of effective tillers m^{-2}, filled grain $panicle^{-1}$ whereas, Azim alone could able to control the weeds of Poaceae family only but on the other hand remaining broadleaf weeds were effectively inhibited by MSM and further more, addition of surf again enhanced the activity. This is supported by the findings of Ghosh *et al.*, (2007) in direct seeded rice and Shirakura *et al.* (1997). Higher efficacy with surf may be due to the reason

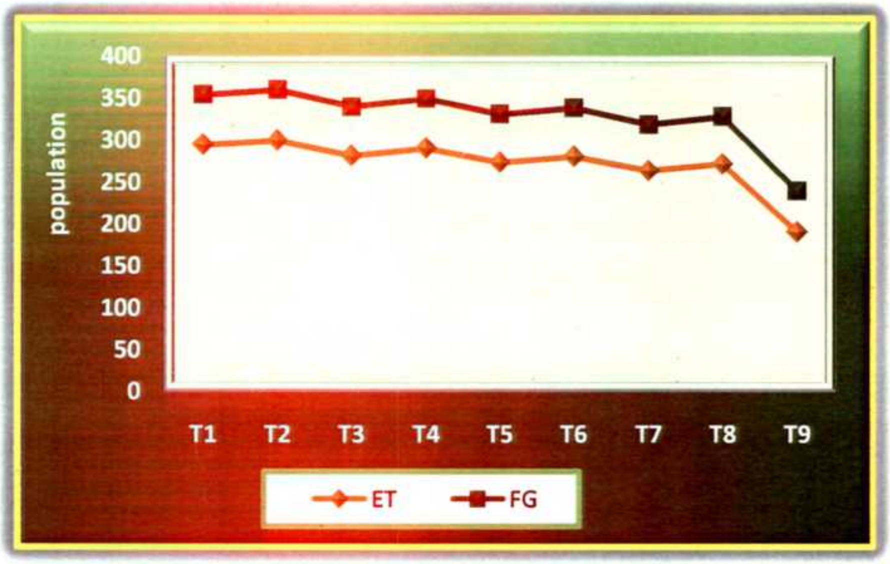


Fig.30 Effective tiller (m^{-2})and Field grain per panicle of direct seeded paddy

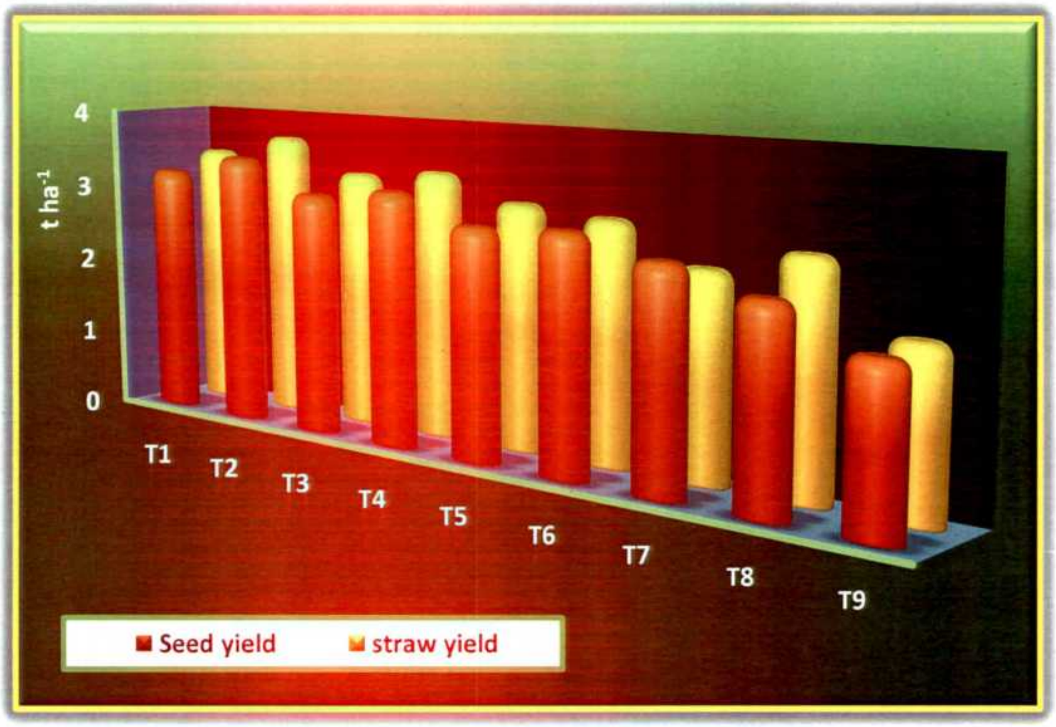


Fig. 31 Grain and Straw yield (t/ha) of direct seeded paddy

that it can improve herbicide performance by increasing the mixing, or emulsifying ability, coverage area, or spray retention and of higher absorption, or penetrating properties. Same view was stated by Sharma *et al.* (1989) and Mousavi *et al.*(2008) from Iran. Higher efficacy of Azimsulfuron along with surf for controlling weeds and thus increasing yield was also reported by Lee *et al.*, (2000) and also from AICRP-WC at IGKV, Raipur (Annual Report 2007-08).

5.1.2.4 Economics of direct seeded paddy cultivation

In direct seeded paddy cultivation treatment T_2, Azim 40 + MSM 2 + 0.2 % surf recorded the maximum net return (Rs 9,126.00) followed by the treatment T_1 (Rs 7,676.00) and T_4 (Rs 7,651.00). Unweeded control registered the lowest net return of Rs 1031.00 ha^{-1}. T_2, maximized the return per rupee invested (1.96) which was 56.48 % higher from T_9 and 29.00 % than standard Pretilachlor (T_8). T_4 recorded 6.28 % less return per rupee invested (1.59) from the same treatment with surf (T_2) as surf could influenced the biological yield of direct seeded paddy. Sole application of Azim + 0.2 % surf with both the lower and higher doses gave 38.00 % and 39.44 % more return per rupee than control.

5.1.2.5 Weed status of follow-up rapeseed

From the results (Table 4.77- 4.84), it was very clear the weed density and biomass of weed flora of rapeseed was significantly lower with the chemical treatment applied to the preceding direct seeded paddy only up to 10 DAS but at par on 25 DAS.

Application of T_2 to the earlier crop in the same sequence recorded 65.36 % & 45.79 % and 59.26% & 33.89 % lower weed population & weed dry weight over no herbicides and Pretilachlor treated plot, respectively at 10 DAS. T_2 established initial suppression of total weed floras in the succeeding crop, 21.13 % & 7.44 % and 14.04 % & 10.06 % less weed density and dry weight over to T_4) and same combination with lower dose T_1 at 10 DAS. Though sole application of Azim @ 40 g a.i. ha^{-1} recorded 25.46 % 11.20 % less weed population and biomass over untreated control but the corresponding value was 46.87 % & 35.67& more than T_2 .Use of Azim 40 + MSM 2 + 0.2 % surf applied in the earlier crop recorded 20.71 % lower weed population than MSM to the succeeding rapeseed. But, at later stage at 25 DAS no significant difference was observed because persistency become no more to the field and the second flash of weed emergence occurred.

