STUDIES ON BROADCAST AND DIRECT LINE SEEDED RICE (*Oryza sativa* L.) UNDER DIFFERENT SEED RATE AND WEED MANAGEMENT PRACTICES FOR ALTERNATIVES OF BEUSHENING (*BIASI*) OPERATION

Ph.D. Thesis

by

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DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
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INDIRA GANDHI KRISHI VISHWAVIDYALAYA
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Thesis

Submitted to the

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By

Santosh Kumar Jha

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Agronomy

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July, 2016

CERTIFICATE –I

This is to certify that the thesis entitled **"Studies on broadcast and direct line seeded rice (*Oryza sativa* L.) under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation"** submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Agriculture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) is a record of the bonafide research work carried out by **Santosh Kumar Jha** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by him.

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Member	Head of the Department	

CERTIFICATE –II

This is to certify that the thesis entitled **"Studies on broadcast and direct line seeded rice (*Oryza sativa* L.) under different seed rate and weed management practices for alternatives of beushening (*biasi)* operation"** submitted by **Santosh Kumar Jha** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in the partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Agriculture** in the **Department of Agronomy** has been approved by the external examiner and Student's Advisory Committee after oral examination.

13/11/2016

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Director of instructions _____

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LIST OF ABBREVIATIONS

ABBREVIATION S	DESCRIPTION
%	Percent
@	At the rate of
^{0}C	Degree Celsius
B:C	Benefit: cost ratio
CD	Critical difference
cm	Centimeter
DAP	Days after planting
DAS	Days after sowing
DAT	Days after transplanting
DAI	Days After Inoculation
DHA	Dehydrogenase activity
DMA	Dry matter accumulation
et al	And others/Coworkers
Fig.	Figures
FYM	Farm yard manure
g	Gram
ha^{-1}	Per hectare
HI	Harvest index
HW	Hand weeding
hr^{-1}	per hour
i.e.	That is
K_2O	Potassium
kg	Kilogram
l	Litre
m^2	Square metre
mm	Milimetre
N	Nitrogen
NS	Non –significant
PoE	Post emergence
PE	Pre emergence
P_2O_5	Phosphorus
pH	Logarithm of the H+ activity
q	Quintal
RH	Relative humidity
₹	Rupees
S	Significant
SEm $\pm$	Standard error of means
t ha^{-1}	Tonne per hectare
viz.	Namely

THESIS ABSTRACT

a)	Title of the Thesis	:	Studies on broadcast and direct line seeded rice (*Oryza sativa* L.) under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation
b)	Full Name of Student	:	Santosh Kumar Jha
c)	Major Subject	:	AGRONOMY
d)	Name and Address of the Major Advisor	:	Dr. A.P. Singh, Principal Scientist Department of Agronomy , IGKV, Raipur
e)	Degree to be Awarded	:	Doctor of Philosophy in Agriculture (Agronomy)

Signature of the Student

Signature of Major Advisor

Date:.....

Signature of Head of the Department

Date:.....

ABSTRACT

The present experiment entitled **"Studies on broadcast and direct line seeded rice (*Oryza sativa* L.) under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation"** was conducted during *kharif* 2013 and 2014 at instructional cum research farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The soil of the experimental field was *inceptisols* known as matasi. The soil was neutral in reaction, low in organic carbon, low in nitrogen, medium in phosphorus and high in potash contents. Two field experiment were carried out.

Two different experiments, on broadcast direct seeded rice, and direct line seeded rice were undertaken to achieve the objectives. In both the experiments field was divided into six vertical strips and three horizontal strips. In vertical strips weed management and in horizontal strips seed rate were allocated. **First**

experiment was, on **broadcast direct seeded rice**, the treatment comprised of six weed management practices *i.e. Biasi* method (Farmer's practice) (W_1) , two hand weeding at 20 & 40 DAS (W_2), pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3), pre-emergence (pretilachlor+bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_4), pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS (W_5), weedy check (W_6) in vertical strips; and three seed rates ranging from *viz.,* 120 (S_1), 80 (S_2), and 40 (S_3), kg ha^{-1} in horizontal strips. **Second experiment** was on **direct line seeded rice** the treatment comprised of six weed management practices *i.e.* two hand weeding at 20 and 40 DAS (W_1), bispyribac-Na @ 25 g ha^{-1} at 20DAS (W_2) , pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3) , pre-emergence (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS(W_4) and azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (W_5) and weedy check (W_6) in vertical strips; and three seed rates *viz.*, 80 (S_1), 60 (S_2), and 40 (S_3), kg ha^{-1} in horizontal strips. In both the experiments, rice variety MTU 1010 was taken as test crop. Sowing was done after the monsoon under wet condition with the fertilizer application of 100, 60 and 40 kg N, P_2O_5 and K_2O ha^{-1}. The recommended package and practices except treatment was followed and treatments were imposed as per the plan.

The predominant weed species observed in the experimental field were *Echinochloa colona, Alternanthra triandra, Cyperus iria* and *Cyanotis axillaris* in both the experiment. In broadcast direct seeded rice weeds were effectively controlled by *biasi* method and hand weeding twice at 20 and 40 DAS, among chemical control methods sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS was equally effective as *biasi* method and hand weeding. In direct line seeded rice sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS was similar controlled the weeds as hand weeding twice. Among the seed rates in broadcast direct seeded rice ranging from 120, 80 and 40 kg seed rates ha^{-1} and in direct line seeded rice 80, 60 and 40 kg seed rates ha^{-1} was found non significant on yield, yield attributing parameters ,weed density and weed dry matter during the investigation.

In **first experiment** seed yield of broadcast direct seeded rice was high under the *biasi* method (52.2 q ha^{-1}) and was statistically at par with the hand weeding twice (50.8 q ha^{-1}) and sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS (50.0 q ha^{-1}). It was only 2.7 per cent higher as compared to hand weeding and 4.7 per cent as compared to sequential application of pre and post emergence herbicide. The minimum seed yield was found in the weedy check (11.5 q ha^{-1}), yield loss due to weeds was 350 % as compared to *biasi* method in weedy check plot. Seed rates ranging from 120, 80 and 40 kg ha^{-1} was non significant in seed yield, yield attributes, and on weed density and weed dry weight. However, yield was marginally higher under 40 kg seed rate ha^{-1} in broadcast direct seeded rice. Weed density and dry weight was slightly low in 120 kg seed rate ha^{-1} as compared to low seed rate 80 and 40 kg ha^{-1}. Combination of 40 kg ha^{-1} seed rate with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS was produced similar yield as high seed rate with *biasi* method and hand weeding. Higher yield attributes *i.e.* total tillers, effective tillers, filled grains $panicle^{-1}$ length of panicle and panicle weight was produced by the *biasi* method during both the years whereas, it was at par with two hand weeding at 20 and 40 DAS and sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Whereas, the lowest numbers of yield attributes were recorded under weedy check. Root volume and root dry weight was significantly influenced by the weed management practices and seed rates it was higher under *biasi* method followed by hand weeding and chemical control method. Higher gross income (₹ 92252) and net income (₹ 61341) was found under *biasi* method which was at par with hand weeding twice (₹ 89711 and ₹ 57300) and sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS (₹ 8823 and ₹ 61034)respectively. Higher income from per rupee invested was found under the sequential application of oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (2.25) followed by application of pre-emergence application of (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS (2.13) and *biasi* method (1.99). Net income and B:C ratio was higher under harvesting through harvester as compare to manual harvesting and the difference was significant. Similar output input ratio, energy used efficiency and energy productivity was produced by the *biasi* method and chemical control method during investigation. Whereas, the energy productivity was higher in combine harvester as compared to the manual harvesting. Difference

between *biasi* method and sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in respect to seed yield was 2.2 q ha^{-1} and in net income it was ₹ 306 higher under *biasi* method however, B:C ratio was higher under chemical control. So that, sequential application of pre and post emergence with optimum seed rate might be the alternative for *biasi* method. Herbicides oxadiargyl, bispyribac, pyrazosulfuron and combination of pretilachlor+bensulfuron degraded at last and there residues become non toxic to the microbial activities. Weed density and weed dry matter was less under *biasi* method an was at par with with hand weeding and sequential application of pre emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS and application of sand mix pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20 g h^{-1} at 25 DAS. Sequential application of oxadiargyl and bispyribac Na showed same WCE as *biasi* method and hand weeding twice. Whereas, weed index and weed growth rate was minimum under *biasi* method and nearly equal to hand weeding and chemical control method

In **second experiment** seed yield of direct line seeded rice was produced higher under hand weeding twice and was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Seed rates ranging from 80, 60 and 40 kg ha^{-1} did not influenced significantly seed yield of direct line seeded rice. However, marginally high seed yield was recorded under 40 kg seed rates ha^{-1}. Combination of 40 kg seed rate ha^{-1} with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS gave similar yield as high seed yield with hand weeding in direct line seeded rice. Higher yield attributes *i.e.* total tillers, effective tillers, filled grains $panicle^{-1}$ length of panicle and panicle weight was produced by the hand weeding twice and was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Yield attributes was non significant among 80, 60 and 40 kg seed rates ha^{-1}. Root volume and root dry weight was significantly influenced by the weed management practices and seed rate and was higher under hand weeding twice followed chemical control method. Weed density and weed dry matter was less under hand weeding twice and comparable sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @

20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Weed control efficiency under sequential application of pre and post emergence herbicides was similar as hand weeding twice. Whereas, weed index and weed growth rate was minimum under hand weeding method and nearly equal to chemical control method. Gross income was high in direct line seeded rice under hand weeding twice (₹86690) and was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (₹ 85151) and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (₹ 83238). Similarly higher net income was recorded under hand weeding twice and difference between net income through hand weeding and chemical control method was very marginal. B:C ratio was higher under sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (2.0) and hand weeding twice (1.9). B:C ratio was higher under harvesting through harvester as compared to manual harvesting in direct line seeded rice. Net and gross income and B:C ratio was higher under harvesting through harvester support the *"machine to machine rice production system" v.i.z* sowing through machine, weed management through chemical herbicides and harvesting by harvester . Output energy and output-input energy was higher under two hand weeding and was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Energy use efficiency and energy productivity was recorded higher under application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Output-input energy, energy use efficiency and energy productivity was higher under manual harvesting as compared to harvesting through harvester but the difference was very marginal, but harvesting through harvester gave chance for timely sowing of next crop. At harvest all the herbicides *i.e.* oxadiargyl, Bispyribac-Na, combination of pretilachlor+bensulfuron and azimsulfuron degraded and there residues become non toxic to the microbial activities.

शोध सारांश

अ.	**शोध शीर्षक का नाम**	: बियासी के विकल्प हेतु धान फसल में छिड़का एवं सीधी कतार बोनी के अन्तर्गत विभिन्न बीज मात्रा एवं खरपतवार प्रबंधक क्रियाओं का अध्ययन
ब.	**विद्याार्थी का नाम**	: **संतोष कुमार झा**
स.	**प्रमुख विषय**	: **सस्य विज्ञान**
द.	मुख्य सलाहकार का नाम व पता	: डॉ. ए.पी. सिंह प्रमुख वैज्ञानिक सस्य विज्ञान विभाग, कृषि महाविद्यालय, रायपुर (छ.ग.)
द.	उपाधि से सम्मानित करने के लिए	: कृषि में डॉक्टर ऑफ फिलॉसाफी (सस्य विज्ञान)

विद्यार्थी का हस्ताक्षर

प्रमुख सलाहकार के हस्ताक्षर

दिनांक :

विभागाध्यक्ष के हस्ताक्षर

सारांश

"बियासी के विकल्प हेतु धान फसल में छिड़का एवं सीधी कतार बोनी के अंतर्गत विभिन्न बीज मात्रा एवं खरपतवार प्रबंधक क्रियाओं का अध्ययन" की जांच अनुसंधान प्रक्षेत्र, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर (छ.ग.) में वर्ष 2013 एवं 2014 खरीफ मौसम के दौरान किया गया। प्रयोगात्मक क्षेत्र की मृदा मटासी, मृत्रिकामय, प्रतिक्रिया उदासीन, जैविक में कम, नत्रजन में कम, स्फुर में मध्यम एवं पोटाश में उच्च थी। उद्देश्य प्राप्त करने हेतु दो परीक्षण धान की छिड़का बुवाई एवं कतार बोनी पर उद्देश्य प्राप्ति हेतु किये गये। दोनों ही प्रयोग में खेत को ऊर्ध्वाधर एवं क्षैतिज पट्टियों में विभाजित किया गया। ऊर्ध्वाधर पट्टियों में खरपतवार प्रबंधन एवं क्षैतिज पट्टियों में बीज दर को आबंटित किये गये थे। प्रथम

दिनों पर (w_2), अंकुरण पूर्व आक्साडाइग्रिल 70 ग्राम/हेक्टेयर के साथ अंकुरण प"चात बिसपाइरीबैक 20 ग्राम/हेक्टेयर 25 दिनों प"चात (w_3), अंकुरण पूर्व (प्रिटिलाक्लोर + बैनसल्फुरान) 660 ग्राम/हेक्टेयर के प"चात बिसपाइरीबैक 20 ग्राम/हेक्टेयर 25 दिनों के बाद (w_4), अंकुरण पूर्ण रेत के साथ पाईरेजोसल्फुरान, 20 ग्राम/हेक्टेयर के प"चात बिरुपाइरीबेक 20 ग्राम/हेक्टेयर 25 दिनों बाद (w_5), अनुपचारित नियंत्रण (w_6), को ऊर्ध्वाधर पद्धति में एवं विभिन्न बीज दर, जो क्रम"ाः 120 किलो ग्राम प्रति हेक्टेयर (S_1), 80 किलो ग्राम प्रति हेक्टेयर (S_2), एवं 40 किलो ग्राम प्रति हेक्टेयर (S_3), को क्षैतिज पट्टियों में रखा गया। दूसरा प्रयोग धान की सीधे कतार बोवाई पर किया गया, जिसमें छः नींदा नियंत्रण विधि, जो क्रम"ाः हाथ द्वारा दो नींदा नियंत्रण 20 एवं 40 दिनों प"चात (W_1), अंकुरण पूर्व बिसपाईरीबैक 20 दिनों प"चात (W_2), अंकुरण पूर्ण आक्साडाइग्रिल 70 ग्राम/हेक्टेयर के साथ बिसपाईरीबैक 20 ग्राम/हेक्टेयर 25 दिनों बाद (W_3), अंकुरण पूर्व प्रिटिलाक्लोर एवं बैनसल्फुरान का मिश्रण 660 ग्राम/हेक्टेयर के प"चात बिसपाईरीबैक 20 ग्राम/हेक्टेयर (W_4), एजिमसल्फुरान 35 ग्राम/हेक्टेयर 15 दिनों बाद तत्प"चात बिसपाईरीबैक 20 ग्राम/हेक्टेयर 35 दिनों प"चात (W_5) एवं अनुपचारित नियंत्रक (W_6), ऊर्ध्वाधर पत्तियों में रखा गया विभिन्न बीज मात्रा, जो 80 किलो ग्राम प्रति हेक्टेयर (S_1), 60 किलो ग्राम/हेक्टेयर (S_2), एवं 40 किलो ग्राम/हेक्टेयर (S_3), 60 कि.ग्रा. प्रति हेक्टेयर (S_2), एवं 40 किलो ग्राम/हेक्टेयर (S_3), को क्षैतिज पट्टियों में रखा गया। दोनों ही प्रयोग में धान की किस्म एम.टी.यू.–1010 का परीक्षण प्रयोग किया गया। बीज की बुवाई मानसून आने के प"चात गीली आवस्था में की गई। धान उत्पादन की तकनीक, जो अनु"ांसित है के साथ खाद मात्रा 100:60:40 किलो ग्राम नत्रजन, स्फुर एवं पोटा"ा प्रति हेक्टेयर फसल को दिया गया।

धान की छिड़का विधि से बुवाई में बियासी विधि, हाथ द्वारा नियंत्रण 20 एवं 40 दिनों प"चात, के अंकुर पूर्व आक्साडाइग्रिल 70 ग्राम/हेक्टेयर के साथ अंकुरण प"चात बिसपाइरीबैक 20 ग्राम/हेक्टेयर 25 दिनों प"चात् एवं रेत के साथ पाइरेजोसल्फुरान 20 ग्राम/हेक्टेयर के साथ बिसपाइरीबैक 20 ग्राम/हेक्टेयर 25 दिनों प"चात के द्वारा नींदा का नियंत्रण समान एवं अच्छी तरह से किया गया था। जबकि धान की सीधी कतार बुआई में आनुक्रमिक अंकुरण पूर्व आक्साइडग्रिल 70 ग्राम/हेक्टेयर के साथ अंकुरण प"चात बिसपाइरीबैक 20 ग्राम प्रति हेक्टेयर 25 दिनों बाद एवं ऐजिमसल्फ्युरान का प्रयोग 15 दिनों प"चात के साथ बिसपाइरीबैक 20 ग्राम/हेक्टेयर 35 दिनों बाद खरपतवारों का नियंत्रण ठीक उसी प्रकार किया गया, जैसे हाथ द्वारा नियंत्रण करने पर था। बीज के विभिन्न मात्राओं, जो छिड़का बुआई में 120, 80 एवं 40 किलो ग्राम था एवं धान की सीधी कतार बुआई में 80, 60 एवं 40 किलो ग्राम दर एवं विभिन्न मात्रा में उपज, उपज को प्रभावित करने वाले मापदण्ड, खरपतवार की संख्या एवं उनके शुष्क भार में कोई भी अंतर नहीं पाया गया।

