Bio-efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice (*Oryza sativa* L.)

By

Gourav Pratap Singh

DEPARTMENT OF AGRONOMY

DR. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY, BIHAR, PUSA (SAMASTIPUR) – 848 125

2016

Bio-efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice (*Oryza sativa* L.)

By

Gourav Pratap Singh

A THESIS SUBMITTED TO
THE DR. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY, BIHAR, PUSA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE (AGRICULTURE)
IN
AGRONOMY

DEPARTMENT OF AGRONOMY

DR. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY, BIHAR, PUSA (SAMASTIPUR) – 848 125

2016

Reg. No. M/Agro/60/2014-15 of R.A.U.

Dedicated

to-

My Family

It's

all about love

✍ Gourav

DR. RAJENDRA PRASAD CENTRAL AGRICULTURAL UNIVERSITY
BIHAR, PUSA (SAMASTIPUR) -848125

Dr. D. K. Roy
Sr. Scientist-cum-Assoc. Professor

Department of Agronomy
Dr.R.P.C.A.U., Bihar. Pusa
(Samastipur) 848125

Dated: .19.../.05../2016

Certificate

This is to certify that the work recorded in this thesis entitled **"Bio-efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice (*Oryza sativa* L.)"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science (Agriculture) in Agronomy** of the Faculty of Post-graduate Studies, Dr. Rajendra Prasad Central Agricultural University, Bihar is a genuine record of **bona fide** research work carried out by **Mr. Gaurav Pratap Singh** under my guidance and supervision.

The results 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 this investigation and sources of literature have been duly acknowledged.

19.05.2016

(D. K. Roy)
Chairman, Advisory Committee

ENDORSED

27.5.2016

(Ravi Nandan)
Department of Agronomy
Dr. R.P.C.A.U., Bihar,
Pusa (Samastipur)

Certificate

We, the undersigned, members of the advisory committee of **Mr. Gourav [illegible] Singh**, a candidate for the degree of **Master of Science (Agriculture) in Agronomy**, have gone through the manuscript of the thesis and agree that the thesis entitled **"Bio-efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice (*Oryza sativa* L.)"** may be submitted by him in partial fulfillment of the requirements for the award of the degree.

19.05.2016

(D. K. Roy)
Chairman Advisory Committee

MEMBERS OF THE ADVISORY COMMITTEE

19/05/16.

1. **(Dharminder)**

19.05.2016

2. **(Mukesh Kumar)**

SP Singh 19/5/16

3. **(S. P. Singh)**
Dean's Nominee

Certificate

This is to certify that the thesis entitled **"Bio-efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice (*Oryza sativa* L.)"** submitted by **Mr. Gourav Pratap Singh** in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture) in Agronomy** of the Faculty of Post-graduate Studies, Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar was examined and approved on 28./.09../2016.

28/9/16
External Examiner
(S.S. SINGH)

28.09.2016
(D. K. Roy)
Chairman
Advisory committee

MEMBERS OF THE ADVISORY COMMITTEE

28/09/2016
1. (Vinod Kumar)

28.09.2016
2. (Mukesh Kumar)

28/9/16
3. (S. P. Singh)
Dean's Nominee

ENDORSED

22.10.16
(Ravi Nandan)
Chairman
Department of Agronomy
Dr.R.P.C.A.U.,
Pusa (Samastipur), Bihar

Acknowledgement

I consider it to be a rare opportunity and privilege to express my reverential gratitude and heartiest regard to my supervisor Dr. D.K. Roy, Sr. Scientist-cum-Assoc. Prof, Department of Agronomy, Rajendra Agricultural University, for his esteemed and benevolent guidance, constant encouragement, valuable suggestions, ever-ready assistance, invaluable criticism, keen interest and everlasting affection during the entire course of study and in the preparation of the manuscript. It has indeed been my privilege to work under his supervision and I will remain indebted to him.

I am also thankful to Mr. Dharmindar, Junior Scientist-cum-Assistant Prof., Department of Agronomy, Dr. Mukesh Kumar, Chief Scientist-cum-Univ. Prof., Department of Soil Science and Dr. S. P. Chief Scientist-cum-Univ. Prof., Department of Entomology (DRI-cum-Dean, PGS Nominee) for their erudite suggestions and cooperation.

With the same zeal, I wish to express my sincere gratitude to Dr. Ravi Nandan, Chairman, Department of Agronomy for providing necessary facilities during my work.

My sincere thanks and respect are due to Dr. Vinod Kumar, K.K. Shinha, I. B. pandey, Dr. J. P. Singh, Dr. S. K. Choudhary and Dr. Rajan Kumar for their guidance and cooperation during the course of investigation.

I bow with obligatory gratitude to my MAA and PITA JEE whose faith, selfless sacrifices and blessings is supreme force behind all my aspirations and their fulfilment.

I extend affectionate-cum-laude to my seniors, Mr. Anup chaubey, Mr. Lumro, Mr. Sashidhar Yadav, Mr. Vinay, Mr. Ravikant, Mr. Santanu, Mr. Hans raj and Mr. Nitesh. for their commendable and silent tolerance towards innumerable inconvenience and co-operation during the completion of the program.

I extend thanks to my batchmates, Dinesh, Tulshi, Prakash, Dharmendar, Lokesh, Prakhar, Puspa, Atul, Vipul, Pankaj, Reddy and Thampi for their co-operation and help given from time to time.

I also extend thanks to my UG friends Deepak Kori, Shweta Kumari ,Slu, Vanu, Sambhu and OP who added lot of positivity in my personality.

I am highly thankful to my all loving juniors for their helping attitude.

I wish to thanks Shri R.C. Sharma, Assistant librarian and all staff of university library for their kind & generous help.

I am thankful to Mr. Aditya Kumar for his support in technical this thesis in the shortest possible time.

I am extremely thankful to my friends for their valuable suggestions and help at every stage of my work.

Finally, I owe everything to my spiritual GURU Mr. Abulaish and my Lord KRISHNA for their motivation that's makes me hard worker and restless.

Place :
Date :

Gourav Pratap Singh

◊◊◊

CONTENTS

LIST OF FIGURE

LIST OF TABLE

LIST OF ABREVATIONS

@	:	At the rate of	ml	:	Millilitre
°	:	Degree	mm	:	Millimetre
°C	:	Degree Celsius	m^2	:	Meter square
%	:	Per cent	nm	:	Nanometer
₹	:	Rupees	N	:	Normality
/	:	Per	N	:	Nitrogen
a.m.	:	Ante meridiem	NS	:	Non-significant
Adj.	:	Adjuvant	No.	:	Number (s)
AS	:	Ammonium sulfate			
a.i.		Active ingredient	P	:	Phosphorus
B: C	:	Benefit: Cost	PE	:	Pre-emergence
cm	:	Centimeter	PoE	:	Post-emergence
C	:	Carbon	pH	:	Potential of Hydrogen
CD	:	Critical difference	PM	:	Pendimethalin
dSm^{-1}	:	Deci-simen per meter	pp	:	pages
DAT	:	Days after transplanting	ppm		Parts per million
DAS	:	Days after sowing	PW		Power weeder
DAP	:	Di-ammonium phosphate	q	:	Quintals
et al.	:	Etalli and others (Co-workers)	R.H.		Relative humidity
EC	:	Electrical conductivity	RBD	:	Randomized block design
EC		Emulsifiable concentrates	S	:	Sulphur
Fig.	:	Figure	SL	:	Soluble liquid
fb	:	Followed by	SC	:	Soluble concentrate
g	:	Gram (s)	Sl. No.	:	Serial number
ha	:	hectare	SEm±	:	Standard error of mean
HW		Hand weeding	temp.	:	Temperature
H.I.	:	Harvest index	t	:	Tonnes
hrs	:	Hours	Viz.	:	Namely
i.e.	:	*Id est* (that is)	USDA	:	United states Department of Agriculture
kg	:	Kilogram (s)	U.S.		United States
K	:	Potassium	WI	:	Weed index
K_2O	:	Potassium oxide	WP	:	Wettable Powder
M	:	Meter (s)	WDG	:	Water dispersible granules
Max.	:	Maximum	WCE	:	Weed control efficiency
Min.	:	Minimum			

RAJENDRA AGRICULTURAL UNIVERSITY, BIHAR
PUSA, SAMASTIPUR-848125

Name of the Student	:	**GOURAV PRATAP SINGH**
Registration No.	:	M/Agro/60/2014-2015
Degree to be awarded	:	Master of Science (Agriculture) in Agronomy
Department	:	Agronomy
Major Subject	:	Agronomy
Minor Subject	:	Soil Science
Major Advisor	:	**Dr. D. K. ROY**
Number of Pages	:	65 + viii (Bibliography)
Year	:	2016
Title of Thesis	:	**"Bio-efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice (*Oryza sativa* L.)"**

Abstract

A field experiment was undertaken during *kharif* season of the year 2015 at the Research Farm of Rajendra Agricultural University, Pusa (Samastipur), Bihar to study the **"Bio-efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice (*Oryza sativa* L.)"**.

The experiment was conducted in randomized block design having 12 treatments. T_1- bispyribac- Sodium @ 25 g/ha at 25 DAT, T_2- penoxsulam 24 % SC @ 22.5 g/ha at 15 DAT, T_3- bispyribac – sodium + ethoxysulfuron @ 25 +18.75 g/ha at 25 DAT, T_4- bispyribac – sodium + chlorimuron + metsulfuron(Almix) @ 20 + 4 g/ha at 25 DAT T_5- pretilachlor @ 750 g/ha at 0-3 DAT *fb* ethoxysulfuron @ 18.75 g/ha at 25 DAT T_6- pretilachlor @ 750 g/ha at 0-3 DAT *fb* chlorimuron + metsulfuron(Almix) @ 4 g/ha at 25 DAT, T_7- pyrazosulfuron @ 20 g/ha at 0-3 DAT *fb* chlorimuron + metsulfuron(almix) @ 4 g/ha at 25 DAT, T_8- penoxsulam + cyhalofop 6 % OD (RM) @ 135 g/ha at 15-20 DAT, T_9- triafamone + ethoxysulfuron 30 % WG @ 60 g/ha at 15 DAT, T_{10}- pendimethalin (38.7 % CS) @ 750 g/ha at 0-3 DAT *fb* bispyribac –sodium @ 25 g/ha at 25 DAT, T_{11}- Hand weeding at 25 and 45 DAT and T_{12}- Weedy check replicated thrice with Rajendra Shweta as the test variety.

All the weed management practices either herbicidal or hand weeding had profound effect on growth and yield attributes as well as the ultimate yield as reflected in their superiority over the weedy check. Amongst herbicidal treatments pendimethalin (38.7 % CS) @ 750 g/ha at 0-3 DAT *fb* bispyribac –sodium @ 25 g/ha at 25 DAT was superior to rest of herbicidal treatments. It was also at par with hand weedings at 25 and 45 DAT. pendimethalin (38.7 % CS) @ 750 g/ha at 0-3 DAT *fb b*ispyribac –sodium @ 25 g/ha at 25 DAT recorded top spot in almost all the growth and yield attributing characters and also in the yields of grain and straw.

The results pertaining to weed population, weed dry weight and nutrient uptake by weeds and crop separately were a close reflection of growth and yield pattern whereas hand weeding which was superior to all the herbicidal treatments. Amongst herbicidal treatments pendimethalin (38.7 % CS) @ 750 g/ha at 0-3 DAT *fb* bispyribac –sodium @ 25 g/ha at 25 DAT was superior to rest of herbicidal treatments. Weed control efficiency of pendimethalin (38.7 % CS) @ 750 g/ha at 0-3 DAT *fb* bispyribac –sodium @ 25 g/ha at 25 DAT (63.10%) and weed index (4.15%) was superior to bispyribac– sodium + ethoxysulfuron @ 25 +18.75 g/ha at 25 DAT (54.89%) and weed index (7.32%) respectively. Protein content in grain was similar in all the treatments except the weedy check in which it was significantly lower. The most glaring part of the results rested in its economic studies, where in all the herbicidal treatments either pre-emergence applications or combination of pre and post emergence applications fetched higher net return and scored better B:C ratio than the two hand weedings. Pendimethalin (38.7 % CS) @ 750 g/ha at 0-3 DAT *fb* bispyribac –sodium @ 25 g/ha at 25 DAT (₹ 42,525/ha) cornered the highest net return closely followed by bispyribac– Sodium + ethoxysulfuron @ 25 +18.75 g/ha at 25 DAT (₹ 41,390/ha). As against these treatments, the net return realized by two hand weedings was lower ₹ 37,450/ha. The B:C ratio further widened the gap between manual weeding and herbicidal applications. The highest B:C ratio of 2.61 was recorded from pre-emergence application of bispyribac– Sodium + ethoxysulfuron @ 25 +18.75 g/ha at 25 DAT which was closely followed by pendimethalin fb bispyribac-sodium (2.59) and two hand weedings had a B:C ratio of only 2.06 which was next only to the weedy check (1.81).

Thus, it may be summed up that pendimethalin *fb* bispyribac-sodium is superior to rest of herbicidal treatments. Secondly, high cost involved in manual weeding makes herbicidal treatments more viable preposition. Pendimethalin (38.7 % CS) @ 750 g/ha at 0-3 DAT *fb* bispyribac –sodium @ 25 g/ha at 25 DAT and bispyribac– sodium + ethoxysulfuron @ 25 +18.75 g/ha at 25 DAT are two most effective herbicidal treatments in transplanted rice for control of complex weed flora and higher economic return.

◈◈◈

Chapter - 1

[INTRODUCTION]

INTRODUCTION

Rice (*Oryza sativa* L.) is a leading food crop providing 22% calories and 17% proteins of the world. Rice is staple food of lot of the world's population. In India about 41.3 m ha of lands are under rice cultivation with production of 104.32 million tonnes and an average productivity of about 23.72 q/ha (Ministry of Agriculture 2104). In Bihar rice is cultivated in around 3.34 m ha with a production of 7.2 million tones and productivity of 21.58 q/ha (Agricultural Statistics at a Glance, 2012).

Rice is grown in both *kharif* and *Rabi* seasons under diverse ecological and climatic conditions apart from socio-economic diversities of the state. 33% of total rice land has got irrigation facilities and rest is totally dependent upon rainfall. Among various depressing factors, abiotic stress i.e. water and nutrient stress and biotic stress i.e. weed infestations in the field are the most crucial factors due to which rice production is unpredictable and considerably low.

Rice (*Oryza sativa* L.) is an important food crop of India contributing 45% of the total food grain production. Transplanted rice faces diverse type of weed flora, consisting of grasses, broad-leaved weeds and sedges. Competition offered by weeds is most important and it reduces the grain yield up to the extent of 15-45% (Chopra and Chopra, 2003). One of the most important methods to increase rice production is to minimize crop loss by weed competition. Weeds not only reduce rice production but also have an adverse effect on rice grain quality. Hand weeding is the most effective method, however, high labour wages and non-availability of labour during peak periods of agricultural operations, timely weeding is not possible. Most of the pre-emergence herbicides viz., butachlor, pretilachlor and thiobencarb were applied in large quantities for weed management in transplanted rice. These herbicides are very effective for grasses and less effective against sedges and broad-leaved weeds (Singh *et al.*, 2009). Further, these herbicides are very effective for controlling weeds up to 20 DAT. Application of herbicide mixtures or sequential application of herbicides may be useful for broad-spectrum control of weeds in rice. Recent trend of herbicide use is to find out an alternative and effective weed management by using low dose high efficiency herbicides, which will not only reduce the total volume of herbicide per unit area, but also application becomes easier and economical to the farmer. Hence, the present investigation was carried out to evaluate the relative efficacy of some of the newly developed pre and post-emergence herbicides for control of weeds in transplanted rice.

Transplanted rice encounters the problems of complex weed flora in different regions of the country resulting 15- 76 % reduction in grain yield (Singh and Singh, 2004). Infestation of weeds in transplanted rice not only results in yield reduction but quality of produce is also impaired. It was observed that the major weeds (about 60 %) emerge during 7 – 30 days after transplanting and compete with rice plants up to maximum tillering stage (Saha and Rao, 2007). Timely weed control at early stage is imperative for realizing desired level of productivity from transplanted rice. The use of herbicides offers selective and economic control of weeds right from the beginning, giving crop an advantage of good start and competitive superiority (Saha *et al.* 2005).

A number of pre–emergence herbicides like butachlor, pretilachlor, and anilophos etc have been recommended for the control of early flushes of grassy weeds in transplanted rice field (Budher *et al.* 1991*).* However, these herbicides are specific and are effective against narrow range of weed species (Narayana *et al*. 1999). The need of post emergence herbicides is often realized by growers to combat weeds emerging during later growth stages in the season escape the treatment of pre-emergence herbicides. These situations demand for some suitable post emergence herbicides for controlling broad spectrum of weeds (Yadav *et al*. 2008). Herbicides like ethoxysulfuron, almix, metsulfuron are found effective for post– emergence control of broadleaf weeds and some sedges.

In the recent past, due to hike in labour wages and their non-availability during crucial agricultural operations, manual weeding has become an uneconomical preposition and subsequently farmers are compelled to take up chemical weed control. Many promising herbicides that are selective to rice have been identified and became popular recent times. The use of pre-emergence herbicides made it possible to control weed growth during initial stage of crop and offer scope to the crop for better utilization of resources. However, one hand weeding is essential at 30-40 DAT for getting higher yields in rice. Recent trend of herbicide usage is to find out effective weed control methods using low dose high efficiency herbicides including post emergence selective herbicides which make the application easier and economical to the farmer with wide spectrum weed control in transplanted rice. Sulfonyl urea herbicides includes Bensulfuron-methyl, Metsulfuron-methyl, Chlorimuron-ethyl, Pyrazosulfuron-ethyl etc. As these herbicides are highly effective at very low rate of application, they are known as low dose high efficiency herbicides (LDHE herbicides**).** In cognizance of the above, the present study was undertaken to test the relative efficacy of some sulfonyl urea group herbicides on weed growth and yield of transplanted rice.

Thus, it would be desirable to use the combinations of pre-emergence and post emergence herbicides that may provide wide spectrum of weed control. Therefore, keeping the above facts in view the present investigation entitled **"Bio-efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice"** was planned with following objectives:

1. To study the bio-efficacy of combinations of herbicides against weed flora
2. To evaluate the herbicides combinations on growth and yield of transplanted rice
3. To work out the economics of different treatments

Chapter - 2

[REVIEW OF LITERATURE]

REVIEW OF LITERATURE

In this chapter, attempt has been made to review the pertinent literature on the related matter. These information's are mostly form Indian situation in which the experiment was conducted. However, some foreign literature has also been included in order to get use of information regarding the present investigation.

2.1 Effect on growth characters

Singh *et al.* (2006) observed that maximum plant height was recorded in weed free (86.58 cm) followed by hand weeding at 20 and 40 DAS (84.05cm) which were at par with each other and minimum plant height was recorded in unweeded check (69.78 cm) which was highly significant from rest of treatment.

Rammana *et al.* (2007) observed that maximum number of total and effective tillers were in weed free plots which was statically similar with two hand weeding (20 and 40 DAT).

Singh and Tripathi (2007) observed superiority of herbicidal control over manual weedings in improving growth characters especially in the early stages of growth.

Kiran and Subramanian (2010) reported that all the weed management practices significantly improved the growth parameters *viz.* plant height, dry matter production and tillers/m^2. Among weed management practices sequential application of oxadiargyl 75 g/ha and bisparibac- sodium 30g/ha or penoxsulam 25 g/ha was as effective as HW twice in improving growth parameters *viz.* plant height (73.60 cm), dry matter production (1421 kg/ha) and tillers/m^2 (722/m^2).

Akabar and Ali (2011) reported that hand weeding twice, pretilachlor @ 1 kg/ha and butachlor @ 1.5 kg/ha recorded maximum plant height and tillers per unit area against the minimum in weedy check.

Hossain and Mondal (2014) observed that significant differences on rice height and biomass at 60 DAT. Crop biomass was highest in weed free check and this was closely *fb* bispyribac-sodium + metsulfuron- methyl + chlorimuron-ethyl.

Hossain and Mondal (2104) reported that post- emergence application of bispyribac-sodium + metsulfuron- methyl + clorimuron-ethyl produced highest number of tillers/m^2 closely *fb* bispyribac + ethoxysulfuron, pyrazosulfuron *fb* manual weeding, pretilachlor + bensulfuron and weed free check.

Narolia *et al*. (2014) reported that among weed management practices, pre-emergence application of pendimithalin @ 1.0 kg/ha fb bispyribac sodium @ 35 g/ha showed 16.5% higher plant height than weedy check.

Uma *et al.* (2014) reported that two hand weeding at 20 and 40 DAT had highest plants height (80.12 cm), number of tillers/m^2 (524/m^2) and dry matter (7120 kg/ha) over all other treatments.

Uma *et al.* (2014) reported that plant height and dry matter production of crop was heighest with two hand weedings at 20 DAT and 40 DAT. Among herbicidal treatments, Bensulfuron – methyl 0.6% @ 1.0 kg granules per ha + hand weeding at 40 DAT and Bensulfuron – methyl 0.6% @ 1.0 kg granules ha + Bispyribac- sodium @ 25 g/ha recorded taller plants and higher crop dry matter production and remained at par with two hand weeding at 20 and 40 DAT treatments.

2.2 Effect on yield and yield attributes

Biswas and Thakur (1983) reported that the weed population comprised 14% *Echinochloa spp*., 22% other grasses, 23% *Cyperus spp*. and 41% broadleaved weeds. Highest grain yield of 4 t/ha was obtained by hand weeding or treatment with piperophos/2,4-D or dinitramine.

Bhagat *et al*. (1991) carried out a research work on the performance of herbicides in direct seeded upland rice at Pusa in the *kharif* season during (1989). They reported that highest grain yield of 41.4 q/ha was obtained from hand weeding at 15, 30 and 45 days after seedling emergence (DASE), followed by 40.4 q/ha from application of pendimethalin + one hand weeding 26 DASE. NC-311 10 WP was the least effective of the herbicides tested.

Gautam and Mishra (1995) revealed that the weed caused 35 to 55% reduction in gain yield at rice under transplanted condition. The observed major dominant weeds in rice field were *Echinochloa colona*, *Cyprus difformis*, *Cyprus irria, Fimbrystylis dichotoma*.

Tamilselvan and Budhar (2002) conducted a field experiment at Paiyur, Tamil Nadu, India, from August to December 1999 to study the effects of pre-emergence herbicides (1.0 kg butachlor/ha, 1.0 kg butanol/ha, 0.40 kg pretilachlor/ha, 0.40 kg pretilachlor/ha+safener, and 0.3 kg anilophos [anilofos]/ha) on rice cv. ADT 43 and associated weeds (*Cyperus rotundus, Cyperus iria, Cyperus difformis, Cynodon dactylon, Echinochloa crus-galli, Echinochloa colona, Marsileaqu adrifoliata [M. quadrifolia],* and *Eclipta alba*). The herbicides were applied 8 days after sowing (DAS). The number of filled grains per panicle was highest with 0.3 kg anilophos/ha (131.7), 0.40 pretilachlor kg/ha (126.3), and kg/ha butanol (122.1).

Mahajan *et al*. (2003) reported that highest grain yield was recorded under applications of pretilachlor combinations with Safner.

Fayaz and Singh (2004) observed that uncontrolled weed growth caused 98.6% reduction in grain yield of rice.

Ram *et al.* (2004) reported that significantly higher grain and straw yields were recorded under weed free check than the herbicidal control through pretilachlor either alone or in combination with 2,4-D. They also found that grain yield to the extent of 52.2 q/ha under weed free environment as against only 41.2 q/ha under pretilachlor + 1 HW and 40 q/ha under pretilachor alone.

Singh *et al*. (2006) observed maximum grain yield in weed free plots being on par with hand weeding twice and minimum in weedy check.

Mishra *et al.* (2007) reported that infestation of weeds reduced grain yield of rice by 25.9%. penoxsulam 22.5 g/ha applied at 10 DAT was found most effective in controlling weeds and maximizing rice grain (6287 kg/ha).

Singh *et al*. (2007) reported that weeds caused 30 to 32% loss in grain yield in weedy check as compared to weed free treatment.

Singh *et al*. (2007) conducted a field experiment during the *kharif* season of 2006 and 2007 at Research Farm of Faculty of Agriculture and Regional Research Station, Wadura of SKUAST, Kashmir, to test the efficacy of new herbicides in transplanted rice and found that all the herbicidal treatments were significantly superior to weedy conditions. Hand weeding with a mean grain yield 80.42 q/ha was superior to all other treatment combinations. Almix @ 8 g/ha at 20 DAT with mean grain yield of 70.83 q/ha was significantly superior to metsulfuron-methyl @ 4 and 8 g/ha, chlorimuron- ethyl @ 4 and 8 g/ha and 2, 4-D 0.5 kg/ha.

Payman and Singh (2008) reported that highest panicle length (23.2 cm) was recorded with two hand weeding, which was statistically at par with weed control treatments except weedy check.

Payman and Singh (2008) found that highest test weight (25.2 g) was recorded with two hand weeding, which was statistically at par with weed control treatments except weedy check.

Rajkhowa and Barua (2008) had conducted a research programme to evaluate the integrated weed management in upland rice at the farm of Assam Agriculture University, Jorhat during 2005 and 2006 on the sandy loam soil. They reported that highest straw yield (4.48 t/ha) was obtained with application of Pretilachlor 0.75 kg/ha + safener, which was statistically at par with rest of the treatments, while significantly superior to one hand weeding at 20 DAS.

Sanjay *et al.* (2008) reported that the highest yield under pretilachlor + 1 HW in comparison with two hand weedings or herbicide given alone. In their experiment pretilachlor + 1 HW gave a yield of 62.33 q/ha against which yields of 60.24 and 53.71 q/ha was realized under hand weedings and herbicides alone, respectively.