This variation in weed dynamics in the follow-up zero tilled rapeseed was mainly due to the inhibition effect of applied herbicide to preceding paddy crops which reduces the population of all categories of weed seed. As Azim was highly effective for controlling grassy weed population and reduce the number of viable weed seeds in situ condition and it reflects in follow up crop where lower population of grassy but higher number of broad leaf weeds were there.

In zero tilled rapeseed lower weed emergence was occurred. This might be due to the reason that avoidance conventional tillage results minimum alteration of soil, which directly reduced the weed infestation for not disturbing the vertically distributed weed seed which fail to emergence due to more compactness of soil in upper surface. The reduction of weed population due to adaption of zero tillage was also reported by Brecke and Shilling (1996), Mohler and Galford (1997) and Khan *et al,* (2005).

5.1.2.6 Growth and yield components of follow-up rapeseed

The results presented in Table 4.85-4.86 clearly showed that the maximum growth and yield parameters of follow up zero-tilled rapeseed crop were influenced with the application of herbicide in the previous crop of the same direct seeded –zero tilled rapeseed cropping system. Application of Azim @ 40 g a.i.+ MSM @ 2 g a.i. + 0.2 % surf (T_2) influenced maximum growth and yield attributing characters, recorded 4.79 cm more rapeseed plant height at harvest, 20.22 % more number of primary branch plant^{-1}, 11.11 % more number of siliqua plant $^{-1}$, 0.17 cm higher siliqua length, 12.81 % more seeds siliqua^{-1} and 4.76 % higher test weight over the plot where no chemicals were used as treatment (T_9) and the corresponding figure with the same dose over the standard applied to the same crop were 2.29 cm , 8.27 %, 7.43 %, 0.15 cm, 7.9 % and 2.5 %. Application of Azim + 0.2 % surf used for controlling weeds in *Kharif* transplanted paddy also influence on the yield parameters of follow-up rapeseed by exerting 15.8 % more number of primary branch plant^{-1}

and 10.2 % more seeds siliqua^{-1} over to untreated plot but showed 3.8 % and 1.2% lower values of the same in compare with T_2.

This variation among the different growth and yield attributing character was probably due to the variation in the crop-weed competition faced by rapeseed crop. Application of Azim @ 40 g a.i. +MSM @ 2 g a.i. + 0.2 % surf could have the ability to control the broad spectrum of weed flora in the preceding paddy field but also inhibited the weed seeds in situ of the upper soil surface (0-15 cm). By reducing the first flash weed emergence in the follow-up crop at the earlier stage it reduced the crop weed competition and helped in vigorous seedling growth. Similar observations on higher herbicide efficiency of mixture were also noticed by Ferrucho (2002) and Taylor (2004). Adoption of zero tillage system also reduce the weed growth, by suppressing the weed seeds of deeper soil layer due to avoidance of congenial atmosphere for weed growth. This result corroborate with the findings of Richeyel *al,* (1977), Yaduraju and Mishra (2002) and Thanh (2005).

In the follow up rapeseed crop no phytotoxocity symptoms was there in rapeseed seed regarding germination and on also on the growth due to its selectivity of rapeseed and low to moderate persistence in soil as Azim have the half-life of only 20 days. Ray (1984) also reported about its selectivity.

5.1.2.7 Seed and Stover yield components of follow-up rapeseed

The seed and stover yield of rapeseed after DS paddy as depicted in Fig. 34 and presented Table 4.86 revealed that T_2 (Azim 40 + MSM 2 + 0.2 % surf) applied to preceding paddy crop recorded higher seed and stover yield of 23.55 % & 10.54 % over untreated plot and 11.46 % & 6.81 % over Pretilachlor treated plot, respectively. Azim @ 40 + 0.2 % surf (T_6) also recorded 19.15 % & 3.56 % more seed and stover yield from the untreated control plot (T_9) where no chemical was used. Treatment T_2 also recorded 0.016 % & 0.059 % t ha^{-1} more seed & stover yield over to its lower dose with same combination (T_1). Application of Azim @ 40 with MSM @ 2 g a.i. ha^{-1} along with 0.2% surf (T_2) also recorded 4.44 % and 8.41% higher seed & stover yield over T_4.