प्रथम प्रयोग, जो छिड़का बुआई पर था उसमें बियासी विधि द्वारा (52.2 क्विंटल प्रति. हे) सबसे अधिक उपज दर्ज की गई, जो हाथ द्वारा दो नियंत्रण (50.8 क्विंटल प्रति. हेक्टेयर) एवं अनुक्रमिक अंकुरण पूर्व आक्साडाइग्रिल 70 ग्राम/हेक्टेयर के प"चात बिसपाईरीबैक 25 ग्राम/हेक्टेयर 25 दिनों प"चात के साथ ऑकड़ों की दृष्टि से समान रुप से पाया गया। जबकि सबसे कम उपज अनियंत्रित नियंत्रण (11.5 क्विंटल प्रति हे) से दर्ज किया गया, जो बियासी विधि से 350 प्रति"ात कम था। बीज मात्रा, जो 120, 80 एवं 40 किलो ग्राम था, उपज एवं उपज को प्रभावित करने वाले मापदण्ड में समान रुप से पाया गया। खरतपवार संख्या एवं उनका शुष्क भार 120 कि.ग्रा. प्रति हेक्टेयर बीज दर में अन्य बीज दरों से तुलनात्मक रुप से कम था। साथ ही 120 ग्राम/हेक्टेयर बीज दर अल्प मात्रा में उपज अधिक पाया गया। 40 किलो ग्राम बीज दर के साथ अंकुरण पूर्व आक्साडाइग्रिल 70 ग्राम प्रति हेक्टेयर के प"चात बिसपाइरीबैक 20 ग्राम प्रति हेक्टेयर का प्रयोग बियासी एवं हाथ से खरपतवार नियंत्रण के समान उपज देने वाला पाया गया।

उपज को प्रभावित करने वाले कारक, जैसे कंसों की संख्या, प्रभावी कंसों की संख्या, भरे दाने, बाली की संख्या एवं उनका वजन बियासी विधि से अधिक था किन्तु यह हाथ द्वारा नियंत्रण एवं खरपतवारना"ाी द्वारा नियंत्रण अंकुरण पूर्व आक्साडाइग्रिल 70 ग्राम/हेक्टेयर के प"चात बिसपाइरीबैक 20 ग्राम/हेक्टेयर 25 दिनों प"चात के समान पाया गया, जबकी उपज को प्रभावित करने वाले कारक सबसे कम अनुपचारित खेत में पाया गया। धान की जड़ का आयतन एवं जड़ का सूखा वजन खरपतवार नियंत्रण एवं बीज मात्रा से अत्यधिक प्रभावित हुये। ये दोनों ही बियासी विधि में कम थे, जो हाथ द्वारा खरपतवार नियंत्रण एवं रासायनिक विधि द्वारा नियंत्रण के बराबर पाये गये। कुल आमदनी (रुपये 92252) एवं शुद्ध आय (61341) बियासी विधि में अधिक पाया गया, जो हाथ द्वारा नियंत्रण (89711 एवं 57300) एवं रासायनिक नियंत्रण अंकुरण पूर्व आक्साडाइग्रिल 70 ग्राम/हेक्टेयर के साथ बिसपाइरीबैक 20 ग्राम/हेक्टेयर 25 दिनों प"चात (823 एवं 6103) आकडों की दृष्टि से समान रुप से पाया गया। जबकि आय–व्यय अनुपात से ऊपर वर्णन रासायनिक नियंत्रण में अधिक पाया गया। (प्रति रुपये लाभ 2.25)। यदि फसल की कटाई हारवेस्टर द्वारा की जाती तो हारवेस्टर द्वारा कटाई से मिलने वाला कुल एवं शुद्ध आय हारवेस्टर द्वारा कटाई से अधिक प्राप्त होता, जो हाथ द्वारा कटाई से बहुत अधिक होता। उत्पाद हेतु लगने वाली ऊर्जा, उनके दक्षता प्रयोग में बियासी विधि एवं रासायनिक विधि में कोई अंतर नहीं पाई गई। प्रयोग में उपरोक्त वर्णित रसायन एवं बियासी विधि के उपज में 2.2 प्रति हेक्टेयर एवं शुद्ध आय में रुपये 306 का अंतर था। किंतु आय–व्यय रासायनिक विधि द्वारा अधिक प्राप्त हुआ। अतः यह कहा जा सकता है कि खरपतवार नियंत्रक रसायनों के प्रयोग के साथ आद"ा बीज दर बियासी विधि का विकल्प हो सकता है। विभिन्न रसायन, जो प्रयोग में उपयोग किये गये उनका प्रभाव मृदा सूक्ष्म जीवों पर विषाक्त नहीं पाया गया। खरपतवारों की संख्या, शुष्क भार एवं खरपतवार नियंत्रण दक्षता बियासी विधि, हाथ द्वारा नियंत्रण एवं अंकुरण पूर्व आक्साडाइग्रिल 70 ग्राम/हेक्टेयर के प"चात बिसपाइरीबैक 20 ग्राम/हेक्टेयर 25 दिनों प"चात में समान रुप से पाया गया।

दूसरा प्रयोग, जो बीज की सीधी कतार बुआई पर किया गया, में खरपतवारों का हाथ द्वारा दो नियंत्रण, अनुक्रमिक अंकुरण पूर्व ऑक्साडाइग्रिल 70 ग्राम/हेक्टेयर तत्प"चात बिसपाइरीबैक 20 ग्राम/हेक्टेयर 25 दिनों प"चात एवं 15 दिनों बाद 35 ग्राम/हेक्टेयर ऐजिरोसल्फुरान के प"चात 35 दिनों बाद 20 ग्राम/हेक्टेयर बिसपाईरीबैक का प्रयोग समान उपज देने वाला पाया गया। विभिन्न बीज दर 80, 60 एवं 40 किलो ग्राम/हेक्टेयर का प्रयोग उपज में समान रुप से पाया गया। जबकि, 80 किलोग्राम ग्राम/हेक्टेयर बीज दर से उपज तुलनात्मक रुप से 60 एवं 40 किलो ग्राम ग्राम/हेक्टेयर से अधिक पाया गया, जो उल्लेखनीय ढ़ंग से अधिक नहीं था। 40 किलो ग्राम बीज दर का प्रयोग के साथ अनुक्रमिक अंकुरण पूर्व ऑक्साडाइग्रिल 70 ग्राम/हेक्टेयर एवं अंकुरण प"चात बिसपाइरीबैक 20 ग्राम/हेक्टेयर 25 दिनों प"चात प्रयोग से अधिक उपज प्राप्त की जा सकती है।

अधिक उपज एवं उपज को प्रभावित करने वाले कारक जैसे कुल कंसों की संख्या, प्रभावी कंसों की संख्या, भरे दानों की संख्या प्रति बाली, प्रति बाली का वजन हाथ द्वारा दो नियंत्रण एवं अनुक्रमिक अंकुरण पूर्व ऑक्साडाइग्रिल 70 ग्राम/हेक्टेयर एवं अंकुरण प"चात बिसपाइरीबैक 20 ग्राम/हेक्टेयर 25 दिनों प"चात में अधिक पाया गया। जबकि 80, 60 एवं 40 किलो ग्राम बीज का प्रयोग उपज को प्रभावित करने वाले उपरोक्त उपज वि"ोषताओं में समान रुप से पाये गये। जड़ का घनत्व एवं जड़ की शुष्क भार बीज दर एवं खरपतवार नियंत्रण से प्रभावित हुये, जो हाथ द्वारा दो नियंत्रण में अधिक था। खरपतवारों की संख्या एवं शुष्क भार हाथ द्वारा नियंत्रण में कम था। खरपतवारना"ाी द्वारा नियंत्रण भी उतना ही प्रभावी पाया गया, जितना हाथ द्वारा नियंत्रण। खरपतवार नियंत्रण दक्षता अनुक्रमिक अंकुरण पूर्ण एवं अंकुरण प"चात खरपतवारना"ाी का प्रयोग हाथ द्वारा खरपतवार नियंत्रण के समान ही पाया गया। जबकि खरपतवार सूचिकांक एवं खरपतवार वृद्धि दर हाथ द्वारा नियंत्रण में सबसे कम पाया गया एवं आकड़ों की दृष्टि से खरपतवारना"ाी भी हाथ से नियंत्रण के समान ही थे। सकल आय हाथ द्वारा खरपतवार नियंत्रण से (रुपये 86690 अधिक पायी गयी जबकि खरपतवारना"ाी का अनुक्रमिक प्रयोग अंकुरणपूर्व ऑक्साडाइग्रिल 70 ग्राम/हेक्टेयर एवं अंकुरण प"चात बिसपाइरीबैक 20 ग्राम प्रति हेक्टेयर 25 दिनों प"चात एवं अंकुरण पूर्व ऐजीमसल्फुरान 35 ग्राम प्रति हेक्टेयर 15 दिनों बाद के साथ बिसपाइरीबैक 20 ग्राम प्रति हेक्टेयर 35 दिनों बाद का प्रयोग हाथ द्वारा खरपतवार नियंत्रण के समान ही पाया गया जबकि आय–व्यय अनुपात उपरोक्त वर्णित खरपतवारना"ाी रसायन के प्रयोग द्वारा अधिक प्राप्त हुआ। यदि फसल की कटाई हार्वेस्टर द्वारा की जाये तो अधिक कुल आय, शुद्ध आय एवं आय–व्यय प्राप्त किया जा सकता है। अतः हम कह सकते है कि ''म"ाीन से म"ाीन धान उत्पादन विधि'' जैसे– सीड ड्रिल से बुआई, खरपतवारना"ाी द्वारा खरपतवार नियंत्रण एवं हार्वेस्टर द्वारा कटाई धान उत्पादन के बियासी विधि का विकल्प हो सकता है।

उपज में लगने वाला उत्पादन ऊर्जा, ऊर्जा दक्षता हाथ द्वारा खरपतवार नियंत्रण में अधिक था। खरपतवारना"ाियों का अनुक्रमिक प्रयोग भी हाथ द्वारा खरपतवार नियंतण के समान ही था। धान फसल के कटाई का समय आते–आते सभी खरपतवारना"ाी का विषाक्त प्रभाव मृदा सूक्ष्म जीवों पर खत्म हो गया।

CHAPTER - I
INTRODUCTION

Rice (*Oryza sativa* L.) is the monocot plant belonging to genus *Oryza* under tribe Oryzeae in grass family Poaceae. The genus consists of 26 species, of which 24 are wild species and two *i.e. Oryza sativa* and *Oryza glaberima* stend are cultivated. *Oryza sativa* is grown worldwide, while *Oryza glaberima* is grown in parts of West Africa. The plant, which needs both warmth and moisture to grow, measures 2-6 feet tall and has long, flat, pointy leaves and stalk-bearing flowers which produce the grain known as rice. Rice is rich in genetic diversity, with thousands of varieties grown throughout the world.

Rice (*Oryza sativa* L.) is the most important staple food crop of millions of mankind from dawn of civilization (Chakravarti *et al.* 2012). Among the cereal crops, it serves as the principal source of nourishment for over half of the global population. In Indian agriculture, rice is the main source of livelihood for more than 150 million rural households. In world, rice is the second most widely consumed cereal next to wheat and it has occupied an area of 160.60 million hectares, with a total production of 738.20 million tonnes and productivity of 3424.41kg ha^{-1} FAO, (2015). 80 per cent of the world rice production mainly comes from Asian countries and Brazil. Among these countries, China is the largest producer of rice with a production of 197.3 million tonne and occupying an area of 29.9 million ha with a productivity of 6.59 tonne ha^{-1}. In Asian countries, rice is major staple crop covering about 90 per cent of rice grown in the world. It is the staple food for two thirds of the world's population. Hence, there is a need to increase the productivity of rice.

India is the second largest producer after China and has an area of over 44.1 million hectare with a production of 105.48 million tonnes with a productivity of 3020 kg ha-1 (Anonymous b, 2015) contributing 26.0 per cent of world rice production (FAO, 2015). Rice being the main source of livelihood for more than 120–150 million rural household, the backbone of the Indian Agriculture. It occupies about 23.3 per cent of the food grain production and 55 per

cent of cereal production. The country's population of more than 1.2 billion is growing at 1.8 per cent year^{-1}, outpacing the 1.4 per cent annual growth rate of rice production. In order to maintain self-sufficiency, annual production needs to increase by 2 million tonnes every year.

Chhattisgarh state is popularly known as "Rice bowl" because of maximum area covered during *kharif* under rice contributing major share in national rice production. However, the production and productivity of rice per unit area is very low due to limited irrigation, lack of improved varieties suitable to different ecosystems, low and imbalance use of fertilizer and improper weed management. It has geographical area of 13.51 million hectare of which 5.90 million hectare area is under cultivation. Rice occupies an area of 3.64 million hectare with the production of 7.65 million tonnes and productivity of 1517 kg ha^{-1} (Anonymous c, 2015).

Rice growing ecologies are divided into rainfed uplands, rainfed low land and irrigated land. In Chhattisgarh, rice is grown by different sowing methods broadcast *Biasi* , line sowing, *lehi* and transplanting depending upon the type of soil, topography of the land, availability of water and labour. The predominant method of rice cultivation in Chhattisgarh is broadcast Beushening (*Biasi*). However, these methods have their own limitations. In order to increase the productivity of direct seeded rice (DSR) in the state, efforts have been made in recent years through line sowing system of cultivation, which not only maintain plant population but also offers additive advantages, such as intercultural operations, proper weed management basal application of fertilizers *etc*. Line sowing coupled with application of herbicide may prove to be very promising on farmer field.

The productivity of rice per unit area of Chhattisgarh is low, despite of suitable environmental conditions. One of the major problems for low productivity is weed infestation. Infestation of weeds in transplanted rice not only results in yield reduction but quality of produce is also impaired. Manna (1991) reported a yield reduction of 25 per cent in transplanted rice, 32 per cent in puddle broadcast rice and 52 per cent in direct- sown upland rice due to weeds. Yield

reduction in transplanted rice due to unchecked weed growth is 47 per cent (Mukharjee and Singh, 2004). Rice crop is infested by heterogeneous type of weed flora consisting of grassy, broadleaf weeds and sedges causing yield reduction up to 70 per cent (Singh and Singh, 2004). Weeds can reduce the grain yield of transplanted paddy by 62.6%, wet seeded paddy by 70.6% and dry seeded paddy by 75.8% (Singh *et al*., 2005).

Banerjee *et al*. (2008) observed that the predominant weed flora associated with the rice crop was grasses (*Echinochloa crusgalli*, *Cynodon dactylon*, *Leersia hexandra*), sedges (*Cyperus rotundus*, *Cyperus difformis*, *Fimbristylis littoralis*) and broad leaves (*Ludwigia octovalvis*, *Monochoria vaginalis*, *Marsilea minuta*). Weeds not only cause quantitative but also hamper the quality of produce due to competition for nutrient, moisture, light and to some extent for space. Distribution of weeds is greatly influenced by soil and the prevailing climatic condition and hence they differ place to place.

Majority of farmers in Chhattisgarh region follow a crop management system called broadcast *biasi or bueshening* in drought-prone rice-lands. As we know, in this system when sufficient rainfall occurred for field preparation, after preparing the field, rice seed is broadcast on field and mixes it in soil. The field is ploughed with a non-turning, animal drawn plough between 30 to 40 days after emergence when there is 5-10 cm water standing in the field. Where standing water is inadequate, *biasi* operation may be delayed to as late as 50-60 days after emergence. Due to this, farmers traditionally do basal fertilizer application at *biasi* operation. Delayed *biasi* operation exposes the crop from heavy infestation of weed and also delays the crop and if monsoon receded early then rice suffers from water stress in reproductive stage. Farmers with these problems resort to low risk low input rice technologies that produce low yield and meager income.