Walia *et al.* (2008) had conducted a field expreriment to evaluate the performance of post-emergence application of bispyribac in dry seeded rice at the farm of Punjab Agricultural University, Ludhiana during *kharif* season 2006. They reported that higher grain yield was recorded under treatment receiving postemergence application of bispyribac @ 30 g/ha, which was significantly higher than penoxsulam 20 g/ha and azimsulfuron 20 g/ha.

Bhagat *et al.* (2009) conducted a field experiment at College of Agriculture Farm, CCS HAU, Kaul, Haryana during *kharif* 2005 and 2006 to find out effective and viable system of controlling complex flora of weeds in direct seeded rice. Among different herbicidal treatments, pendimethalin at 1.5 kg/ha (PE) and cyhalofop butyl at 90 g/ha controlled *Echinocoloa* very effectively but failed to check *Cyperus*, whereas pretilachlor + safener at 0.5 kg/ha provided excellent control of *Cyperus*. The grain yield was almost similar under the treatment of pendimethalin at 1.5 kg/ha *fb* HW at 30 DAS in all the sowing methods. Under wet seeding methods, pre-emergence application of pretilachlor + safener resulted in significantly higher grain yield of rice, whereas under dry seeding methods higher grain yield was recorded in the treatment of pre-emergence application of pendimethalin.

Mirza *et al*. (2009) reported that grain yield produced by W (Topstar® 400 SP @ 190 ml ha $^{-1}$ + 1 hand weeding at 25 DAT) and W (2 hand weeding at 25 and 50 DAT) was 104.90% and 92.65% higher than the yield obtained$_3$ from unwedded control (W). Among the preemergence herbicides, Sunrice 13.75 WG showed better$_1$ performance to control weed. Considering weed control cost W found to be most economic weed control$_7$ method for transplanted *aus* rice.

Singh *et al*. (2009) reported that higher grain yield was obtained with penoxsulam at 22.5 and 25 g/ha at 3 DAT during 2005 and 2006, respectively. Weedy plot recorded 41.0 and 34.3% lower grain yield as compared to the treatment having highest grain yield during both the years.

Yadav *et al.* (2009) observed that bispyribac-sodium 25 g/ha applied at 15 or 25 DAT was adjusted the most suitable herbicidal treatment resulting in 174-199% and 37-47% increases in the grain yield over weedy check during 2006 and 2007, respectvly.

Kiran *et al.* (2010) reported that sequential application of oxadiargyl 75 g/ha and bispyribac-sodium 30 g/ha or penoxsulam 25 g/ha was as effective as HW in improving yield attributes and yield of rice. However, hand weeding twice and sequential application of oxadiargyl 75 g/ha and bispyribac-sodium 30 g/ha were found at par with each other with respect to all the yield attributes.

Upasani *et al*. (2010) reported that the highest 1000-grain weight (22.3 g) was recorded under application of chemical herbicides and lowest in weedy check (21.4 g), while the rest of the treatments performed equally well in this regard. Jayadeva *et al.* (2009) found that the application of pyrazosulfuron @ 25 g/ha at 5 DAS and one hand weeding at 20 and 40 DAS recorded significantly higher grain yield (5082 and 4305 kg/ha in summer and *kharif*, respectively) over other treatments.

Daniel *et al.* (2012) found among different weed control treatments, pendimithalin 0.75 kg/ha + HW at 40 days after sowing registered significantly higher grain (1.53 t/ha) and straw yield (2.74 t/ha).

Dixit and Sondhia (2012) reported that among the herbicides all the herbicidal treatments enhanced the grain yield by 50% over weedy check and were statically at par with each other. The grain yield of rice crop was highest under weed free situation followed by almix and ethoxysulfuron application.

Reddy *et al.* (2012) conducted an experiment at ARS gangavathi, Karnatka and the results revealed that pre – emergence application of bensulfuron methyl 0.6% + pritilachlor 6.0% G @ 75 + 750 g/ha at 5 DAT resulted in higher mean yield (6.06 t/ha) than the recommended herbicide butachlor.

Singh (2012) repored the highest grain yield (3.28 t/ha and 2.53 t/ha) and straw yield (4.16 t/ha and 3.16 t/ha) with penoxsulam @ 22.5 g/ha at 8-12 DAT *fb* penoxsulam @ 25 g/ha at 0-5 DAT.

Lap *et al.* (2013) reported that combination of products containing penoxsulam + cyhalofop- butyl can increase rice productivity in direct – seeded, water seeded and transplanted rice production system.

Madhukumar *et al.* (2013) conducted a filed trial during 2010-11 at Main Research Station, Hebbal, University of Agricultural Sciences, Blanalore to study the efficacy of pre and post emergence herbicides on growth and yield of *kharif* aerobic rice and found that pre-emergence application of bensulfuron methyl @ 30 g/ha + pretilachlor @ 600 g/ha recorded significantly higher No. of filled spikelets per penicle, grain and straw yield fllowed by two hand weedings at 20 and 40 DAS and oxyfluorfen @ 90 g/ha as pre-emergent spray + 2, 4-DEE as post emergent spray @ 500 g/ha at 25 DAS which were statically on par with each other.

Prakash *et al.* (2013) reported that the highest rice yield was recorded from weed free plot, followed by two hand weedings treatment. Among the herbicides, bispyribac- sodium 50 g/ha at 15-20 DAT resulted highest yield, which was at par with bispyribac- sodium 35 g/ha. Hussain *et al*. (2008) reported similar result.

Hossain and Mondal (2014) reported that post- emergence application bispyribac-sodium + ethoxysulfuron, pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl, pyrazosulfuron *fb* manual weeding, pretilachlor + bensulfuron and weed free check more grain yield.

Kabdal *et al.* (2014) observed that the highest rice grain yield (6.74 t/ha) was recorded in weed free plots which was statistically at par with post emergence application of bispyribac – sodium at 25 g/ha + ethoxysulfuron at 18.75 g/ha followed by pre emergence application of chlorimuron ethyl + metsulfuron methyl at 4 g/ha.

Narolia *et al*. (2014) A filed experiment was carried out at Agricultural Research Station, Kota, Rajsathan during the rainy (*kharif*) season of 2011 and 2012, they reported that among weed management practices, pre-emergence application of pendimithalin @ 1.0 kg/ha *fb* bispyribac sodium @ 35 g/ha showed 25.6% higher panicle length than weedy check.

Nath *et al.* (2014) reported that highest grain yield (4.56 t/ha) was recorded in weed free check treatment followed by two hand weeding treatment (4.09 t/ha) which was statistically at par with penoxsulam 25 g/ha, bispyribac sodium 25 g/ha and pyrazosulfuron ethyl 20 g/ha.

Uma *et al*. (2014) conducted a field experiment during *kharif* 2011 at College of Agriculture, Rajendranager. The results revealed that pre-emergence application of Bensulfuron- methyl 0.6% + Pritilachlor 6% @ 10 kg granule/ha + Hand weeding at 40 DAT (5455 kg/ha and 6345 kg/ha) and Bensulfuron- methyl 0.6% + Pritilachlor 6% @ 10 kg granule/ha + Bispyribac- sodium @ 25 g/ha recorded significantly higher grain and straw yield (5365 and 6265 kg/ha, respectively) which remain at par with two hand weedings at 20 and 40 DAT (5580 and 6464 kg/ha).

Kumar *et al.* (2015) reported that Maximum mean grain yield 4.72 t/ha was recoded in two hand weeding at 20 and 40 DAS and was statistically at par with PE Pendimithlin 30 EC @ of 1.0 kg/ha *fb* POE Bispyribac 10 SC @ 35 g/ha (4.43t/ha).

2.3 Effect on weed infestation and weed control efficiency

Tuteja *et al.* (1995) reported that both monocot and dicot weed dry matter were higher under herbicidal control in comparison with two hand weedings. Monocot and dicot weeds under two hand weedings were 22 and 3 g/m^2 respectively. The corresponding values under butachlor were 53 and 18 g.

Halder (2000) reported that the pyrazosulfuron ethyl applied as pre- emergence provided an excellent control of broad leaf weeds and sedges and lowered both the weed population and dry weight throughout the growing period.

Nair *et al.* (2002) observed that *Echinochloa colonum* [*Echinochloa colona*], *Eclipta alba*, *Eleusine indica* and *Ischaemum rugosum* were the most dominant weed species under 0, 25, 40, and 35% N at 0, 20, 35, and 60 DAS, respectively.

Ram *et al.* (2004) reported that higher weed count was recorded under pretilachlor application than weed free check. In their experiment, weed free check had no weeds as against 780/m^2 under pretilachlor application. However, it was far less than that under weedy check (155). Weed dry matter (11.61 g/m^2) was also far less under pretilachlor in comparison with that (23.5 g/m^2) under weedy check.

Subramanian and Martin (2006) reported that weed dry weight under pretilachlor on 30 and 60 DAS were 37.1 and 18.9 g/m^2. As against this weed dry weight under two hand weedings were 28.6 and 18.6 g/m^2. Whereas weed dry matter under the weedy check were 121.3 and 185.9 g/m^2. Weed density under pretilachlor, 2 HW and weedy check at 60 DAS were 25, 26 and 218, respectively.

Channabasanava and Biradar (2007) in their field experiment during *kharif* season found that hand weeding twice recorded lower weed population than unweeded check.

Mishra *et al.* (2007) observed that the major weeds in transplanted rice were *Echinochloa colonum, Cyperus spp, Caesulia axillaris, Commelina spp. Ammenia baccifera, Lindernia crustacea, Eriocaulon spp*. and *Alternanthera sessilis*.

Sharma *et al.* (2007) reported that maximum number of effective panicles /m^2 (367) was found under two hand weeding at 20 and 40 DAS, which was statistically at par with all other treatments except weedy check (164).

Singh *et al.* (2007) conducted a field experiment at CCSHAU Rice Research Station, during *kharif* seasons of 2006 and 2007 to evaluate the efficacy of new herbicide penoxsulam with different rates and time of application in transplanted rice and proved that significantly better in controlling grassy, sedges and broadleaf weeds and higher weed control efficiency than the standard herbicide butachlor at 1.5 kg/ha (1-3 DAT).

Singh and Tripathi (2007) reported that weed count under two hand weedings. Herbicidal control and weedy check were 60, 80 and 365, respectively. The corresponding values for weed dry matter (g/m^2) were 21.5, 26.25 and 108, respectively.

Banarjee *et al.* (2008) found that pyrazosulfuron ethyl was significantly superior over pretilachlor for controlling the population and dry matter of weeds.

Dharmbir *et al.* (2008) evaluated that pretilachlor as pre-emergence application @ 800-1000 g/ha was very effective in control of complex weed flora in transplanted rice in comparison to other herbicidal treatments.

Dixit and Varshney (2008) reported that post-emergence application of pyrazosulfuron @ 25 g/ha effectively controlled the infestation of *Phyllanthus niruri*, *Alternantheria sessilin*, *Commelina benghalensis* and *Cyprus iria* over pre-emergence application of butachlor followed by one hand weeding.

Ravisankar *et al*. (2008) found that pre-emergence application of pretilachlor @ 0.30 kg/ha on 2 DAS + hand-weeding at 45 DAS registered lower total weed density (53.6/m^2) and higher weed control efficiency as well as markedly improving the growth and yield parameters and grain yield of wet seeded rice (5.6 t/ha). The maximum rice yield (3.41 t/ha) was obtained from fenoxaprop (0.7 kg/ha), being on a par with each other, proved quite effective against weeds and gave significantly higher grain yield and benefits than weedy check (Mishra and Singh 2008).

Ravishankar *et al.* (2008) found that weed count under two hand weeding and weedy check were 63 and 190. The figure in respect of pretilachlor followed by 1 HW was 53.6.

Jaydeva *et al.* (2009) observed that hand weeding twice (20 and 40 DAT) recorded lower dry weight in comparision to chemical weeding.

Singh *et al*. (2009) reported that penoxsulam was found effective especially against *Echinochloa* species and *Cyperus difformis* as compared to butachlor and pritilachlor and it recorded lower weed dry weight.

Yadav *et al.* (2009) reported that bispyribac-sodium applied at 15 or 25 DAT was found equally effective against grassy weeds but control of broad leaves weeds and sedges was comparatively more when apllied at 15 DAT.

Shan *et al.* (2012) reported that maximum grain yield and weed control efficiency was recorded in transplanted rice with the application of butachlor @ (1.5 kg *a.i.*/ha) + almix 4 g/ha.

Singh (2012) conducted a field experiment during wet season of 2006 and 2007 at Ghaghraghat, Uttar Pradesh to find out the comparative efficacy of different formulations of penoxsulam on weeds and yield in transplanted rice in low lands. The result reveals that the major weed flora recorded in the experimental site was *Echnochloa crus-gali, Echonochloa colona, Commelina benghalensis, Caesulia axillaris, Cynotis axillaris, Ammenia baccifera, Cyperus spp., cynodon dactylon*. The lowest density of weed was recorded with two hand weeding at 20 and 40 DAT, however, application of penoxsulam @ 22.5 g/ha at 8-12 DAT resulted in the lowest dry weight of weeds and higher weed control efficiency at 30, 60 and 90 DAT. This treatment also resulted the lowest weed index (18.88%) followed by penoxsulam @ 25 g/ha at 0-5 DAT.

Lap *et al.* (2013) reported that penoxsulam, a triazolopyrimidine sulphonamide rice herbicide, controls *Echinochloa* spp., annual sedges and many broadleaf weeds. cyhalofop- butyl, an aryloxy phenoxypropionate rice herbicide, controls many grass weeds including *Echinochloa* spp. and *Leptochloa chinensis*. The pre-mix formulation of 10 g, penoxsulam + 50 g. cyhalofop- butyl/litre the tank-mix of penoxsulam + cyhalofop- butyl are broad spectrum herbicide products that are applied post-emergence and provide residual control of many grass, broadleaf and sedge weeds with excellent rice tolerance in ASEAN countries.

Prakash *et al*. (2013) reported that significantly lower weed density (9-10/m^2) and weed dry weight (12.5-13.7 g/m^2) were recorded in the plots where bispyribac-sodium 35g/ha at 15-20 DAT was applied. Significantly higher weed control efficiency and herbicidal efficiency index were recorded with bispyribac-sodium 35g/ha at 15-20 DAT.

Hossain and Mondal (2014) conducted a field experiments were conducted in transplanted rice at Visva-Bharati, Sriniketan during *Kharif* seasons of 2012 and 2013. The predominant weed species were: *Ludwigia parviflora*, C*yanotis axillaris*, *Commelina diffusa* and *Spilanthes acmella*. Pre-emergence application of pretilachlor + bensulfuron at 660 g/ha and post-emergence application of bispyribac-sodium *fb* metsulfuron-methyl + chlorimuron ethyl at 4 g/ha effectively controlled grassy weed population. Post-emergence application of bispyribac *fb* metsulfuron-methyl + chlorimuron-ethyl was found to be most effective in controlling broad-leaved weeds and it was closely *fb* bispyribac + ethoxysulfuron applied as post-emergence. Application of bispyribac-sodium *fb* metsulfuron-methyl + chlorimuron-ethyl as post-emergence and pyrazosulfuron ethyl as pre-emergence were effective in controlling sedge population.

Kabdal *et al.* (2014) reported that weed control efficiency (WCE) with respect to grass, sedge and broad-leaved weeds (98.2%) was highest with post-emergence application of bispyribac-sodium at 25 g/ha + ethoxysulfuron at 18.75 g/ha followed by pre-emergence application of pretrilachlor at 750 g/ha *fb* post-emergence application of chlorimuron-ethyl + metsulfuron-methyl at 4 g/ha (93.4%).

Kabdal *et al.* (2014) observed that highest dry matter accumulation was recorded in weedy check. The increase in dry weight of weeds in weedy check may be attributed to more nutrition available to the weeds. The results are in conformity with the findings of Ehsanullah *et al.* (2009) who observed numerically higher dry weight of weeds in weedy check over other treatments.

Uma *et al.* (2014) conducted a field experiment was conducted during *kharif* 2011 at College of Agriculture, Rajendranagar. The experiment consisted of 12 treatments laid out in randomized block design with three replications consisting of two pre-emergence herbicides integrated with post emergence herbicides and one hand weeding at 40DAT and two post emergence herbicide, hand weeding twice at 20 and 40 days after transplanting, compared with weed free and unweeded check. The predominant weed flora observed in the experimental field were *Echinochloa crusgalli, Panicum repens, Cynodon dactylon, Cyperus rotundus, Cyperus difformis, Eclipta alba and Ammania baccifera*.

Uma *et al.* (2014) observed that performance of combination of pre and post emergence herbicides was found equally effective as that of hand weeding at 20 DAT, showing that hand weeding can be substituted by these herbicides if labour availability is a problem. Pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% @ 1.0 kg granules per ha^{-1} was found effective even at 40 DAT and recorded significantly lower weed density compared to that of weedy check.

Mathiyalgen and Muraliathanari (2015) conducted field experiment during *kharif* 2012 to identify the effect of sequential application of herbicides for weed control in transplanted rice. Herbicides were applied at different stages of crop. Among the herbicide combinations sequential application of Pre-emergence application of pretilachlor fb post-emergence application of admixture of chlorimuron ethyl 10 % + metsulfuron methyl 10 % @ 4 g/ha effectively controlled the weeds in terms of reduced density of weeds, weed dry weight and higher weed control efficiency at all the stages of observation.

2.4 Effect on uptake of nutrients by crop and weeds

Kumar *et al.* (2010) found that uptake of nutrients was higher by direct seeded rice crop and decreased nutrient uptake by weeds with hand weedings and pre-emergence application of pendimethalin @1.0 kg/ha + anilophos @ 0.4 kg /ha over rest of the treatments.

Mukherjee and Maity (2010) reported that weeds in complete weedy situation removed 37.7 to 50.9 kg N, 10.3 to 15.7 kg P and 47.4 to 63.7 kg K/ha in wet seeded rice during 2006 and 2007.

Nath *et al.* (2014) reported that all the weed control treatments significantly decreased the nutrient uptake by weeds and in turn increased the nutrient uptake by rice than unweeded control. Two hand weeding at 20 and 40 DAS treatment which was at par with penoxsulam 25 g/ha caused significant reduction in nutrient uptake by weeds than all other herbicidal treatments. N and P uptake by crop plants was similar by two hand weeding at 20 and 40 DAS and weed free check treatment but significantly higher than rest of treatments whereas K uptake was significantly higher in weed free check. All the herbicidal treatments remained at par with each other with respect to N, P and K uptake by crop plant.

Uma *et al*. (2014) reported that maximum NPK uptake (kg/ha) by weeds was observed in weedy check at 40 DAT and at harvest followed by 2 mechnical weedings at 20 and 40 DAT. Whereas minimum NPK uptake by weeds was recorded by hand weeding at 20 and 40 DAT followed by bensulfuron methyl + pritilachlor *fb* bispyribac sodium @ 25 g/ha at 20 DAT and bensulfuron methyl + pretilachlor fb HW at 40 DAT.

2.5 Effect on economics of rice yield

Subramanian *et al.* (2006) found that application of Bispyribac-sodium @ 20 g/ha was more remunerative having B: C ratio (2.38) than application of cyhalofob-butyl @ 75 g/ha (20.38) and butachlor @ 1.5 kg/ha (2.42).

Singh *et al*. (2007) found that among weed control treatments, almix 8 g/ha proved most profitable with net returns of Rs. 26269/ha and B: C ratio of 1.46.

Sanjay *et al.* (2008) reported through their experiment that two hand weedings fetched net return of ₹18,296/ha as against ₹2,719/ha under the weedy check. The net return under herbicidal control and herbicide + 1 HW were ₹15, 968 and ₹19,725/ha.

Gowda *et al.* (2009) conducted an experiment during *kharif* season 2005 in Karnataka to study the efficacy of some herbicides on rice. The result of the experiment revealed that the application of pyrazosulfuron ethyl (30 g/ha) recorded significantly higher gross return, which was statistically at par with two hand weeding and significantly superior to rest of the treatments.

Bhurer *et al.* (2013) reported that stale seed bed followed by pendimethalin 30 EC @ 1 kg/ha followed by bispyribac- sodium @ 25 g/ha at 20 DAS resulted best alternative for manual hand weeding practices giving higher net return per unit investment.

Pradhan *et al.* (2013) found that almix was found to be more economic and remunerative in realizing maximum benefit cost ratio (3.5). Despite giving higher grain yield than pretilachlor, oxadiargyl and HW Twice proved to be less economic due to higher cost involvement.

Hossain and Mondal (2014) found that the highest net returns and B:C ratio were recorded with bispyribac *fb* metsulfuron-methyl + chlorimuron-ethyl and pre-emergence application of pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl. Herbicides applied in combination recorded more net returns and B:C ratio as compared to sole application of herbicide.

Prabhakaran *et al.* (2014) reported that cost of cultivation was 23.0% lower in pendimethalin 1000 g/ha *fb* bispiribac-sodium 25 g/ha *fb* hand weeding on 45 DAS (₹ 28,247/ha and 28,367/ha during *kharif* and *rabi*, respectively) when compred to hand weeding on 20, 40 and 60 DAS with ₹36,677/ha and ₹36,797/ha during *kharif* and *rabi* respectively.

Uma *et al.* (2014) reported that highest net returns (Rs. 33,189 ha) and B:C ratio (1.40) were also recorded with the preemergence application of bensulfuron-methyl 0.6%+ pretilachlor 6% @ 10 kg granules ha^{-1}+ bispyribac sodium @ 25 g ha^{-1} at 20 DAT (1.40) compared to that of two hand weedings (Rs. 31,952 ha^{-1}) and benefit cost ratio (1.17).

◈◈◈

Chapter - 3

[MATERIALS AND METHODS]

MATERIALS AND METHODS

The present investigation entitled **"Bio- efficacy of Herbicides Combinations Against Weed flora in Transplanted Rice (*Oryza sativa* L)"** was carried out during *kharif* season of 2015 at the Research Farm of Rajendra Agricultural University, Pusa (Samastipur), Bihar (India). A detailed account of the materials used, experimental procedure and methods adopted during the course of field investigation are described in this chapter.

3.1 Experimental Site

The aforesaid Rajendra Agricultural University, Pusa farm is situated on the southern bank of the river *Budhi Gandak* in Samastipur district at 25.59^0 North latitude and 84.40^0 East longitude with an altitude of 52.3 m above the mean sea level (MSL).

The experiment was laid out in nursery Jhilli field at above mentioned Research Farm. Experimental field was homogeneously fertile with even topography and uniform textural make up and was attached to the main irrigation channel connecting the farm tube well for quick, regular and timely irrigation. Proper drainage facility was also provided in order to remove excess water during experimental period.

3.2 Experimental Soil

The soil, as a medium of plant support and growth is bound to affect profoundly and substantially the rate of growth as well as development and eventually the final and economical yield through its biotic and abiotic activities and geo-physico-chemical properties.

The composite samples from 0-30 cm depth were randomly collected from the experimental field with the help of screw auger prior to experimentation. All the possible technical precautions as prescribed for standard soil sampling, was also taken. Then samples were brought to the laboratory, air-dried and ground, thereafter sieved through 20 mm mesh. The soil samples thus obtained were subjected to various mechanical, physical and chemical analysis to assess the physical and chemical properties of soil. The soil of the experimental site was calcareous alluvium in nature and slightly alkaline in reaction, which developed mainly by deposition of sediments of the river *BudhiGandak* through the ages (Table 3.1). The soil of the experimental field was low in available nitrogen, phosphorus and potassium (Table 3.2).

It is quite evident from the data that soil of the experimental site was calcareous (clay loam). Experimental site was situated almost in the middle of the Indo-Gangetic Alluvial Plain having deep, flat and well drained alluvial soils characteristics by clay loam in the texture and moderately fertile, being low in available nitrogen, phosphorous and potassium.

Table 3.1 Physical constants of experimental soil

Sl. No.	Particulars	Value (%)	Method adopted
1.	Fine Sand	24.75	Hydrometric method (Bouyoucos,1962)
2.	Silt	49.18	
3.	Clay	26.07	
4.	Textural class	Clay loam	
5.	Bulk density (g/cc)	1.42	Core sampler (Piper, 1950)

Table 3.2 Chemical properties of experimental Soil

Particulars	Values	Method adopted
Organic carbon (%)	0.41	Walkley and Black method (1934)
pH (1: 2.5)	8.69	Buckman pH meter (Jackson, 1973)
Electrical conductivity (m. mhos cm^{-1} at 25^0C)	0.43	Systronics electrical conductivity meter (Richards, 1954)
Available Nitrogen (kg /ha)	203.2	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available P_2O_5 (kg/ha)	17.5	Olsen's method (0.5 N $NaHCO_3$ extractable) (Olsen *et al.*, 1954)
Available K_2O (kg/ha)	101.7	Flame photometric method (Jackson, 1973)

3.3 Weather and Climate

The climate is sub-tropical, greatly influenced by hot-dry summer and too cold winter. It falls in the region of south-west monsoon and generally monsoon starts from mid-June and continued up to October. The mean average annual rainfall is 1240 mm out of which nearly 80-90 % is received between June to October. The day length varied from 10 hours 12 minutes to 13 hours 43 minutes.

The meteorological data related to the weather conditions prevailing during crop season *Kharif* 2015 with respect to rainfall, relative humidity (at 7:00 hours and 14: 00 hours) and temperature obtained from Agro-meteorological advisory services, Department of Agronomy, RAU, Pusa (Table 3.3 and Fig. 3.1).

3.3.1 Rainfall

Monsoon shower was received quite normal trend during the year of experimentation. The total rainfall of 1089.8 mm was recorded during the cropping period. Out of which 316.2 mm precipitation occur during 34th Standard Mean Week (SMW) which is between active tillering and maximum tillering stage of rice. However, only 25.4 mm rain was recorded in 35th SMW during the experimental crop period of 2015 coinciding with the panicle initiation stage of crop. Otherwise, the weather remained almost dry for the most of the part of the experimental period during the year 2015.