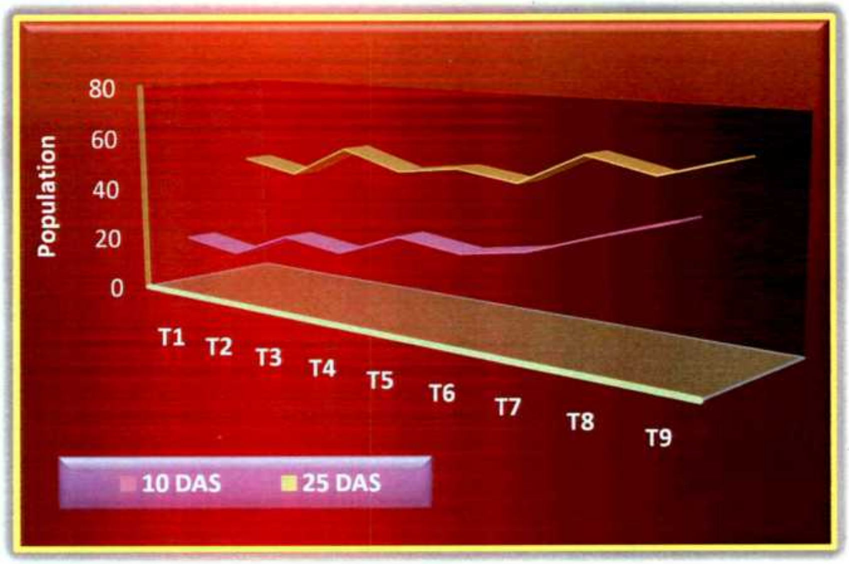


Fig. 32 Population of total weed flora of succeeding zero-till rapeseed

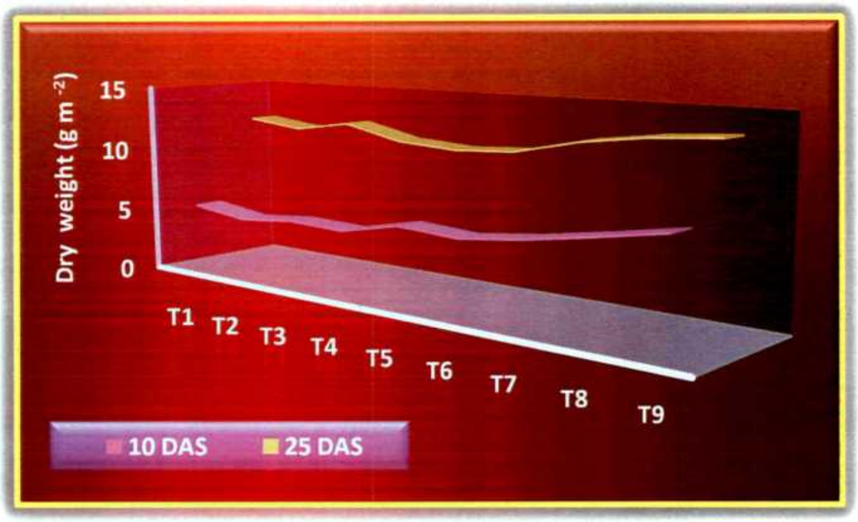


Fig. 33 Population of total weed flora of succeeding zero-till rapeseed

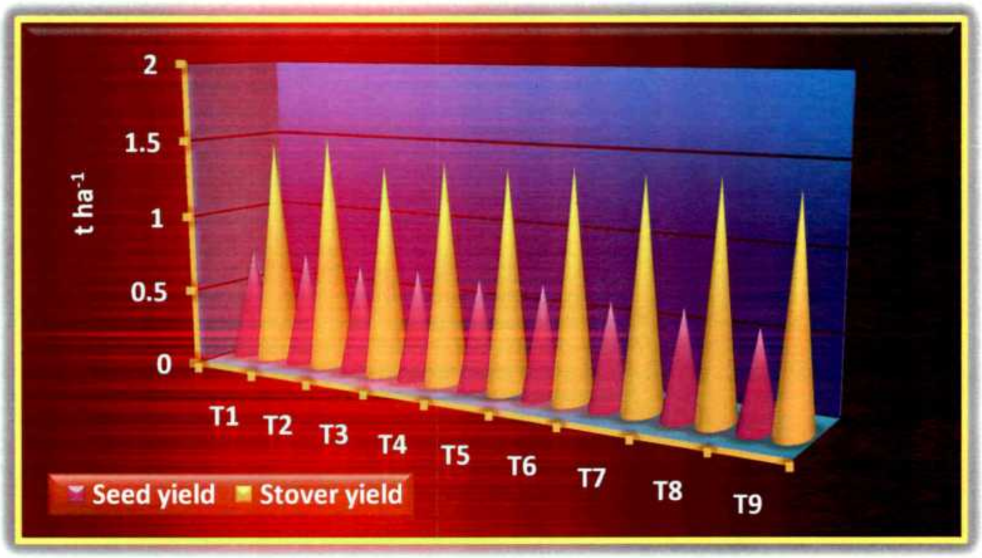


Fig. 34 Seed and stover yield (t / ha) of follow up zero-till rapeseed after DS paddy

This difference in growth parameters and yield components were might be due to difference in the weed. The maximum seed and stover yield of follow up rapeseed from Azim 40 + MSM 2 + 0.2 % surf over the others was due to the reason that this herbicide mixture had the capacity to reduce of all categories of weeds irrespective of types of weed flora and decrease the number of viable weed seeds in the upper soil surface, as because of these two herbicides, having different area of control (Azim for grass & sedge and MSM for broadleaf) again addition of surf further enhanced the activity of the herbicide. This target selectivity of Azim and MSM was also reported by Beyer *et al.* (1988) Pons and Barriuso, (1998) and higher effectively of combination was also supported by Taylor (2004).

Growing of rapeseed after DS paddy as zero tilled crops again also minimises the weed infestation. Due to avoidance of conventional tillage no or minimum alteration of soil was done and thus weed seeds remained in the deeper layer stayed in an unfavourable situation for their growth fail to germinate or even germinate fail to emerge because of higher soil depth. Richeyel *al.* (1977), Mohler and Galford (1997) also viewed same kind of results. Again growing of rapeseed with zero tillage management help of conserved soil moisture regulated proper plant water status, soil temperature, and lowered soil mechanical resistance, leading to better root growth and higher seed yield. Rathore *et al.* (1998) reported similar advantages of zero tillage.

5.1.2.8 Economics of follow up rapeseed

The economics of zero tilled rapeseed grown with the residual soil moisture after transplanted paddy were presented in Table 4.87 clearly stated that use of herbicides in the previous crop of same system for controlling weeds were more economical over the untreated plot. Treatment T_2 when applied to paddy recorded the maximum net return of Rs 3381.00 followed by treatment T_1 (Rs 3129.00) and T_4 (Rs 2947.00).Untreated control plot recorded the minimum return of Rs1414.00 may be due to higher competition from all categories of weeds and inability of crop to get the advantage of residual soil moisture. The maximum net return per rupee investment was registered from T_2 (1.50) which was 23.96 % & 11.94 % more than untreated control (T_9) and the standard Pretilachlor (T_8), respectively.

5.1.2.9 Economics of direct seeded paddy – rapeseed crop sequence

DS puddle rice followed by zero-till rapeseed was found to be economical and exhibited highest return per rupee investment (1.63) when Azim 40 + MSM 2 + 0.2 % surf were applied to the DS rice for controlling weeds (Table 4.88). This treatment also established the superiority by achieving more return per rupee, 44.24 % & 23.48 % over control and standard Pretilachlor, respectively. This better economic return from this treatment was mainly attributed to higher net return in proportion with cost of cultivation in both the crop of this sequence.

5.2 Experiment 2 Influence of herbicides on microbial population and urease enzyme activity in rhizosphere soil of transplanted paddy

All the chemicals exerted a only detrimental influence on the proliferation of total bacteria in the rhizosphere soil of transplanted paddy up to 15 days after application of the herbicides (Table 4.89). The detrimental effect might be due to impact of activated compound (Deshmukh and Shrikhande, 1974). Azimsulfuron along with Metsulfuron methyl at 5 DAA found to cause maximum reduction among the all tested herbicides. After 30 DAA, there was a rapid recovery in growth and a notable increasing trend in the proliferation of total bacteria was noticed at 45 and 60 DAA over to weedy check.

The harmful effect might be due to the interference of herbicides, in the metabolism of bacterial flora by restricting the normal function of enzyme. However, the detrimental influence did not last long as Azim degraded rapidly through microbial mechanism in soil, indirect photolysis & photoxidation. Same was opined by Barefoot *et al.* (1995). The beneficial effect of herbicides could be due to the surviving genera, which increased in number in less competitive environments. This substantiated the views of Das (1993). Alternatively, this marked improvement might be due to the influence of the carbon, nitrogen and energy produced after the degradation of herbicide resulting in the anabolic metabolism of chemo-heterotrophic bacteria (Paul and Clark, 1989).Same kind of observations was made by Tiwari and Kolhe (2002) and Ghosh *et al.* (2005).