In traditional broadcast *biasi* method, labour requirement is nearly 176 man days per hectare, in which labour requirement for (i) land preparation and sowing, (ii) weed control (iii) fertilizer, water and insect pest management and (iv)harvesting, threshing, winnowing are 24, 83, 18 and 52 man days per hectare respectively. Thus, peak labour requirement in this method is for weeding

operation. As this method is practiced by more than 80% farmers in the state and *biasi* operation is performed after receipt of sufficient rainfall for ploughing. Hence, the operation is performed by all the farmers at the same time causing labour crisis in the area temporarily. It is well established that the *biasi* operation in rice, delayed its maturity by one week. Thus, timely *biasi* operation and sufficient labour availability and favorable water regimes are the factors that help in production of good rice yield but these conditions are rarely available causing low productivity of rice under broadcast *biasi* method of rice cultivation. Therefore, on availability of water for irrigation, farmers prefer to do transplanting. But due to high labour (nearly 80 maydays' per hectare) requirement in field preparation, uprooting of nursery and it's transplanting; farmers do not have any choice rather adopting broadcast *bias*i method of rice cultivation.This system has some advantages over several problem associated with this system *v.i.z* loosens the soil, controls weeds, improves water-use efficiency, improves tillering and nutrient uptake, reduces insect pests, and helps redistribute seedlings. Resource-poor farmers in these areas therefore achieve moderately good production with limited inputs

Direct seeding of rice has evolved as a potential alternative to the current detrimental practice of puddling and nursery transplanting. The associated benefits include higher water productivity, less labor and energy inputs, less methane emissions, elimination of time and edaphic conflicts in the rice–wheat cropping system, and early crop maturity. Realization of the yield potential and sustainability of this resource-conserving rice production technique lies primarily in sustainable weed management, since weeds have been recognized as the single largest biological constraint in direct-seeded rice (DSR). Weed competition can reduce DSR yield by 30–80% and even complete crop failure can occur under specific conditions. The direct-seeded rice (DSR) offers the advantage of faster and easier sowing, ensure proper plant population, reduced labour and hence less drudgery, 10-12 days earlier crop maturity, more efficient water utilization and often higher profit in areas with assured water supply. Although labor and its associated costs may be reduced for crop establishment, other technologies are

essential to overcome constraints imposed by direct seeding. We should enhance the interaction of crop stand establishment, water management, and weed control.

Hand weeding is the most common and effective method of weed control in rice, but it is being difficult and uneconomical day-by-day due to high wages and non-availability of labours at peak period of farm operation (Singh *et al*. 1999). In Chhattisgarh state, farmers generally control weeds manually. The physical methods are costly and labour intensive and advantage of manual weeding could only be achieved when it is performed timely.

Herbicide is the most effective and economic means of weed control, but inappropriate or wrong application may not only increase production cost and yield penalty but also may cause development of herbicide resistant weeds and environmental hazard (Karim *et al*. 2004). Now a day, herbicides are gaining popularity because of their selectiveness, effectiveness and convenience to use. Herbicides have resulted in easier crop husbandry and have lowered down the cost of cultivation. Herbicidal weed control appears to be good alternative for controlling the weed. In recent years, some new herbicides are being introduced, which have excellent weed control efficiency even with their low doses of application, the uses of such low doses may be useful to minimize the hazard of herbicide in soil and water pollution

For control of weeds, several methods have been tried in the past with varying degree of success, which include hand hoeing, intercropping etc. are the environmentally safe and more effective practices of weed removal in cereals. These practices have certain limitations like non-availability of labours at right time and higher wages. Under such situation, the use of selective herbicides may provide more effective and economical control of weeds as compared to manual weeding.

Generally herbicides are not harmful when it is applied in recommended levels in soil (Selvamani and Sankaran, 1993) but reports are there which envisaged that herbicidal application has adverse effect on bacterial, fungal and actinomycetes population (Chowdhury *et al*., 2008). Considering the above fact, there is a need to manage the weeds during critical crop-weed competition

period either by physical methods or through herbicides. Hand weeding is expensive, time consuming, difficult and often limited by scarcity of labourers in time. On the other hand, herbicides offer economic and efficient weed control if applied at proper dose and stage.

Seed rate is an important agronomic parameter, the seed rate per unit area depends upon germination of seed, size of the seed, growing habit of the crop, time of sowing, type of farming, variety *etc*. Extremes from the recommended seed rate (i.e. too high or too low) affect the plant population and yield of crop. Higher seed rate will influence higher plant population per unit area. It result in heavy competition within the crop plants and suppresses the crop growth. Whereas lower seed rate will result lower plant population thereby lowers the yield per unit area.

In Chhattisgarh, about 85 per cent of the rice crop is direct seeded. Line sowing coupled with application of suitable herbicide may prove to be very promising on farmer's field. Manual weeding in rice is not only costly and difficult but, it is time consuming also due to morphological similarity of grass type weeds and the rice crop, especially during early growth stages. The physical methods are costly, labour consuming and the advantage of manual weeding could only be achieved when it is performed timely. Chemical weed control is regarded to be better than hand weeding due to drudgery of weeding and meager availability of labour at peak period of weed infestation. Although several herbicides are available for pre and post emergence application in direct seeded rice but, they have their own limitations, so testing and evaluation of new herbicide molecules is important to assess the suitability of new herbicides for Chhattisgarh plain ecosystem and comparison of new and old promising herbicidal methods prevailed in this region. Weeds not only cause quantitative, but also hamper the quality of produce due to competition for nutrients, moisture, and light and to some extent for space. Some of the weeds harbour many insects, pests and pathogens and acts as alternate hosts resulting in poor crop growth.

In direct-seeded rice heavy seed rate is a common practice; it has two major disadvantages *i.e.* consumption of large amount of seed and more problems of insects and diseases (Tan *et al*., 1998 and Tan *et al*., 2000). Higher than

optimum initial seeding density for obtaining more panicles m^{-2} is often accompanied by decrease in panicle length and panicle grain weight (Chauhan *et al.*, 2011). On the other hand, weeds in plots with a lower seeding rate have a better chance to emerge, grow and build up a strong population and thus pose a serious crop-weed competition. The optimum seed rate is an important factor that affects crop micro-environment by influencing the degree of inter-plant competition. Therefore, while fixing seed rate for direct-seeded crop, the plants should be planted neither too thick nor too thin, so that the inputs-use efficiency may be enhanced to the maximum possible extent. In Chhattisgarh state, consumption of new herbicides is very meager. Therefore, there is a need to evaluate the suitability of these new herbicides with the combination of different seed rates under broadcast direct seeded and direct line seeded rice in the agro-climatic condition of Chhattisgarh plain.

Considering the above facts, the experiment entitled **"Studies on broadcast and direct line seeded rice (*Oryza sativa* L.) under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation"** was undertaken during *kharif* 2013 & 2014 with the following objectives:

1. To find out the alternate practice for *biasi* system.
2. To find out the optimum seed rate for the alternate system of *biasi* as well as direct line seeded rice.
3. To develop suitable weed management measures for alternate system of *biasi and* direct line seeded rice.
4. To study the effect of weed management practice on rhizosphere microflora.
5. To study the economic feasibility of manipulated system.

CHAPTER-II
REVIEW OF LITERATURE

In this chapter, an attempt has been made to present the research work done on standardization of seed rate and weed management in direct seeded rice and broadcasted rice in the country and abroad related to present investigation entitled **"Studies on broadcast and direct line seeded rice (*Oryza sativa* L.) under different seed rate and weed management practices for alternatives of beushening (*biasi)* operation"** under the following aspects:

2.1 Effect of seed rate on productivity of broadcast and direct seeded rice

2.2 Effect of seed rate on weed density and dry weight in broadcast and direct seeded rice

2.3 Effect of weed management practices on productivity of broadcast and direct seeded rice

2.4 Effect of direct seed rice on root

2.5 Effect of weed management practices on

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2.1 Effect of seed rate on productivity of broadcast and direct seeded rice

Phung *et al.* (2003) reported that seeding rate applying as low as 60 kg ha^{-1} can also give high yield provided that land levelling maintained properly. The finding clearly indicates that cost of rice production can be reduced further by saving seeds for farmers.

Nadeem (2004) reported that the sowing density of 80 kg ha^{-1} recorded significantly the highest number of panicle-bearing tillers m^{-1} row length, spikelets per panicle and 1000-grain weight. Grain yield showed an increase of 30% at sowing rate of 80 kg ha^{-1}.

Phuong *et al*. (2005) carried out experiment with treatments consisted of four seeding methods: conventional and modified broadcast seeding, drill seeding with east-west and north-south row orientations; three seeding rates: 40, 80 and 160 kg seed ha^{-1} as well as two weed control levels: weed control with herbicide and no weed control. Among the seeding methods drill seeding with east-west row orientation had the lowest rice grain yield loss caused by weeds (38 % in the wet and 20 % in the dry season), whereas, the highest losses were observed with conventional broadcast seeding (59 % in the wet and 27 % in the dry season) due to weed.

FAQ (2007) supported that higher seed rate increases costs, proportion of infertile tillers and incidence of plant hopers *etc*. and also suffer from nitrogen shortages. The optimum seed rate for direct-seeded rice seems around 35±2kg ha^{-1} depending on seed test weight.

Gill *et al.* (2007) also supported that, contrary to effective tillers, the panicle length, grains $panicle^{-1}$ and 1000-grains weight gave the highest values at lower seed rate (50 kg ha^{-1}) which were significantly higher than 100 and 150 kg ha^{-1} respectively.

Yadav *et al*. (2007) observed that the crop stand establishment was higher in direct-drilled compacted plots with 50 kg seed ha^{-1}.Ravi (2008) conducted an experiment in Bihar and concluded that 150- 200 seeds m^{-2} (26-30 kg ha^{-1}) with good weed management condition led to highest grain yield of dry direct seeded rice. Walia *et al.* (2009) found that seed rate of 37.5 to 45 kg/ha depending upon varieties was found optimum for successful cultivation of direct-seeded rice (DSR) under irrigated condition.

Mahajan *et al.* (2010) carried out experiment with five seed rates (15, 30, 60, 120, and 240 kg/ha) and two weed-pressure treatments (weedy-check and weed-free). Weed pressure caused a significant reduction in yield; there was up to 36.2% reduction in yield for weedy check as compared with the weed-free treatment. Seeding rate was inversely correlated to weed interference. The results suggested that higher seed rates caused significant reductions in weed dry matter, whereas higher than optimum seed rate (15-30 kg ha^{-1}) caused reduction in yield.

Of all the seeding rates used, 15-30 kg ha^{-1} had the lowest grain-yield losses caused by weeds. This investigation supports use of hybrid rice cultivars in DSR using a seed rate of 15-30 kg ha^{-1}.

Dixit *et al.* (2010), evaluated treatment consisting, *viz* T_1, direct-seeded drill with adjustment of 30 kg ha^{-1} seed rate, T_2, direct-seeded drill with adjustment of 15 kg ha^{-1} seed rate, T_3, drum-seeded puddled transplanted rice with seed rate of 50 kg ha^{-1}, T_4, transplanting with Japanese manual transplanter. Grain yield found to be highest in T_4 treatment (7.85 t ha^{-1}), followed by T_1 (7.8 t ha^{-1}), T_2 (7.2 t ha^{-1}) and T_3 treatments (6.1 t ha^{-1}). However, it was found statistically same in T_1, T_2 and T_4 treatments. Grain yield in drum-seeded puddled transplanted rice decreased due to poor crop establishment which favoured more crop-weed competition at the early stage caused reduction in panicles m^{-2} and 1000-grain weight. Yield attributes were also found statistically same in T_1, T_2 and T_4 method. In direct seeded crop, T_1 showed more superiority than T_2 treatment revealed that 30 kg ha^{-1} seed rate in direct-seeded drill is optimum which favoured better plant growth, especially at the early stage due to having smothering effect on weeds.

2.2 Effect of seed rate on weed density and dry weight in broadcast and direct seeded rice.

Phuong *et al*. (2005), concluded that, seeding rate was inversely correlated to weed interference. Severe rice yield reduction (71 %) caused by weeds was found at a seeding rate of 40 kg seed ha^{-1} in the wet season. Using seeding rates of 80 and 160 kg seed ha^{-1} lowered yield loss to 47 and 26 % in the wet season, 32 and 18 % in the dry season respectively. Therefore, suitable method and/or rate of seeding can significantly suppress weeds in direct-seeded lowland rice.

Mahajan *et al.* (2006), reported that seed rate of 100 kg ha^{-1} caused significant reduction in dry matter of weeds and significantly increased the grain yield over seed rate of 50 kg ha^{-1}. Integrated weed management comprising two hand-weedings in addition to application of 0.75 kg ha^{-1} pretilachlor caused significant reduction in dry matter of weeds and significantly increased grain yield through marked improvement in yield attributes over that of chemical control of weeds alone. Interaction of seed rates and methods of weed control revealed that dry matter of weeds in case of integrated weed control with 50 kg ha^{-1} seed rate

was significantly lower than that of chemical weed control with seed rate of 150 kg ha^{-1}. Panicles m^{-2} and grains $panicle^{-1}$ were significantly higher with 50 kg ha^{-1} seed rate in integrated compared to seed rate of 100 kg ha^{-1} in chemical weed control. Mean grain yield with seed rate of 100 kg ha^{-1} in integrated weed control (6.47 t ha^{-1}) was significantly higher than with 150 kg ha^{-1} in chemical weed control (5.91 t ha^{-1})

Rao *et al*. (2007) found that increased seeding rates of the crop suppress weed growth and reduced grain yield losses from weed competition. However, it is not necessary to use high seeding rates to suppress weeds in DSR, if effective herbicides are used. Payman and Singh (2008) found that with increasing seed rate from 40 to 60 kg ha^{-1} and row spacing from 15 to 20 cm, respectively, did not reduce the total weed population and weed dry matter at maturity. Seed rate and row spacing did not influence the grain yield significantly.

Roy *et al*. (2009) observed that lowest total number of weeds 11.54 m^{-2} under broadcasting with a seed rate 80 kg ha^{-1} and the highest number of effective tillers $hill^{-1}$ (18.02) was recorded from direct seeding with wider spacing 25 cm x 20 cm with the maximum number of total filled grains $panicle^{-1}$ (96.64) was found from direct seeding. Chauhan *et al*. (2011) reported that weed biomass decreased linearly with increasing seeding rates from 15 to 125 kg $ha^{-1}$and also seeding rates greater than 80 kg ha^{-1} are advisable where there are risks of severe weed competition. Hence, increasing seeding rate of aerobic rice suppress weed growth and reduce grain yield losses from weed competition.

2.3 Effect of weed management practices on productivity of broadcast and direct seeded rice

Mamun (1990) suggested that weed growth reduced the grain yield by 68-100% for direct seeded *aus* rice, 16-48% for transplant aman rice and 22.36% for modern boro rice. Ramamurthy (1991) revealed that excessive weed growth and severe crop- weed competition drastically reduced the crop yield in the unweeded control and it was 88 % of the treatments where herbicides were at higher doses in the *kharif* rice.

Gnanasambandan and Murthy. (2000) reported that treatments with pretilachlor and oxadiargyl in conservation tillage plots gave good control of total weed number and resulted in high rice yield.

Nagappa and Biradar (2002) reported that among the weed management practices, two hand weeding at 20 and 40 days after sowing produced significantly higher yield (5872 kg ha^{-1}) over the unweeded check (3698 kg ha^{-1}). On the other hand Tiwari (2002) reported that significantly higher number of tillers, effective tillers, dry matter of rice, crop growth rate, panicle length, panicle weight, grains $panicle^{-1}$, test weight, grain yield, straw yield, harvest index and lowest sterility per cent were obtained when hand weeding was done twice.

Pal *et al.* (2002) reported that the hand weeding, application of ethoxysulfuron @ 0.02 kg ha^{-1} + anilofos @ 0.375 kg ha^{-1} and oxadiargyl @ 0.1 kg ha^{-1} resulted in higher yield and less weed growth compared to other treatments. Saini (2003) found that the application of pyrazosulfuron-ethyl @ 20 g a.i.ha^{-1} enhanced the grain yield and almost all the yield attributes of rice. Thura (2003) reported that longer panicle length and number of spikelets $panicle^{-1}$ was higher in weed free plot than in unweeded check.

Gitsopoulos *et al* (2004) observed that, crop sensitivity to oxadiargyl was comparatively greater for wet-seeded (anaerobic) than for dry-seeded rice (aerobic). Bhagirath and Abugho (2004), evaluated the efficacy of bispyribac-sodium, fenoxaprop + ethoxysulfuron, and penoxsulam 12 + cyhalofop was evaluated against barnyardgrass, Chinese sprangletop, junglerice, and 13 southern crabgrass when applied at four, six, and eight-leaf stages. When applied at the 14 four-leaf stage, bispyribac-sodium provided greater than 97% control of barnyardgrass, jungle rice, and southern crabgrass; however, it was slightly weak (74% control) on Chinese sprangletop. Irrespective of the weed species, fenoxaprop + ethoxysulfuron provided greater than 97% control when applied at the four-leaf stage. At the same leaf stage, penoxsulam + cyhalofop controlled 89 to 100% barnyardgrass, Chinese sprangletop, and junglerice and only 54% of southern crabgrass. The efficacy of herbicides was reduced when applied at the

eight-leaf stage of the weeds; however, at this stage, fenoxaprop + ethoxysulfuron was effective in controlling 99% of Chinese sprangletop.