3.3.2 Temperature

Temperature is one of the major meteorological variable influencing germination, growth and development of plants in a given agro-climatic condition. The mean maximum temperature ranges between 30.5 to 35.5ºC and the mean minimum temperature ranged between 17.1 to 26.5ºC during experimental period of 2015. The maximum and minimum temperature was recorded in the last week of June (35.5ºC) and in the first week of November (17.1ºC) respectively. The average temperature ranged between 23.4 to 33.6ºC during *kharif* season of 2015.

3.3.3 Relative humidity

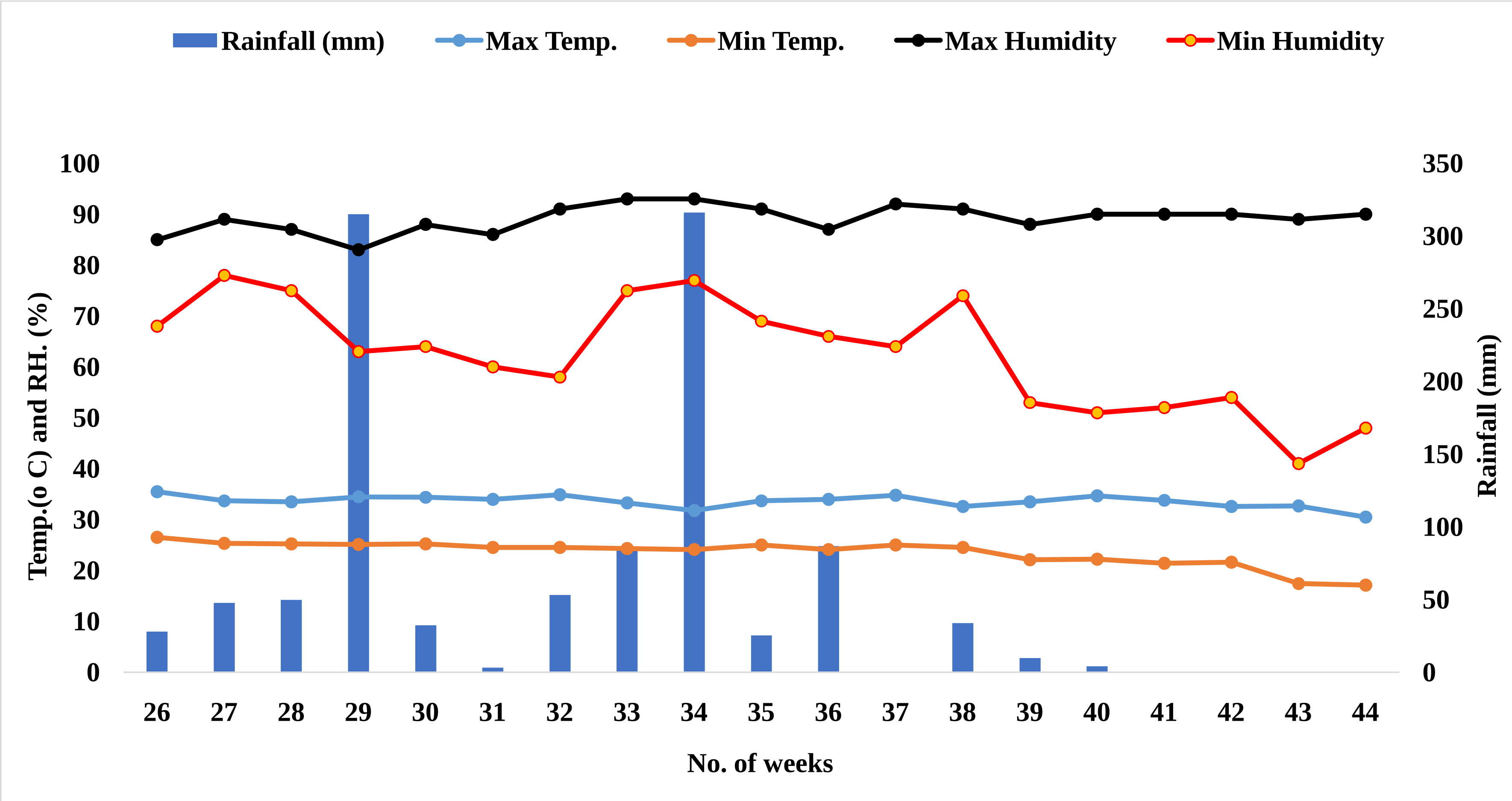
The maximum relative humidity varied between 83 to 93 % during the experimental period 2015. It attained the maximum level during 33rd and 34th SMW in the *kharif* season of the year 2015. The minimum relative humidity fluctuated between 51 to 78 % in *kharif* season of 2015. It touched the maximum value at 27th SMW during the experimental period. While, minimum relative humidity was recorded during the maturity period of the crop.

3.3.4 Sunshine duration

The average bright sunshine hours per day was higher with 6.14 hours in *kharif* season of 2015. The value ranged from 2.6 to 10.7 hours during *kharif* season of 2015.

Table 3.3 Meteorological data during cropping season

Week No.	Temperature		Relative Humidity (%)		Rainfall (mm)	Evaporation (mm)	Bright sunshine (hours)
	Max.	Min.	Max.	Min.			
26 (28 June – 4 July)	35.5	26.5	85	68	28.0	4.5	5.9
27 (5 July – 11 July)	33.7	25.3	89	78	47.8	3.1	3.3
28 (12 July - 18 July)	33.5	25.2	87	75	49.8	3.9	5.3
29 (19 July – 25 July)	34.5	25.1	83	63	315	4.5	6.1
30 (26 July – 1 Aug.)	34.4	25.2	88	64	32.4	4.2	6.0
31 (2 Aug. - 8 Aug.)	34.0	24.5	86	60	3.2	3.8	4.9
32 (9 Aug. - 15 Aug.)	34.9	24.5	91	58	53.2	4.0	4.8
33 (16 Aug. – 22Aug.)	33.3	24.3	93	75	84.2	4.5	5.0
34 (23 Aug. – 29 Aug.)	31.8	24.1	93	77	316.2	5.3	2.6
35 (30 Aug. – 5 Sept.)	33.7	25.0	91	69	25.4	3.3	5.7
36 (6 Sept. - 12 Sept.)	34.0	24.1	87	66	86.8	4.0	4.7
37 (13 Sept. - 19 Sept.)	34.8	25.0	92	64	0.0	3.5	6.9
38 (20 Sept. – 26 Sept.)	32.6	24.5	91	74	33.8	3.3	5.5
39 (27 Sept. – 3 Oct.)	33.5	22.1	88	53	9.8	3.1	7.9
40 (4 Oct. – 10 Oct.)	34.7	22.2	90	51	4.2	3.6	8.6
41 (11 Oct. - 17 Oct.)	33.8	21.4	90	52	0.0	3.6	8.3
42 (18 Oct. – 24 Oct.)	32.6	21.6	90	54	0.0	3.1	6.6
43 (25 Oct. - 31 Oct.)	32.7	17.4	89	41	0.0	2.8	7.9
44 (1 Nov. – 7 Nov.)	30.5	17.1	90	48	0.0	2.5	10.7



F ig. 3.1 Metrological data during crop season

3.4 Cropping history of the experimental field

The production potential of the experimental field can be judged from its cropping history. The details of the cropping history of the experimental field for preceding three years of the experimentation are given in Table 3.4. The cropping pattern indicates that the fertility status of the field is not much disturbed by the previous crops as it was continuously occupied by rice during *kharif* and wheat during *rabi* season from 2012- 13 till experimental period.

Table 3.4 Cropping history of the experimental plot

Years	Season	Crop
2012- 2013	*Kharif*	Rice
	Rabi	Wheat
2013-2014	*Kharif*	Rice
	Rabi	Wheat
2014-15	*Kharif*	Rice
	Rabi	Wheat
2015-16	*Kharif*	Rice (experimental crop)

3.5 Experimental design and layout

The experiment was conducted during *kharif* season of 2015. The factors under study comprised Bio- efficacy of herbicides combinations against weed flora in transplanted rice.

Experimental design	:-	R.B.D
Number of replication	:-	3
Number of treatments	:-	12
Total number of plots	:-	36
Gross plot size	:-	7m x 3.9m =27.3m^2
Net plot size	:-	6.0m x 3.0m =18m^2
Variety	:-	Rajendra Shweta

The classified descriptions of the treatments with corresponding symbols are given below in order to facilitate their presentation in the text (Table 3.5)

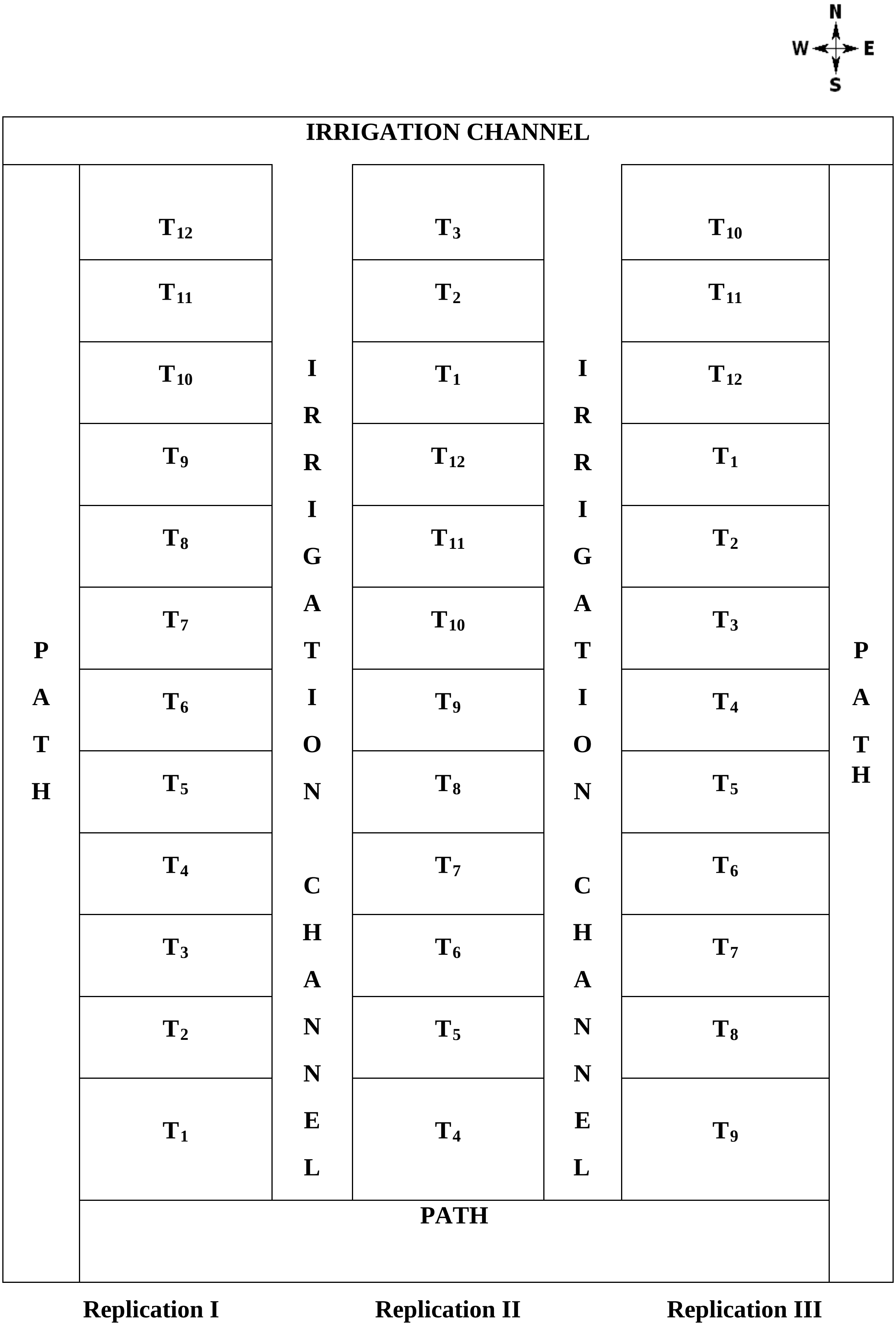


Fig 3.2. Layout of the experiment

Table 3.5 Treatments details

	Treatments	Dose (g/ha)	Time (DAT)
T_1	Bispyribac- Sodium	25	25 DAT (3-4 leaf stage)
T_2	Penoxsulam 24 % SC	22.5	15
T_3	Bispyribac– Sodium + ethoxysulfuron	25 + 18.75	25 DAT (3-4 leaf stage)
T_4	Bispyribac–Sodium + Chlorimuron + metsulfuron (Almix)	20 + 4	25 DAT (3-4 leaf stage)
T_5	Pretilachlor *fb* ethoxysulfuron	750/18.75	0 – 3 *fb* 25 DAT (3-4 leaf stage)
T_6	Pretilachlor *fb* Chlorimuron + metsulfuron (Almix)	750/4	0 – 3 *fb* 25 DAT (3-4 leaf stage)
T_7	Pyrazosulfuron ethyl *fb* Chlorimuron ethyl + metsulfuron methyl (Almix)	20/4	0 – 3 *fb* 25 DAT (3-4 leaf stage)
T_8	Penoxsulam + cyhalofop butyl 6 % OD (RM)	135	15 - 20
T_9	Triafamone + ethoxysulfuron 30 % WG	60	15
T_{10}	Pendimethalin (38.7 % CS) *fb* Bispyribac–Sodium	750/25	0 – 3/25
T_{11}	Hand weeding at 25 and 45 DAT		
T_{12}	Weedy check		

3. 6 Calendar of operation and cultural practices

The particulars of important operations starting from field preparation to crop harvest are presented in Table 3.6.

Table 3.6 Schedule of various cultural operations followed in the experimental plots

Sl. No.	Field operations	Date of operation
1.	**Preparatory tillage**	-
(a)	Tractor disking	19.07.2015
(b)	Cultivator ploughing	23.07.2015
2.	**Layout**	24.07.2012
3.	**Transplanting and fertilizer application**	25.07.2012
4.	**Irrigation**	-
(a)	First	09.08.2015
(b)	Second	16.09.2015
(c)	Third	10.10.2015
5.	**Harvesting**	06.11.2015
6.	**Threshing and bundling**	10.11.2015

3.6.1 Selection and field preparation

A rectangular plot having uniform fertility and even topography was selected for experimental trial. The land was ploughed by soil turning plough followed by two disking. The field was irrigated to obtain proper tilth. Finally, the lay out was done to meet the requirements of the experimental design.

3.6.2 Seed rate

The seed rate of 35 kg /ha was used establishment methods.

3.6.3 Fertilizer application

The fertilizer dose viz. 120-60-40 kg N - P_2O_5 - K_2O/ha were applied in experimental field. Nitrogen was applied through urea and P_2O_5 as DAP where as K_2O was applied through MOP. One third dose of nitrogen and full dose of phosphorus and potash were applied as basal dose at the time of sowing and remaining two third dose of nitrogen was applied in two equal splits at 30 and 60 DAT.

3.6.4 Seed treatment and sowing

Crop seeds were treated with SAAF (Carbendazim +Mancozeb) @ 3 g/kg seed before sowing to protect the crops from seed borne diseases.

3.6.5 Weed management

Herbicides and different weed management practices were adopted as per treatment.

3.6.6 Irrigation

Three irrigations were given uniformly in all the plots during the year of experimentation. First irrigation was applied at 14 DAT followed by second irrigation at 51-52 DAT and third was applied at 75-76 DAT.

3.6.7 Plant protection measures

Furadon 3G was applied for the control of rice insect pest.

3.6.8 Harvesting

The crop was harvested by serrated edged sickles manually at physiological maturity. At first border rows around the individual plots were harvested and removed leaving only the net plot area. The harvesting of each net plot area was done separately and the harvested material from each plot were carefully bundled, tagged and taken to the threshing floor and kept separately for sun drying.

3.6.9 Threshing

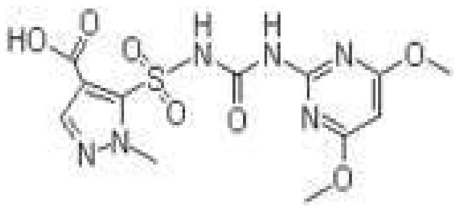
Each bundle was weighed after proper sun drying and then threshed plot wise. The grain yield was recorded separately after winnowing and cleaning. The straw yields were calculated by subtracting seed yield from the bundle weight and were converted to quintal/ ha based on net plot size harvest.

3.6.10 Sampling procedure and observations

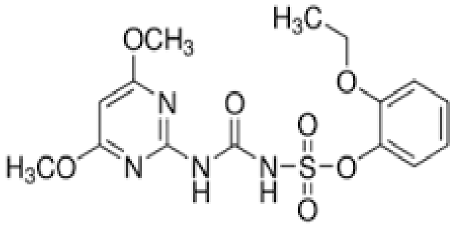
An appropriate sample is one that provides an estimate or a sample value that is as close as possible to the value that would have been obtained, had all plants in the plot been measured. The difference between the sample and plot values constitutes the sampling error. Thus, a good sampling technique is one that gives a small sampling error. Error of a sample estimate generally decreases with the size of sampling, sampling unit number per plot and the sampling design. However, an increase in either size or number of sampling unit almost always results an increase in cost. Therefore, the choice of an appropriate sampling technique is of prime concern to maintain proper balance between the size of sampling unit, sampling size and sampling design to achieve the maximum precision with the minimum cost. Single plot as a sampling unit, five plants or appropriate plant number according to requirement per experimental plot as a sample size and a random sampling technique (Gomez and Gomez, 1984) were adopted for recording growth and development of the test crops at various stages of observations. Destructive sampling was done for dry matter accumulation studies.

The growth indices of the crop during the experimental year were recorded at regular intervals in order to assess the probable relationship between growth attributes and the final yield. The observations were made at 30 DAT at appropriate interval depending upon crop indices only to receive a precise observation of growth analysis.

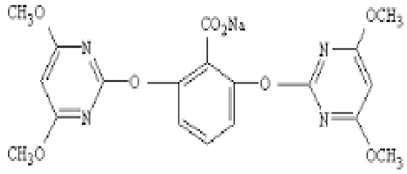
3.6.11Herbicides
Pyrazosulfuron ethyl
Molecular formula: $C_{14}H_{18}N_6$
Trade name: Sathi



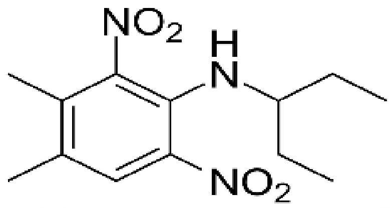
Ethoxysulfuron
Molecular
formula: $C_{15}H_{18}N_4O_7S$
Trade name: Sunrice



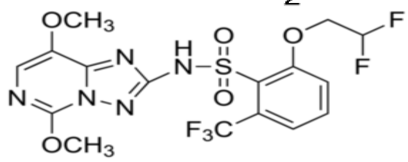
Bispyribac-sodium
Molecular
formula: $C_{19}H_{17}N_4NaO_8$
Trade name: Nominee Gold



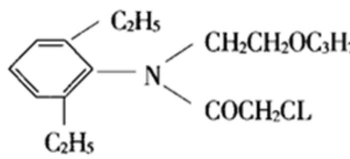
Pendimethalin
Molecular formula: $C_{13}H_{19}N_{13}O_4$
Trade name: Stomp



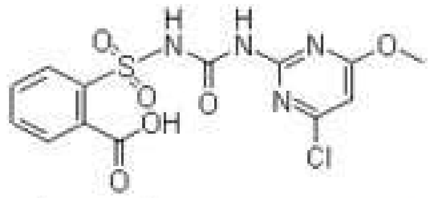
Penoxsulam
Molecular
formula: $C_{16}H_{14}F_5N_5O_5S$
Trade name: Granite



Pretilachlor
Molecular
formula: $C_{17}H_{126}ClNO_2$
Trade name: Sofit

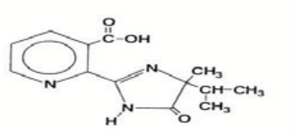


Chlorimuron
Molecular
formula: $C_{15}H_{15}ClN_4O_6S$
Trade name: Classic

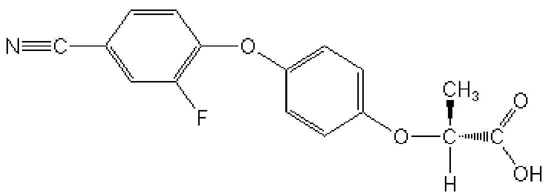


Metsulfuron
Molecular formula $C_{14}H_{15}N_5O_6S$
Trade name: Blade

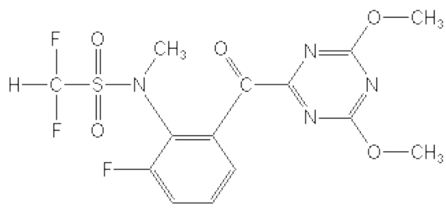
Imazapyr acid



Cyhalofop
Molecular
formula: $C_{20}H_{20}FNO_4$
Trade name: Clicher



Triafamone
Molecular
formula: $C_{14}H_{13}F_3N_4O_5S$



3.7 Growth and yield attributing characters

Sample plants were selected at random in net plot area and tagged for recording observations. Almost all the growth parameters were recorded at 30, 60, 90 DAT and at harvest.

3.7.1 Growth parameters

3.7.1.1 Plant height (cm)

The height of randomly selected five tagged rice plants in net plot area was measured from the base of the plant to the tip of the upper most leaf at all the growth stages. The plant height was expressed as average plant height in centimeter.

3.7.1.2 Number of tillers/m^2

The number of tillers per m^2 was counted at 30, 60, and 90 DAT and also at harvest stage. The tagged plants were used for the purpose at different crop growth stages by visual counting.

3.7.1.3 Plant dry weight (g/m^2)

The samples were collected at 30 DAT and regular intervals of 30 days and also at harvest stage. Plants enclosed in a quadrant of 0.50 m^2 placed randomly in the border area and were uprooted from each plot. The samples were washed, sun dried and then kept in oven at 65 ^{0}C $\pm$ 5 till constant weight reached. The dry matter production was converted into g/m^2.

3.7.2 Yield attributing characters

3.7.2.1 Number of panicles/m^2

The total number of panicles bearing tillers/m^2 were counted at the time of harvesting from the net plot area with the help of quadrant (0.50 m^2) placed randomly at three places in each plot and were counted and then converted as per square meter.

3.7.2.2 Numbers of grain/panicle

Total number of grains/panicle was calculated by adding the numbers of filled.

3.7.2.3 Length of panicle (cm)

Five panicles were randomly selected from the tagged plants harvested separately. The lengths of panicles were measured in cm from the neck node to its tip and finally the average length of panicle was worked out.

3.7.2.4 1000- grain weight (g)

To avoid biasness, handful seeds were taken from each net plot and thousand seeds were counted randomly and weighed.

3.7.3 Yield and harvest index

3.7.3.1 Grain yield (t/ha)

Grain yield was determined from the net plot area and was weighed in kg and converted into t/ha. Grains were harvested, dried and weighed, and grain weight is adjusted to a moisture content of 0.14 g H_2O g/ha fresh weight.

3.7.3.2 Straw yield (t/ha)

The sun dried straw obtained from net plot area were weighed plot wise in kg and converted into ton per hectare separately at 10 per cent moisture level.

3.7.3.3 Harvest index (%)

Theharvest index was calculated by using the formula as described by Singh and Stockopf (1971).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain + straw yield)}} \times 100$$

3.7.4 Chemical Studies

3.7.4.1 Soil reaction and conductivity

The pH of the soil was measured with the help of a systronic pH meter maintaining the soil: water ratio at 1: 2.5 as described by Jackson (1973).

Conductivity was also measured in same extract by the conductivity bridge.

3.7.4.2 Available Nitrogen (kg N /ha)

The available nitrogen of the soil was measured by alkaline permanganate method as described by Subbaiah and Asija (1956).

3.7.4.3 Available Phosphorus (kg P_2O_5 /ha)

Available phosphorus in the soil was determined by using Olsen's method described by Jackson (1973).

3.7.4.4 Available Potassium (kg K_2O /ha)

Available potassium in the soil was determined by extracting the soil with neutral normal ammonium acetate solution in soil extractant ratio of 1:5 and potassium was taken and estimated with the help of flame photometer (Piper, 1973).

3.7.4.5 Organic carbon (%)

The organic carbon of soil was determined by Wakley and Black method, 1934.

3.7.4.6 Crude protein (%)

Crude protein content in grains was calculated by multiplying the percent nitrogen content in grain with a factor 6.25.

3.7.4.7 Nitrogen uptake

The nitrogen content in plant was determined by kjeldahl's method (Jackson, 1973)**.** The grain and straw were separated and then grinded. The grinded material was digested in concentrated sulphuric acid using copper sulphate and potassium sulphate mixture as catalyst. The digested material was then distilled with 40 percent sodium hydroxide and distillate was collected in boric acid containing the mixed indicator. The content was estimated by titrating the distillate against N/20 sulphuric acid. The nitrogen uptake was calculated by multiplying the dry weight with nitrogen content. In order to get total uptake of nitrogen, the uptake values for grain and straw were added together.

3.7.4.8 Phosphorus uptake

Total phosphorus uptake was determined in the extract by vandomolybdate yellow color method (Jackson, 1973). The optical density (OD) was measured with photoelectric colorimeter at 470 nm. The content was estimated with calibration curve.

The phosphorous uptake by grain and straw per hectare was calculated with the help of per cent value of phosphorus and yield of grain and straw. In order to get total uptake of phosphorous, the uptake value for grain and straw were added together plot wise.

3.7.4.9 Potassium uptake

The potassium content was determined with the help of flame photometer (Jackson, 1973) and was estimated with calibration curve.

Total uptake of potassium by rice grain and straw was calculated by multiplying their relative contents with yield and values were added to know the total uptake of potassium in kg/ha.

3.7.5 Weed parameters

3.7.5.1 Weed population (No./m^2)

Weed population was counted from an area enclosed in a quadrant of 0.50 m^2 from each plot and then converted into per meter square.