Perusal of results (Table 4.90) in both the years all the herbicide caused short-term fluctuations in the actinomycetes population and suppression was noticed up to 5 days after their application, but thereafter, the population enhanced steadily upto 60 DAA over weedy check in rhizosphere soil of *Kharif* transplanted paddy. From mean data it was found that MSM + 0.2 % surf recorded 55 % reduction in population at 5 DAA, which was maximum among all herbicidal treatment but sole application of Azimsulfuron showed higher proliferation rate in population. After the initial suppression the population was gradually increased from 15 DAA while the population of actinomycetes reduced thereafter from 45 DAA.

The harmful effect at initial stage might be due to the interference of herbicides in metabolism of actinomycetes population. Mandal *et al.* (1987) found similar observation when Butachlor was applied during *pre-kharif* season in direct seeded rice. However, the detrimental influence of herbicide did not persisted last long and their degraded products were utilized as a source of energy, carbon and nutrients by the actinomycetes population for their metabolism (Valle *et al.*, 2006). The increase in the population of actinomycetes might be due to the greater resistance of actinomycetes to different groups of chemicals; otherwise, it might be due to the protocooperative or commensalic effect. Alternatively actinomycetes are known as better competitors (Alexander, 1977) and hence derive nutrients from organic substances present in soil rhizosphere more efficiently than that of other groups of microorganisms. Consequently the population increased, on and on, by utilizing the resistant organic matter from soil. Donkova and Perkova (2003), Mitra and Khan (2005) and Ghosh *et al.* (2008) also expressed similar views.

The fungal population sharply declined from initial stage under the influence of all herbicides, but gradually increased thereafter (Table 4.91). Metsulfuron methyl (T_7) was found to cause reduction in the population of fungi through out the observation whereas; Azim + 0.2 % surf did up to 5^{th} day in both the years of investigation. After the initial reduction in fungal population, the herbicides showed an enhancement in fungal population up to 60 DAA.

The reason behind this observation is that, Azim, a sulfonyl urea group herbicide has the half-life of only 20 days while in case of MSM it was 5 weeks and in Pretilachlor this figure was 4 weeks only. The variations in ALS sensitivity to different classes of herbicide may be due to slightly binding domains within a common binding site on the protein and also the interference of herbicides on the metabolism of fungi, having direct influence on respiration, ATP content (Moreno *et al.,* 2006). The detrimental effect of MSM may be because of greater herbicide persistence. Same kind of results was informed by Gigliotti *et al.* (1998) while working on the Bensulfuron methyl. The recovery from initial depression may because of the degraded products were utilized as energy and nutrient sources by fungi, for their metabolism. This substantiated the results of Rajendran *et al.,* (1999), Ming Hang *et al.* (2001) and by Patel *et al.* (2005).

The activity of urease enzyme in soil during the experimentation was increased with the application of all type of herbicides than that of untreated control except MSM where the uraese activity was decreased in all the dates of observation (Table 4.92). Application of Azim as a sole or in combination upsursed the urease activity over control even over to the standard Pretilachlor. The urease activity was found to be maximum at 30 DAA. Treatment T_6 recorded the highest urease activity than the others.

This may be due to that there was a positive correlation between the soil microbial population (Total bacteria, actinomycetes and fungi) and the urease enzyme activity in soil rhizosphere of transplanted paddy, but only, the total bacterial populations showed a significant positive relation. Increase in the population of beneficial bacteria like *Pseudomonus* and *Bacillus* (ammonification), *Nitrosomonus* and *Nitrobacter* (nitrification) may be the major reason for this positive correlation between the soil microflora mainly bacterial population and the urease enzyme activity. Same view was shared by Nannipieri *et al.* (1983), Frankenberger and Dick (1983), Klose and Tabatabai (1999) and Perucci (1990).

The reduction of urease activity in treatment T_7 i.e. application of MSM @ 2 g a.i. ha^{-1} along with surf may be due to that at initial stage it significantly reduced the population of the total bacteria and actinomycetes. The ineffectiveness of MSM was recorded by Ismail *et al.* (1998) in loamy sandy soil. Azimsulfuron caused a reduction in the microbial population at very initial stage up to 5^{th} day in both the years of investigation but there after, this herbicides showed an distinct enhancement in the proliferation of microbial population throughout the growth period and thus showed higher activity of urease enzyme after addition of energy source mainly due to increase in bacterial biomass as a significant positive relation was found among them. Combination product showed though a initial depression may because of MSM on it but recovered vary quickly and gave at par results at 30 DAA with the other treatments as Azim could able to increase the soil micro flora population after total degradation of herbicide and increase urease activity. Kim and Hong (1988) also reported the same inhibition of urease activity at initial with herbicide and have similar views with Gianfreda *et al.* (1994) and Wang *et al.* (2007) with butachlor.

5.3 Experiment 3 Biology of some important weeds

It is imperative to know the major weeds associated with the crop before planning any weed control measure, which is mostly regulated by growing conditions, irrigation practice and agro-ecological factors (Bhan, 1994).

E. crus-galli was found vigorously at anaerobic low land ecosystem might be due to their better competitive ability over other *Echinochloa sp.* From the mean data presented in Table 4.95 that average plant height of 106 cm was recorded though it varied from 94-118 cm .les and having slightly hairy awns and flowers within 35 days after emergence. The dormancy period of this phenotypic mimicry was 9 days. Similar findings were reported by Dhawn and Malik (2003), Norris (1992) and Ghosh (2006).

Cyperus rotundus, commonly known as purple nutsedge is the most troublesome weeds in tropical and subtropical regions of the world prefers to grow in aerobic condition and can proliferate its population vary rapidly e due to presence of tubers, which can survive year after year and propagate vegetatively. *C. rotundus* originate from the base of the plant having average plant height of 43.27 cm and ranged between 20- 49 cm height, solid and triangular stem with branched root system and red to purplish brown spikelets. Neese, and Varshney (2001), Horowitz, (1992), Nishimoto. (2001), Prabukumar *et al.* (2005) and Inder *et al.* (1998) have also expressed the similar view about its dominancy in aerobic land situation and biology.

5.4 Experiment 4 Management of *Cyperus rotundus*

In respect of management of *Cyperus rotundus,* the most pernicious weed is becoming threat to agriculture, all the chemical treatments as normally recorded the most controlling efficiency exhibiting 76.54 %, 73.86 % & 57.83 % less population of *Cyperus* over to weedy check (T_1) at 20, 60 and 60 DAA, respectively, than biological, cultural and physical method of weed control due to presence of toxic ingredient in herbicides were presented in Table 4.98 – 4.99 and depicted in Fig. 35&36.