Jadhav *et al* (2007) concluded that, foliar spray of oxadiargyl @ 0.08 kg+2, 4-D @ 0.4 kg ha^{-1} was found to be the significantly higher plant height, No. of tiller, total chlorophyll content, No. of panicle $plant^{-1}$, harvest index and grain yield as against the weedy check (control).

Saha *et al*. (2005 a), observed that the maximum yield reduction due to weeds were 41 per cent found in the farmer practice of one hand weeding at 45-50 DAS. Singh *et al*. (2005 b), reported significant increase in the number of panicles per unit area and panicle weight was brought by different weed control treatments as compared to weedy check Singh *et al*. (2005 c), reported that reduction in grain yield (51.9%) due to weed was registered in weedy check treatment.

Thakur *et al*.(2005) revealed that when compared between bueshening and non- bueshening treatments of wet seeding, the bueshening had given additional advantage by increased yield through more rooting, better tillering, more panicle density and better HI over WSR(broadcasted without bueshening).

Rajkhowa *et al.* (2005) reported that, oxadiargyl at 100 g ha^{-1} resulted in the lowest weed density and highest rice grain yield. Butachlor was as effective as oxadiargyl. Oxadiargyl does not show phytotoxic to rice.

In another experiment, Singh *et al*. (2005) revealed that the higher yield of rice crop with two hand weeding and anilophos + 2,4-D supplement with one hand weeding at 40 DAS. Treatments were mainly owing to more effective panicles m^{-2}, higher panicle weight and 1000 grain weight and more grains $panicle^{-1}$.Yadav *et al.* (2007),evaluated Bispyribac-sodium against mixed weed flora in transplanted rice. Weeds allowed to grow throughout crop season caused 68 and 27% yield reduction Bispyribac applied at 15 or 25 DAT was found equally effective against grassy weeds, but control of broad-leaved weeds and sedges was comparatively more when applied at 15 DAT. Bispyribac 25 g ha^{-1} applied at 15 or 25 DAT was adjusted the most suitable herbicidal treatment resulting in 174–199% and 37–41% increase in the rice grain yield over weedy check during 2006 and 2007, respectively.

Payman and Singh (2008) found that application of pretilachlor 0.75 kg, pendimethalin 0.75 kg and thiobencarb 1.5 kg ha^{-1} produced significantly higher yield attributes which ultimately resulted in higher grain yield of paddy as compared to weedy check. Among different herbicidal treatments, thiobencarb 1.5 kg ha^{-1} produced highest grain yield of 5.51 t ha^{-1} which was at par with other weed control treatments.

Kumar *et al*. (2008) reported that in the absence of weed control, rice yield get reduced by 35-100% in direct-seeded. Hussain *et al*. (2008) tested and compared efficacy of four herbicides with hand weeding. Among the herbicides Nominee gold 10 SC (bispyribac sodium) and Sunstar Gold 60WG (Ethoxysulfuron) proved as the superior herbicides. Rice yield in both the herbicides was also comparatively higher than other herbicides. Similarly, in another experiment, Khaliq *et al*. (2011) stated that, bispyribac sodium (3.51 t ha^{-1}) appeared superior in enhancing rice yield over penoxsulam (3.03 t ha^{-1}).

Walia *et al*. (2008) found that, integration of pre-emergence application of pendimethalin 0.75 kg ha^{-1}followed by post-emergence (30 DAS) application of bispyribac 25 g ha^{-1} or azimsulfuron 20 g ha^{-1} or 2,4-D 500 g ha^{-1} resulted in effective weed control and higher rice grain yields. Pendimethalin pre-emergence application provided effective control of non-predominant paddy weeds, whereas bispyribac controlled all typical predominant paddy weeds including *Echinochloa colona* and all *Cyperus* species as compared to unweeded control.

Walia *et al*. (2009) concluded that, weeds in DSR can be controlled effectively with the integration of post-emergence (25-30 DAS) application of bispyribac 25 g ha^{-1} or azimsulfuron 20 g ha^{-1}. Higher rate of oxadiargyl can increase yield by suppressing weeds in dry-seeded rice systems. Similar to the results of oxadiargyl, pendimethalin at higher rates also greatly suppressed weeds; however, yield decreased due to phytotoxicity to rice seedlings. Among herbicide treatments, the highest yield (3.7-4.0 t ha^{-1}) was recorded in plots treated with oxadiargyl at 160 g ai ha^{-1} and the lowest yield (2.4-2.8 t ha^{-1}) was in plots treated with pendimethalin at 1600 g ai ha^{-1}.

Walia *et al.* (2009) studied on the integration of post-emergence (25-30 DAS) application of bispyribac 25 g ha^{-1} or azimsulfuron 20 g ha^{-1} with pre-emergence application of pendimethalin 0.75 kg ha^{-1}. Integration of pre-emergence application of pendimethalin 0.75 kg ha^{-1} with post-emergence application of bispyribac 25 g ha^{-1} or azimsulfuron 20 g ha^{-1} produced 61.7 and 42.1% higher yield, respectively, than alone application of pendimethalin 0.75 kg ha^{-1}.

Hussain *et al.* (2009) found that among the weedicides, Nominee gold 100SC (bispyribac sodium) and Sunstar Gold 60 WG (Ethoxy sulfuron) proved as the best weedicides with 90.5 and 87.19% weed control, respectively. The paddy yield in both the weedicide treatments was also comparatively higher than other weedicides. The highest net benefit was obtained by the application of nominee 100SC followed by Sunstar Gold 60 WG treatment while the lowest net benefit was provided by control (weedy check).

Mahajan *et al.* (2009) reported aerobic direct seeded rice ADSR treatment produced yield similar to transplanted rice treatment when weeds were controlled effectively. Post-emergence application of bispyribac Na 25 g ha^{-1} and penoxsulam 25 g ha^{-1} could effectively control all the weeds in ADSR. Irrigation water productivity remained statistically the same in both ADSR and CPTR under the weed-free situation or when bispyribac Na herbicide was applied as post-emergence because of effective weed control in ADSR.

Walia *et al*. (2009) reported that pre-emergence application of pendmethalin 0.75 kg ha^{-1} followed by post-emergence application of bispyribac 25 g ha^{-1} was found to be significantly superior as compared to all other herbicidal treatments as it recorded highest rice grain yield (45.06 q ha^{-1}). Saha (2009) studied that the tank mix application of bensulfuron-methyl + pretilachlor (50 + 500 g ha^{-1}) was found to be the most effective herbicide treatment and produced 5.72 t ha^{-1} yield.

Yadav *et al*. (2009) stated that bispyribac @ 25 g ha^{-1} applied at 15-25 DAT resulted 37-41 per cent increase in the grain yield (6615 kg ha^{-1}) of rice over weedy check (4704 kg ha^{-1}) on clay loam soils. Jayadeva *et al.* (2010) reported that the application of azimsulfuron at 27.5 g a.i. ha^{-1} + metsulfuron-methyl at 2 g

a.i. ha^{-1} + 0.2% surfactant was more effective in controlling weeds and recorded more grain and straw yield (6004 and 6634 kg ha^{-1}, respectively), which was on par with application of azimsulfuron at 30 g a.i. ha^{-1}+ metsulfuron-methyl at 2 g a.i. ha^{-1} + 0.2% surfactant (6289 and 6923 kg ha^{-1}, respectively) compared to application of lower dose of azimsulfuron (27.5 g a.i. ha^{-1}).

Kiran *et al.* (2010) stated that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} or penoxsulam 75 g ha^{-1} was as effective as hand weeding twice in improving growth, yield attributes and yield of rice. Prasad *et al*. (2010) reported that the weeding efficiency of biasi plough (88.15) was found better than the other implement. The implement intercultural plough gave maximum growth (24.73 q ha^{-1}) and straw yield (47.23 q ha^{-1}). Khaliq *et al*. (2011 a) evaluated the efficacy of pre and post emergence herbicides applied either alone or in a sequence for weed control in dry seeded fine rice .Three herbicides namely Stomp 455CS (pendimethalin) at 1650 g a.i. ha^{-1} as pre-emergence, Nominee 100SC (bis-pyribac sodium) and Ryzelan 240SC (penoxsulam) at 30 and 15 g a.i. ha^{-1} respectively, were used as early post emergence (15 DAS). Pendimethalin was also followed by either of these herbicides. Maximum paddy yield (2.79 t ha^{-1}) and net benefit of Rs. 83712 ha^{-1} were recorded where pendimethalin was followed by penoxsulam. Results indicated that pendimethalin followed by post emergence application of bispyribac sodium and penoxsulam gave more than 80% reduction in weed density and weed dry weight over control.

Rao and Ratnam (2010) reported that among the treatments, post emergence application of bispyribac-sodium 30 g ha^{-1} recorded higher crop dry weight but was on par with the other doses (20,40, and 50 g ha^{-1}) and also with alone application of cyhalofop butyl, ethoxysulfuron and their combination. In another experiment Jaya Suria *et al*. (2011) reported that the highest number of total tillers m^{-2} was obtained with bispyribac-sodium fb. manual weeding (338.1) and the lowest with fenoxaprop-p ethyl/safener fb. bentazon/MCPA (227.5).

Sunil *et al* (2011) reported pre-emergent application of bensulfuron methyl+ pretilachlor (6.6 GR) @ 0.06+0.60 kg *a. i.* ha^{-1}+one intercultivation at 40

DAS recorded higher grain yield. This was at par with bensulfuron methyl+ pretilachlor (6.6 GR) @ 0.06+ 0.60 kg a. i. ha^{-1}.

Saha and Rao (2012) reported that higher number of panicles m^{-2} and grains $panicle^{-1}$ were recorded at the application rate 30-35 g a.i. ha^{-1} of azimsulfuron over pretilachlor. Soni *et al.* (2012) revealed that pyrazosulfuron recorded higher grain and straw yields (64.14 and 123.43 q ha^{-1}) followed by fenoxaprop-p-ethyl +almix (62.14 and 119.47 q ha^{-1}). Prakash *et al*. (2013) revealed that application of pretilachlor 50 EC @ 0.75 kg a.i.ha^{-1} at 3-5 DAT registered significantly higher number of panicles m^{-2} (381 and 278), panicle weight (3.7 and 3.8 g), grain (4.96 and 4.23 t ha^{-1}) and straw yield (6.61 and 5.81 t ha^{-1}) in 2007 and 2008, respectively. The per cent increase in grain yield was 34.78 and 42.42 with the application of pretilachlor 50 EC @ 0.75 kg a.i. ha^{-1} at 3-5 DAT control in 2007 and 2008, respectively.

Jalindar *et al.* (2013) observed that among the post plant weed management methods, number of productive tillers m^{-2}, grains $panicle^{-1}$, panicle weight, grain yield and net returns were higher in early post emergence application of bensulfuron methyl+pretilachlor (6.6 GR) @ 0.06+0.60 kg *a.i* ha^{-1} at 10 DAT followed by pretilachlor at 0.75 kg *a.i* ha^{-1} + HW at 40 DAT and HW twice at 20 and 40 DAT, which were comparable.

Birendra Kumar *et al* (2013) observed that maximum mean grain yield of (5.91 t ha^{-1}) was recorded from the plots where two hand weeding at 20 and 40 DAT was performed and statistically *at par* with the mean grain yield obtained under different weed management practices *i.e* butachlor @ 1.5 kg *a.i* ha^{-1} as pre-em *fb* azimsulfuron @ 25.0 g *a.i* ha^{-1}, bispyribac 12.5 g a.i ha^{-1} + azimsulfuron 12.5 g *a.i* ha^{-1} post emergence.

Suresh *et al.* (2014) concluded pre-emergence application of bensulfuron methyl+pretilachlor at 660 g a.i. ha^{-1} on 3 DAT *fb* one hand weeding on 35 DAT recorded significantly higher grain and straw yield (6710 and 7717 kg ha^{-1}, respectively), lower weed population (31.33 no. m^{-2}) and their dry weight (37.80 kg ha^{-1}). Further the net return and B:C ratio were also high with this treatment.

Kaur and singh (2015) reported that, maximum grain yield was recorded in weed free treatment which was statistically at par with sequential use of pendimethalin 0.75 kg/ha with bispyribac 0.025 kg or azimsulfuron 0.02 kg ha^{-1}.

Ahmed and Chauhan (2015) evaluated oxadiargyl and pendimethalin at in rice plant density was greatly affected by weed control treatments, lower density and lower uniformity of the rice plant stand occurred as a result of increased rates of herbicides. Study suggests that a higher rate of oxadiargyl can increase yield by suppressing weeds in dry-seeded rice systems.

Singh and painkra (2015) indicated that the two hand weeding at 20 and 40 DAT registered maximum yield attributing characters like effective tillers $hill^{-1}$, number of total and filled grains $panicle^{-1}$, panicle weight, panicle length, grain and straw yield and harvest index followed by bispyribac Na 10% SC @ 20 g a.i. ha^{-1}.

Sangeetha *et al*. (2015) concluded that the combination of mechanical transplanting with conoweeding four times at 10 days interval starting from 10 DAT registered significantly higher growth characters and yield attributes, which in turn exhibited higher grain yield, which was comparable with mechanical transplanting with pretilachlor (0.75 kg ha^{-1} PE)+ bispyribac (20 g ha^{-1} EPOE)+conoweeding at 40 DAT.

2.4 Effect of direct seeded rice on root

The rice establishment methods, namely, direct seeding (dry and wet) and transplanting (manual and mechanical) provide different growth environment mainly because of different tillage operation adopted and differential soil moisture regimes. The crop growth behavior of direct seeded line sown rice is more advanced than that of transplanted (Torres *et al.,* 1994). Line seeded rice is usually faster and easier than transplanting and promotes high initial growth. One significant advantage of direct seeding is the shorter cropping cycle because of avoiding transplanting shock, which delays rice growth, therefore, the crop mature a week to 10 days earlier (De Datta, 1981) and facilitates timely sowing of succeeding crop.

Root growth pathways differ depending on aggregate density and strength (de Freitas*et al.*, 1999). The root weight density decreased with increasing soil depth and increasing bulk density .The penetration rate and root length density in deeper (0.45-1.2 m) layers under drier regimes were higher than that under wet regime (Sarkar and Kar, 1995). Direct drilling had well elongated root system (Ingram *et al.*, 1994) and increased number of roots at greater depths but root density was higher and more uniform in the tilled layers of ploughed plots (Ruggiero *et al.*, 1990). In contrast, greater root growth has been reported in direct seeding than transplanting by Bridgit and Potty (2002).Root distribution is controlled by soil physical properties such as porosity, compaction, water content and concentration of organic matter (Klepper, 1990).

Kunwar and Shrestha (1979) reported that the earlier sown crop benefited from better sunshine and appropriate temperature that resulted into a more vigorous and extensive root system leading to increased vegetative growth means more efficient sink formation and greater sink size, greater carbohydrate translocation from vegetative plant parts to the spikelets and longer leaf area index during grain filling period, thus resulted to high yields in early seeding.

Singh *et al*. (1991) observed that timely sowing at the on set of monsoon (fourth week of June) recorded good growth of the crop and finally high grain yield. It causes significant increase in yield attributes (panicle m^{-2}, panicle length, grains $panicle^{-1}$, percentage of filled grain and 1000 grain weight). Delay in sowing by 15 days after onset of monsoon adversely affected rice yield.

Rathore and Sahu (2002) Root weight density of rice was greater in the direct seeded rice as compared to transplanting. root weights of transplanting were similar but higher than the rest of the treatments. The root density was greater in lower layers in DSR compared to WSR and TPR. The results indicate that the DSR may tolerate more water stress than WSR and TPR owing to its deeper and denser rooting. The maximum root length density of rice was recorded in the surface profile layer (0–10 cm depth). In the upper soil depth (0–10 cm), the density was similar in direct seeded rice and broadcasted rice but the lowest density was

recorded in transplanting. The root length density was the maximum in DSR in all the profile layers.

Ghosh (2007) reported that root volume increases with increasing phosphorus level. Phosphorus @ 20 kg ha^{-1} give 26.09 % while no phosphorus gives 22.93% increase of root volume. He also reported that effect of phosphorus causing less depletion of root biomass due to flooding was pronounced in rice treated with phosphorus (15.57%) compared with that devoid of phosphorus (19.35%).

Sridhara *et al.* (2011) concluded that among planting geometry, 30cm x 30cm recorded significantly higher root length (24.4cm), root volume (60.30cc), root number (154.2) and root weight (6.5g) as compared to 45cm x 20cm. Direct seeded recorded significantly higher root length (25.9cm), root volume (67.66cc), root number (161.1) and root weight (7.6g) compared to other methods.