3.7.5.2 Weed dry weight (g /m^2)

Weeds were removed from an area of 0.09 m^2 and were cleaned, washed, air dried and then kept in the oven at 60^0C till constant weight reached. The dry weight of weeds was expressed on oven dry basis in g/m^2.

3.7.5.3 Weed control efficiency (WCE)

Weed control efficiency (WCE) was computed by the formula**:**

$$\text{WCE (\%)} = \frac{X-Y}{X} \times 100$$

Where,

X = Dry weight of weed in unweeded check, and

Y = Dry weight of weed under the treatment for which WCE is being calculated.

3.7.5.4 Weed index

The efficacy of the weed index was calculated by the following formula:

$$\text{W.I. (\%)} = \frac{X-Y}{X} \times 100$$

Where, X was the grain yield (q/ha) in weed free plot, Y was the grain yield (q/ha) in treated plot.

3.7.6 Economics

Economics of different treatments was calculated by taking into account the prevailing market price of inputs and produce (grain and straw). The detail cost of cultivation as per treatments and market price of inputs and produce are given in Appendices I.

The gross return (₹/ha), net return (₹/ha) and Benefit: cost ratio were calculated for each treatment, using the purchase price of inputs and selling price of out puts prevailing in the local market.

Gross return (₹/ha) = Selling price of grain (₹/q) × grain yield (q/ha) + Selling price of straw (₹/ha) × straw yield (q/ha).

Net return (₹/ha) = Gross return – Total cost of cultivation.

$$\text{Benefit : cost ratio} = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

3.7.7 Statistical analysis

Data pertaining to various parameters were subjected to statistical analysis by the technique of analysis of variance as described by Cochran and Cox (1962). The significance of treatment effect was tested by F-test. Standard errors of differences were computed and recorded along with the summary results. Critical differences for different groups of treatments and their interactions at 5 percent level of significance were calculated where ever F-test was significant. The results were then interpreted logically to derive definite conclusion.

◈◈◈

Chapter - 4

[EXPERIMENTAL FINDINGS]

EXPERIMENTAL FINDINGS

An attempt has been made to ascertain the degree of variation exhibited by crop parameters and soil characteristics due to treatment variables in the experiment entitled "**Bio- efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice (*Oryza sativa* L.)**". The data have been statistically analyzed, presented in tables and suitably illustrated by graphs and figures wherever necessary.

1. Crop parameters

A. Growth parameters

1.1 Plant height (cm)

The data on progressive plant height recorded at 30 days' interval have been presented in Table 4.1 and graphically depicted in Fig. 4.1.

Table: 4. 1. Effect of different weed management treatments on plant height (cm) at different stages of crop growth

	Treatments	30 DAT	60 DAT	90 DAT	At harvest
T_1-	**Bispyribac- Sodium**	58.12	78.39	94.01	95.69
T_2-	**Penoxsulam 24 % SC**	58.64	77.46	93.69	95.04
T_3-	**Bispyribac – Sodium + Ethoxysulfuron**	62.32	83.60	98.08	99.08
T_4-	**Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)**	61.65	82.59	97.39	98.47
T_5-	**Pretilachlor *fb* Ethoxysulfuron**	60.57	81.35	96.31	98.05
T_6-	**Pretilachlor *fb* Chlorimuron + Metsulfuron (Almix)**	61.05	80.25	97.38	98.32
T_7-	**Pyrazosulfuron *fb* Chlorimuron + Metsulfuron (Almix)**	60.31	80.25	96.54	97.13
T_8-	**Penoxsulam + Cyhalofop 6 % OD**	59.67	80.13	95.24	96.95
T_9-	**Triafamone + Ethoxysulfuron 30 % WG**	59.63	78.85	94.30	96.03
T_{10}-	**Pendimethalin (38.7 % CS) *fb* Bispyribac – Sodium**	63.52	85.46	99.13	101.82
T_{11}-	**Hand weeding at 25 and 45 DAT**	64.47	85.64	100.44	104.44
T_{12}-	**Weedy check**	56.83	77.05	92.84	94.17
	SEm±	0.972	1.502	1.329	1.306
	LSD (P=0.05)	2.86	4.43	3.92	3.85

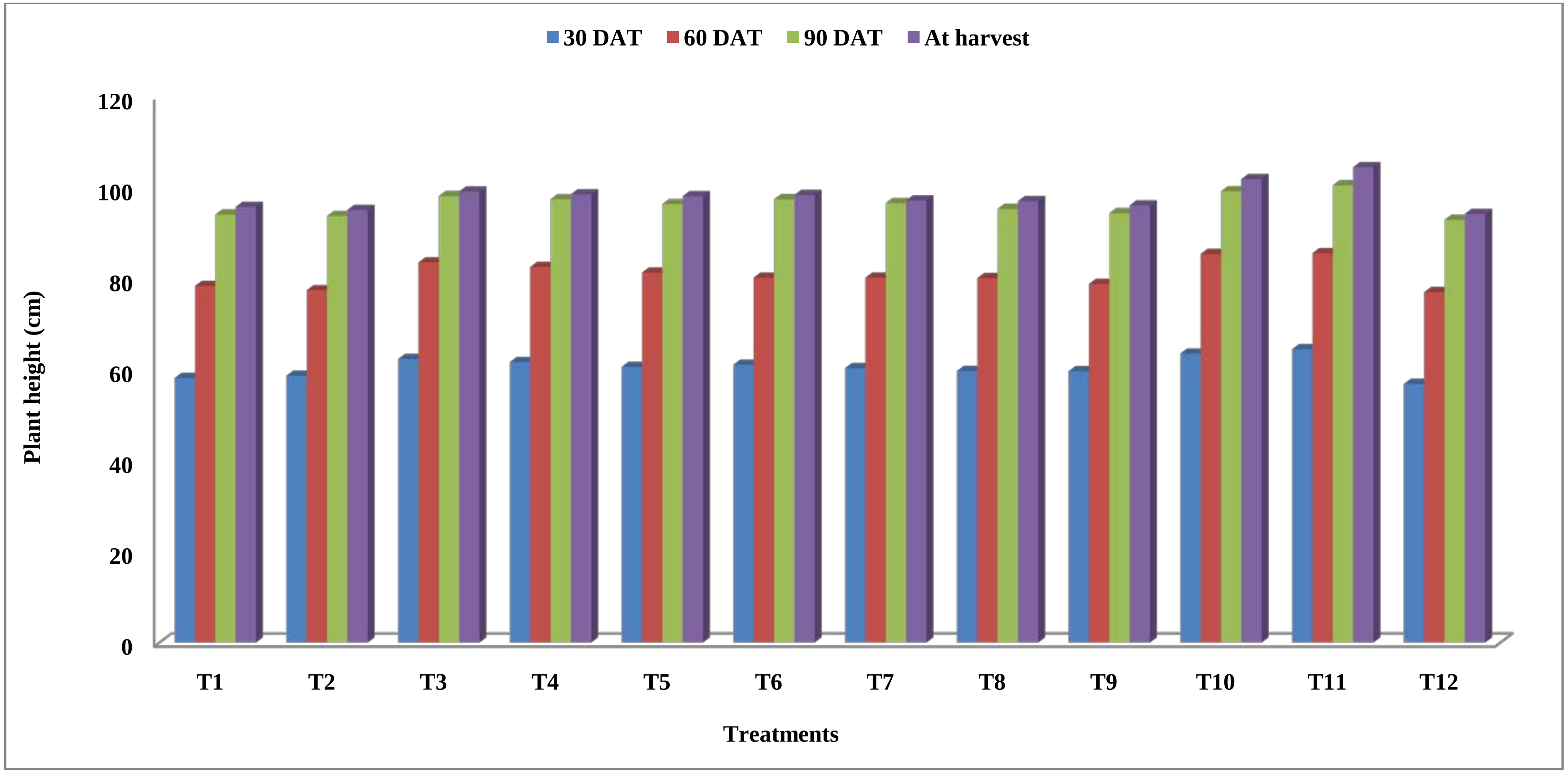


Fig. 4.1 Plant height (cm) as affected by different weed management treatments

1.1.1 Plant height at 30 DAT

An appraisal of data regarding plant height at 30 DAT revealed that crop grown under different weed management treatments produced significant effect on plant height. The longest plant height (64.47 cm) was recorded under T_{11}- weed free (2 hand weeding 25 and 45 DAT) and shortest plant height obtained under weedy check T_{12}- (56.83 cm). The highest plant height was statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (63.52 cm), T_3- bispyribac-sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (62.32 cm), T_4- bispyribac-sodium + chlorimuron + metsulfuron (Almix) 20 + 4 g/ha (25 DAT)- (61.65 cm) and significantly superior to rest of the treatments.

1.1.2 Plant height at 60 DAT

A close study of data regarding plant height at 60 DAT indicated that different weed management treatments exerted significant effect of plant height. Maximum plant height (85.64 cm) was observed in T_{11}- weed free (2 hand weeding 25 and 45 DAT) and lowest obtained under T_{12}- weedy check (77.05 cm). The highest plant height was statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (85.64 cm), T_3- bispyribac- sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (83.60 cm), T_4- bispyribac- sodium + chlorimuron + metsulfuron (Almix) 20 + 4 g/ha (25 DAT)- (82.59 cm), T_5-pretilachlor 750 g/ha (0-3 DAT) *fb* ethoxysulfuron 18.75 g/ha (25 DAT) and significantly superior to rest of the treatments.

1.1.3 Plant height at 90 DAT

A close study of data regarding plant height at 90 DAT indicated that different weed management treatments exerted significant effect of plant height. Maximum plant height (100.44 cm) was observed in T_{11}- weed free (2 hand weeding 25 and 45 DAT) and lowest obtained under T_{12}- weedy check (92.84 cm). The highest plant height was statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (99.13 cm), T_3- bispyribac- sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (98.08 cm), T_4- bispyribac- sodium + chlorimuron + metsulfuron (Almix) 20 + 4 g/ha (25 DAT)- (97.39 cm), T_6- pretilachlor 750 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (97.38 cm), T_7- pyrazoslfuron 20 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (96.54) and significantly superior to rest of the treatments.

1.1.4 Plant height at harvest

Citation of data regarding plant height at harvest revealed that different weed management treatments exerted significant effect on plant height. Maximum plant height (104.44 cm) was observed in T_{11}- weed free (2 hand weeding 25 and 45 DAT) and lowest obtained under T_{12}- weedy check (92.84 cm). The highest plant height was statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (101.82 cm) and significantly superior to rest of treatments.

1.2 Number of tillers/m^2

Number of tillers/m^2 was counted at monthly interval starting from 30 DAT to harvest. The result so obtained is given in Table 4.2 and graphically depicted in Fig. 4.2.

1.2.1 Number of tillers/m^2 at 30 DAT

An appraisal of data regarding number of tillers/m^2 at 30 DAT indicated that different weed management treatments exerted significant effect on number of tillers/m^2. Maximum number of tillers/m^2 (190.84) was obtained under application of T_{10}- pendimethalin @ 750 g/ha *fb* bispyribac- sodium @ 25 g/ha which was statistically at par with T_{11}- hand weeding at 25 and 45 DAT (190.42), T_3- bispyribac-sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (187.34), T_4- bispyribac- sodium + chlorimuron + metsulfuron (Almix) 20 + 4 g/ha (25 DAT)- (185.75), T_6- pretilachlor 750 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (179.59), T_5-pretilachlor 750 g/ha (0-3 DAT) *fb* ethoxysulfuron 18.75 g/ha (25 DAT)- (178.71) and significantly superior to rest of the treatments.

1.2.2 Number of tillers/m^2 at 60 DAT

A close scrutiny of data regarding number of tillers/m^2 at 60 DAT revealed that different weed management treatments significantly influenced number of tillers/m^2. The maximum number of tillers/m^2 (280.84) was observed in treatment T_{11} - hand weeding at 25 and 45 DAT was statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (275.75), T_3- bispyribac-sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (271.41), T_4- bispyribac-sodium + chlorimuron + metsulfuron (Almix) 20 + 4 g/ha (25 DAT)- (266.49), T_5- pretilachlor

750 g/ha (0-3 DAT) *fb* ethoxysulfuron 18.75 g/ha (25 DAT)- (265.33), T_6- pretilachlor 750 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (265.33), T_7- pyrazoslfuron 20 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (265.22) and significantly superior to rest of the treatments.

Table:4.2. Effect of different weed management treatments on Number of tillers/m^2 at different stages of crop growth

	Treatments	30 DAT	60 DAT	90 DAT	At harvest
T_1-	**Bispyribac- Sodium**	173.21	243.34	290.00	270.00
T_2-	**Penoxsulam 24 % SC**	169.32	241.83	280.78	264.00
T_3-	**Bispyribac – Sodium + Ethoxysulfuron**	187.34	266.49	324.05	301.00
T_4-	**Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)**	185.75	265.33	323.84	296.00
T_5-	**Pretilachlor *fb* Ethoxysulfuron**	178.71	265.33	318.24	290.00
T_6-	**Pretilachlor *fb* Chlorimuron + Metsulfuron (Almix)**	179.59	265.33	321.88	294.00
T_7-	**Pyrazosulfuron *fb* Chlorimuron + Metsulfuron (Almix)**	177.66	265.22	312.69	287.00
T_8-	**Penoxsulam + Cyhalofop 6 % OD**	176.66	254.50	307.00	283.00
T_9-	**Triafamone + Ethoxysulfuron 30 % WG**	176.11	244.84	299.41	275.00
T_{10}-	**Pendimethalin (38.7 % CS) *fb* Bispyribac –Sodium**	190.84	275.73	325.15	305.00
T_{11}-	**Hand weeding at 25 and 45 DAT**	190.42	280.84	340.15	328.00
T_{12}-	**Weedy check**	165.46	212.80	225.24	215.00
	SEm±	4.348	6.760	5.902	1.623
	LSD (P=0.05)	12.83	19.95	17.42	4.79

1.2.3 Number of tillers/m^2 at 90 DAT

A close scrutiny of data regarding number of tillers/m^2 at 90 DAT revealed that different weed management treatments significantly influenced number of tillers/m^2. The maximum number of tillers/m^2 (340.15) was observed in treatment T_{11} - hand weeding at 25 and 45 DAT was statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (325.15), T_3- bispyribac-

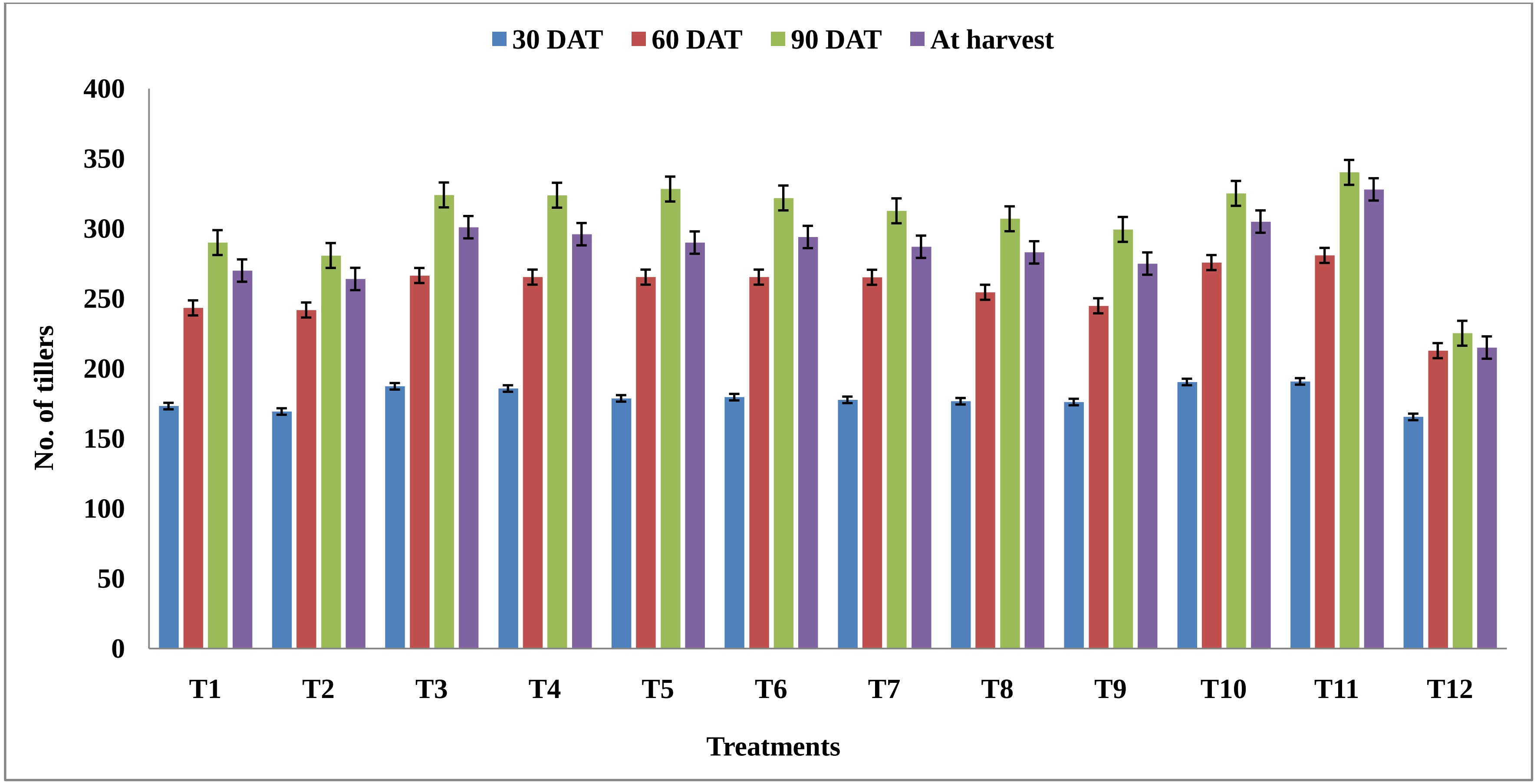


Fig. 4.2 No. of tillers/m^2 as affected by different weed management treatments

sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (324.05), T_4- bispyribac-sodium + chlorimuron + metsulfuron (Almix) 20 + 4 g/ha (25 DAT)- (323.84) and significantly superior to rest of the treatments.

1.2.4 Number of tillers/m^2 at harvest

Number of tillers/m^2 differed significantly under different weed management practices. The maximum number of tillers/m^2 (328) was recorded under treatment T_{11}- weed free (2 hand weeding at 25 and 45 DAT) lowest number of panicles/m^2 obtained under weedy check T_{12}- (215). The highest number of tillers/m^2 significantly superior to treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac- sodium 25 g/ha (25 DAT)- (305), T_3- bispyribac- sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (301), T_4- bispyribac- sodium + chlorimuron + metsulfuron (Almix) 20 + 4 g/ha (25 DAT)- (296), T_6- pretilachlor 750 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (294), T_5- pretilachlor 750 g/ha (0-3 DAT) *fb* ethoxysulfuron 18.75 g/ha (25 DAT)- (290),T_7- pyrazoslfuron 20 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (287), T_8- penoxsulam + cyhalofop 135 g/ha (15-20 DAT)- (275), T_1- bispyribac- sodium 25 g/ha (25 g/ha)- (270), T_2- penoxsulam 22.5 g/ha (15 DAT)- (264) and weedy check.

1.3 Plant dry matter production (g/m^2)

Data on dry matter production as affected by different weed management treatments are presented in Table 4.3. and graphically depicted in Fig.4.3.

1.3.1 Plant dry matter production (g/m^2) at 30 DAT

A perusal of the data regarding dry matter production indicated that different weed management treatments on transplanted rice did not exert any significant effect on dry matter production. However, the maximum dry matter production (153.42 g/m^2) was recorded under T_{11}- weed free (2 hand weeding 25 and 45 DAT) and lowest plant dry matter obtained under weedy check- (145.68 g/m^2).

Table:4.3. Effect of different weed management treatments on plant dry matter production (g/m^2) at different stages of crop growth

	Treatments	30 DAT	60 DAT	90 DAT	At harvest
T_1-	**Bispyribac- Sodium**	148	481.46	694.94	996.30
T_2-	**Penoxsulam 24 % SC**	146.58	477.56	683.75	983.50
T_3-	**Bispyribac – Sodium + Ethoxysulfuron**	151.37	521.98	728.94	1,061.50
T_4-	**Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)**	151.23	513.27	719.84	1,053.00
T_5-	**Pretilachlor *fb* Ethoxysulfuron**	150.01	502.59	708.51	1,030.00
T_6-	**Pretilachlor *fb* Chlorimuron + Metsulfuron (Almix)**	150.59	506.33	712.18	1,039.50
T_7-	**Pyrazosulfuron *fb* Chlorimuron + Metsulfuron (Almix)**	149.50	495.31	705.64	1,020.00
T_8-	**Penoxsulam + Cyhalofop 6 % OD**	149.49	492.73	704.67	1,015.00
T_9-	**Triafamone + Ethoxysulfuron 30 % WG**	149.46	486.53	701.75	1,005.00
T_{10}-	**Pendimethalin (38.7 % CS) *fb* Bispyribac –Sodium**	152.05	526.86	733.88	1,068.00
T_{11}-	**Hand weeding at 25 and 45 DAT**	153.42	539.53	742.53	1,083.02
T_{12}-	**Weedy check**	145.68	469.98	679.523	962.09
	SEm±	2.162	3.683	4.001	9.002
	LSD (P=0.05)	NS	10.87	11.81	27.13

1.3.2 Plant dry matter production (g/m^2) at 60 DAT

Amongst different weed management practices, significant effect on plant dry matter production was observed at 60 DAT. The maximum dry matter (539.53 g/m^2) was recorded under T_{11} receiving two hand weeding at 25 and 45 DAT which was significantly superior to rest of the weed management practices.

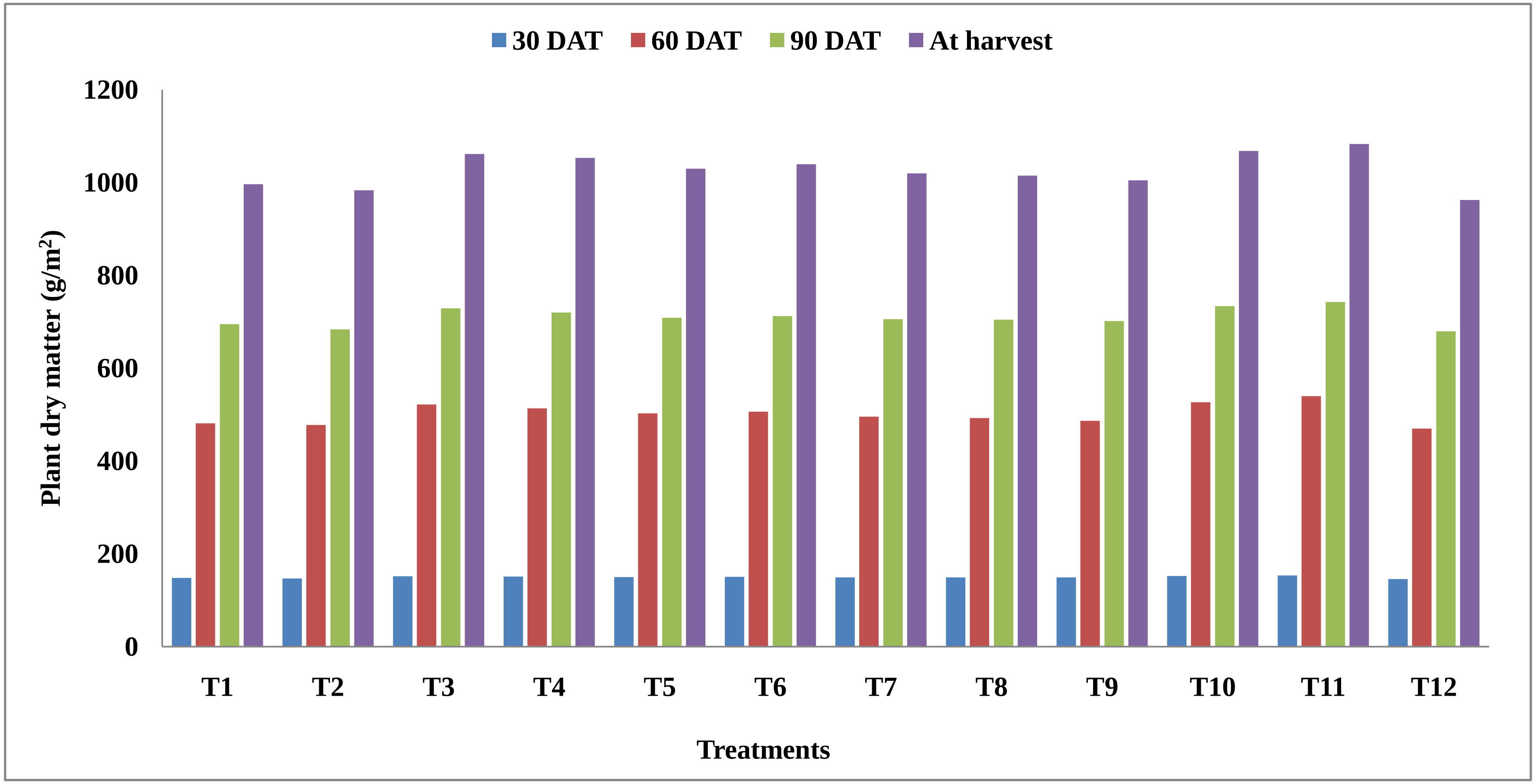


Fig. 4.3 Plant dry matter (g/m^2) as affected by different weed management treatments

1.3.3 Plant dry matter production (g/m^2) at 90 DAT

A close scrutiny of data regarding dry matter production at 90 DAT revealed that different weed management treatments significantly influenced dry matter production. The maximum dry matter production (742.53 g/m^2) was observed in treatment T_{11} - hand weeding at 25 and 45 DAT was statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac- sodium 25 g/ha (25 DAT)- (733.88 g/m^2) and significantly superior to rest of the treatments.