Application of XL-COMBI-SG (35 % ammonium salt of Glyphosate + 35 % of 2,4-D ammonium salt) @ 5 g l^{-1} (T_7) found to be most effective throughout the period resulting 85.01 %, 95.31%,& 90.52% of lower population and 85.46%, 96.57% & 86.77 % lesser weed biomass over untreated control at 20, 40 and 60 DAA, respectively. The corresponding figures for Glyphosate 41 % SL @ 10 ml l^{-1} of water (T_8) were 80.42 %, 92.23 % & 82.45 % and 81.39 %, 95.17 % & 83.39 %. Resurgence even at 60 DAA was also very negligible. This may be due to the devastating effect of Glyphosate 41 % SL which could kill the *Cyperus rotundus* very effectively. Again addition of 2,4-D ammonium salt further increased the efficiency of control. Similar kind of result with Glyphosate was recorded by Blatazar *et al.* (1997), Molin and Hirase (2004) and also from AICRP-07 report from TNAU Center, Coimbatore.

The early post emergence application of Azim 40 + MSM 2 + 0.2 % surf (T_{11}) at 14 DAE showed 76.99 % & 83.72 % and 75 % & 79.52 % lower density and dry weight at 20 & 40 DAA over control but at 60 DAA this efficiency was reduced to 69.22 % & 53.11 % at 60 DAA and some resurgence of *C. rotundus* was occurred. This reduction of *Cyperus* was due to killing effect of this combination where tuber sprouting was almost inhibited due to the herbicidal action but did not show any concrete spoiling activity on tubers and thus re-growth was observed. Fuentes and Ferrucho (2002) also opined similar view with lower dose of this combination.

The traditional method, hand pulling also recorded 69.75 % reduction in population after first hand pulling at 15 DAE & 78.78 % reduction after the second one at 30 DAE but thereafter the density of *Cyperus rotundus* was more (only 23.36

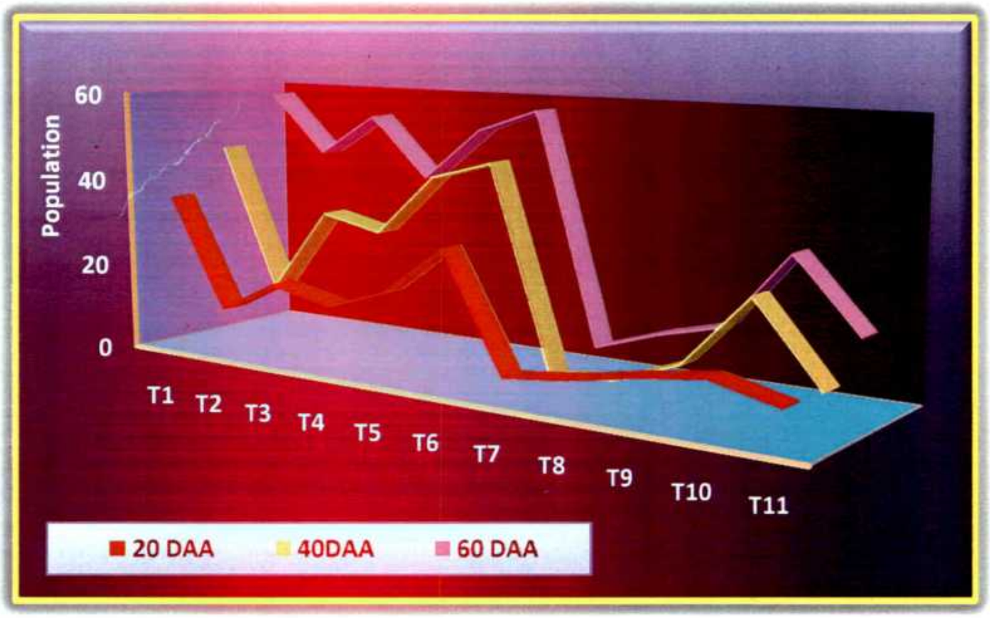


Fig. 35 Density (no. m $^{-2}$) of *Cyperus rotundus*

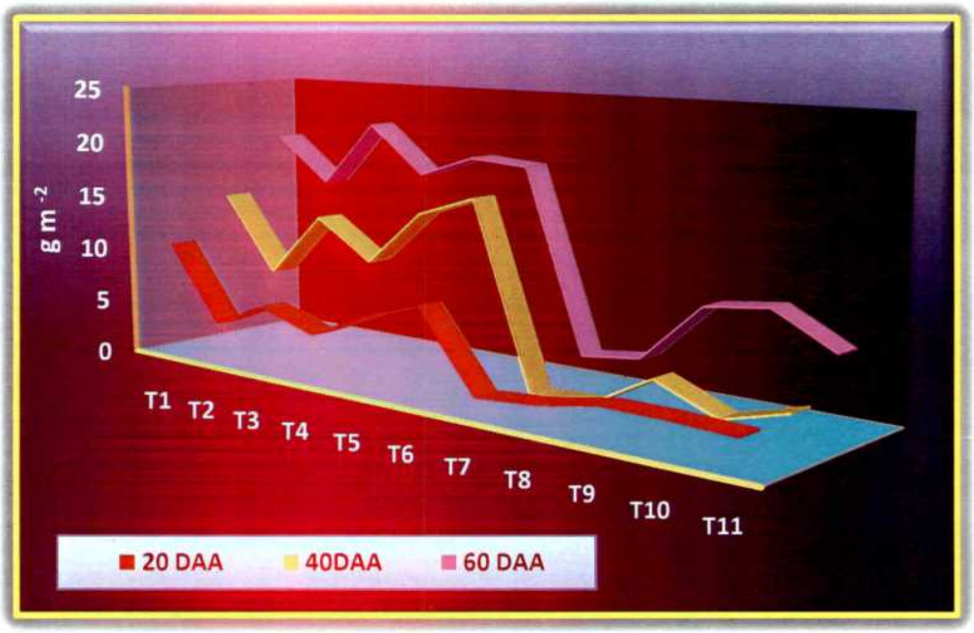


Fig. 36 Dry weight (g m $^{-2}$) of *Cyperus rotundus*

% efficiency at 60 DAA) because of its natural growth and no weeding was done eventually. The effectiveness of hand weeding was also found by Kathiresan (2002), Chaubey *et al.* (2005), Dubey *et al.* (2005) and Ghosh *et al.* (2005).

Soil solarization (T_3) with polyethelene sheet could also reduce the density of this purple nut sedge to the tune of 49.45 % at 20 DAA, 29.63 % at 40 DAA but showed at par with the highest density obtained from weedy check followed. The initial lower values were because no sprouting occurred below 10°C. But the increasing rate of *Cyperus* population might be due to the alteration of temperature because of scattered rainfall during pre-*kharif* season , greatly stimulated the sprouting of *Cyperus* nut and shoot elongation. Nishimoto (2001) also expressed similar findings of *Cyperus rotundus* with changing climate.