Devi *et al.* (2013) reported that root system plays an important role under drought conditions. Among all the genotypes of rice showed highest root length under moisture stress condition

Anil *et al.* (2014) concluded that highest root volume and dry weight (21.8cc $plant^{-1}$and 12.3g $hill^{-1}$) was recorded with application of 240 kg ha^{-1} which is on par with 180 kg N ha^{-1}(21.6 cc $plant^{-1}$ and 11.6 g hil^{-1}) and significantly superior to 120 kg N ha^{-1}(19.3cc $plant^{-1}$ and 9.0g $hill^{-1}$)

Sangeetha, C (2015) studied the root characteristics of rice under different establishment techniques and weed management practices. Results revealed that the root dry weight, root volume, root length and root length density were recorded higher values in SRI machine transplanting than conventional system at all growth stages during both the years of investigation. Similarly in case of weed management practices, the above said root growth parameters of rice, also expressed significantly higher values at various observational growth stages when crop made free with conoweeding 4 times at 10, 20, 30 and 40 DAT over unweeded control during both years of field study. The treatment combination of mechanical transplanting with four conoweeding at 10 days interval starting from 10 DAT registered significantly higher values for growth characters and yield

attributes, and resulted in higher grain yield, which is comparable with mechanical transplanting with pretilachlor (0.75 kg ha^{-1} PE)+bispyribac sodium (20 g ha^{-1} EPOE)+conoweeding at 40 DAT.

Chao and Jun (2015) reported root system under direct seeding grew rapidly in the early growth stage with a larger root number and a thinner root type and the number of root tips and root-shoot ratio were larger than those under mechanical transplanting and artificial transplanting in the heading stage. Among root traits, dry root weight recorded highly positive significant association with root:shoot ratio, root length, root thickness and root volume. Root traits *viz.*, root volume, root thickness, root length, dry root weight and root length density were the major contributors of grain yield by way of their positive and high indirect effects.

Lenka. and Gulati.J. (2015) reported that, all the root traits recorded higher values with aerobic transplanting (20cmx20cm) and modified SRI (20cmx20cm) under aerobic and anaerobic conditions, respectively. Aerobic (25cmx25cm) and conventional transplanting recorded higher root-length ratio of 3.82 and 2.55 under aerobic and anaerobic situations respectively. The ratio of root length to root dry weight was however, higher with direct seeding (29.83) and conventional planting (22.2) under similar situations.

2.5 Effect of weed management practices on

2.5.1 Weed flora

Kurmi and das (1993) observed that the major weed flora of the experimental field consisted of *Echinochloa crus-galli* (L.) P. Beauv., *E. colonum* (L.) Link; *Digitaria* spp., *Cyperus rotundus* (L.); *C. difformis, C. iria* (L.); *Eleusine indica* Gaertn; *Fimbristylis miliacea* and *Monochoria vaginalis* (Presl.). Ravichandran (1993) found that the weed flora of the experimental field consisted of *Echinochloa colonum* (Link.); *E. crusgalli* (L.); *Digitaria sanguinalis* (Scop.); *Chloris inflata* (Link.); *C. barbata* (Sw.); *Cynodon dactylon* (Pers.); *Cyperus rotundus* (L.); *Croton bonplandianum* Baill.; syn. *C. sparsiflorus* Morong, *Trianthema portulacastrum* L., and *Eclipta alba* (L.) Hassk. The predominant

weeds, comprising more than 85 % of the total weed flora were *E. colonum, C. bonplandianum* and *T. portualcastrum*.

Sharma *et al.* (1994) noticed that the major weed species in rice were: *Cyperus iria* (L.); *Ageratum conyzoides* (L.); *Cyperus rotundus* (L.), *Echinochloa colona* (L.) Link, *Chenopodium ambrosiodes* L., *Plantago major* L., *Imperata cylindrical Beauv*. and *Spergula arvensis* L. Narwal et al. (2002) noticed that among the different categories of weeds, *Ludwigia perennis* L., *Enhydra fluctuans Lour* in broad leaved weeds, *Digitaria sanguinalis* (L.) *Scop, Echinochloa colona* (L) in grasses and *Cyperus iria* L., *Cyperus difformis* L. and *Fimbristylis miliacea* (L) *Vahl*.among the sedges were observed.

Samantaray *et al.* (2000) studied the weed flora period of their dominance and effectiveness on direct seeded rice on puddled soil revealed that sedge weed consisted the highest proportion (45.5%) of the total weeds, followed by grasses (32.2%) and broad leaf weeds (10.3%) in weedy check at 90 days of the crop growth. Dwivedi *et al.* (2003) reported that the following species of weeds namely *Echinochloa colona Cyperus difformis, Eclipta alba, Fimbristylis miliacea, Commelina benghalensis and Cynodon dactylon* were observed in direct seeded rice. Singh *et al.* (2005) reported that the common weeds observed in the direct seeded rice were *Cynodon dactylon and Echinochloa* spp. among grassy weeds (70.2%) and *Phyllanthus niruri, Commelina benghalensis* and *Euphorbia* spp. among broad leaf weeds (17.0%), *Cyperus rotundus* among sedge (12.8%).

Singh *et al*. (2006) concluded that the major weeds associated with dry-seeded rice were *Echinochloa crus-galli* (L.) *P. Beauv., Echinochloa colona* (L.) *Link, Dactyloctenium aegyptium* (L.) *Willd., Leptochloa panicea (Retz.) Ohwl, Caesulia axillaris Roxb, Euphorbia hirta* (L.), *Lindernia sp., Commelina benghalensis* (L.), *Eclipta prostrata* (L.), *Trianthema portulacastrum* (L.), *and Portulaca oleracea* (L.). Mann *et al.* (2007) conducted a field experiment and noted that in dry seeded rice the major weeds associated was *Echinochloa crus-galli* (L.), *Eclipta prostrata* (L.), *Trianthema portulacastrum* (L.), *Cyperus difformis, Cyperus iria* and *Paspalum distichum*.

Kumar *et al.* (2009) reported that the predominant weed species present in the experimental site were *Echinochloa colonum* among grasses, *Commellina benghalensis* and *Ceasulia oxilaris* among non grasses and *Cyperus rotundus* among sedges. Whereas, Singh and Singh (2010) reported that weeds namely grasses *like Echinochloa colona, Echinochloa crusgalli, Cynodon dactylon*; sedges like *Cyperus rotundus, Cyperus iria, Fimbristylis miliaceae*; and broad-leaved weeds like *Eclipta alba* and *Ceasulia oxilaris* were observed in direct seeded rice. The dominant weed flora of the experimental field consisted of grassy weeds such as *Echinochloa colona* and *Dinebra retroflexa*; sedges like *Cyperus rotundus* and broad leaf weeds *Commelina benghalensis, Phyllanthus niruri, Cynotis cucullata, Eclipta alba,Digeria arvensis,* and *Trianthema portulacastrum* observed by Rao and Ratnam (2010).

Singh *et al*. (2010) reported that *Echinochloa colona,* among grasses, *Alternanthera triandra, Cynotis axillaries, Croton banplandianum, Physalis minima, Ludwigia parviflora, Eclipta alba*, among broad leaf weeds and *Cyperus rotundus, Cyperus iria, Fimbristylis* miliaceae among sedges were dominant weeds in the experimental field in both the years. Weed flora of the experimental site were comprised of *Trianthema portulacastrum, Echinochloa colona, Dactyloctenium aegyptium, Elusine indica, Echinochloa crus-galli, Spergula arvensis, Leptochloa chinensis, Cyperus rotundus and Cyperus iria* in direct seeded rice as observed by Khaliq *et al*. (2011 b).

2.5.2 Weed density and dry matter of weeds

Chandra *et al*. (1998) found that the lowest weed density of some species, total weed dry weight, greatest weed control efficiency (93.9%) were achieved by manual weeding at 25 and 40 DAS. Manual weeding was found best method of weed control. Venkateswarlu (1999) concluded that beushening suppresses weeds, leads to root pruning and incorporates weeds and excess rice seedlings as green manure for the standing rice crop.

Saha *et al*. (1999) concluded that hand weeding twice at 25 + 40 DAS controlled weeds most effectively of all treatments in direct seeded lowland rice followed by *beushening* (25 DAS) + hand weeding (HW) at 40 DAS and

application of butachlor 2 kg ha^{-1} (20 DAS) + 1 HW (40 DAS). Weed suppression was greatest with hand weeding twice Samantaray *et al*. (2000) studied the weed flora period of their dominance and effectiveness on direct seeded rice on puddled soil and revealed that sedge weed consisted the highest proportion (45.5%) of the total weeds, followed by grasses (32.2%) and broad leaf weeds (10.3%) in weedy check at 90 days of the crop growth

Bhattacharya *et al.* (2001) reported that among the chemical treatments, fenoxaprop-p-ethyl at 1000 ml ha^{-1} at 15 DAT recorded the lowest weed density (1.6, 3.8 and 16.7m^{-2}) and weed dry matter accumulation (0.18, 0.82 and 4.01 gm^{-2}), and the highest weed control efficiency (80.2, 72.0 and 49.0%) at 30, 60 and 90 DAT, respectively. The same chemical treatment also gave the highest grain (4.67 t ha^{-1}) and straw yield (5.11 t ha^{-1}), with 45.93% increase in grain yield over the control. Prasad *et al.* (2001) also obtained similar results.

Chinnusamy *et al*. (2002) found that pre-emergence application of pretilachlor + safener at 0.45 kg ha^{-1} followed by one manual weeding at 35 DAS registered less weed density and weed dry weight in direct wet seeded rice. Nair *et al.* (2002) reported that mechanical weeding (20 DAS) followed by hand weeding (35 DAS) showed lower weed population and dry matter production at harvest. Chopra and Chopra (2003) observed that the application of pyrazosulfuron @ 20 and 25 g ha^{-1} significantly reduced the density and total dry weight of *Cyperus iria, Echinocloa colona*, *Leptochloa panacea* and *Sphenoclea zeylanica* when applied 3-10 DAT.

Risi et al. (2004) reported that bispyribac-sodium is a new post emergence herbicide for the control of *Echinochloa crusgalli* and a wide range of weeds *Alisma spp., Murdania keisak and Heteranthera spp*. infesting rice. Herbicide application from the 3rd or 4th unfolded leaf stage up to the tillering stage provides effective weed control and is not phytotoxic to rice, hence ensuring an increase in yield. Similar result was obtained by Mahajan *et al.* (2008). Singh *et al*. (2005 b) reported that the common weeds observed in the direct seeded rice were *Cynodon dactylon* and *Echinochloa spp*. among grassy weeds (70.2%) and *Phyllanthus*

niruri, *Commelina benghalensis* and *Euphorbia spp*. among broad leaf weeds (17.0%), *Cyperus rotundus* among sedges (12.8%).

Guan LiQin (2004) reported that thiobencarb + bensulfuron (100, 150, and 200 g/667 m^2), pretilachlor + bensulfuron (100 and 60 g/667 m^2), and pendimethalin + bensulfuron (50, 80, 100, and 120 g/667 m^2) had a persistent effect for weed control and was not phytotoxic to rice.

Dubey *et al*. (2005) noted that application of acetachlor + bensulfuron-methyl @ 250 g ha^{-1} resulted in broad spectrum weed control and recorded the lowest weed population and weed dry weight. The loss in grain yield due to unchecked weed growth was 49 per cent. Park *et al.* (2005) reported that bensulfuron – methyl and bispyribac – Na, post-emergence herbicides active on annual and perennial grasses, especially on *E. crus-galli,* sedges and broadleaf weeds. The combination of herbicides and manual weed control has significant effect on controlling weed of rice field (Singh *et al*., 2005 b).

Patra *et al*. (2006) reported that two hand-weeding at 20 and 40 DAT recorded the minimum weed population and dry weight and the highest weed control efficiency at 60 DAT and at harvest. Jadhav *et al*. (2008) stated that pre-emergence application of oxadiargyl 75 g ha^{-1} effectively control the weeds at early stage of crop growth followed by post-emergence application of bispyribac-Na 30 g ha^{-1} control the late coming weeds.

Kurmi (2008) reported that pretilachlor (750 or 1250 g ha^{-1}) was effective against dicot weeds and pyrazosulfuron–ethyl (5 or 10 g ha^{-1} at 3 or 7 DAT) was almost equally effective in controlling both monocot and dicot weeds. On the other hand, Dixit and Varshney (2008) reported that the post- emergence application of pyrazosulfuron at 25 g ha^{-1} effectively control the infestation of *Pyhllanthus niruri, Alternanthera sessilis*, *Commellina benghalensis, Physalis minima* and *Cyperus iria* and gave greater reduction in total weed density and dry matter accumulation and resulted maximum weed control efficiency (73 %) as compared to the pre-emergence application of butachlor followed by one hand weeding.

Cheng *et al* (2008) reported that bensulfuron-methyl mixed with pretilachlor (BMP) control weeds in the field. Application of 40% BMP WP (50,

60, 70 and 120 g/ha) and weedy check. The control efficiencies against gramineous weeds, broadleaved weeds and *Cyperaceae* weeds.

Yadav *et al*. (2009) reported that hand weeding twice completely removed all the categories of weeds including sedges. pyrazosulfuron 35 g ha^{-1} was very effective in reducing the density and dry weight of sedges. Kiran *et al*. (2010) observed that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} gave lowest density and dry weight of weeds with maximum weed control efficiency. Rathore *et al.* (2010) reported that combined application of tank mixed fenoxaprop-p-ethyl 60 g ha^{-1} and chlorimuron+ metsulfuron 4 g ha^{-1} + one hand weeding , control weeds effectively in direct seeder rice. In addition to effective control of weeds, it enhanced 26% seed yield of rice compared to inter-culture *biasi* operation.

Khaliq *et al*. (2011a) shows that pendimethalin followed by post emergence application of bispyribac sodium and penoxsulam gave more than 80% reduction in weed density and weed dry weight over control. Similarly Mahajan *et al*. (2008) found that post emergence application of bispyribac sodium 25 g ha^{-1} and penoxsulom 25g ha^{-1} could effectively control all the weed species in aerobic direct seeded rice. Khaliq *et al*. (2011b) shows that maximum reduction (99%) in weed density over control was obtained with manual weeding. Bispyribac sodium was quite effective and reduced total weed density by more than 80%. Maximum (99%) reduction in weed dry weight was recorded in manual weeding. Bispyribac sodium and penoxsulam reduced weed dry weight by 78 and 60%, respectively over control.

Yadav *et al*. (2011) reported that tank mix application of azimsulfuron with bispyribac was realized useful only in the fields dominated by sedges particularly *Cyperus rotundus*. Tank-mix or sequential application of pyrazosulfuron 25 g/ha with bispyribac 25 g/ha also provided excellent control of all type of weeds.

Yadav *et al.* (2011) reported that post-emergence herbicides bispyribac, penoxsulam and azimsulfuron provided lower density and dry weight of BLW and sedges at 15 DAS stage than 25 DAS. Azimsulfuron 30 g ha^{-1} at 15 DAS was the best treatment among the post-emergence herbicides against the and sedges.

Bhandare *et al* (2011) reported that, among herbicidal treatment lowest dry matter of weeds was recorded under application of oxadiargyl @ 75 g ha^{-1} at 3-4 days after transplanting+one hoeing and one weeding.

Manjunatha *et al*.(2012) concluded among the herbicidal treatments, pre-emergent application of bensulfuron methyl 0.6% G at 60 g *a.i*. ha^{-1} + pretilachlor 6% G at 600 g *a.i*.ha^{-1} recorded significantly lower weed population and dry weight of weeds. Khaliq *et al.* (2012) reported that combination of bispyribac sodium+ethoxysulfuron realized greater suppression of weeds both in terms of density and dry weight. This treatment also improved rice yield and kernel quality attributes over weedy check.

Pal *et al.* (2012) revealed that pyrazosulfuron-ethyl at 42 g ha^{-1}applied at 3 DAT was most effective in managing associated weeds spp. and yielded maximum grain yield (3.3 t ha^{-1}) of rice with lower weed index (10.8%). Prakash *et al*. (2013) reported that pretilachlor 50 EC @ 0.75 kg *a.i*.ha^{-1} at 3-5 DAT registered significantly lowest weed density (16 and 15) ,weed dry weight (29.34 and22.10 g m^{-2}) at 60 DAT over other herbicidal treatments, leading to highest weed control efficiency of 79.73 and 90.23 per cent and lowest weed index value of (3.95 and 14.52). He also revealed that application of glyphosate @ 0.75 kg a.i. ha^{-1} at 15 days before crop establishment + bensulfuron-methyl + pretilachlor (6.6 GR) @ 0.06 +0.60 kg a.i. ha^{-1} at 8-15 DAT was found most effective in lowering the weed density of grassy and non-grassy weeds and their dry weight.