1.3.4 Plant dry matter production (g/m^2) at harvest

Citation of the data regarding the dry matter production revealed that different weed management treatments significantly affected the dry matter production at harvest stage. The maximum dry matter (1083.02 g/m^2) was recorded under T_{11} receiving two hand weeding at 25 and 45 DAT which was significantly superior to rest of the weed management practices.

B. Yield and yield attributes

1.4 Number of panicles/m^2

The data obtained with respect to number of panicles/m^2 as influenced by various treatments have been summarized in Table 4.4 and graphically depicted in Fig.4.4.

Number of panicles/m^2 differed significantly under different weed management practices. The maximum number of panicles/m^2 (328) was recorded under treatment T_{11}- weed free (2 hand weeding at 25 and 45 DAT) lowest number of panicles/m^2 obtained under weedy check T_{12}- (215). The highest number of panicles/m^2 significantly superior to treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (305), T_3- bispyribac-sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (301), T_4- bispyribac- sodium + chlorimuron + metsulfuron (Almix) 20 + 4 g/ha (25 DAT)- (296), T_6- pretilachlor 750 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (294), T_5-pretilachlor 750 g/ha (0-3 DAT) *fb* ethoxysulfuron 18.75 g/ha (25 DAT)- (290), T_7- pyrazoslfuron 20 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (287), T_8- penoxsulam + cyhalofop 135 g/ha (15-20 DAT)- (275), T_1- bispyribac- sodium 25 g/ha (25 g/ha)- (270), T_2- penoxsulam 22.5 g/ha (15 DAT)- (264) and weedy check.

1.5 Length of panicle (cm)

The statistical analysis of the data revealed that maximum length of panicle (19.23 cm) was recorded under treatment T_{11}- hand weeding at 25 and 45 DAT and lowest length of the panicle (16.15 cm) under treatment T_{12}- weedy check.

Table: 4.4 Effect of different weed management treatments on yield attributes

	Treatments	No. of panicles/ m^2	Panicle length (cm)	No. of grains/ panicle	1000 grains weight (g)
T_1-	Bispyribac- Sodium	270	17.47	54	21.15
T_2-	Penoxsulam 24 % SC	264	17.18	53	20.79
T_3-	Bispyribac – Sodium + Ethoxysulfuron	301	19.09	63	22.21
T_4-	Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)	296	18.30	62	22.03
T_5-	Pretilachlor *fb* Ethoxysulfuron	290	18.10	60	21.92
T_6-	Pretilachlor *fb* Chlorimuron + Metsulfuron (Almix)	294	18.01	59	21.89
T_7-	Pyrazosulfuron *fb* Chlorimuron + Metsulfuron (Almix)	287	19.97	58	21.83
T_8-	Penoxsulam + Cyhalofop 6 % OD	283	17.85	56	21.51
T_9-	Triafamone + Ethoxysulfuron 30 % WG	275	17.82	55	21.32
T_{10}-	Pendimethalin (38.7 % CS) *fb* Bispyribac –Sodium	305	19.12	64	22.87
T_{11}-	Hand weeding at 25 and 45 DAT	328	19.23	67	23.21
T_{12}-	Weedy check	215	16.15	39	17.89
	SEm±	1.623	1.126	1.486	0.957
	LSD (P=0.05)	4.79	N/A	4.38	NS

1.6 No. of grains/panicle

Citation of the data regarding the number of grain per panicle indicated that different weed management treatments had exerted significant effect on number of grain per panicle. The highest grain per panicle (67) was recorded under treatment T_{11}- weed free (2 hand weeding at 25 and 45 DAT) and lowest grain per panicle obtained under weedy check T_{12}- (39). The highest grain per panicle was statistically at par with

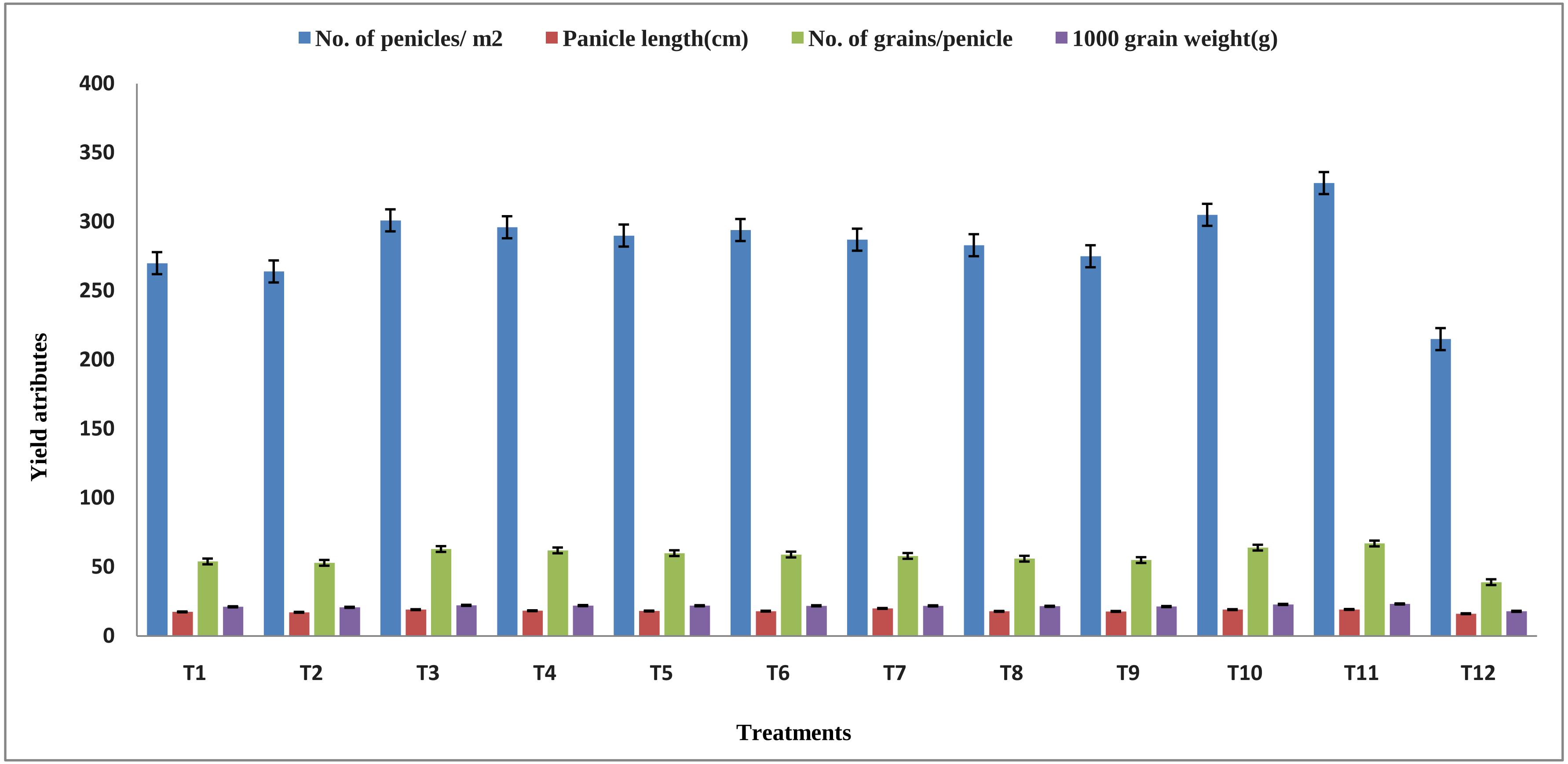


Fig. 4.4 Yield attribute as affected by different weed management treatments

treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (64), T_3- bispyribac-sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (63) and significantly superior to rest of the treatments.

1.7 1000 grains weight (g)

The differences in 1000-grain weight due to different weed management practices was found to be non significant and treatment T_{11}- weed free (2 hand weedings at 25 and 45 DAT) recorded the maximum 1000 grain weight (23.21 g) which was closely followed by T_{10} (22.87 g), T_3 (22.21 g) and T_4 (22.03 g).

1.8 Grain yield (t/ha)

The data gathered in respect of grain yield of rice as affected by different weed management practices have been summarized and presented in table 4.5 and also graphically illustrated in Fig.4.5

Citation of the data regarding grain yield of rice indicated that different weed management treatments on transplanted rice had exerted significant effect on grain yield obtained under treatment T_{11}- weed free (2 hand weeding at 25 and 45 DAT)- (5.05 t/ha) and lowest grain yield obtained under weedy check T_{12}- (2.92 t/ha). The highest grain per panicle was only statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (4.84) and significantly superior to rest of the treatments.

1.10 Straw yield (t/ha)

The data gathered in respect of straw yield of rice as affected by different weed management practices have been summarized and presented in table 4.5 and also graphically illustrated in Fig.4.5.

A close scrutiny of data regarding straw yield reveals that different weed management treatments exert significant effect on straw yield. The maximum straw yield obtained under treatment T_{11}- weed free (2 hand weeding at 25 and 45 DAT)- (6.35 t/ha) and lowest grain yield obtained under weedy check T_{12}- (3.62 t/ha). The highest straw yield was significantly superior over treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (5.83 t/ha), T_3- bispyribac- sodium

+ ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (5.71 t/ha), T_6- pretilachlor 750 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (5.62 t/ha), T_4- bispyribac- sodium + chlorimuron + metsulfuron (Almix) 20 + 4 g/ha (25 DAT)- (5.53 t/ha), T_7- pyrazoslfuron 20 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT)- (5.49 t/ha) and also significantly superior to rest of the treatments.

Table: 4.5. Effect of different weed management treatments on grain yield (t/ha), straw yield (t/ha) and harvest index (%)

Treatments		Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
T_1-	Bispyribac- Sodium	4.01	4.88	45.10
T_2-	Penoxsulam 24 % SC	4.05	4.93	45.10
T_3-	Bispyribac – Sodium + Ethoxysulfuron	4.68	5.71	45.04
T_4-	Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)	4.31	5.53	43.80
T_5-	Pretilachlor *fb* Ethoxysulfuron	4.30	5.37	44.46
T_6-	Pretilachlor *fb* Chlorimuron + Metsulfuron (Almix)	4.37	5.62	43.80
T_7-	Pyrazosulfuron *fb* Chlorimuron + Metsulfuron (Almix)	4.35	5.49	40.12
T_8-	Penoxsulam + Cyhalofop 6 % OD	4.27	5.17	40.90
T_9-	Triafamone + Ethoxysulfuron 30 % WG	4.18	5.09	40.70
T_{10}-	Pendimethalin (38.7 % CS) *fb* Bispyribac –Sodium	4.84	5.83	45.36
T_{11}-	Hand weeding at 25 and 45 DAT	5.05	6.35	44.29
T_{12}-	Weedy check	2.92	3.62	44.64
	SEm±	0.113	0.14	1.85
	LSD (P=0.05)	0.33	0.43	NS

1.11 Harvest index (%)

The data gathered on harvest index as affected by different treatments were put to statistical analysis and the mean values have been presented in Table 4.5. and depicted in Fig.4.5.

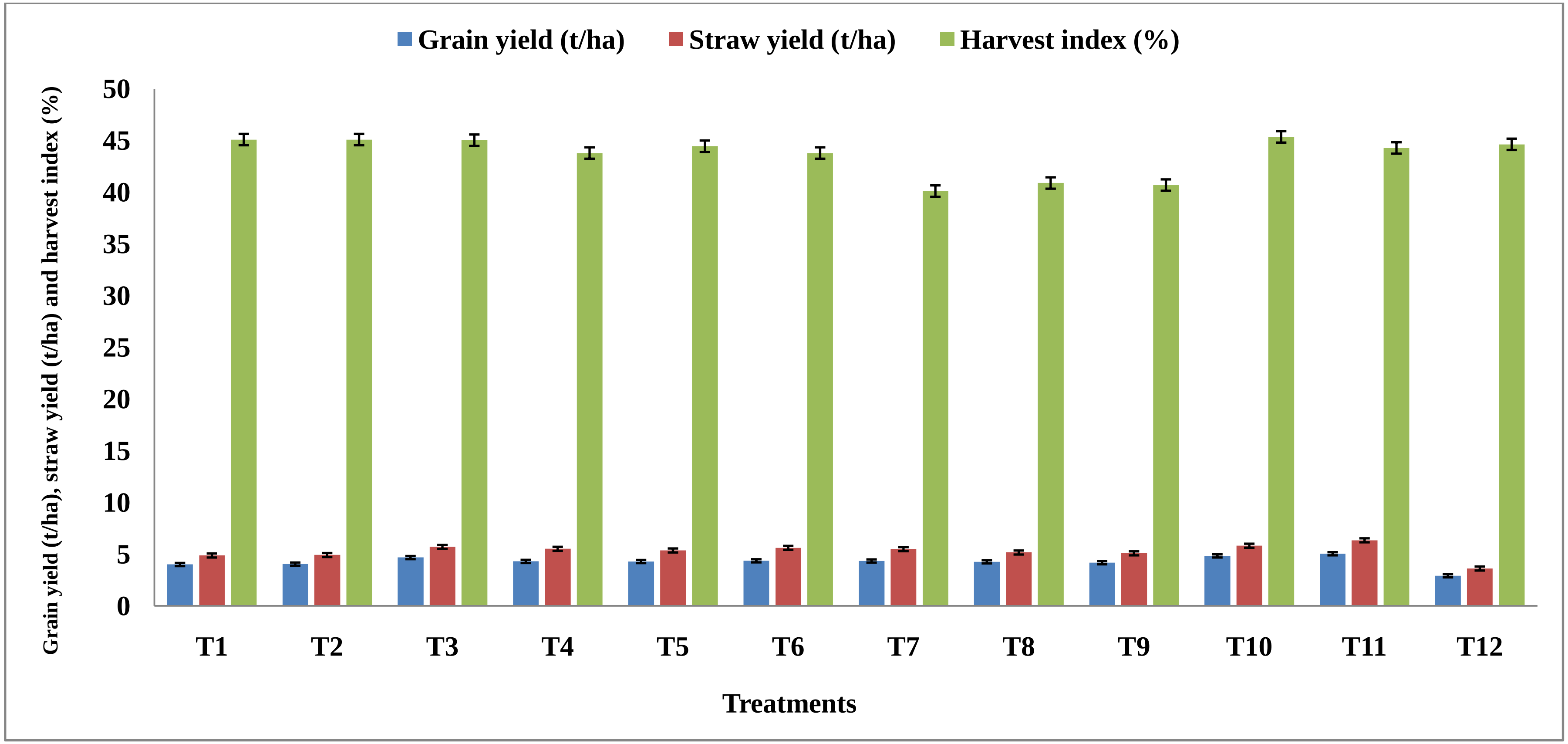


Fig. 4.5 Grain yield (t/ha), straw yield (t/ha) and harvest index (%) as affected by different weed management treatments

A close scrutiny of data revealed that different crop establishment methods had not significant effect on the harvest index. Though maximum value of harvest index (45.36 %) was recorded under treatment T_{10}- pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac- sodium 25 g/ha (25 DAT) and lowest under T_7- pyrazoslfuron 20 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT) - (40.12 %)

2. Weed parameters

2.1 Weed population (No./m^2)

The data recorded in respect of weed population was statistically analysed and mean values have been presented in Table 4.6 and illustrated in Fig.4.6. and major weeds in experimental field were: *Echinochloa crusgalli, Echinochloa colonum, Cynodon dactylon*, *Cyperus spp*., *Phyllanthus niruri*, *Eclipata alba*, *Commelina benghalensis* and *Fimbristylis miliacea*.

2.1.1 Weed population (No./m^2) at 30 DAT

A close scrutiny of data regarding weed population (No./m^2) at 30 DAT indicated that different herbicidal treatments showed significant effect on weed population/m^2. The minimum weed population (2.63/m^2) was recorded under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT), among herbicidal treatments application of T_{10}- pendimethalin @ 750 g/ha *fb* bispyribac- sodium @ 25 g/ha (6.24/m^2) which was significantly superior to rest of the weed management treatments.

2.1.2 Weed population (No./m^2) at 60 DAT

An appraisal of data regarding weed count at 60 DAT revealed that weed count was recorded significantly lowest (6.09/m^2) under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT), which was superior over T_{10} - pendimethalin @ 750 g/ha *fb* bispyribac- sodium @ 25 g/ha (9.13/m^2) and also rest of weed management treatments.

2.1.3 Weed population (No./m^2) at 90 DAT

An appraisal of data regarding minimum weed population (No./m^2) (5.11) at 90 DAT indicated that different weed management treatments exerted significant effect on weed population/m^2. Minimum weed population/m^2 (5.11) was obtained under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT), among herbicidal treatments application of T_{10}- pendimethalin @ 750 g/ha *fb* bispyribac @ 25 g/ha (8.44) which was significantly superior to rest of the herbicidal treatments.

Table: 4.6. Effect of different weed management treatments on weed population ($No./m^2$) at different stages of crop growth

	Treatments	30 DAT	60 DAT	90 DAT
T_1-	**Bispyribac- Sodium**	15.41 (3.99)	19.21 (4.44)	18.44 (4.35)
T_2-	**Penoxsulam 24 % SC**	15.65 (4.02)	19.68 (4.49)	18.94 (4.41)
T_3-	**Bispyribac – Sodium + Ethoxysulfuron**	8.31 (2.97)	11.89 (3.52)	10.81 (3.36)
T_4-	**Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)**	9.94 (3.23)	13.67 (3.76)	12.33 (3.38)
T_5-	**Pretilachlor *fb* Ethoxysulfuron**	10.95 (3.38)	14.95 (3.93)	13.94 (3.80)
T_6-	**Pretilachlor *fb* Chlorimuron + Metsulfuron (Almix)**	11.05 (3.40)	14.58 (3.88)	13.58 (3.75)
T_7-	**Pyrazosulfuron *fb* Chlorimuron + Metsulfuron (Almix)**	11.87 (3.52)	15.72 (4.03)	14.74 (3.90)
T_8-	**Penoxsulam + cyhalofop 6 % OD**	14.21 (3.84)	18.23 (4.33)	17.35 (4.22)
T_9-	**Triafamone + Ethoxysulfuron 30 % WG**	13.79 (3.78)	17.85 (4.28)	16.83 (4.16)
T_{10}-	**Pendimethalin (38.7 % CS) *fb* Bispyribac – Sodium**	6.24 (2.60)	9.13 (3.10)	8.44 (2.99)
T_{11}-	**Hand weeding at 25 and 45 DAT**	2.63 (1.77)	6.09 (2.57)	5.11 (2.37)
T_{12}-	**Weedy check**	20.45 (4.58)	30.47 (5.57)	34.41 (5.91)
	SEm±	0.886	0.994	0.831
	LSD (P=0.05)	2.61	2.93	2.45

***Figures in parenthesis indicates the transformed value.**

2.2 Weed dry weight (g/m^2)

Observations on weed dry weight (g/m^2) of weed as influenced by different weed management practices were recorded at 30, 60 and 90 DAT. Data on weed dry weight (g/m^2) at different stages have been presented in Table 4.7. and graphically depicted in Fig.4.7.

2.2.1 Weed dry weight (g/m^2) at 30 DAT

A perusal of the data regarding weed dry matter at 30 DAT as affected by different weed management treatments revealed that weed dry weight gets affected significantly. Minimum dry weight (5.23 g/m^2), was recorded under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT) and highest weed dry weight (32.60 g/m^2) was recorded under treatment T_{11}- weedy check treatment. Among herbicidal treatments minimum dry weight (7.13 g/m^2) under treatment T_{10}- pendimethalin @ 750 g/ha *fb* bispyribac @ 25 g/ha (8.44) which was significantly superior to rest of the herbicidal treatments.

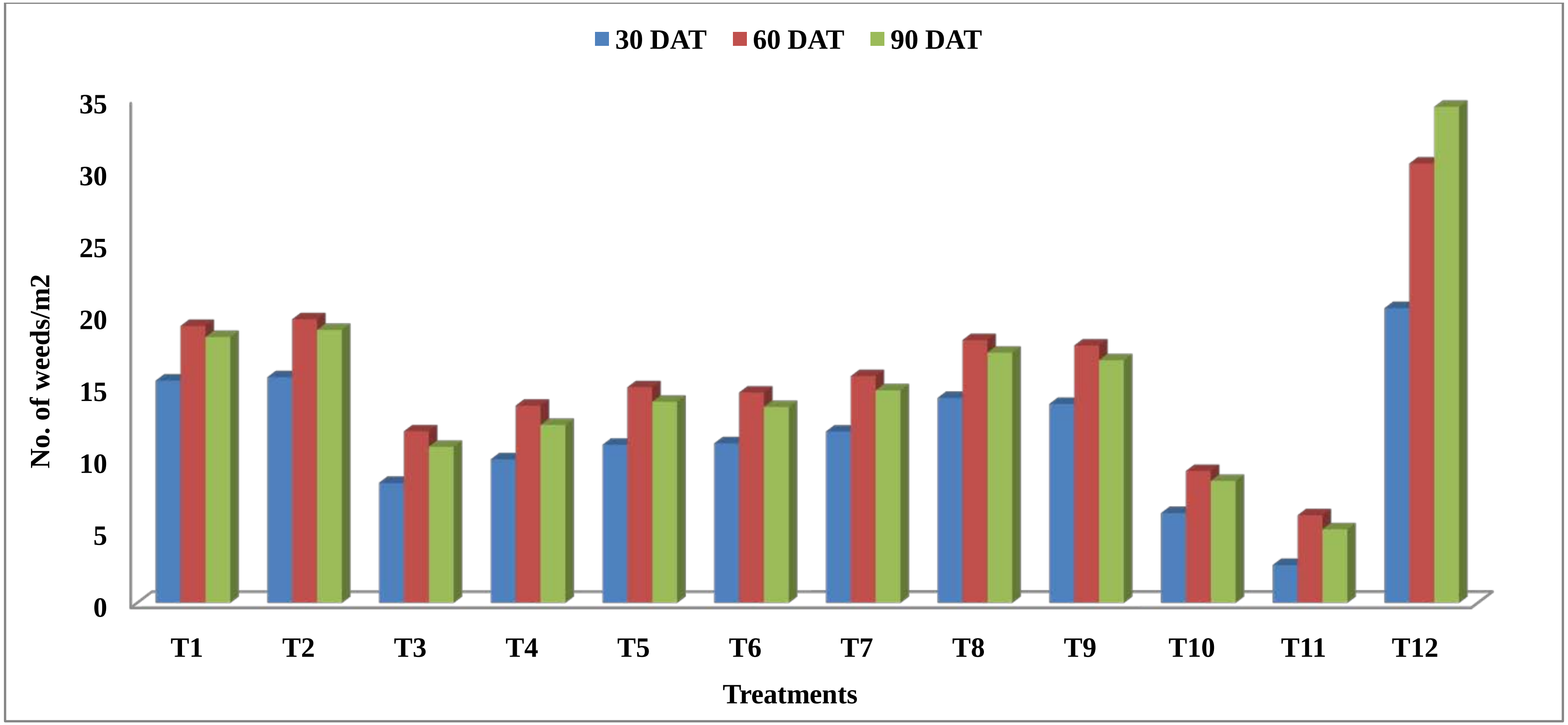


Fig. 4.6 Weed population as affected by different weed management treatments

Table: 4.7. Effect of different treatments on weed dry weight (g/m^2) at different stages of crop growth

	Treatments	30 DAT	60 DAT	90 DAT
T_1-	Bispyribac- Sodium	16.40	33.11	69.03
T_2-	Penoxsulam 24 % SC	16.47	35.49	85.45
T_3-	Bispyribac – Sodium + Ethoxysulfuron	8.05	21.31	13.51
T_4-	Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)	8.35	25.11	17.23
T_5-	Pretilachlor *fb* Ethoxysulfuron	9.23	27.05	21.59
T_6-	Pretilachlor *fb* Chlorimuron + metsulfuron (Almix)	9.49	27.03	24.53
T_7-	Pyrazosulfuron *fb* Chlorimuron+ Metsulfuron (Almix)	9.73	29.23	42.33
T_8-	Penoxsulam + Cyhalofop 6 % OD	10.43	31.08	56.47
T_9-	Triafamone + Ethoxysulfuron 30 % WG	12.43	32.72	21.31
T_{10}-	Pendimethalin (38.7 % CS) *fb* Bispyribac –Sodium	7.13	17.43	8.21
T_{11}-	Hand weeding at 25 and 45 DAT	5.23	11.37	6.13
T_{12}-	Weedy check	32.6	47.24	115.39
	SEm±	0.891	0.969	1.601
	LSD (P=0.05)	2.62	2.86	4.72

2.2.2 Weed dry weight (g/m^2) at 60 DAT

A close study of data regarding weed dry weight at 60 DAT indicated that different weed management treatments exerted significant effect of weed dry weight. Minimum weed dry weight (11.37 g/m^2) was observed under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT) and highest weed dry weight (47.24 g/m^2) was recorded under treatment T_{12}- weedy check treatment. Among herbicidal treatments minimum dry weight (17.43 g/m^2) under treatment T_{10}- pendimethalin @ 750 g/ha *fb* bispyribac @ 25 g/ha which was significantly superior to rest of the herbicidal treatments.