Extracts of *Calotropis gigantea* (T_4) 10 ml l^{-1} water recorded 58 % & 43.11 % reduction in weed density & biomass at 20 DAA might be due to the reason that it inhibited the growth and physiological metabolism of weeds. *Parthenium* extract (T_5) also recorded 27.90 % & 22.57 % lower *Cyperus rotundus* density and biomass might be due to its allelopathic inhibition on shoot length, shoot weight. But this much of decreasing performance was not governed with the spray of extracts of *Pistia stratiotes* (T_6) 12 ml l^{-1} water (only 14 %). During the later growth stages no remarkable variations were found regarding the density or biomass at 60 DAA due to absence of toxic effects provided by these biological means of control. The biological weed control method with the extract of *Calotropis gigantea* was also observed by Mandal and De (2001) and Swain *et al.* (2005). Similar germination inhibition was also recorded by Ghosh (2006). Allelopathic inhibition of *Parthenium hyserophorus* was also reported by Swain *et al.* (2005).

CHAPTER VI

Summary and Conclusion

SUMMARY AND CONCLUSION

Field experiments were carried out during the *kharif* and winter seasons of 2006-07 and 2007-08 on sandy loam soil of mediumland with good irrigation facility, at the 'C' Block Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, to study on the relative efficacy and soil environment of chemical weed management approaches and their influences on various growth attributing and yield components of both transplanted as well as direct seeded paddies with its residual effect on the succeeded crop alongwith the biology of major associated weeds.

Those field experiments were started with both the paddy crops in *kharif* 2006 and all the recommended package of practices were adopted during the period of experimentation except weed management. In Experiment 1, 11 treatments comprising with 6 combined doses of Azim + MSM (among which 2 was only for phytotoxicity), sole use of Azim (2) and MSM (1), standard Pretilachlor and untreated control were evaluated in a randomized block design in three replicates with transplanted paddy cv. IET 4094 (Experiment 1 A) as well as direct seeded paddy cv. IET 4786 (Experiment 1 B) to study the effect of herbicides on severity of different categories of weeds and crop yield alongwith their residual effects on the follow up zero tilled rapeseed cv. B-9 during winter season.

Experiment 2 was conducted to study the influence of herbicides on soil urease enzyme and soil microflora status of transplanted paddy with the same treatments as in Experiment 1 A. In Experiment 3, for achieving the information with regard to the crop-weed competition period, the biology of the most important weeds (*Echinochloa crus-galli* in anaerobic and *Cyperus rotundus* in aerobic situation), was studied in that investigation; whereas in Experiment 4, an attempt was made to control the most problematic *Cyperus rotundus* through cultural, biological and chemical means of control. The salient findings of this present investigations as have been presented and discussed in detail in the previous chapter 4 and 5 are hereby summarized as follows.

In Experiment 1 A, grassy weeds were the most dominant ones throughout the experimental period in transplanted paddy due to the inherent potentiality of this weed category towards quick germination, early seedling vigour and quick rooting ability; whereas in Experiment 1 B, broadleaf weeds were dominant alongwith sedges also may because of its favourable growing condition in aerobic situation.

In transplanted paddy culture *Echinochloa crus-galli* was the most important dominating weeds and the puddled condition effectively controlled grassy weeds like *Cynodon dactylon, Digitaria sanguinalis, Dactyloctenium aegyptium* and *Eleusine indica* as they were less tolerant to water stagnation, thereby reduced weed dynamics. However, direct seeded paddy significantly exhibited higher biomass of total grass of weeds and *Echinochloa colona* was the most important grassy weed there associated with *Dactyloctenium aegyptium and Eleusine indica.*

Among the sedges, in direct seeded paddy, the density and biomass of sedge weeds were dominated by *Cyperus rotundus* which was virtually absent in transplanted rice culture. However, the presence of *Cyperus iria* was prominent in both aerobic and anaerobic ecosystems and the biomass of sedge weed was found to be significantly higher in DS that in TR paddies.

The puddling soil favoured rapid growth of aquatic and semi-aquatic broadleaf weed, e.g. *Alternanthera philoxeroides, Stellaria media, Marsilea quadrifolia* and *Ammania baccifera* in anaerobic rice ecosystem. The biomass of broadleaf weeds showed a similar trend as was observed in case of grassy weed.

Minimum density and biomass of all categories of weeds in both the transplanted as well as the direct seeded paddy was recorded with the application of Azim @ 40 g a.i. ha^{-1} in combination with MSM @ 2 g a.i. ha^{-1} along with 0.2% surf because of their capacities to control the broad spectrum of weeds (grass + sedge + broadleaf) and thus reduced the competition for resources of the crop with the weeds. Whereas, with sole Azim treatment, lower minimization of all kind of weed flora was due to the reason that Azim could able to control of only the grassy weeds (Gramineae and Cyperaceae) effectively, thus competition from BL weeds were existed although recorded significantly better WCE than that of MSM and the standard Pretilachlor but use of only MSM proved to be ineffective against the most dominant weed category, i.e., grassy weeds, hence the biomass of total weed was found to be more.

Lower population and dry weight of weeds was recorded with the addition of surfactant than the treatment where same dose and same combinations were applied without surfactant. This might be due to the reason that addition of surfactant with polar herbicides increased the controlling efficiency by enhancing the foliar retention, penetration, altering droplet size, spray distribution and wettability.

No phytotoxocity symptom was observed regarding epinasty, hyponasty, leaf tip yellowing or wilting, surface injury and chlorotic or necrotic symptoms as well as stunting growth of the plant in both TR and DS paddy with the application of Azim either as sole or as mixture with Metsulfuron methyl with or without surf even with its double dose. All the crop plants looked healthy in the experimental field during both the years of experimentation. The reason behind the selectivity of the paddy and rapeseed plants in ALS (Acetolactate synthase) enzymatic process of biosynthesis of branched chain amino acid inhibition mechanism.

The highest reduction in grain and straw yields were observed from untreated control with both the paddy cultures where the competition between crop and weeds were more intense throughout the crop growth period. On the other hand, Azim 40 + MSM 2 + 0.2 % surf gave rise to 74.33 % & 52.78 % higher grain and straw yield, respectively; whereas, the corresponding values for direct seeded paddy was 71.15 % and 44.59 % mainly due to the reason that by minimizing the weed competition this treatment increased the yield components particularly number of effective tillers m^{-2} and number of panicles $plant^{-1}$ very effectively.