Manjunatha *et al.* (2012) reported pre-emergent application of bensulfuron methyl 0.6% G at 60 g *a.i*. ha^{-1} + pretilachlor 6% G at 600 g *a.i.* ha^{-1} recorded significantly lower weed population and dry weight of weeds. Among the herbicidal treatments, pre-emergent application of bensulfuron methyl 0.6% G at 60 g a.i. ha^{-1} + pretilachlor 6% G at 600 g *a.i.* ha^{-1} recorded higher NPK uptake followed by bispyribac sodium at 25 g *a.i*. ha^{-1} which were on par with each other.

The nutrient uptake by crops was inversely proportional to nutrient uptake by weeds.

Cheng (2013) found that 40% bensulfuron-methyl + pretilachlor WP could control barnyard grass, *Bidens tripartita* and *Sagittaria trifolia* with the optimum dosage of 900-1125 g ha^{-1}.

Mahajan *et al.* (2013) observed that single application of pre emergence application pendimethalin (750 g ai. ha^{-1}) and pyrazosulfuron (15 g ai ha^{-1}) post emergence application of bispyribac-sodium (25 g ai ha^{-1}) and penoxsulam (25 g ai ha^{-1}) and azimsulfuron (20 g ai ha^{-1}) reduced total weed. Azimsulfuron and pyrazosulfuron proved effective against purple nutsedge and crowfootgrass, respectively.The sequential application of herbicides proved better than single applications. The lowest weed biomass was observed with the sequential application of pendimethalin followed by azimsulfuron, and rice yielded 228% more than the nontreated control

Chandra Prakash *et el al* (2013) reported that application of glyphosate @ 0.75 kg *a.i*.ha^{-1} at 15 days before crop establishment+bensulfuron-methyl+pretilachlor (6.6GR) @ 0.06+0.60 kg *a.i*.ha^{-1} at 8-15 DAT was found most effective in lowering the weed density of grassy and non-grassy weeds and their dry weight, and thus enhancing yield attributes and yield (6.06 and 5.76 t ha^{-1}) of rice. Among the weed control treatments maximum weed control efficiency (83.83 and 82.37%) and higher herbicide efficiency index (2.82 and 2.39) was under this treatment compared with the other sequential application of herbicides.

Raj *et al* (2013) concluded that early post emergence herbicides like pyrazosulfuron ethyl 10% WP and bensulfuron methyl + pretilachlor (6.6 GR) were found effective in controlling sedges and broad leaved weeds, while the post emergence herbicides, bispyribac sodium was found effective against grassy weeds and broad leaved weeds. Post emergence application of bispyribac sodium 10% SC @ 30 g ai ha^{-1} and penoxsulam 24 SC @ 25 g ai ha^{-1} and early post emergence application of pyrazosulfuron ethyl 10% WP @ 20 g ai/ha recorded higher yield which was on par with each other with better weed control efficiency and low weed index.

Ihsan*et al.* (2014) observed that early post-emergence application of bispyribac sodium supplemented with manual weeding was a promising weed control treatment that effectively suppressed weeds and helped to secure quantity and quality of produce.

Ahmed. *et al*. (2014) observed that best herbicide for broadleaf weed control was oxadiargyl whereas, acetachlor+bensulfuraonmethyl were not effective for this purpose. The best combination for weed control was oxadiargyl followed by ethoxysulfuron.

Prabhakaran *et al* (2014) reported that PE pendimethalin 1000 g ha^{-1} *fb* early post emergencebispyribac sodium 25 g ha^{-1} at 25 DAS *fb* hand weeding on 45 DAS effectively reduced the weed density and dry weight and registered higher grain yield and net returns in direct seeded rice.

Prabhakaran *et al.* (2016) concluded that pre emergence application of pendimethalin 1000 g ha^{-1}*fb* early post emergence bispyribac sodium 25 g ha^{-1} at 25 DAS *fb* hand weeding on 45 DAS effectively reduced the weed density and dry weight and registered higher grain yield and net returns in direct seeded rice

2.5.3 Weed control efficiency

Saha *et al*. (1999) concluded that hand weeding twice at 25 + 40 DAS controlled weeds most effectively in direct seeded lowland rice followed by beushening (25 DAS) + hand weeding (HW) at 40 DAS and application of butachlor 2 kg ha^{-1} (20 DAS) + 1 HW (40 DAS). Weed suppression was greatest with hand weeding twice.

Dixit *et al.* (2010) from Jabalpur reported post-emergence application of chlorimuon+metsulfuron 4 g ha^{-1}, bentazone 1250 g $ha^{-1}$and pyrazosulfuron 25 g ha^{-1} were most promising for controlling broad leaved weeds and sedges in direct seeded drilled rice experiment.

Hooda (2002) concluded that hand hoeing improves soil physical condition, 2-3 manual weeding at 25 and 45 DAS in direct seeded rice and at 15 and 30 DAT in transplanted rice is the best and most effective way of weed management.

El-Desoki (2003) found that two hand weeding at 20 and 40 DAT was very effective in controlling rice weed growth and increasing the yield. Singh and Namdeo (2004) found that hand weeding (20 and 40 days after sowing) showed 72 per cent weed control efficiency.

Saha (2006) reported that the tested herbicides, trisulfuron + pretilachlor at both the doses (6+500 and 9+500 g ha^{-1}) showed very good suppression of all the types of weeds, with WCE 92.5 and 95.1 per cent, respectively. Trisulfuron at both the doses (6 and 9 g ha^{-1}) applied alone or as tank mixture with pretilachlor along with bensulfuron –methyl (at 60 g ha^{-1}) reduced the density of all the sedges as well as of broad leaf weeds observed in the experimental field.

Saha (2009) observed that tank-mix application of bensulfuron-methyl+pretilachlor (50+500 g ha^{-1}) was found to be the most effective herbicide treatments with weed control efficiency 95 per cent and produced 5.72 tonnes ha^{-1} yield fallowed by bensulfuron-methyl alone (60 g^{-1} ha^{-1}) applied at 18 DAT produced comparable yield.

Singh *et al.* (2008) revealed that the application of alachlor significantly reduce the dehydrogenase activity, while the post-emergence herbicides did not show the significant variation. Hussain *et al*. (2008) conducted an experiment to manage the weeds in direct seed rice and concluded that the herbicides nominee gold 100SC (bispyribac sodium) and sunstar gold 60WG (Ethoxysulfuron) proved as the best herbicides with 90.5 and 87.19% weed control respectively.

Yadav *et al*. (2008) reported that azimsulfuron 25-30 g ha^{-1} at 15 DAT stage provided 93-99 per cent control of broadleaf weeds and was better than pretilachlor (85%).There was almost complete control of sedges (100% at 15 DAT ,93-100% at 25 DAT application) under all the treatments of azimsulfuron including the lowest doses (10-15 g ha^{-1}).

Shukla (2009) revealed that weed management is a critical factor in direct seeding. Hence, timely application of herbicides (timing is dependent on the method of seeding) and one or two hand weedings provide effective control.

Walia *et al*. (2009) reported that weeds in DSR can be controlled effectively with the integration of post-emergence (25–30 DAS) application of bispyribac 25 g ha^{-1} or azimsulfuron 20 g ha^{-1} with pre-emergence application of pendimethalin 0.75 kg ha^{-1}. Nevse *et al*. (2010) reported that under the various weed management practices the treatment hand weeding twice (20 and 40 DAS) exhibited 95 percent and 89 percent weed control efficiency during the year followed by use of pyrazosulfuron (85 percent) and conoweeder (70 percent), respectively.

Whereas, Rao and Ratnam (2010) stated that among the treatments, post emergence application of bis-pyribac sodium 30 g ha^{-1} reduced weed growth with higher weed control efficiency (WCE) of 74 % and at par with its higher doses of 40 and 50 g ha^{-1} and also with hand weeding at 15 DAS and significantly superior to post emergence application of cyhalofop butyl 100 g ha^{-1}, propaquizafop 50 g ha^{-1} and 2, 4-D Na salt 800 g ha^{-1}.

Khaliq *et al*. (2011 b) manual weeding showed 99% efficiency as it completely knocked out the weeds. Bispyribac sodium was the second effective treatment regarding its efficacy (>50%).

In another experiment Al-Mamun *et al*. (2011) found that herbicides of pyrazosulfuron ethyl and oxadiazon group control weeds above 80% using recommended dose. About 60% WCE was recorded by Butachlor 5G 25 kg ha^{-1}, pyrazosulfuron 10WP 125g ha^{-1} and pretilachlor 500EC 1.00 L ha^{-1}. butachlor 5G 20 kg ha^{-1}, pyrazosulfuron 10WP 100g ha^{-1} and pretilachlor 500EC 0.80 L ha^{-1} gave less than 60% WCE.

Saha and Rao (2012) reported that azimsulfuron at 35 g a.i. ha^{-1} applied 18 DAT was found to be the most effective (weed control efficiency 98.5%) in controlling the complex weed flora and produced comparable grain yield (5.93 t ha^{-1})with weed free check thereby realizing an increase of 91 per cent yield over weedy check.

Walia *et al.* (2012) reported that integration of post emergence application (30 DAS) of bispyribac (25 and 30 g ha^{-1}) or azimsulfuron (20 g ha^{-1}) with pre-emergence application of pendimethalin 0.75 kg ha^{-1}, pretilachlor 0.5 kg ha^{-1} and

thiobencarb 1.25 kg ha^{-1} provided effective control of weeds and produced significantly higher grain yield than unweeded treatment.

Revathi *et al.* (2014) found that hand weeding twice at 20 and 40 DAS registered higher weed control efficiency and productivity of rice and it was comparable with PE pyrazosulfuron ethyl 30 g *a.i.* ha^{-1} + POE bispyribac sodium 20 g *a.i.* ha^{-1} . In economic point of view, PE pyrazosulfuron ethyl 30 g *a.i.* ha^{-1} + POE bispyribac sodium 20 g a.i. ha^{-1} recorded higher net income, and B:C ratio.

Prameela *et al.* (2014) observed that lowest grass population was noticed in bispyribac sodium which was free of sedges also. Bispyribac sodium registered the highest weed control efficiency next to hand weeding.

2.5 Effect of different herbicides on enzyme activity.

Davies and Greaves (1981) found that herbicides at prescribed dose might cause temporary changes in the dehydrogenase activity. Aon and Colaneri, (2001) revealed that, all the transformation of nutrients occurring in soil are simulated by the enzymes that facilitate their conversion in to forms available to plants and microorganisms. Enzymes are frequently refered to as markers of soil environment purity.

Das *et al.* (2002) revealed that, the herbicides are not always inhibitory in action and a stimulatory effect on important soil enzyme as well as microbial population is often observed. Quilchano and Maranon. (2002) stated that dehydrogenase is thought to be an indicator of overall microbial activity, because it occurs intercellularly in all living microbial cells and is linked with microbial oxydoreduction process.

Stepniewska and Wolinska (2005) it is a specific kind of enzyme which play significant role in the biological oxidation of soil organic matter by transforming protons and electrons from substrates to acceptors. Soil dehydrogenase activity is considered to be a valuable parameter for assessing the side effects of herbicides treatments on the soil microbial biomass.

2.6 Economics.

Sharma *et al.* (1995) revealed that transplanted rice required more expenditure initially for nursery raising tillage and transplanting, while direct seeded rice required more expenditure during early to mid crop season for weeding. Ahmed *et al.* (2000) revealed that herbicidal weed control methods offer an advantage to save labour and money, as a result, regarded as cost effective method of weed control. Islam *et al.* (2000) compared hand weeding with different herbicides and found that pretilachlor (500 g a.i. ha^{-1}) was the most successful herbicide with higher yield and cost-benefit ratio.

Kumar *et al*. (2002) observed the maximum net realization (Rs.23835 ha^{-1}) and net realization Per rupee invested (Rs.2.01) was recorded in broadcasting with biasi. Singh and Singh (2003), reported that direct-seeded rice was privately profitable for farmers, giving net returns of Rs.13,350 per ha for dry direct-seeded and Rs.11,592 per ha for wet direct-seeded rice, compared with Rs.10,343 ha^{-1} for transplanted rice. Net labour savings with direct-seeded rice compared with transplanting averaged 27 days ha^{-1}.

Bahar and Singh (2004) reported that weed control in direct seeded rice can be accomplished by cultural and mechanical method, which are labour intensive and reduce the benefit: cost ratio. Chemical method of weed control may be best suited as it can take care of weeds right from the beginning of crop growth. Rathore *et al*. (2004) reported that the net returns and B:C ratio were more in dry seeded rice than wet seeded rice , broadcasted rice and transplanted rice. Singh and Namdeo (2004) found that hand weeding (20 and 40 DAS) gave net return of Rs. 5,042 ha^{-1} over unweeded control.

Ali *et al*. (2006) found that the benefitcost ratio was consistently higher in dry seeding rice than transplanted rice. Purohit *et al*. (2006) reported that the maximum net realization (Rs 16202 ha^{-1}) under broadcasting with biasi, followed by transplanting and drilling method of rice, respectively.

Rao *et al*. (2007) concluded that hand weeding is at least five times more expensive than herbicides for weed control in DSR, especially under labour-scarce or high labour cost environments Hand weeding in DSR should only be done

when there are typical weeds that cannot be controlled by either pre- or post-emergence herbicide application, or when labours are cheap and are in abundant supply.

Hussain *et al*. (2008) revealed that the highest net benefits (Rs. 18725 ha^{-1}) were observed in the plots treated with bispyribac sodium followed by ethoxysulfuron 60 WG (Rs. 13900 ha^{-1}) and hand weeding, respectively. Gowda *et al*. (2009) reported that the maximum gross return was (Rs. 31,203 ha^{-1}) under hand weeded twice which was closely followed by pyrazosulfuron ethyl at 30 g ha^{-1} (Rs. 30,782 ha^{-1}). The net returns and benefit: cost ratio were maximum with pyrazosulfuron ethyl at 30 g ha^{-1} (Rs. 21,019 ha^{-1} and 2.16). The net return and benefit: cost ratio were quite lower (Rs. 10,940 ha^{-1} and 1.77) under two hand weedings at 20 and 45 DAS.

Similarly Rathore *et al*. (2010), reported that labour requirement was substantially reduce (21%) with application of post- emergence herbicide for weed control compared to intercultue *biasi* operation. Post emergence herbicide, substantially (2.5 times) reduced the labour requirement in the BCR for weed control. Weed management by post emergence herbicide significantly reduced cost of cultivation in rice.

Kiran *et al*. (2010) recorded that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 75 g ha^{-1} gave highest net return (Rs 58,407 ha^{-1}) and benefit: cost ratio (3.06) due to increased grain yield and lesser cost of herbicide. In another experiment, Khaliq *et al*. (2011 b) economic analysis revealed that besides weed free treatment, sequential application of pendimethalin and penoxsulam produced maximum net benefits of Rs. 83712. Pendimethalin followed by bispyribac sodium ranked second with net benefits of Rs. 76985 ha^{-1}.

Al-Mamun *et al*. (2011) evaluated in terms of profitability of rice production, application of pyrazosulforon 10WP 150g ha^{-1} gave highest gross return and gross margin than other weed control treatments. The highest (2.77) benefit cost ratio (BCR) of pyrazosulforon 10WP 150g ha^{-1} suggested that it could be an alternative weed control option for profitable rice production.

In another experiment Mamun *et al*. (2011) evaluated that gross return from dry season rice cultivation was found to be maximum with the treatment three hand weeding *fb* Oxadiazon 1.2 l ha^{-1} and pyrazosulfuron 187 g ha^{-1}. Soni *et al.* (2012) reported that higher net monetary returns (Rs 60579 ha^{-1}) and benefit: cost ratio (3.24) was recorded with the application of pyrazosulfuron-ethyl 25 g ha^{-1} and lowest in control plot (Rs 3282 ha^{-1} and 2.22).

Singh *et al* (2016) concluded that the oxadiargyl by mixing with sand flooded field was less effective than spray applications in non-flooded field. The benefit-cost ratio of rice crop was higher with herbicide treatments at both sites as compared with the non-treated weed-free check

2.7 Energy studies

Singh *et al.* (1985) reported that application of herbicides were the best in terms of energy output (25076 MJ ha^{-1}) than unweeded check. Jain *et al.* (1998) reported that maximum energy utilization was obtained by hand weeding at 20 DAS (41262 MJ ha^{-1}), while the minimum energy utilization was recorded in unweeded check (22416 MJ ha^{-1})

Billore *et al.* (1999) concluded that application of pre-emergence and pre-plant incorporated herbicides were inferior to post-emergence herbicide treatment with respect to energy output, energy use efficiency and energy productivity and labour productivity. Balasubramanian and Hill (2002) reported that the direct seeding method reduces labour and require less drudgery, having more efficient water use and higher tolerance to water deficit.