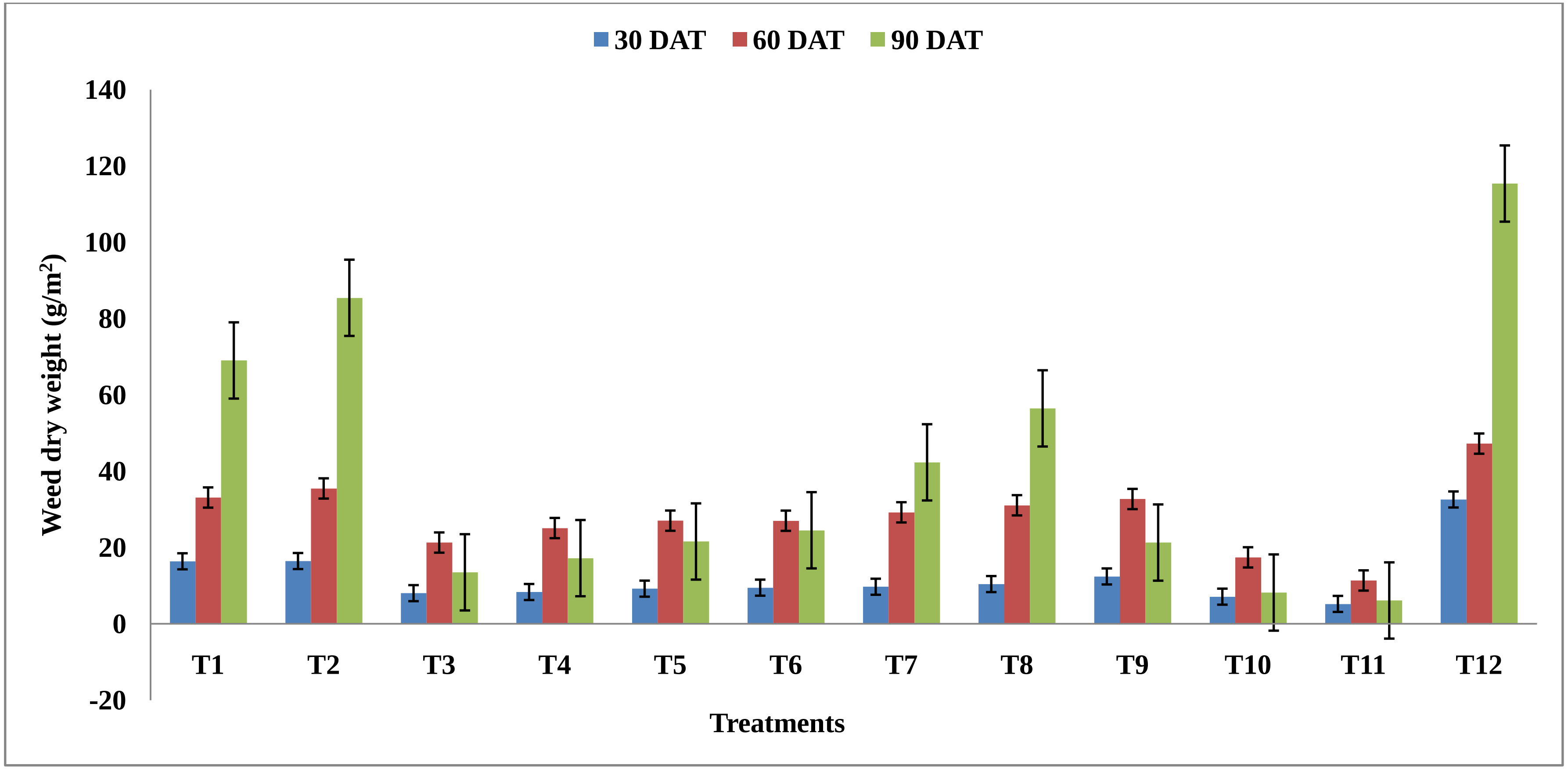


Fig. 4.7 Weed dry weight (g/m^2) as affected by different weed management treatments

2.2.3 Weed dry weight (g/m^2) at 90 DAT

A close scrutiny of data regarding weed dry matter production at 90 DAT revealed that different weed management treatments significantly influenced dry matter production. The minimum dry matter production (6.13 g/m^2) was observed in treatment T_{11}- hand weeding at 25 and 45 DAT was statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (8.21 g/m^2) and significantly superior to rest of the treatments.

2.2.4 Weed control efficiency

Data pertaining to Weed control efficiency of weed as affected by different treatments were recorded. The value has been presented in Table 4.8.

Significant differences were observed in term of weed control efficiency (%) under different weed management treatments. Maximum value of (75.93 %) was recorded under treatment T_{11}- hand weeding at 25 and 45 DAT which followed by T_{10}, T_3, T_4, T_6, T_5, T_7, T_8, T_9, T_1 and T_2.

2.2.5 Weed index

Data pertaining to Weed index of weed as affected by different treatments were recorded. The value has been presented in Table 4.8.

Significant differences were observed in term of weed index (%) under different weed management treatments. The minimum value of weed index (4.15 %) was recorded under treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac- sodium 25 g/ha (25 DAT) and maximum value of weed index (42.17 %) was recorded under treatment T_{12}- weedy check treatment.

Table: 4.8. Effect of different weed management treatments on weed control efficiency (%) and weed index (%)

	Treatments	Weed control efficiency (%)	Weed index (%)
T_1-	Bispyribac- Sodium	29.91	20.59
T_2-	Penoxsulam 24 % SC	24.87	19.80
T_3-	Bispyribac – Sodium + Ethoxysulfuron	54.89	7.32
T_4-	Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)	46.85	14.65
T_5-	Pretilachlor *fb* Ethoxysulfuron	42.74	14.85
T_6-	Pretilachlor *fb* Chlorimuron + Metsulfuron (Almix)	42.78	13.46
T_7-	Pyrazosulfuron *fb* Chlorimuron+ Metsulfuron (Almix)	38.12	13.86
T_8-	Penoxsulam + Cyhalofop 6 % OD	34.21	15.44
T_9-	Triafamone + Ethoxysulfuron 30 % WG	30.74	17.22
T_{10}-	Pendimethalin (38.7 % CS) *fb* Bispyribac – Sodium	63.10	4.15
T_{11}-	Hand weeding at 25 and 45 DAT	75.93	-
T_{12}-	Weedy check	-	42.17

3. Chemical studies

3.1 N uptake by crop

The data obtained in respect of N uptake by crop as affected by different weed management practices were statistically analysed and the mean values have been presented in Table 4.9.and graphically depicted in Fig.4.9.

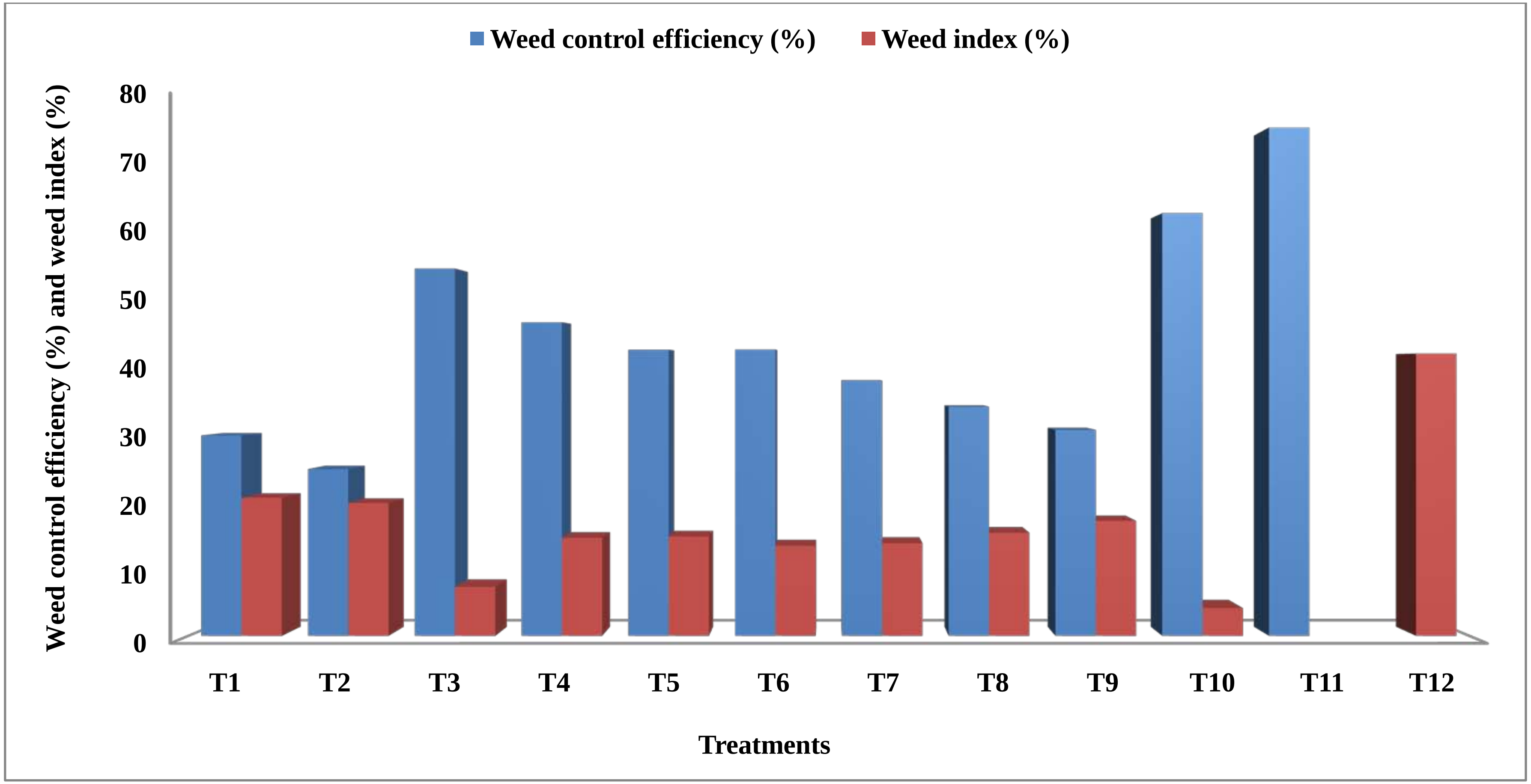


Fig. 4.8 Weed control efficiency (%) and weed index (%) as affected by different weed management treatments

Table: 4.9 Effect of different weed management treatments on NPK uptake kg / ha by Crop

	Treatment	NPK uptake by crop (kg/ha)		
		N uptake by crop (kg/ha)	P uptake by crop (kg/ha)	K uptake by the crop (kg/ha)
T_1-	**Bispyribac- Sodium**	55.99	11.41	58.56
T_2-	**Penoxsulam 24 % SC**	56.33	12.32	59.36
T_3-	**Bispyribac – Sodium + Ethoxysulfuron**	65.85	15.79	64.92
T_4-	**Bispyribac – Sodium + Chlorimuron + metsulfuron (Almix)**	61.25	13.67	62.72
T_5-	**Pretilachlor *fb* Ethoxysulfuron**	61.15	13.23	62.23
T_6-	**Pretilachlor *fb* Chlorimuron + Metsulfuron (Almix)**	62.26	14.71	63.72
T_7-	**Pyrazosulfuron *fb* Chlorimuron+ metsulfuron (Almix)**	61.63	14.18	63.30
T_8-	**Penoxsulam + Cyhalofop 6 % OD**	59.58	13.15	61.30
T_9-	**Triafamone + Ethoxysulfuron 30 % WG**	58.36	12.56	60.42
T_{10}-	**Pendimethalin (38.7 % CS) *fb* Bispyribac –Sodium**	68.91	16.60	65.76
T_{11}-	**Hand weeding at 25 and 45 DAT**	72.29	19.00	67.23
T_{12}-	**Weedy check**	43.04	8.1	51.61
	SEm±	1.02	0.50	0.58
	LSD (P=0.05)	3.02	1.49	1.71

Mean data of N uptake by crop indicated that different weed management practices exerted significant effect on N uptake by crop. The maximum N uptake by crop (72.29 kg/ha) was found under treatment T_{11}- hand weeding at 25 and 45 DAT and minimum uptake was obtained under treatments T_{12}- weedy check. The maximum uptake by crop under treatment T_{11}- hand weeding at 25 and 45 DAT which was significantly superior over rest of the treatments.

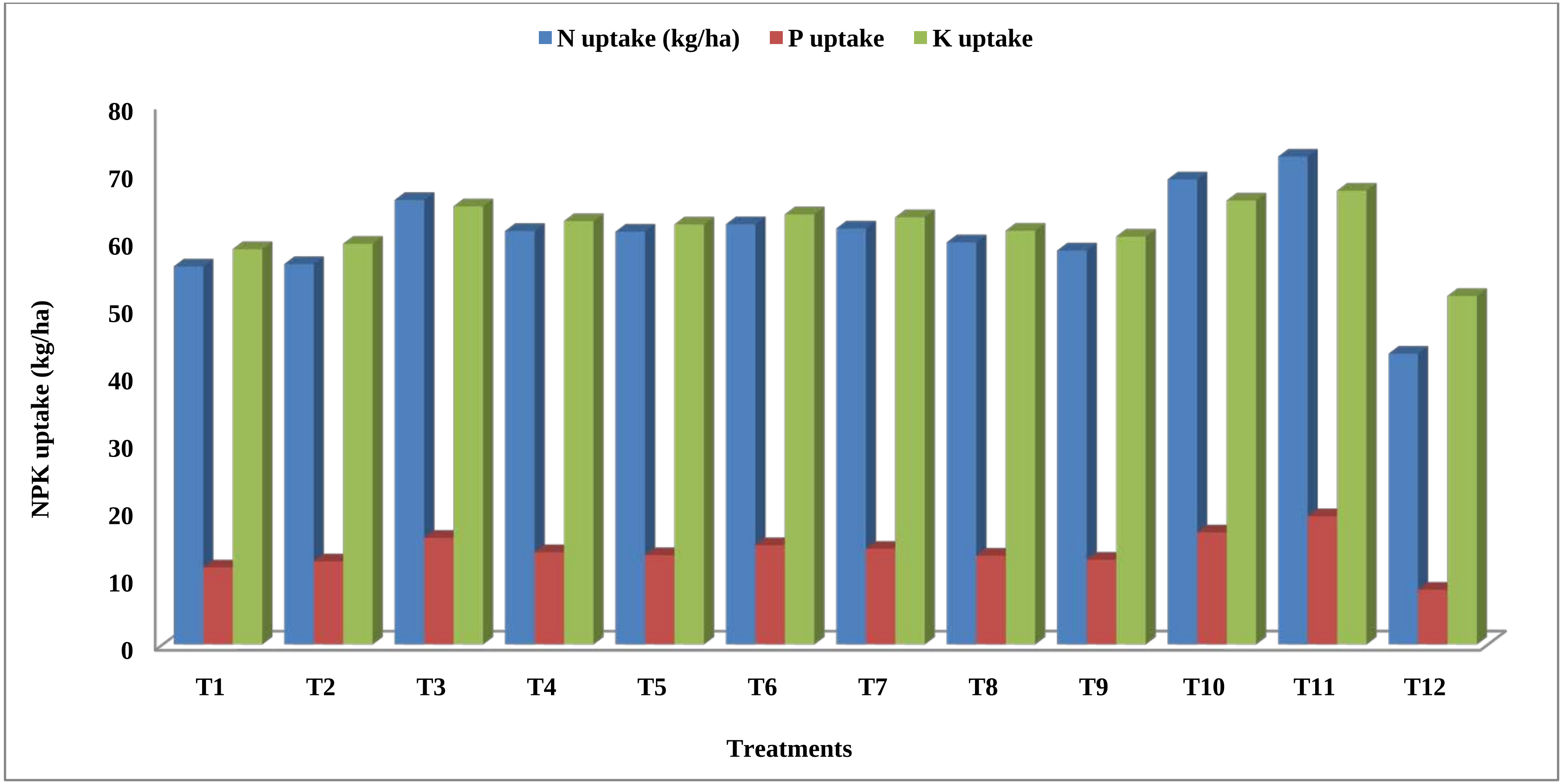


Fig. 4.9 NPK uptake (kg/ha) by crop as affected by different weed management treatments

3.2 P uptake by crop

Data on P uptake by crop as affected by different treatments are presented in Table 4.9 and illustrated in Fig.4.9.

Citation of the data regarding P uptake by crop revealed that different weed management practices had significant effect on P uptake by crop. The maximum P uptake by crop (19.00 kg/ha) was found under treatment T_{11}- hand weeding at 25 and 45 DAT and minimum uptake (8.10 kg/ha) was obtained under treatments T_{12}- weedy check. The maximum P uptake by crop under treatment T_{11}- hand weeding at 25 and 45 DAT which was significantly superior to rest of the treatments.

3.3 K uptake by crop

The data obtained with respect to K uptake by crop as influenced by various treatments have been summarized in Table 4.9 and graphically depicted in Fig.4.9.

Citation of the data regarding K uptake by crop revealed that different weed management practices had significant effect on K uptake by crop. The maximum K uptake by crop (67.23 kg/ha) was found under treatment T_{11}- hand weeding at 25 and 45 DAT and minimum uptake (51.61 kg/ha) was obtained under treatments T_{12}- weedy check. The maximum P uptake by crop under treatment T_{11}- hand weeding at 25 and 45 DAT which was statistically at par with T_{10} and significantly superior to rest of the treatments.

3.4 N uptake by weed

The data gathered on N uptake by weed as affected by different treatments were put to statistical analysis and the mean values have been presented in Table 4.10 and graphically depicted in Fig.4.10.

Mean data of N uptake by weed indicated that different weed management practices exerted significant effect on N uptake by weed. The minimum N uptake by weed (0.39 kg/ha) was found under treatment T_{11}- hand weeding at 25 and 45 DAT and maximum N uptake (10.03 kg/ha) was obtained under treatment T_{12}- weedy check. The minimum N uptake treatment T_{11} was statistically at par with T_{10} and T_3 and significantly superior to rest of the treatments.

3.5 P uptake by weed

The data pertaining to P uptake by weed have been statistically analysed and presented in Table 4.10 and graphically illustrated in Fig.4.10.

Mean data of P uptake by weed indicated that different weed management practices exerted significant effect on P uptake by weed. The minimum P uptake by weed (0.067 kg/ha) was found under weed management practice treatment T_{11} - hand weeding at 25 and 45 DAT and maximum P uptake (2.42 kg/ha) was obtained under treatment T_{12}- weedy check. The minimum P uptake treatment T_{11} was statistically at par with T_{10}, T_3 and T_9 and significantly superior to rest of the treatments.

3.6 K uptake by weed

Data on K uptake by weed as affected by different treatments are presented in Table 4.10 and graphically depicted in Fig.4.10.

Citation of the data regarding K uptake by weed revealed that different weed management practices had significant effect on K uptake by weed. The minimum uptake of K (0.091 kg/ha) by weed was noticed under weed management practice treatment T_{11} - hand weeding at 25 and 45 DAT and maximum K uptake (2.42 kg/ha) was obtained under treatment T_{12}- weedy check. The minimum K uptake treatment T_{11} was statistically at par with T_{10}, T_9 and T_3 and significantly superior to rest of the treatments.

Table: 4.10 Effect of different weed management treatments on NPK uptake (kg/ha) by weeds

	Treatments	NPK uptake by weeds (kg/ha)		
		N uptake by the weeds (kg/ha)	P uptake by weeds (kg/ha)	K uptake by the weeds (kg/ha)
T_1-	**Bispyribac- Sodium**	5.72	1.03	1.24
T_2-	**Penoxsulam 24 % SC**	7.01	1.36	1.54
T_3-	**Bispyribac – Sodium + Ethoxysulfuron**	0.69	0.15	0.21
T_4-	**Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)**	1.18	0.22	0.27
T_5-	**Pretilachlor *fb* ethoxysulfuron**	1.68	0.28	0.32
T_6-	**Pretilachlor *fb* Chlorimuron + Metsulfuron (Almix)**	1.91	0.31	0.39
T_7-	**Pyrazosulfuron *fb* Chlorimuron+ metsulfuron (Almix)**	3.34	0.59	0.67
T_8-	**Penoxsulam + Cyhalofop 6 % OD**	4.46	0.78	0.96
T_9-	**Triafamone + Ethoxysulfuron 30 % WG**	1.04	0.15	0.17
T_{10}-	**Pendimethalin (38.7 % CS) *fb* Bispyribac –Sodium**	0.53	0.09	0.12
T_{11}-	**Hand weeding at 25 and 45 DAT**	0.38	0.06	0.09
T_{12}-	**Weedy check**	10.03	2.42	2.65
	SEm±	0.13	0.04	0.15
	LSD (P=0.05)	0.39	0.14	0.15

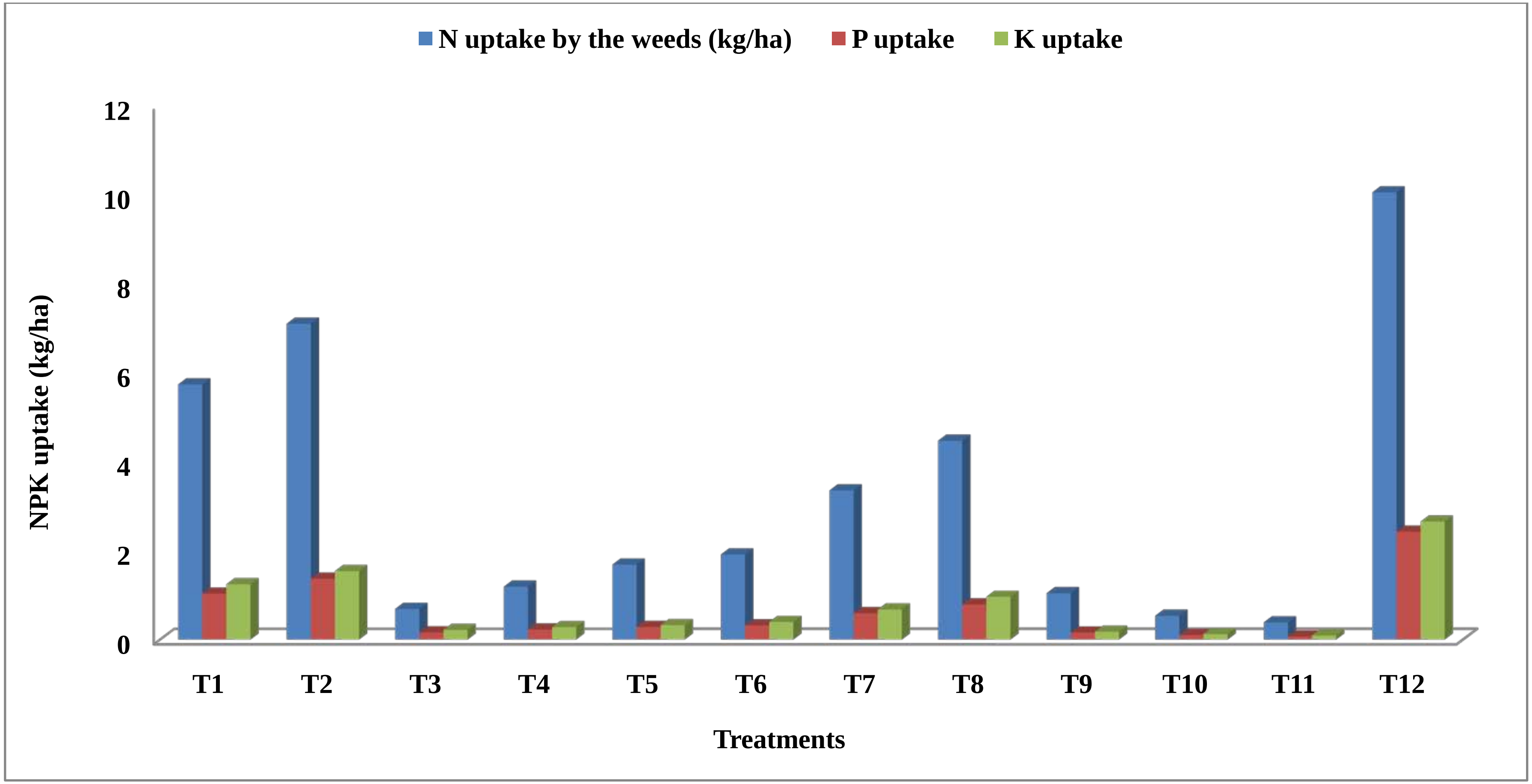


Fig. 4.10 NPK uptake (kg/ha) by weeds as affected by different weed management treatments

4. Qualitative studies

4.1 Protein content in rice grain (%)

The data pertaining to protein content in rice grain as affected by different weed management treatments have been summarized and presented in Table 4.11 and graphically depicted in Fig.4.11.

Table: 4.11. Effect of different weed management treatments on protein content in rice grain (%)

	Treatments	Protein content in grain (%)
T_1-	Bispyribac- Sodium	7.938
T_2-	Penoxsulam 24 % SC	7.938
T_3-	Bispyribac – Sodium + Ethoxysulfuron	8.229
T_4-	Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)	8.188
T_5-	Pretilachlor *fb* ethoxysulfuron	8.188
T_6-	Pretilachlor *fb* Chlorimuron + metsulfuron (Almix)	8.125
T_7-	Pyrazosulfuron *fb* Chlorimuron+ Metsulfuron (Almix)	8.188
T_8-	Penoxsulam + Cyhalofop 6 % OD	8.063
T_9-	Triafamone + Ethoxysulfuron 30 % WG	8.00
T_{10}-	Pendimethalin (38.7 % CS) *fb* Bispyribac –Sodium	8.375
T_{11}-	Hand weeding at 25 and 45 DAT	8.438
T_{12}-	Weedy check	7.688
	SEm±	0.042
	LSD (P=0.05)	0.125

A perusal of mean data revealed that different weed management practices had significant effect on protein content in rice grain. Weed management practice T_{11} recorded the highest protein content in rice grain (8.43%) which was statistically at par with T_{10} and superior to rest of the weed management practices.