Despite of giving the highest net return (Rs 14,595.00) in transplanted paddy, application of Azim 40 + MSM 2 + 0.2 % surf was found to be more remunerative and economical with maximum return Re^{-1} investment (1.96) which was 66.10 % higher return than control. In direct seeded paddy too, the same treatment realized to be the best in economic point of view and recorded highest return of Rs 9,126.00 with the highest return Re^{-1} invested (1.92) which was 56.48 % higher than control.

In follow up zero tilled rapeseed, lower number of weeds $unit^{-1}$ was recorded initially where Azim + MSM + 0.2 % surf was applied to the preceding rice was able to control the broad spectrum of weeds in situ condition, besides, inhibited the viable weed seeds present in the upper soil surface (0-15 cm) very effectively and thereby reduced the first flash emergence of weeds in the follow up crop.

Because of shifting from the conventional tillage system, zero tillage management, restricted soil alterations, directly affected the weed seed bank in under surface rhizosphere soil by not allowing the weed seeds to emerge due to compactness of the upper soil layer and thus helped to minimise the weed infestation in the follow up zero tilled rapeseed.

Chemical weed management in the paddy crop under different ecosystem also played a vital role in follow-up rapeseed yield. Adoption of Azim 40 + MSM 2 + 0.2 % surf to the preceding TR rice recorded 14.45 % and 10.46 % higher seed and stover yield, respectively compared with the untreated plots. Rapeseed after DS paddy also increased seed and stover yields to the tune of 23.55 % and11.46 % in comparison with the control plot where no chemical was used in the earlier crop with the same sequence.

The zero tilled rapeseed, grown with the residual soil moisture after transplanted paddy, were more economical when herbicides were used in the previous crop of the same system for controlling weeds. Azim 40 + MSM 2 + 0.2 % surf when applied to paddy recorded the maximum net return Re^{-1} invested were 1.56 and 1.50 which was 13.04% and 23.96 % higher than untreated control in TR and DS follow-up crop, respectively.

In the crop sequence, paddy – rapeseed as a whole, application of Azim 40 + MSM 2 + 0.2 % surf in paddy was found to be economical and provided the highest return Re^{-1} investment: 1.84 & 1.63 which was 48.18% & 44.24 % higher than control in TR and DS rice sequence, respectively.

In Experiment 2, all the chemicals exerted a detrimental influence on the proliferation of total bacteria, actinomycetes and fungi in the rhizosphere soil of transplanted paddy upto 15 DAA of the herbicides; but thereafter, a rapid recovery in growth and a notable increasing trend was observed over to untreated control excepting the sole MSM which showed a long lasting detrimental effect upto 35 days. The urease enzyme activity of soil during the experimentation was also increased with application of all herbicide than that of untreated control except MSM where the uraese activity was decreased in all the dates of observation. The soil microbial population and the urease enzyme activity were positively correlated but among the three, only the total bacterial populations have a significant positive relation with the activity of soil urease enzyme.

In Experiment 3, *E. crus-galli*, the phenotypic mimicry was found vigorously under anaerobic lowland ecosystem whereas *Cyperus rotundus*, the pernicious weed was dominated in aerobic condition and both of which used to flower within 35 days after emergence.So, in order to reduce these problems it is essential to manage them within one month of sowing or transplanting.

The nut of *Cyperus*, contains 1.54% of oil with good insence used in perfumery compounds manufacture.

In Experiment 4, chemical control was found to be superior to other ecological, cultural and biological methods for controlling *Cyperus rotundus*. XL-COMBI-SG (35 % Glyphosate + 35 % 2,4-D ammonium salt) @ 5g l^{-1} was found to be the best for controlling that problematic weed. Glyphosate 41 % SL @ 10 ml and Azimsulfuron 50 G + MSM + 0.2 % surf @ 40 + 2 g a.i. ha^{-1} might also be applied according to the land situation where less regrowth was observed. But application of the extracts of *Calotropis gigantea* @ 10 ml l^{-1} water also recorded a good control of *Cyperus rotundus* at the very early stage as its' activity persists only for a month. Extracts of *Parthenium hysterophorus* @ 10 ml l^{-1} water also showed quite similar results with further lesser duration of its' activity in controlling purple nut sedge.

From the experimental findings, summarized above, it may be concluded

1. In paddy-rapeseed crop sequence, transplanted paddy followed by zero – tilled rapeseed is the most promising and remunerative in the *Inceptisol* than the rapeseed after direct seeded paddy.
2. In both the ecosystem of rice crop, application of Azim @ 40 g a.i. ha^{-1} in combination with MSM @ 2 g a.i. ha^{-1} in addition to 0.2 % surf is the most economical, effective and eco-friendly herbicide in augmenting rice yield over Pretilachlor and sole application of Azim, because of its better weed control efficiency, higher net return and no phototoxicity affect on rice plants as well as on the succeeding crop.

3. Due to moderate to low persistency and faster recovery on soil microbial population and urease enzyme, Azim as sole or in combination is safe to apply in this *Inceptisol.*

4. *Echinochloa crus-galli* in anaerobic and *Cyperus rotundus* in aerobic situation are very much essential to be managed them before flowering,within one month of sowing or transplanting of rice.

5. XL-COMBI-SG (35 % Glyphosate + 35 % 2,4-D ammonium salt) @ 5 g l^{-1} is the best one for controlling *Cyperus rotundus*. Glyphosate 41 % SL @ 10 ml and Azimsulfuron 50 G + MSM + 0.2 % surf @ 40 + 2 g a.i. ha^{-1} may also be applied in accordance with the site and situation rather than HW.

6. Extracts of *Calotropis gigantea* and *Parthenium hysterophorus* are asowed initial resistance of the growth of *Cyperus rotundus* upto one month.

CHAPTER VIII

Future Scope of Research

FUTURE SCOPE OF RESEARCH

In the present investigation, the severity of different categories of weed was studied in transplanted as well as in direct seeded paddy – zero-tilled rapeseed crop sequence and its impact on soil environment especially on the beneficial microbes (total bacteria, actinomycetes and fungi) and soil urease enzyme alongwith the biology of most two important weeds under both aerobic and anaerobic land ecosystems. In addition to these, an attempt has been made to find out the best management practices for the most pernicious weed, *Cyperus rotundus*, the purple nut sedge.

As there are several research gaps which deserve due attention in order to exploit the arena of weed management and also to mitigate the problem related with lower agricultural production. Following points are suggested to be taken into consideration while formulating future research for more qualitative and quantitative improvement on this subject and interpret better in this aspect:

1. To express the dominance and ecological success of crop and weed species, Importance Value Index (IVI) is essential and should be taken into consideration.
2. Weed dynamics and their management in the major crop sequence of *Inceptisol*, should be studied in detail.
3. The change in physico - chemical behaviour of soil under different paddy cultures and the follow up zero tilled rapeseed should be studied.
4. Saving of irrigation water in direct seeding over transplanting is to be quantified to verify the real advantage keeping the idea of Global Water Technology of producing more crops using minimum water.
5. Effect of herbicides on other micro-organisms present in soil alongwith the detailed study on more enzymatic activity of soil and correlation with biomass carbon.
6. Detailed study on weed biology of these weeds and also on other major associated weed species should be studied to formulate their management practices effectively.