Pandey and Velasco (2002) reported that direct-seeding saves labor depending on the nature of the production system direct seeding can reduce the labor requirement by as much as 5 percent. In an experiment labour use (person-day ha^{-1}) was recorded in dry seeded rice, wet seeded rice, and transplanted rice 72, 66, and 112 respectively.

Jabbar *et al*. (2008) reported that labor requirements under different methods of crop establishment dry seeded rice, drum seeded rice, transplanted with herbicide, transplanted without herbicide were 101, 96, 131 and 151Tk ha^{-1}

respectively. Seedlings raising, seeding/uprooting, and transplanting and weeding are the major operation in which labour employment was reduced. The higher net return from DSR was due largely to savings in labour costs.

Mazid *et al*. (2008) reported that the labour input needed to establish dry-seeded rice 79 persons-hour per ha compared with farmer estimates of 240 hours per ha for uprooting and transplanting seedlings. There is an additional benefit that no rice nursery is needed.

Orr *et al*. (2008) reported that DSR, a labour-saving technology, the benefits come not from higher rice yields but from the lower cost of labour required for crop establishment and weeding. Shukla (2009) revealed that direct seeded rice saves energy: labor, fuel, and seed and solves labor scarcity problem and reduces drudgery of labors. Gangwar and Singh (2010) reported that the output energy was highest in drum seeded (212711 MJ ha^{-1}) followed by direct seeded (211361 MJ ha^{-1}) and lowest was 193483 MJ ha^{-1} in manually transplanted. The net return energy of the system was found to be high in drum seeded (170839 MJ ha^{-1}) followed by direct seeded (169081 MJ ha^{-1}) and lowest was 150108 MJ ha^{-1} in manually transplanted.

Weerakoon *et al.* (2011) reported that direct seeding of rice is an alternative option to cope with the problems of water and labor scarcity associated with conventionally flooded

CHAPTER -III
MATERIAL AND METHODS

The experiment entitled **"Studies on broadcast and direct line seeded rice (*Oryza sativa* L.) under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation"** was carried out during the *kharif* season of 2013 and 2014. This chapter deals with the concise description of the soil, weather conditions, materials and methods used during the course of investigation.

3.1 Experimental site

The experimental site was located at the Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) where adequate facilities for irrigation and drainage existed. The site selected represented the major rice growing area of the region where cultivation of rice is very common. The topography of the experimental site was uniform.

3.2 Geographical location

Geographically, Raipur is situated in the centre of Chhattisgarh and lies between 21°4´ N Latitude and 81°39´ E Longitude at an altitude of 298 metres above the mean sea level.

3.3 Climatic condition

The experimental site, Raipur comes under the seventh Agro-climatic region of India *i.e.* eastern plateau and hills which is termed as sub-humid with hot summer and cold winter. The source of rainfall is south-western monsoon. It receives an average annual rainfall of 1326 mm (based on 80 years mean), mostly (85%) concentrated during the period of June to September. A few showers are expected during winters and occasionally during summer months. May is the hottest and December is the coolest month of the year. The weekly maximum temperature raised up to 46°C during summer and minimum temperature reaches as low as to 6°C during winter season.

3.4 Weather conditions during the crop growing period

Meteorological data on temperature, rainfall, relative humidity and sunshine hours recorded at the Meteorological Observatory Unit, Department of Agro-meteorology, IGKV Raipur, during the cropping period are presented in Appendix I and II and illustrated graphically in Fig. 3.1 and Fig. 3.2. The rainfall received during the cropping season of *kharif* 2013 and 2014 was 1574 mm and 1029 mm, respectively. The mean maximum temperature ranged from 25.7 ^{0}C to 21.4 ^{0}C and 27^{0}C to 17.6 ^{0}C during *kharif* season of 2013 and 2014, respectively. It was higher at the time of sowing of the crop in the month of June - July and gradual decrease in temperature was noticed. Meteorological observatory during the crop period indicated that sun shine hours ranged from 8.6 to 0.7 and 8.3 to 0.5 per day during 2013 and 2014, respectively.

Relative humidity throughout the crop season varied between 80 to 95 per cent at morning and 44 to 80 per cent in evening hours in both the years. The open pan evaporation mean values ranged from 8.8 to 2.1 mm day^{-1}in 2013 and 8.5 to 1.7 mm day^{-1}in 2014. The monthly wind velocity ranged between 8.8 to 2 km hour^{-1} and 9 to 1.9 km hour-^{1} during 2013 and 2014, respectively.

3.5 Cropping history of the experiment field

The field selected for experiment purpose was situated in rice area. Rice was being cultivated since last 20 years. The recommended doses of fertilizers were applied to grow the crop, and the fertility status of the experimental field was homogenous during the present investigation.

Table 3.1: Cropping history of the experimental field

Year	Crops	
	Kharif	***Rabi***
2010-11	Rice	Wheat
2011-12	Rice	Wheat
2012-13	Rice	Wheat
2013-14	Rice	Wheat
2014-15	Rice	Wheat

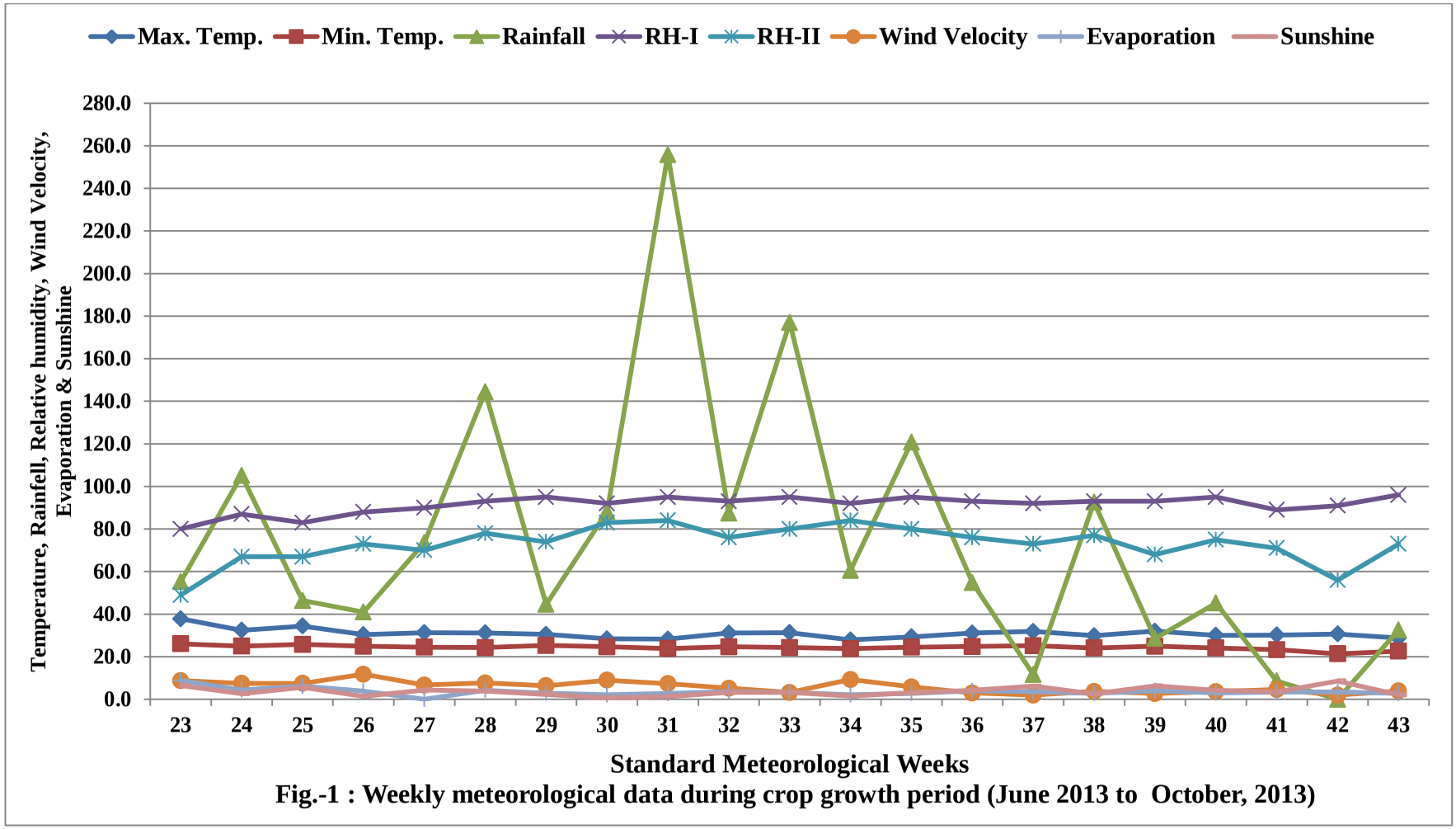


Fig.-1 : Weekly meteorological data during crop growth period (June 2013 to October, 2013)

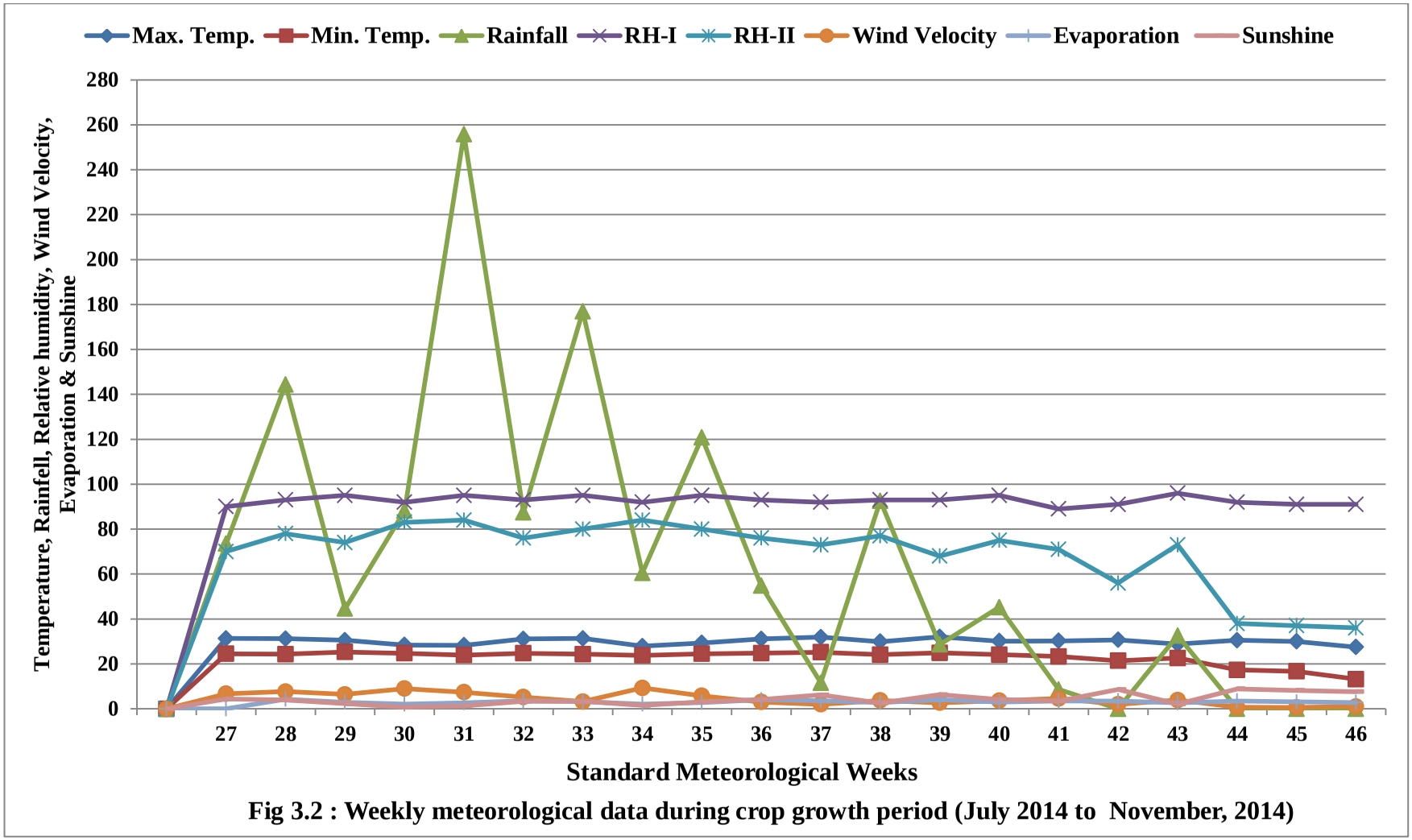


Fig 3.2 : Weekly meteorological data during crop growth period (July 2014 to November, 2014)

3.6 Physico-chemical characteristics of the experimental field

Random soil samples were collected just before initiation of experiment up to 15 cm depth from 10 places to determine the physico-chemical properties of the soil. A composite sample was drawn from mixed representative sample and used for analysis. The procedures adopted for analysis and values obtained are given in Table 3.2.

Table 3.2: Physico-chemical properties of the experimental site

No.	Particulars	Values	Rating	Methods used
A.	**Physical-Mechanical composition**			
1.	Sand (%)	56.8		International pipette method (Black, 1965)
2.	Silt (%)	27.0		
3.	Clay (%)	25.1		
4.	Textural class	Sandy loam (*Inceptisols*) Local Name : Matasi		
5.	Bulk density (g cc^{-1})	1.54		Soil core method (Black, 1965)
B.	**Chemical composition**			
1.	Available N (kg ha^{-1})	211	Low	Alkaline permanganate method (Subbiah and Asija, 1956)
2.	Available P (kg ha^{-1})	19	Medium	Olsen's method (Olsen, 1954)
3.	Available K (kg ha^{-1})	320	High	Flame photometric method (Jackson, 1967)
4.	pH (1:2.5, Soil:water)	7.5	Neutral	Glass electrode pH meter (Piper, 1967)
5.	Organic carbon (%)	0.44	Low	Walkey and Black method (Black, 1965)
6.	Electrical conductivity (m mhos cm^{-1} at 25°C)	0.42	Normal	Solubridge method

3.7 Tested variety (MTU 1010)

MTU 1010 is a semi dwarf variety. It is a cross of Krishnaveni and IR-64. The crop matures in about 115-125 days, medium grain type and having yield potential of 5-6 t ha^{-1}. It is susceptible to brown spot.

3.8 Experimental details and Layout

Two experiments on Rice crop were undertaken during two consecutive *kharif* seasons of 2013 and 2014. In first experiment, sowing method was broadcasting with three seed rates into horizontal plot and six weed management practices including the *biasi* method into vertical plots in the strip plot design (Fig 3.3). The second experiment also conducted in strip plot design with direct line seeded rice with the help of tractor drawn seed cum ferti drill divided into three different seed rates in the horizontal plots and six weed management practices in vertical plots (Fig 3.4). The details of the experiments are given below:

Experiment No 1: Broadcast direct seeded rice

"Studies on broadcast rice (*Oryza sativa L.)* under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation"

Treatment detail:

A: Vertical Strip: Weed management (6)

W1:- *Biasi* method (Farmer's practice)

W2:- Two hand weeding at 20 & 40 DAS

W3:- Pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS

W4:- Pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS

W5:- Pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g h^{-1} at 25 DAS

W6:- Weedy check

B. Horizontal Strip: Seed rate, broadcasting (3)

S1:- 120 kg ha^{-1}

S2:- 80 kg ha^{-1}

S3:- 40 kg ha^{-1}

Design : Strip Plot

No. of Replications	:	Three
No. of treatments	:	18
Gross plot size	:	4 X 8 m (32 m^2)
Net Plot size	:	3 X 7m (21 m^2)
Crop	:	Paddy
Variety	:	MTU 1010
Soil Type	:	*Inceptisols* (Matasi)
Sowing	:	Post monsoon (wet condition)
Fertilizer	:	100:60:40 kg N: P_2O_5: K_2O ha^{-1}
Date of sowing	:	23/June/2013 and 8/July/2014
Date of harvesting	:	25/October/2013and 8/November/2014

Experiment No 2: Direct line seeded rice

"Studies on direct line seeded rice (*Oryza sativa L.*) under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation"

Treatment detail:

A: Vertical Strip: Weed management (6)