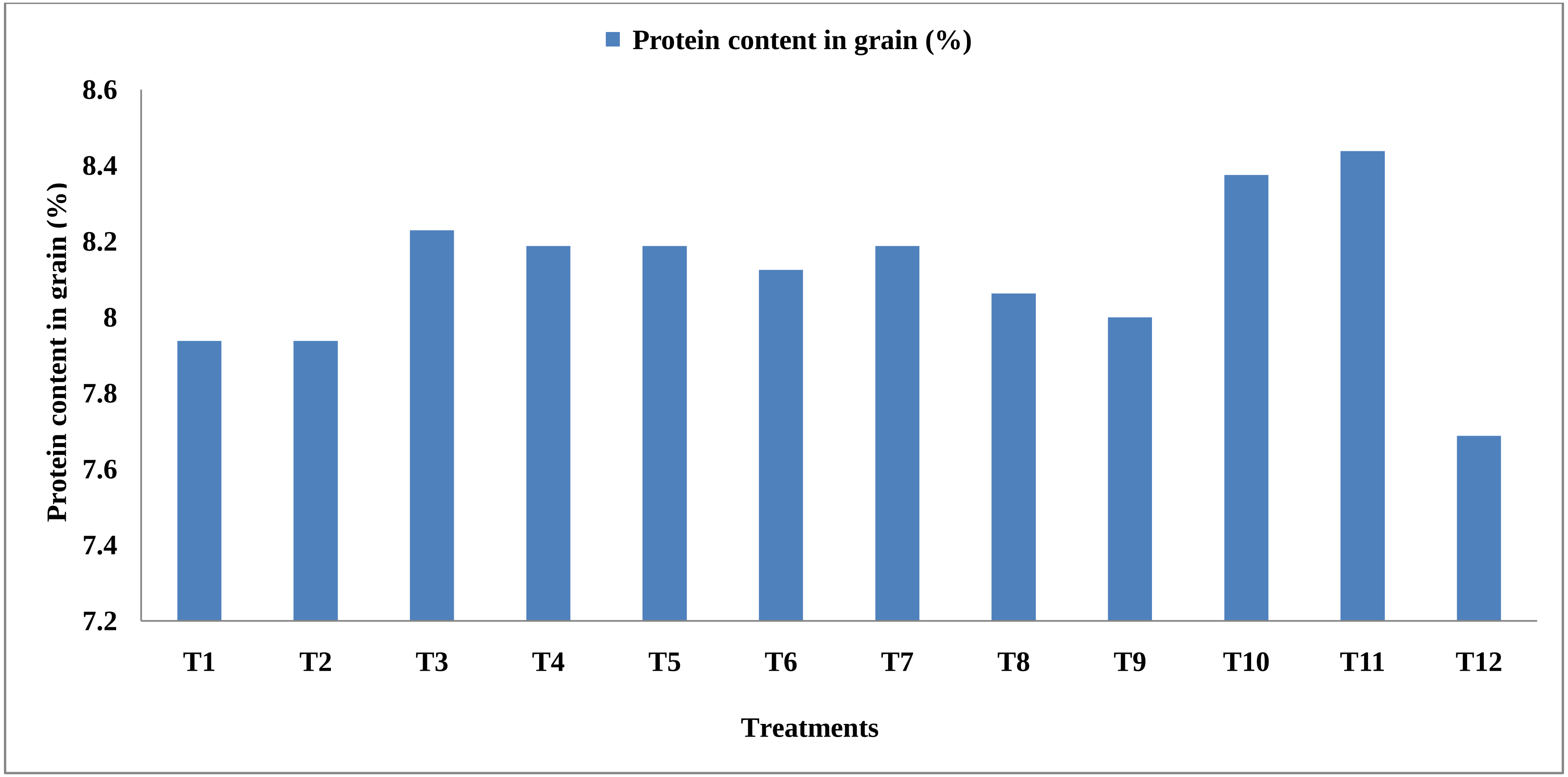


Fig. 4. 11 Protein content in grain (%) as affected by different weed management treatments

5. Economics

5.1 Gross return

Citation of data regarding gross return revealed that different weed management treatments had exerted significant effect. The maximum gross return (72,650 ₹/ha) was obtained under treatment T_{11}- weed free (2 hand weeding at 25 and 45 DAT) and lowest gross return was recorded under T_{12}- weedy check treatment (41,930 ₹/ha). The highest gross return was only statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (69,245 ₹/ha) and significantly superior over rest of the treatments.

5.2 Net return

A perusal of the data regarding net return revealed that different weed management treatments showed significant effect on net return. The highest value of net return (42,525 ₹/ha) was recorded under treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT) and lowest net return was recorded under T_{12}- weedy check treatment (18,730 ₹/ha). The highest net return, which was statistically at par with T_3- bispyribac- sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (41,390 ₹/ha) and significantly superior to rest of the treatments.

5.3 Benefit: Cost Ratio

An appraisal of data regarding Benefit: Cost ratio was indicated that different weed management treatments on transplanted rice had exerted significant effect on Benefit: cost ratio. The highest value of benefit cost ratio (2.61) was obtained under T_3- bispyribac- sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT) and lowest under T_{12}- weedy check treatment (1.81). The highest value of benefit cost ratio which was statistically at par with treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)- (2.59), T_6- pretilachlor 750 g/ha (0-3 DAT) *fb* chlorimuron + metssulfuron(Almix) 4 g/ha (25 DAT)- (2.51), T_7- pyrazoslfuron 20 g/ha (0-3 DAT) *fb* chlorimuron + metssulfuron (Almix) 4 g/ha (25 DAT)- (2.50), T_5-pretilachlor 750 g/ha (0-3 DAT) *fb* ethoxysulfuron 18.75 g/ha (25 DAT)- (2.49) and also significantly superior over rest of the treatments.

Table: 4.12 Effect of different weed management treatments on gross return (₹/ha), net return (₹/ha) and B:C ratio

Treatments		Gross return (₹/ha)	Net return (₹/ha)	B : C Ratio
T_1-	Bispyribac- Sodium	57,445	32,470	2.30
T_2-	Penoxsulam 24 % SC	58,020	31,150	2.16
T_3-	Bispyribac – Sodium + Ethoxysulfuron	67,020	41,390	2.61
T_4-	Bispyribac – Sodium + Chlorimuron + metsulfuron (Almix)	62,170	36,160	2.39
T_5-	Pretilachlor *fb* Ethoxysulfuron	61,805	37,005	2.49
T_6-	Pretilachlor *fb* Chlorimuron + metsulfuron (Almix)	63,055	37,920	2.51
T_7-	Pyrazosulfuron *fb* Chlorimuron+ metsulfuron (Almix)	62,610	37,615	2.50
T_8-	Penoxsulam + Cyhalofop 6 % OD	61,130	33,760	2.23
T_9-	Triafamone + Ethoxysulfuron 30 % WG	59,885	34,185	2.33
T_{10}-	Pendimethalin (38.7 % CS) *fb* Bispyribac –Sodium	69,245	42,525	2.59
T_{11}-	Hand weeding at 25 and 45 DAT	72,650	37,450	2.06
T_{12}-	Weedy check	41,930	18,730	1.81
	SEm±	1,465	1,465	0.06
	LSD (P=0.05)	4,325	4,325	0.17

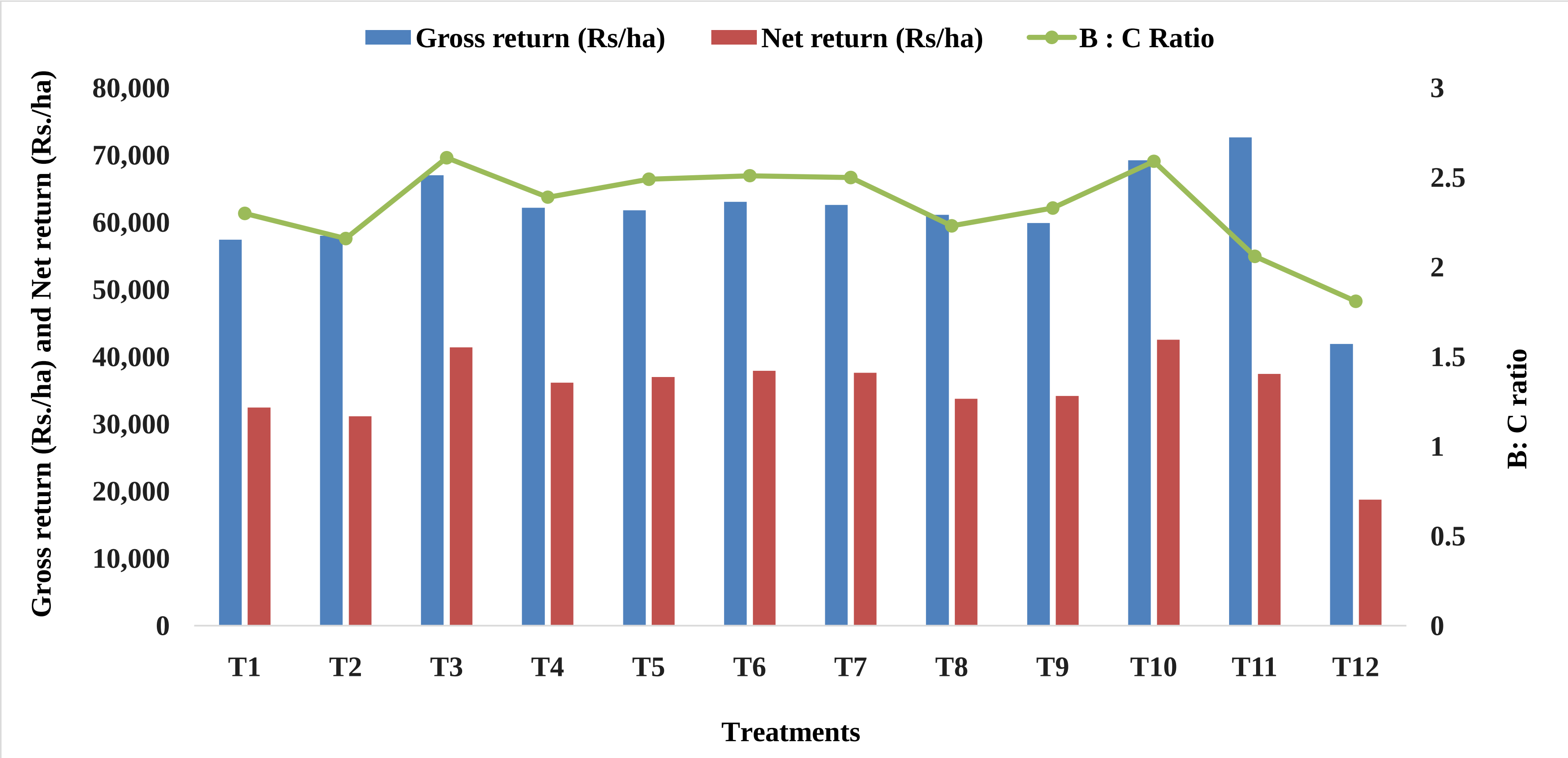


Fig. 4.12 Gross return (Rs./ha), Net return (Rs./ha) and B: C ratio as affected by different weed management treatments

Chapter - 5

[DISCUSSION]

DISCUSSION

A field experiment was conducted at the experimental farm of RAU, Pusa, Bihar during *Kharif* season of 2015 to study the **"Bio-efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice (*Oryza sativa* L.)"**. The main objective of the present investigation was to evaluate the efficacy of herbicides against complex weed flora in transplanted rice and to increase the productivity and profitability of transplanted rice.

In this chapter an effort has been made to discuss the result of experiment and to offer explanation and experimental evidences, wherever possible for noted variation with a view to understand the cause and effect relationship as far as possible. Efforts have also been made to search out reasons for variations and superiority or inferiority of one factor over the others.

Effect of Weather on Crop

Growth and development of crop plants depend on judicious management of intrinsic (genetic or hereditary) and extrinsic (environment) factors. Basically the crop environment is represented by soil and atmosphere. The interaction of these two natural entities acting in conjunction with the genetic makeup of plant is compounded by the man's interference in the form of various inputs supplied by him and decides the pattern of plant growth and ultimately its end product i.e. yield. However, environmental factors are relatively more dynamic in determining the extent of growth and development of plants and play a vital role in completion of plant life cycle due to their close association with different phenological stages of crop plants. The meteorological data presented in Table 3.3 during the experimental periods showed that the weather conditions were more or less congenial for the normal growth of the test crop during the experimental year. However, the temperature during the crop season was quite congenial for growth and development of rice plants. The temperature (17.4^0C) did not drop in the month of October to the extend to cause any detrimental effect on flowering, anthesis and grain filling. The rainfall (883.2mm) during the vegetative phase was higher than the normal for the place that is good for growth of rice while that under the reproductive phase was close to (45.4 mm) normal. Thus, the weather conditions were quite favorable for proper growth & development and highest yield. The relative humidity was marginally higher which again did not affect performance of rice.

Effect of different weed management practices on crop growth parameters

Growth parameters

Plant height is an important vegetative character as it is an index of plant growth and vigor, which ultimately reflected in its productivity. Observations of plant height revealed that the effect of weed management practices on plant height was found to be significant at all the crop growth stages. (Table 4.1). The longest plant height was recorded under treatment T_{11}-weed free (2 hand weeding at 25 and 45 DAT), which was significantly superior to all other treatments. This might be due to effective weed control by weed free treatment which resulted into less or nearly no crop weed competition for nutrient, light, moisture and space which leads to higher accumulation of photosynthate and subsequently resulted in longest plant height. This result is in close conformity of Singh *et al*. (2006). The shortest plant height was recorded with treatment T_{12}-weedy check. This might be due to highest crop-weed competition in weedy check in which individual plants of the plots faced highest competition from weed population apart from crop plant. Hence crop did not get opportunity to proliferate laterally due to less lateral space. Hossain and Mondal (2014) and Singh *et al.* (2006) also reported similar findings. Among the herbicidal treatments the highest plant height recorded under T_9-Pendimethalin 750 g/ha (0-3 DAT) *fb* Bispyribac-Na 25 g/ha (25 DAT), this might be due to effective control of weeds throughout critical period of crop growth, initially 20 days by pendimethalin (pre-emergence) and further with Bispyribac-sodium resulted in increased growth of the crop. Similar opinion has also been expressed by Narolia *et al.* (2014).

The number of tillers/m^2 is also one of the important growth parameters. The periodical observations on the number of tillers/m^2 (Table 4.2) revealed that number of tiller/m^2 increased up to 90 DAT and there after a declining trend was observed irrespective of treatments. This might be due to the mutual competition among the tillers for light, nutrients, space, water and other growth factors resulting in mortality of tillers after 90 DAT. The maximum number of tillers/m^2 was recorded under the treatment T_{11}-weed free (2 hand weedings at 25 and 45 DAT), which was significantly superior over rest of the treatments except T_3 and T_4 treatments. These findings were in close conformity with the results obtained by Hossain and Mondal (2014), Akabar *et al*. (2011) and Rammana *et al.* (2007). At 90 DAT all the weed control treatments showed significantly superiority over T_{12}- Weedy check and was comparable to each other (weed control treatments). This might be due to the facts that weed free environment helps the crop for better establishment and subsequence growth. Similar view was expressed by Akabar *et al.* (2011). Among the herbicidal treatments the highest tillers/m^2 recorded under T_9-pendimethalin 750 g/ha (0-3 DAT) *fb* bispyribac-Na 25 g/ha (25 DAT). This might be effective control of weeds with pre-emergence and post-emergence application of herbicides resulted favorable environment for growth of the crop. Pre and post emergence herbicides collectively reduce the weed population up to minimum threshold level starting from field preparation to 90 DAT and crop height had edge over weed flora of rice. Similar opinion has also been expressed by Narolia *et al.* (2014).

The dry matter production is the cumulative effects of various growth factors viz. plant height, number of tillers, number of leaves, well develop root system, etc and favorable environmental condition. The dry matter accumulation by rice plants increased progressively with advancement of growth of crop. Dry matter accumulation by rice plants was influenced significantly by weed management treatments at all the growth stages of rice. The maximum dry matter accumulation (Table 4.3) was observed under treatment T_{11}-weed free (2 hand weeding at 25 and 45 DAT) at harvest stage which was significantly superior to rest of the treatments. Similar opinion has also been expressed by Uma *et al*. (2014) and Kiran *et al*. (2010). The dry matter production with weedy plots were significantly lowest among all the treatments in all the stages of crop growth it may be due to when multiple weed problems. Therefore, it becomes advantageous to use a mixture of herbicides to control complex weed flora which comprises of broad leaved weeds, grassy and sedges. Similar results were found by Uma *et al.* (2014).

Effect of different weed management practices on yield attributing characters

Growth parameters form the foundation on which development of yield attributing characters stand. The attributing characters envisaged of number of effective tillers/m^2, length of panicle, number of grains/panicle, panicle length and test weight in rice were greatly influenced by genetic characters but it was also influenced by external factors.

The highest number of panicle/m^2, panicle length, number of grains/panicle were obtained under weed free (2 hand weeding at 25 and 45 DAT) treatment (Dixit and Varshney, 2008) and lowest under weedy check(T_{12}). Better expression of growth parameters under the conditions in which plots were kept weed free is self-explanatory. Panicle length and number of grains/panicle were higher in all weed control treatments than the Weedy check, while test weight was found to be almost similar in all the treatments. This might be due to the reason that lower weed population had provided favorable and least crop-weed competition environment to the crop, which has resulted in higher photosynthetic accumulation rate and better translocation of the sink as compared to weedy check. This is in conformity with results of Payman and Singh (2008).

Application of T_{10}-pendimethalin 750 g/ha (0-3 DAT) *fb* bispyribac-Na 25 g/ha (25 DAT) treatments among herbicidal treatments resulted in higher grains/panicle as well as higher test weight than other herbicidal treatments. This might be due to significantly reduction in weed density and weed dry weight. Effective controls of weeds with pre-emergence and post-emergence application of herbicide might have resulted in increased yield attributes of the crop which reduces resource used by dynamic weed flora. These results are in accordance with the findings of Mathiyalayan and Muraliarthanari (2015), Narolia *et al*. (2014) and Nath *et al.* (2014).

Effect of different weed management practices on yield

Yield is the ultimate outcome of the crop as influenced by various management practices. Proper management of production factors under given set of environment gave high dividend in the form of yield increase. Prakash *et al.* (2013) were reported higher grain yield under hand weeding and herbicidal treatments which was attributed to better utilization of applied nutrients by crop as compared to weedy check. The results were similar to that of the experimental findings of Kabdal *et al.* (2014). Environmental and management practices act on the plant, which ultimately produce the desirable economic product. This was because of the total dry matter accumulation as well as efficiency of its conversion, amenable to various management practices. Therefore, proper management of plant is necessary for successful production of any crop. The final yield of rice was the result of the successful competition of the growth and development activities which in turn depends on the hereditary potential of variety, the environmental condition to which it was exposed during the course of its life cycle and agronomic management practices.

Commensuration with the growth and yield attributing character the weed management practices, significantly lower yield was recorded with T_{12}–weedy check which yielded, 29.2 q/ha grain yield. This finding is in conformity with those of Chopra and Chopra (2003) who reported yield losses due to weeds in transplanted rice varies from 15-45 % depending upon the weed flora, their intensity and duration of competition. The maximum grain yield (50.50 q/ha) was obtained under T_{11}-Weed free (2 hand weeding at 25 and 45 DAT), this might be due to excellent performance of these treatments in terms of grain and straw yield due to better management practices and reduction in weed dry weight and its population. The result was close conformity to those given by Prakash *et al.* (2013), Singh *et al*. (2007) and Singh *et al.* (2006). Growth requirement of crop and weed are identical therefore weeds always start growing with crops. They compete with plants for all natural factors or costly inputs. The weeds absorb nutrient and moisture faster than crop and smother the crop plants leading to poor growth and development which ultimately reduce yield. Several reports indicated the effectiveness of T_{11}-hand weeding, weedicides alone or in combination for control of weed infestation in rice crop and increasing the grain and straw yield over no weeding treatments (Ram *et al*. 2004, Subramanian and Martin, 2006 and Ravishanker *et al*. 2008). So far as straw yield is concerned the similar trend was recorded as that in grain yield of the rice crop. Harvest index is the ratio of economic yields to the total biological yield so economic yield in relation to the biological yield is the key factor in determining the success of crop production. So for as, harvest index is considered it was varying non-significantly due to various weed control treatments in the experimentation.

Effect of different weed management practices on weed parameters

All weed control treatments were found effective over T_{12}-weedy check at all the stages of crop growth in relation to weed population/m^2, weed dry weight (g/m^2), weed control efficiency (%) and weed index (%). Among the herbicide treatments, weed population/m^2 and weed dry weight (g/m^2) was registered significantly lowest under T_{11}-pendimethalin 750 g/ha (0-3 DAT) *fb* bispyribac-Na 25 g/ha (25 DAT), at all crop growth stages and maximum weed control efficiency was also observed with T_{10}-pendimethalin 750 g/ha (0-3 DAT) *fb* bispyribac-Na 25 g/ha (25 DAT). This may be attributed due to earlier and effective control of weeds by pendimethalin and subsequently flushes of weeds were controlled by bispyribac-sodium efficiently. This result was similar to that of the experiment at findings of Narolia *et al*. (2014) and Nath *et al.* (2014). The lower weed density with that treatment might be due to inherent ability of chemical to affect the cell division, cell growth and hampering the germination of weeds. Similar findings were reported by Mathiyalayan and Muraliarthanari (2015). The lowest weed biomass observed with those treatments was due to efficient control of dominant weed from the beginning of crop growth Uma *et al.* (2014). It might be due to the use of mixture of herbicides which showed broad spectrum control of weeds. This finding is in conformity with those of Lap *et al.* (2013).

Similarly weed dry weight was also registered significantly lower under T_{11}-weed free (2 hand weedings at 25 and 45 DAT), at all crop growth stages and it was statistically at par withT_{10}-pendimethalin 750 g/ha (0-3 DAT) *fb* bispyribac-Na 25 g/ha (25 DAT). Hand weeding exhibited significant influence on weed population at all different growth stages. Significantly the lowest weed density was observed with hand weeding at all stages of crop growth. This might be due to timely reduction of weed below threshold level by intercultural tools. The weeds were uprooted and killed. Similar findings were observed by Singh (2012). Hand weeding twice recorded lowest weed biomass per m^2 at all growth stages of crop. At all the stages of crop, weedy check exhibited significantly highest weed biomass per m^2. Weed control efficiency was found to be maximum under treatment T_{11}-weed free (2 hand weeding at 25 and 45 DAT) due to best control on most of the sedges besides controlling the broad leaf weeds and grassy weeds. This has resulted in significant lower weed population and had also led to very less weed dry weight as compared to other treatments. This finding is in conformity with those of Dixit and Varshney (2008).

Effect of different weed management practices on nutrient uptake

Nutrient uptake being a function of dry matter production and partly due to increase in its concentration, gave more total dry matter and registered significantly higher uptake of N, P_2O_5 and K_2O. (Uma *et al.* 2014). The N, P_2O_5 and K_2O nutrients did not differ significantly for their concentration in grain and straw. The N, P_2O_5 and K_2O concentration in grain and straw does not appear to be a function of weed management methods. Since, the available N, P_2O_5 and K_2O were at the same level for all the treatments. The variations clearly related to the variations in yields and not due to the concentration of nutrients. The N, P_2O_5 and K_2O uptake both in grain and straw were higher in weed free plots. (Kumar *et al*. 2010). All weed control treatments recorded significantly higher N, P_2O_5 and K_2O uptake by crop plants than weedy check. Among the herbicidal treatments maximum uptake of N, P_2O_5 and K_2O was obtained by T_{10}-pendimethalin 750 g/ha (0-3 DAT) *fb* bispyribac-Na 25 g/ha by rice crop due to less weed infestations. This might be due to application of herbicides controlled weed effectively and made available more nutrients to rice crop and consequently resulted in higher yield. Similar findings had also been reported by Kumar *et al*. (2010). Nutrient uptake by the weeds followed just opposite trend of crop nutrient uptake. Minimum uptake by weeds in weed free condition and maximum uptake in weedy check. This finding is in conformity with those of Nath *et al*. (2014).

Effect of different weed management practices on economics

The maximum gross return was recorded with T_{11}-Weed free (2 hand weeding at 25 and 45 DAT). This finding is in conformity with those of Gowda *et al.* (2009). However maximum net return was recorded with T_{10}-Pendimethalin 750 g/ha (0-3 DAT) *fb* Bispyribac-Na 25 g/ha (25 DAT) than the other weed control treatments. This finding is in conformity with those of Bhurer *et al.* (2013). B: C ratio is maximum in T_3 -Bispyribac-Na 25 g/ha (25 DAT) + ethoxysulfuron 18.5 g/ha (25 DAT). This might be due to lowest cost of cultivation. This finding is in conformity with those of Hossain and Mondal (2014). The lowest net return obtained in weedy check were due to high infestation of weeds resulting in low weed control efficiency. These results are in conformity with those reported by Sanjay *et al*. (2007). The gross and net return were the reflection of economic yield, while B: C ratio gets influenced due to cost of cultivation including respective weed control treatments. The cost of weeding was comparatively higher with hand weeding (twice) than herbicidal treatments, that's why lowest B: C ratio recorded under weed free except weedy check (Uma *et al.* 2014).

◈◈◈

Chapter - 6

[SUMMARY AND CONCLUSION]

SUMMARY AND CONCLUSION

An experiment under Randomized block design replicated thrice, was conducted at University Research Farm of Rajendra Agricultural University, Pusa, Samastipur, Bihar during rainy season of 2015 to study the **"Bio-efficacy of Herbicides Combinations Against Weed Flora in Transplanted Rice (*Oryza sativa* L.)"**. The results obtained have been summarized here under:

1. An appraisal of data regarding plant height revealed that crop grown under different weed management treatments produced significant effect on plant height. The longest plant height was recorded under T_{11}- weed free (2 hand weeding 25 and 45 DAT) and shortest plant height obtained under weedy check T_{12}. The highest plant height was statistically at par with treatment T_{10}- pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT) at all growth stages of crop.
2. The maximum number of tillers/m^2 was observed in treatment T_{11}- hand weeding at 25 and 45 DAT was statistically at par with treatment T_{10}- pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT) almost all crop growth stages and lowest number of tillers/m^2 observed in weedy check. The highest number of tillers/m^2 was counted at 90 DAT and there after declining trend was recorded.
3. Dry matter production had increased trends throughout crop growth period. The highest dry matter was obtained under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT), at harvest stage and lowest under T_{12} weedy check treatment.
4. Number of panicles/m^2 gets significantly affected by different weed management treatments. The highest number of panicle/m^2 was obtained under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT), which was superior to rest of treatments and lowest count was under T_{12} weedy check treatment.
5. The panicle length did not affect by weed management practices. However, the longest panicle length (19.97 cm) was obtained under treatment T_7- Pyrazosulfuron *fb* Almix, while shortest was under T_{12} weedy check treatment.
6. Different weed management treatments had exerted significant effect on number of grains/panicle. The highest number of grains/panicle was recorded under

treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT), which was statistically at par with treatment T_{10}- pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT) and T_3- bispyribac- sodium + ethoxysulfuron 25 + 18.75 g/ha (at 25 DAT) and superior to rest of treatments.