7. Critical crop - weed competition alongwith the detailed study on resource competition for the clear understanding on these processes should be undertaken.
8. Observation towards development of resistance on weeds with herbicide is to be kept under clear consideration.
9. The similar experiment should be conducted under different agro-climatic regions and various systems of cropping.
10. The potentiality of botanicals (*Calotropis gigantea, Parthenium hysterophorus, Pistia stratiotes*) alongwith other wasteland weeds as bio-mulch, organic manures or their allelopathic effects on weed management should be explored.
11. Detailed study on different eco-physical, cultural, biological and chemical method for controlling Cyperus rotundus is to be undertaken.
12. The residual toxicity of the herbicides should be investigated in both plant products and in soil.
13. The fates of herbicides and botanicals in soil (residues, adsorption, leaching and ground water contamination) need to be studied.

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Appendix

Appendix – I

1.1 Cost of cultivation of transplanted paddy culture

During the experimental year 2006 - 2007

Particulars	Quantity required	Rate (Rs unit^{-1})	Cost (Rs ha^{-1})
1.Raising nursery			
a. Nursery bed preparation	For 1000 m^{-2}	2,000.00	200.00
b. FYM and fertilizer and their application	For 1000 m^{-2}	5,000.00	530.00
2.Planting materials			
a. Seed	60	14	840.00
b. Seed treatment			60.00
3. Bullock labour			
a. Ploughing	10 no.	150.00	1,500.00
b. Puddling	4 no.	150.00	600.00
4.Seedling pulling & transplanting	42 no.	70.00	
5. Fertilization			
a. Nitrogen (through urea)	60 kg	10.97	658.20
b. Phosphorus (through SSP)	30 kg	24.00	720.00
c. Potassium (through MOP)	30 kg	7.75	232.5
d. Application	4 m. u^{-1}	70.00	280.00
6. Irrigation	3 no.	250.00	750.00
7. Plant protection			
a. Polytrin C	1 litre	350.00	350.00
b. Application	2 m. u^{-1}	70.00	140.00
8. Harvesting, threshing etc.	60 m. u^{-1}	70.00	4200.00
Subtotal cost			14,000.70

Cost of treatments

Chemical	For 1 ha area (Rs)	Application (Rs ha^{-1})	Cost ha^{-1}
T_1 - Azim 35 +MSM 2 +0.2%Surf	(350.00 + 340.00 + 275.00)	140.00	1105.00
T_2 - Azim 40+MSM 2+0.2%Surf	(400.00 + 340.00 + 275.00)	140.00	1155.00
T_3 – Azim 35 +MSM 2	(350.00 + 340.00)	140.00	830.00
T_4 - Azim 40 +MSM 2	(400.00 + 340.00)	140.00	880.00
T_5 - Azim 35+0.2%Surf	(350.00 + 275.00)	140.00	805:00
T_6 - Azim 40+0.2%Surf	(350.00 + 275.00)	140.00	855.00
T_7 - MSM+0.2%Surf 2	(340.00 + 275.00)	140.00	755.00
T_8 - Pretilachlor 30.7 EC	(300.00)	140.00	505.00
T_9 - Untreated Control	0	-	-

Value of produce: Rice seed Rs. 6.25 ka^{-1} ; Straw Rs 0.50.

Appendix – II

1.2 Cost of cultivation of direct seeded paddy culture

During the experimental year 2006 - 2007

Particulars	Quantity required	Rate (Rs unit^{-1})	Cost (Rs ha^{-1})
1.Raising nursery			
c. Nursery bed preparation	-	-	-
d. FYM and fertilizer and their application	-	-	-
2.Planting materials			
c. Seed	60	14	840.00
d. Seed treatment			60.00
3. Bullock labour			
c. Ploughing	10 no.	150.00	1,500.00
d. Puddling	4 no.	150.00	600.00
4.Line sowing of germinated seed	13 no.	70.00	940
5. Fertilization			
e. Nitrogen (through urea)	60 kg	10.97	658.20
f. Phosphorus (through SSP)	30 kg	24.00	720.00
g. Potassium (through MOP)	30 kg	7.75	232.5
h. Application	4 m. u^{-1}	70.00	280.00
6. Irrigation	3 no.	250.00	750.00
7. Plant protection			
c. Polytrin C	1 litre	350.00	350.00
d. Application	2 m. u^{-1}	70.00	140.00
8. Harvesting, threshing etc.	60 m. u^{-1}	70.00	4200.00
Subtotal cost			12,000.00

Cost of treatments

Chemical	For 1 ha area (Rs)	Application (Rs ha^{-1})	Cost ha^{-1}
T_1 - Azim 35 +MSM 2 +0.2%Surf	(350.00 + 340.00 + 275.00)	140.00	1105.00
T_2 - Azim 40+MSM 2+0.2%Surf	(400.00 + 340.00 + 275.00)	140.00	1155.00
T_3 – Azim 35 +MSM 2	(350.00 + 340.00)	140.00	830.00
T_4 - Azim 40 +MSM 2	(400.00 + 340.00)	140.00	880.00
T_5 - Azim 35+0.2%Surf	(350.00 + 275.00)	140.00	805.00
T_6 - Azim 40+0.2%Surf	(350.00 + 275.00)	140.00	855.00
T_7 - MSM+0.2%Surf 2	(340.00 + 275.00)	140.00	755.00
T_8 - Pretilachlor 30.7 EC	(300.00)	140.00	505.00
T_9 - Untreated Control	0	-	-

Value of produce: Rice seed Rs. 6.25 ka^{-1} ; Straw Rs 0.50.

Appendix – III

1.3 Cost of cultivation of zero tilled rapeseed

During the experimental year 2006 – 07 and 2007-08

Particulars	Quantity required	Rate (Rs $unit^{-1}$)	Cost (Rs ha^{-1})
1..Planting materials			
Seed	7.5 kg	25	187.50
Seed treatment			7.50
2. Fertilization			
Nitrogen (through urea)	80 kg	10.97	879.00
Phosphorus (through SSP)	40 kg	24.00	960.00
Potassium (through MOP)	40 kg	7.75	310.00
3. Irrigation	2 no.	250.00	500.00
4. Plant protection	1 litre	300.00	300.00
5. Total human power (Line sowing, 1 HW at 30 DAS, plant protection, Harvesting)	52 m. u^{-1}	70.00	3640.00
6. Miscellaneous			41.00
Total cost			6825.00