7. 1000- grain weight of Rajendra Shweta did not show any variation due to weed management practices. However, highest test weight was recoded under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT) and lowest under T_{12} weedy check treatment.
8. Different weed management treatments had significant effect on grain yield. Maximum grain yield was recorded under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT), which was statistically at par with treatment T_{10}- pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT) and superior to rest of treatments.
9. The highest straw yield was obtained under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT), which was superior to rest of treatments and lowest straw yield obtained under treatment T_{12} weedy check.
10. The highest harvest index was recorded under treatment T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT) and lowest under treatment T_7- pyrazosulfuron *fb* almix.
11. The weed population differed significantly at different crop growth stages. Lowest weed population was recorded under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT), while highest weed population was recorded under treatment T_{12} weedy check at all crop growth stages.
12. Different weed management treatments exerted significant effect on weed dry weight at all crop growth stages. The lowest weed dry weight of weed was recoded under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT), while highest weed dry weight was recorded under treatment T_{12} weedy check at all crop growth stages.
13. The highest weed control efficiency was recorded under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT).
14. The minimum weed index was recorded under treatment T_{10}- pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT).

15. Nutrient uptake differed significantly due to different weed management treatments and highest nutrient uptake was recorded under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT) and lowest under treatment T_{12} weedy check by the crop.
16. Nutrient uptake by weeds differed significantly due to different weed management treatments and lowest nutrient uptake was recorded under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT) and highest under treatment T_{12} weedy check.
17. The highest cost of cultivation was recorded under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT).
18. Different weed management treatments had exerted significant effect on gross return. Maximum gross return was observed under treatment T_{11}- weed free (2 hand weeding 25 and 45 DAT) and lowest was under treatment T_{12} weedy check.
19. Maximum net return was recorded under treatment T_{10}- pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT) which was statistically at par with T_3- bispyribac- sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT) and significantly superior over rest of the treatments.
20. Benefit: Cost ratio also differed significantly under different weed management treatments. Maximum B:C ratio was observed under T_3- bispyribac- sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT) (2.61) and lowest under treatment T_{12} weedy check.

CONCLUSION

1. The lowest weed count, weed dry weight and highest weed control efficiency were recorded by treatment T_{11}- weed free (2 hand weeding at 25 and 45 DAT). Among herbicidal treatments the lowest weed count, weed dry weight and highest weed control efficiency were recorded by treatment T_{10}- pendimethalin (38.7 % CS) *fb* bispyribac -sodium and was significantly superior to other herbicidal treatments.

2. The highest growth yield attributes, yield and quality of rice were recorded by treatment T_{11}- weed free (2 hand weeding at 25 and 45 DAT). Among

herbicidal treatments the highest growth yield attributes, yield and quality of rice were recorded by treatment T_{10}- pendimethalin (38.7 % CS) *fb* bispyribac-sodium and was significantly superior to other herbicidal treatments.

3. The heighest Net return was recorded by treatment T_{10}- pendimethalin (38.7 % CS) *fb* bispyribac-sodium which was statistiically at par with T_3- bispyribac-sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT)- (41,390 Rs/ha) and significantly superior to rest of the treatments.

   The highest value of benefit cost ratio (2.61) was obtained under T_3-bispyribac- sodium + ethoxysulfuron 25 + 18.75 g/ha (25 DAT) and was statistically at par with T_{10} - pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT)-(2.59). Both the treatments (T_3 & T_{10}) were significantly superior to T_{12}- weedy check treatment (1.81).

- ❖ If labour cost is higher or labour availability is a problem then herbicides combinations is a better tool for the farmers for controlling weeds flora in transplanted rice.
- ❖ Thus, on the basis of one year research data, it may be concluded that application of bispyribac sodium 25 g/ha + ethoxysulfuron 18.75 g/ha at 25 DAT or pendimethalin 750 g/ha (0-3 DAT) followed by bispyribac-sodium 25 g/ha (25 DAT) or either pretilachlor 750 g/ha or pyrazosulfuron ethyl 20 g/ha (0-3 DAT) followed by chlorimuron + metsulfuron (Almix) 4 g/ha (25 DAT) is quite effective in controlling weeds and obtaining higher yield of transplanted rice and fetching higher net return and B:C ratio.

BIBLIOGRAPHY

BIBLIOGRAPHY

Akabar, N. and Ali, Ehsanullah. 2011. Weed management improves yield and quality of direct seeded rice. *Australian Journal of Crop Science* **5**(6): 688-694.

Banerjee, P., Dutta, D., Bandopadhyay, P. and Moity, D. 2008. Production potential, water use efficiency and economics of hybrid rice under different levels of irrigation and weed management practices. *Oryza* **45**(1): 30-35.

Barker, R.D. Dawe, T.P., Tuong, S.I. Bhuiyan and Guerra, L.C. 1999. The outlook of water resources in the year 2020: Challenges for research on water management in rice production. Assessment and Orientation towards the 21st century. Proceedings of 19^{th} session of the International Rice.

Bhagat, K.L., Dahama, A.K. and Singh, H. 1991. Performance of herbicides in direct seeded upland rice. *Annals of Agricultural Research* **12**(4): 422-424.

Bhagat, S., Malik, R.K., Ashok, Y. and Nandal, D.P. 2009. Herbicide efficacy in direct seeded rice with different methods under wet and dry conditions. *Indian Journal of Weed Science* **41**(1&2): 37-40.

Bhurer, K.P., Yadav, D.N., Ladha, J.K., Thapa, R.B. and Pandey, K. 2013. Effect of integrated weed management practices on performance of dry direct seeded rice (*Oryza sativa* L.). *Agronomy Journal of Nepal* **3**: 53-63.

Biswas, S.B and Thakur, R. C. 1983. Weed control in direct-seeded upland rice. *International Rice Research Newsletter* **8**(6): 20.

Bouyoucos, G.T. 1962. Hydrometer method for measuring particle size analysis of Soil. *Agronomy Journal* **54**: 464-465.

Budher, M.N., Krishnasamy, M. and Rammaswamy, C. 1991. Evaluation of herbicides for weed control in low land rice. *Indian Journal of Weed Sciences* **23**: 87-88.

Channabasanva, A.S. and Biradar, D.P. 2007. Evaluation of herbicides in transplanted rice (*Oryza sativa*). *Agronomy Digest* 6&7: 2-3.

Chopra, N.K. and Chopra, N. 2003. Effect of doses and stages of application of pyrzosulfuron- ethyl on weeds in transplanted rice. *Indian journal of weed Science* **35**: 27-29.

Cochran, W.G. and Cox, C.M. 1962. *Experimental Design*. John Wiley and Sons Inc., New York, USA.

Commission, Cario, Egypt. 7-9 September, 1998. pp. **96-109**. FAO, Rome

Daniel, P.S.J., Poonguzhalan, R., Mohan, R. and Suburayalu, E. 2012. Weed management for enhanced production of aerobic rice. *Indian journal of Weed Science* **22**(4): 270-273.

Dharmbir, Punia, S.S. and Lal, R. 2008. Evaluation of pretilachlor for control of weeds in transplanted rice. National Symposium on “New Paradigm in Agronomic Research”. Nov. 19-21, 318-319, Navsari, Gujrat.

Directorate of Statistics & Evaluation, Patna, Bihar, 2012. Online www.krishi.bih.nic.in

Dixit, A. and Sondhia, S. 2012. Bioefficacy and persistence of ethoxysufuron in rice. *Oryza* **49**(3): 178-182.

Dixit, A. and Varshney, J.G. 2008. Assessment of post-emergence herbicides in transplanted rice. *Indian Journal of Weed Science* **40**(3&4).

Fayaz, A.B. and Singh, G. 2004. Effect of herbicides on dry seeded rice (*Oryza sativa* L.) and associated weeds. Indian Journal of Weed Science **36**(3&4): 269-270.

Gautam, K.C. and Mishra, J.S. 1995. Problems, prospects and new approaches in weed management. *Pesticides Information* **21**: 7-19.

Gomez, K. and Gomez, A. 1984. *Statistical procedures for agricultural research*.

Gowda, P.T., Shankaraiah, C., Jnanesh, A.C., Govindappa, M. and Murthy, K. N. 2009. Studies on chemical weed control in aerobic rice. *Journal of Crop and Weed* **5**(1):321-324.

Halder, P. 2000. Comparative efficacy of pyrazosulfuron ethyl alone and its combination with molinate against weed complex of boro paddy M.Sc. Thesis. Deptt. Of Agronomy, BCKV, W.B.

Hossain, A. and Mondal, D.C. 2014. Weed management by herbicide combinations in transplanted rice. *Indian journal of weed Science* **46**(3): 220-223.

Jackson, M.L. 1973. Soil chemical analysis prentice hall of India Pvt. Ltd, New Delhi, India, PP-183-204.

Jayadeva, H.M., Bhairappanavar, S.T., Somasheharappa, P.R. and Rangaswamy, B.R. 2009. Efficacy of Azimsulfuron for weed control in transplanted rice. *Indian journal of weed Science* **41**(3&4): 172-175.

Kabdal, P., Pratap, T., Singh, V.P., Singh, R. and Singh, S.P. 2014. Control of complex weed flora in transplanted rice with herbicide mixture. *Indian journal of weed Science* **46**(4): 377-379.

Kiran, Y.D. and Subramanian, D. 2010. Performance of pre and post emergence herbicides on weed flora and yield of transplanted rice. *Indian journal of Weed Science* **42**(3&4): 226-228.

Kumar, B., Haque, M., Kalpana, A. and Nagarjuna, D. 2015. Bioefficacy of chemical herbicides in weed management of aerobic rice at Sabour region of Bihar. *Jounal of Crop and Weed* **11**(2): 138-143.

Kumar, J., Singh, D., Puniya, R. and Pandey, P.C. 2010. Effect of weed management practices on nutrient uptake by direct seeded rice. *Oryza* **47**(4): 291-294.

Lap, N., Somsak, S., Yuli, I.M., Duy, L., Choy, L.L., Victoriya, B., Niranjan, B.V. and Mann, R.K. 2013. Efficacy and rice tolerance to penoxulam + cyhalofop herbicides mixtures in Asian countries. *Asian- Pecific weed Science Society cinference* **24**: 424-430.

Madhukumar, V., Murthy, K., Sanjay, K.N., Prashanth, R. and Kumbar, B. 2013. Efficacy of pre and post emergent herbicides growth and yield of *kharif* aerobic rice. *International Journal of Advanced Biological Research* **3**(3): 360-365.

Mahajan, G., Boparai, B.S., Brar, L.S. and Sardana, V. 2003. Effect of pretilachlor on weeds in direct seeded puddled rice. *Indian Journal of Weed Science* **35**(1/2): 128-130.

Mahajan, G., Chauhan, B.S. and Gill, M.S. 2011. Dry- seeded rice culture in Punjab state of India: lessons learned from farmers. *Field Crops Research* **144**: 89-99.

Mathiyalgen, S. and Muraliathanari P. 2015. Sequential application of herbicides for weed control in transplanted rice. *International Journal of Farm Sciences* **5**(2): 27-33.

Ministry of Agriculture 2013. www.ministry of agriculture.in

Mirza, H., Ali, M.H., Alam, M.M., Akther, M. and Alam K.F. 2009. Evaluation of Pre-Emergence Herbicide and Hand Weeding on the Weed Control Efficiency and performance of transplanted Aus Rice. *American- Eurasian Journal of Agronomy* **2**(3): 138-143.

Mishra, J.S., Dixit, A. and Varshney, J.G. 2007. Efficacy of penoxsulam on weeds and yield of transplanted rice. *Indian journal of weed Science* **39**(1&2): 24-27.

Mukherjee, P.K. and Maity, S.K. 2010. Weed control in transplanted and wet seeded rainy season rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences* **81**(2): 134-139.

Nair, H.G., Choubey N.K. and Shrivastava G.K. 2002. Influence of nitrogen and weed management practices on weed dynamics in direct seeded rice. *Indian J. Weed Sci.* **34**(1&2): 134-136.

Narayana, A.L., Veerabadram, V. and Poonguzhalan, R. 1999. Performance of low doses high efficacy herbicide for weed control in transplanted rice. *Oryza* **36**(4): 292-295.

Narolia, R.S., Singh, P., Prakash, C. and Meena, H. 2014. Effect of irrigation schedule and weed management practices on productivity and profitability of direct-seeded rice (*Oryza sativa*) in south eastern Rajsathan. *Indian jounal of Agronomy* **59**(3): 398-403.

Nath, C.P., Saha, M., Pandey, P.C., Das, T.K., Meena, R.K. and Paul, T. 2014. Bioefficacy evaluation of different herbicides on weed population, grain yield, and nutrient uptake in direct seeded puddled rice (*Oryza sativa* L.). *Ann. Agric. Res. New Series* **35**(2): 217-223.

Olsen, S.R., Cole, C.V., Watanabe, F.S. And Dean, L.A. 1954. Estimation of available phosphorous in soil by extraction with sodium bicarbonate. *U. S. department of Agriculture. Circular*, **939**, pp. 19-23.

Payman, G. and Singh, S. 2008. Effect of seed rate, spacing and herbicides use on weed management in direct seeded upland rice. *Indian journal of weed Science* **40**(1&2): 11-15.

Piper, C.S. 1950. *Soil and Plant Analysis*. University Adelaide, Australia, p.368.

Prabhakaran, N.K., Sakthivel, N. and Nithya, C. 2014. Effect of Herbicide Combinations on Weed Control Efficacy and Grain Yield of Direct Seeded Rice. *Trands in Biosciences* **7**(24): 4244-4247.

Pradhan, M.R., Khuntia, A. and Goswami, S. 2013. Weed control efficiency of different herbicides and their economics in the various weed management practices of transplanted rice under north eastern plain zone of Odisha. *International Journal of Advanced Chemical Science and Application* **1**(1): 38-42.

Prakash, C., Shivran, R.K. and Koli, N.R. 2013. Bioefficacy of new herbicides in transplanted rice. *Indian journal of weed Science* **45**(4): 282-284.

Prameela, P., Menon, S.S. and Menon, M.V. 2014. Effect of new post emergence herbicides on weed dynamics in wet seeded rice. *Journal of Tropical Agriculture* **52**(1): 94-100.

Rajkhowa, D.J. and Barua, I.C. 2008. Integrated weed management in upland rice. *Indian Journal of Weed Science* **39**(3 & 4): 176-177.

Ram, M., Orn, H., Kumar, S. and Dhiman, S.D. 2004. Chemical weed control in direct seeded rice *(Oryza sativa)* under puddled lowlands. *Indian Journal of Agronomy* **49**(2): 108-110.

Rammana, A.V., Naidu, G.J. and Murthy, K.V.R. 2007. Integrated weed management in rainfed upland rice (*Oraza sativa*). *Indian journal of Agronomy* **52**(4): 311-314.

Ravishankar, Chandra, N., Sekaran, B., Raja, R., din, M. and Chaudhuri, S. G. 2008. Influence of integrated weed management practices on productivity and profitability of wet seeded rice. *Indian Journal of Agronomy* **53**(1): 57-61.

Reddy, B.G., Masthana, Ravisanker, G., Balganvi, Subhash, Joshi, V.R. and Negalur, R.K. 2012. Efficacy of bensulfuron methyl plus pretilachlor for controlling of weeds in transplanted rice. *Oryza* **49**(1): 69-67.

Richards, L.A. (ed.) 1954. Diagnosis and improvement of saline alkali soil, U.S.D.A. Agric. Handbook, No. 60.

Saha and Sanjoy 2005. Efficacy of certain new herbicide formulations in transplanted rice under rainfed shallow land. *Indian Journal of Weed Science* **37**(1&2): 109-110.

Saha, S. and Rao, K.S. 2007. Weed management in rice. Res. Bull. No. 2, Central Rice Research Institute, Cuttack, Orissa, India, p 14.

Sanjay, M.T., Setty, L.K., Prabhakara and Nanjappa, H.V. 2008. Investigation of crop establishment methods and weed management practices on productivity and economics in rice. *Mysore Journal of Agriculture Science* **42**(1): 60-66.

Shan, F.A., Bhat, M. Anwar, Ganai, A. Manzoor, Hussain, A. and Bhat, Tanseef A. 2012. Effect of crop establishment and weed control practices on the performance of rice (*Oryza sativa*). *Applied Biological Research* **14**(1): 79-85.

Sharma, R.P., Pathak, S.K. and Singh, R.C. 2007. Effect of nitrogen and weed management in direct seeded rice under upland conditions, *Indian Journal of Agronomy* **52**(2): 114-119.

Singh L.D. and Stoskopt N.C. 1971 Harvest Index in Cereals. *Agron J*. 63:224226.

Singh, G. 2012. Efficacy of different formulation of penoxsulam on weeds and yield of transplanted rice. *Oryza* **49**(3): 195-199.

Singh, I., Ram, M. and Nandal, D.P. 2007. Efficacy of new herbicides for weed control in transplanted rice under rice- wheat system. *Indian journal of weed Science* **39**(1&2): 28-31.

Singh, K. and Tripathi, H.P. 2007. Effect of nitrogen and weed-control practices on performance of irrigated direct seeded rice *(Oryza sativa). Indian Journal of Agronomy* **52**(3): 231-234.

Singh, K.N., Singh, P. and Singh, R. 2007. Efficacy of new herbicides in transplanted rice (*Oryza sativa*) under temprate conditions of Kashmir. *Indian journal of weed Science* **39**(3&4): 167-171.

Singh, P. and Singh, S.S. 2004. Efficacy of low doses of herbicides on divergent weed flora in transplanted rice. *Oryza* **41**(1): 20-23.

Singh, P., Singh, P., Singh R. and Singh, K.N. 2006. Efficacy of new herbicides in transplanted rice under temprate conditions of Kashmir. *Indian Journal of Weed Science* **39**: 167-171.

Singh, V.P., Singh S.P., Tripathi, N., Singh M.K. and Kumar A. 2009. Bioefficacy of penoxulam on transplanted rice weeds. *Indian journal of weed Science* **41**: 28-32.

Singh, V.P., Singh, S.P., Tripathi, N., Singh, M.K. and Kumar, A. 2009. Bioefficacy of penoxsulam on transplanted rice weeds. *Indian journal of weed Science* **41**(1&2): 28-32.

Subbiah, B.V. and Asija, C.L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* **25**: 328.

Subramanian, E. and Martin, G. J. 2006. Effect of chemical, cultural and Mechanical methods of weed control on wet seeded rice. *Indian Journal of Weed Science* **38**(3&4): 218-220.

Subramanian, E., Martin, G. and Balasubramanian, R. 2006. Effect of integrated weed management practice on growth and yield of wet- seeded rice (*Oryza sativa* L.) and their residual effect on succeeding pulse crop. *Indian Journal of Agronomy* **51**(2): 93-96.

Tamilselvan, N and Budhar, M. N. 2002. Weed control in direct seeded puddled rice. *Madras Agricultural Journal* **88**(10&12): 745-746.

Tuteja, S.S., Chandrakar, B.L. and Tripathi, R.S. 1995. Economic feasibility of different herbicides on direct-seeded, lowland rainfed rice *(Oryza sativa). Indian Journal of Agronomy* **40** (2): 286-287.

Uma, G., Ramana, M., Venkata, Reddy, A., Pratap, K. and Prakash. T.R. 2014. Evalution of low dose herbicides in transplanted rice. *International Journal of Applied Biology and Pharmaceutical Technology* **5**: 96-101.

Upasani, R.P., Thakur, R. and Singh, M.K. 2010. Influence of sowing time and weed control methods on weed flora and productivity of direct seeded upland rice. *Indian Journal of Weed Sciecnce* **42**(1&2): 14-16.

Walia, U.S., Bhullar, M.S., Nayar, Shelly and Walia, S.S. 2008. Control of complex weed flora of Dry-seeded rice with pre and post-emergence herbicides. *Indian Journal Weed Science* **40**(3 & 4): 161 -164.

Walia, U.S., Singh, Onkar, Nayyar, Shelly and Sindhu, Vinay. 2008. Performance of post-emergence application of Bispyribac in dry seeded rice. *Indian Journal Weed Science* **40** (3 & 4): 157 -160.

Walkley, A.J. and Black, I.A., 1934. An examination of degtganeff method for determining soil organic matter and a proposal modification of the chronic acid titration method. *Soil science* **37**: 29-39.

Yadav, D.B., Yadav, A. and Balyan, R.S. 2008. Evaluation of azimsulfuron for the control of complex weed flora in transplanted rice. *Indian Journal of Weed Science* **40**(3&4): 132-136.

Yadav, D.B., Yadav, A. and Punia, S.S. 2009. Evaluation of bispyribac-sodium for control in transplanted rice. *Indian journal of weed Science* **41**(1&2): 23-27.

APPENDICES

Appendix I

Details of common cost of cultivation of M_1- transplanted rice (₹/ha)

Sl. No.	Particulars	Quantity	Rate (₹/unit)	Cost (₹/1000m^2)
A.	**Nursery raising (Area 1000 m^2)**			
1.	Land preparation (ploughing)	2	107/1000m^2	214
2.	Seed bed preparation	2 man days	184/man day	368
3.	Seed	35 kg	25/kg	875
4.	Seed sowing	2 man days	184/man day	368
5.	Irrigation	1	90/1000m^2	90
	Total			**1915**
B.	**Transplanting**			**(₹/ha)**
1.	Puddling with rotavator	2	950/cross	1900
2.	Layout preparation	2 man days	184/man day	368
3.	Uprooting and transplanting	23 man days	184/man day	4232
4.	Fertilizer			
	a) Urea (120 kg N)	260 kg	6.3/kg	1638
	b) SSP (60 kg P_2O_5)	375 kg	7.24/kg	2715
	c) MOP (40 kg K_2O)	66.66 kg	16.8//kg	1120
5.	Irrigation	3	700/irrigation	2100
6.	Cost of applying irrigation	3 man days	184/man day	552
7.	Insecticide (Furadon 3G)	8 kg	80/kg	640
8.	Cost of applying insecticide	1 man days	184/man day	184
9.	Harvesting	15 man days	184/man day	2760
10.	Threshing	10 man days	184/man day	1840
11.	Cleaning, drying and storage	4 man days	184/man day	736
12.	Land rent	6 month	1000/ha/year	500
	Total			**21285**
	Grand total (A+B)			**23200**

Appendix II

Total cost of different treatments.

Treatment	Common cost (₹/ha)	Variable cost (₹/ha)	Total (₹/ha)
T_1- Bispyribac- Sodium	23200	1775	24975
T_2- Penoxsulam 24 % SC	23200	3670	26870
T_3-Bispyribac – Sodium + ethoxysulfuron	23200	2475	25675
T_4- Bispyribac – Sodium + Chlorimuron + metsulfuron (Almix)	23200	2810	26010
T_5- Pretilachlor *fb*ethoxysulfuron	23200	1600	24800
T_6- Pretilachlor*fb*Chlorimuron + metsulfuron (Almix)	23200	1935	25135
T_7- Pyrazosulfuron*fb*Chlorimuron + metsulfuron (Almix)	23200	1795	24995
T_8- Penoxsulam + cyhalofop 6 % OD (RM)	23200	4170	27370
T_9- Triafamone + ethoxysulfuron 30 % WG	23200	2500	25700
T_{10}- Pendimethalin (38.7 % CS) *fb*Bispyribac –Sodium	23200	3520	26720
T_{11}-Hand weeding at 25 and 45 DAT	23200	12000	35200
T_{12}-Weedy check	23200	-	23200

Appendix III

NPK content in grain and straw in percentage

Treatments	N, P & K content in crop (%)					
	N (%)		P (%)		K (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1	1.27	0.46	0.17	0.1	0.19	1.11
T_2	1.27	0.46	0.18	0.11	0.2	1.117
T_3	1.317	0.5	0.21	0.13	0.23	1.18
T_4	1.31	0.48	0.2	0.11	0.22	1.16
T_5	1.31	0.48	0.19	0.11	0.22	1.15
T_6	1.3	0.5	0.21	0.12	0.23	1.17
T_7	1.31	0.48	0.2	0.12	0.22	1.17
T_8	1.29	0.47	0.19	0.11	0.21	1.14
T_9	1.28	0.47	0.18	0.11	0.193	1.14
T_{10}	1.34	0.51	0.22	0.13	0.24	1.18
T_{11}	1.35	0.53	0.24	0.15	0.25	1.19
T_{12}	1.23	0.41	0.12	0.1	0.18	1.01
SE. (m)	0.007	0.007	0.007	0.007	0.008	0.009
C.D.	0.02	0.022	0.022	0.02	0.025	0.027

Appendix IV

NPK content in weeds

Treatments	NPK content in weeds (%)		
	N (%)	P_2O_5 (%)	K_2O (%)
T_1	0.83	0.15	0.18
T_2	0.83	0.16	0.18
T_3	0.77	0.12	0.16
T_4	0.69	0.13	0.16
T_5	0.78	0.13	0.15
T_6	0.78	0.13	0.16
T_7	0.79	0.14	0.16
T_8	0.79	0.14	0.17
T_9	0.67	0.15	0.17
T_{10}	0.65	0.12	0.15
T_{11}	0.63	0.11	0.15
T_{12}	0.87	0.21	0.23
SE. (m)	0.007	0.008	0.008
C.D.	0.02	0.025	0.023