W1:- Two hand weeding at 20 and 40 DAS

W2:- Bispyribac-Na @25 g ha^{-1} at 20DAS

W3:- Pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS

W4:- Pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS

W5:- Azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS

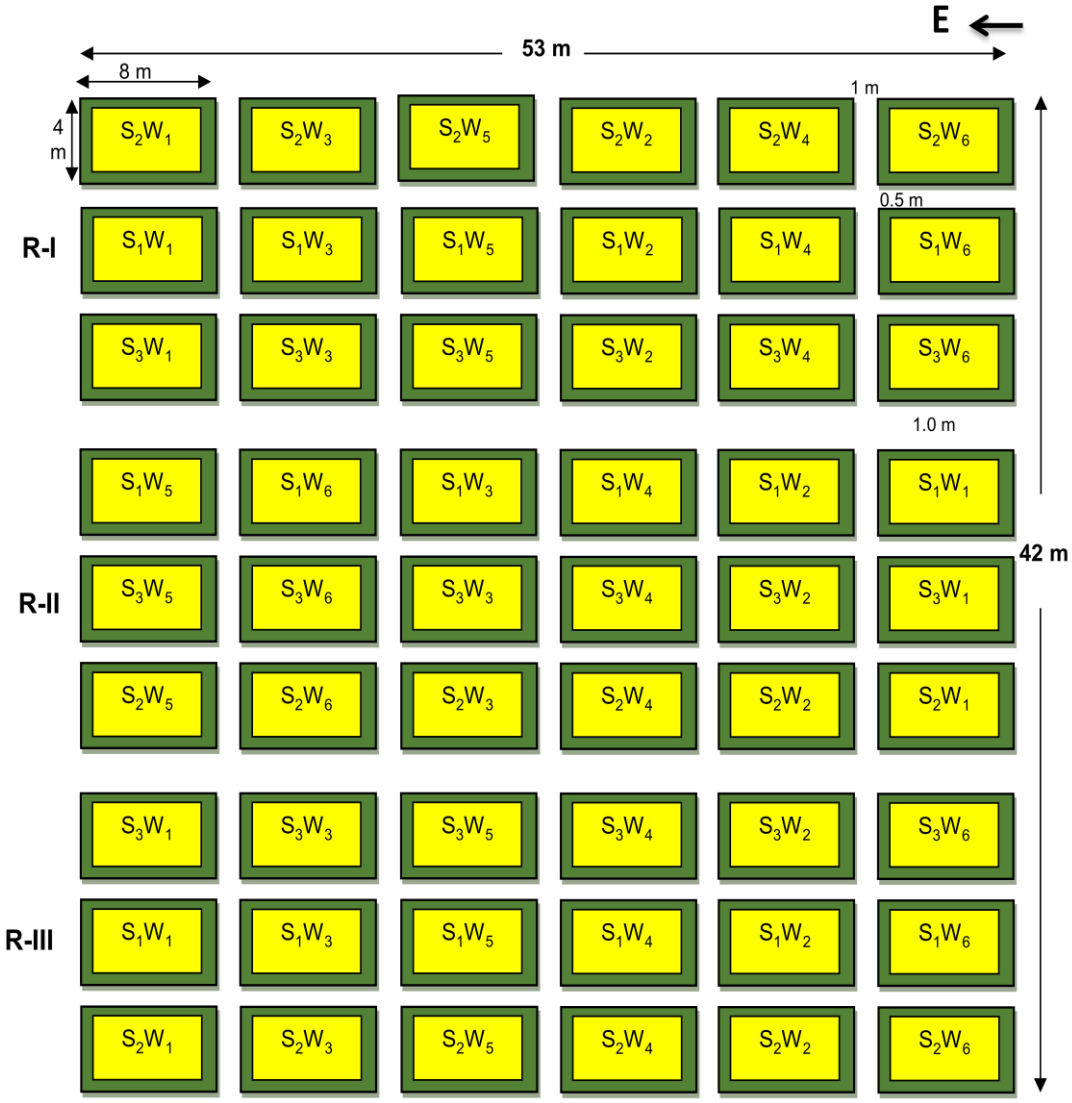
W6:- Weedy check

B. Horizontal Strip Seed rate, Line Sowing (3)

S1:- 80 kg ha^{-1}

S2:- 60 kg ha^{-1}

S3:- 40 kg ha^{-1}

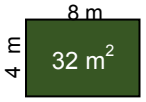


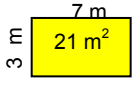
(A) Vertical Strip : Weed management (6)

W_1 : Biasi method (Farmers practice)
W_2 : Two hand weeding
W_3 : Pre-emergence oxadiargyl 70 g ha^{-1} *fb* Post-emergence bispyribac-Na 25 DAS @ 20 g ha^{-1}
W_4 : Pre-emergence (Pretilachlor+Bensulfuron) 660 g ha^{-1} *fb* Post-emergence bispyribac-Na 25 DAS @ 20 g ha^{-1}
W_5 : Pre-emergence pyrezosulfuron (Sand Mix) 20 g ha^{-1} *fb* Post-emergence bispyribac-Na 25 DAS @ 20 g ha^{-1}
W_6 : Weedy Check

(B) Horizontal Strip: Seed rate, Broadcasting (3)

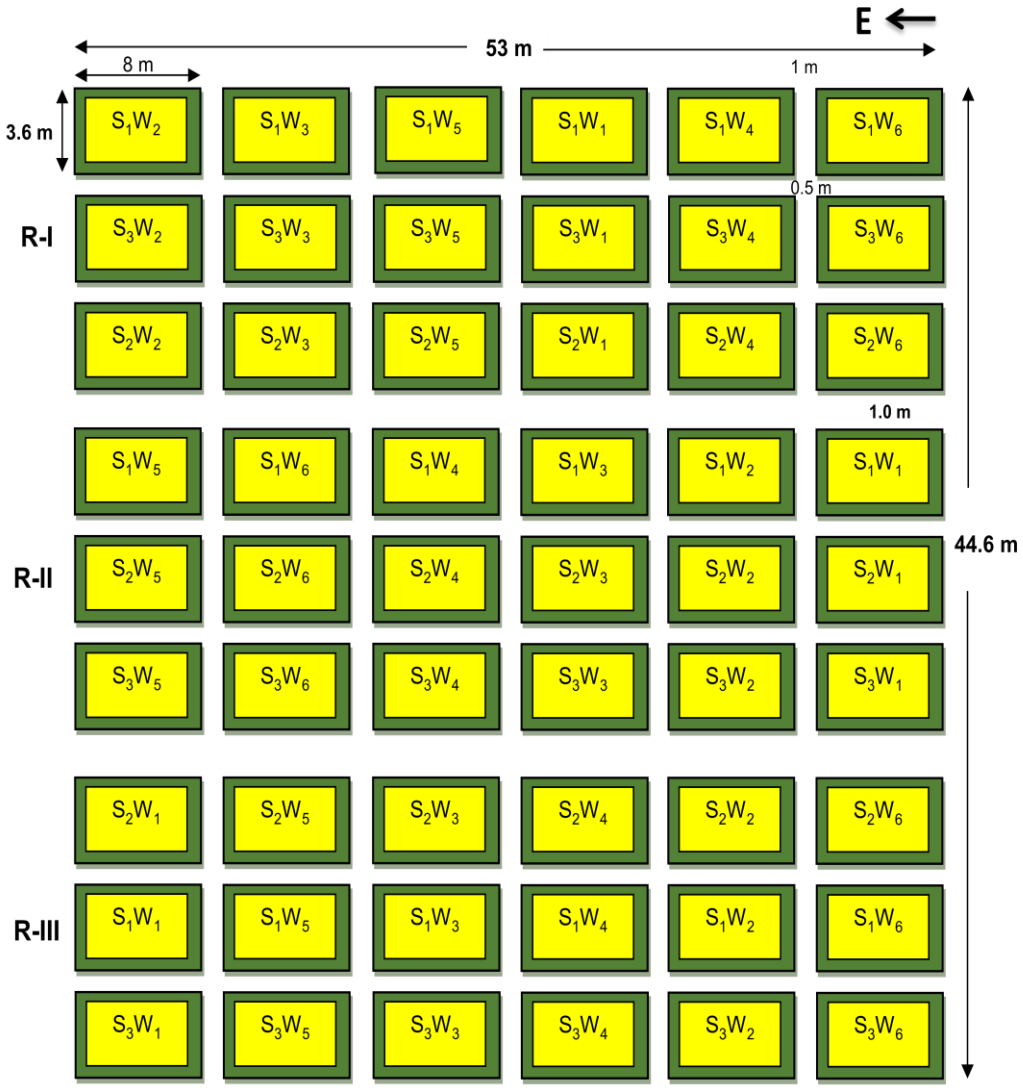
S_1 : 120 kg ha^{-1}
S_2 : 80 kg ha^{-1}
S_3 : 40 kg ha^{-1}





Design	:	**Strip Plot Design**			
Replications	:	Three	Treatment	:	18
Total no. of plots	:	54	Vertical Strip	:	6
Horizontal Strip	:	3			
Crop	:	Rice (*Oryza sativa* L.)			
Soil Type	:	Inceptisols (Matasi)			
Sowing	:	Post monsoon (wet condition)			
Variety	:	MTU 1010			
Fertilizer	:	100:60:40 Kg N : P_2O_5 : K_2O ha^{-1}			
Date of sowing	:	21.06.2013 & 05.06.2014			
Date of harvesting	:	25.10.2013 & 08.07.2014			

Fig.-3.3: Layout of first experiment alternative to *Biasi* (*Beushening* system) during *Kharif* 2013 and 2014

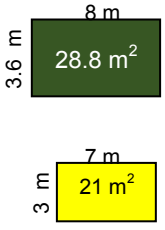


(A) Vertical Strip : Weed management (6)

W_1 : Two hand weeding (20 & 40 DAS)
W_2 : Bispyribac-Na at 20 DAS @ 25 g ha^{-1}
W_3 : Pre-emergence oxadiargyl 70 g ha^{-1} *fb* post-emergence bispyribac-Na 25 DAS @ 20 g ha^{-1}
W_4 : Pre-emergence (Pretilachlor+Bensulfuron) 660 g ha^{-1} *fb* post-emergence bispyribac-Na 25 DAS @ 20 g ha^{-1}
W_5 : Pre-emergence azimsulfuron 35 g ha^{-1} *fb* Post-emergence bispyribac-Na @ 20 g ha^{-1} 15 and 35 DAS
W_6 : Weedy Check

(B) Horizontal Strip: Seed rate, Broadcasting (3)

S_1 : 800 kg ha^{-1}
S_2 : 60 kg ha^{-1}
S_3 : 40 kg ha^{-1}



Design	:	**Strip Plot Design**			
Replications	:	Three	Treatment :	18	
Total no. of plots	:	54	Vertical Strip	:	6
Horizontal Strip	:	3			
Crop	:	Rice (*Oryza sativa* L.)			
Soil Type	:	Inceptisols (Matasi)			
Sowing	:	Post monsoon (wet condition)			
Variety	:	MTU 1010			
Fertilizer	:	100:60:40 Kg N: P_2O_5 : K_2O ha^{-1}			
Date of sowing	:	22.06.2013 & 23.06.2014			
Date of harvesting	:	28.11.2013 & 29.11.2014			

Fig.3.4: Layout of second experiment direct line seeded rice during *Kharif* 2013-2014

Design	:	Strip Plot
No. of Replications	:	Three
No. of treatments	:	18
Gross plot size	:	3.6 m X 8 m (28.8 m^2)
Net Plot size	:	3m X 7 m (21 m^2)
Soil Type	:	*Inceptisols* (Matasi)
Sowing	:	Post monsoon (wet condition)
Crop	:	Paddy
Variety	:	MTU 1010
Fertilizer	:	100:60:40 kg N: P_2O_5:K_2O ha^{-1}
Date of sowing	:	22/June/2013 and 23/June/2014
Date of harvesting	:	28/October/2013and 27/October/2014

3.9 Field preparation

The preparation of field was done when soil reached to the working condition. The field was prepared by ploughing with tractor drawn cultivator followed by harrowing to pulverize the soil. Finally, the field was leveled with planker. Thereafter, layout of the experiment was carried out in the field.

3.9.1 Sowing

In the first experiment after the lay out seeds wwre broadcast manually as per the different seed rate treatments in the plot after that different weed management practices were performed timely. In the *Biasi method* after receiving the good amount of rain *Biasi* operation was done by the help of bullock drawn *biasi* implement as farmer practice in the field. In the second experiment sowing was done with the help of tractor operated ferti cum seed drill with 20 cm spacing after calibration of seed drill for different seed rates in strip after that layout of vertical plots was carried out in the field and different weed management treatment was imposed as per the schedule.

3.9.2 Nutrient management practices

Recommended dose of fertilizer 100 kg N, 60 kg P_2O_5, 40 kg K_2O ha^{-1} was applied to rice crop through DAP, urea and muriate of potash . Full quantity of P and K and ¼th amount of nitrogen was applied as basal dose. The remaining

nitrogen was top dressed in two equal splits at the maximum tillering and panicle initiation stage.

3.9.3 Weed management practices

3.9.3.1 Manual weed management

The weed management practices were adopted as per treatment. Hand weeding was done at 20 and 40 DAS, to check the flushes of weeds.

3.9.3.2 Chemical weed management

In the first experiment *biasi,* operation was done at the 41DAS in 2013 and 36 DAS in 2014 after the sowing. Treatment of oxadiargyl 70 g ha^{-1} as pre-emergence and bispyribac Na @ 20 g ha^{-1} as post – emergence were applied with the help of knapsack sprayer by flat fan nozzle. Even broadcasting of granular herbicide (pretilachlor + bensulfuron) 660 g ha^{-1} and sand mix application of pyrazosulfuron 20 g ha^{-1} was done in the field as pre – emergence in both the year.

In the second experiment oxadiargyl 70 g ha^{-1} and broadcasting of granular herbicide (Pretilachlor + Bensulfuron) 660 g ha^{-1} as pre- emergence was applied by calculating the dose. Bispyribac-Na @25 g ha^{-1} at 20 DAS in the (W2) bispyribac-Na @25 g ha^{-1} at 20DAS treatment and bispyribac Na @ 20 g ha^{-1} at 25 and 35 DAS in the(W3) Pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS ,(W4) pre-emergence (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS treatment respectivly as post - emergence aplication with the help of knapsack sprayer timely. Application of azimsulfuron 35 g ha^{-1} as early post – emergence after 15 DAS was imposed in the field. Natural growth of weeds was allowed throughout the crop growth period in unweeded control.

3.9.3.3 *Biasi* or Beushenin

Biasi is an interculture operation in which bullock drawn country plough is run in standing crop of rice at 30-35 DAS under 5-10 cm submergence, to reduce the weed density, excessive plant population and increase the aeration in root zone.

The *biasi* was performed on the 3rd August 2013 (40 DAS) and 12th August 2014 (37 DAS) respectively in the broadcast sowing experiment.

3.9.3.4 *Chalai*

The uprooted and tilted seedling was planted in gap in spaced area. This phenomenon of gap filling is called *Chalai* or *Khelua*, to maintain the plant population. The *Chalai* was performed on 4rd August 2013 and 13thAugust 2014.

3.10 Cultural operations

The detail of the various field operations followed during *kharif* season in both the years of experimentation are given in chronological order in Table no 3.3 and 3.4

Table 3.3: Schedule of cultural operations in broad casted direct seeded rice

S. No.	Cultural operations	Implements/ Methods used	Date of Operation	
			2013	2014
1.	Soil sampling	Manual	20rd June	4th July
2.	Field preparation	Tractor drawn Cultivator	21st June	5th July
3.	Layout of experimental field	Manual	22nd June	7th July
4.	Sowing and fertilizer application (Basal dose)	Broadcasting Manual	23rd June	8th July
5.	Application of pre - emergence T_3 , T_4 , T_5	T_3 - Knapsack sprayer T_4 - Broadcast Granular T_5 - Broadcast Sand Mix	23rd June 23rd June 23rd June	8th July 8th July 8th July
6.	Application of post - emergence T_3 , T_4 , T_5	Knapsack sprayer 500 lt water ha^{-1}	12th July	2nd August
7.	*Biasi* opration	Manual	3rd August	12thAugust
8.	*Chalai* opration	Manual	4th August	13thAugust
9.	Hand weeding	Manual First Manual Second	5th July 25th July	25th July 16th July
10.	Harvesting	Manual	25th October	8th November
11.	Threshing and Winnowing	Manual	28th October	11th November

Table: 3.4 Schedule of cultural operations in direct line seeded rice

S. No.	Cultural operations	Implements/ Methods used	Date of Operation	
			2013	2014
1.	Soil sampling	Manual	20th June	22th June
2.	Field preparation	Tractor drown Cultivator	22nd June	23rd June
3.	Layout of experimental field	Manual	23rd June	24th June
4.	Sowing and fertilizer application (Basal dose)	Broadcasting Manual	24rth June	25thJune
5.	Application of pre - emergence T_2 , T_3 , T_4	T_3 – Broadcast sand mix T_4 - Broadcast Granular	23th June 23th June	24rd June 24rd June
6.	Application of post - emergence T_2, T_3 , T_4 , T_5	T_2,T_3,T_4-Knapsack sprayer T_5 -Knapsack sprayer	15rdJuly, 10thJuly,25th July	16rdJuly, 12rdJuly,26rd July
9.	Hand weeding	Manual First Manual Second	10thJuly 30thJuly	1rdJuly 31rdJuly
10.	Harvesting	Manual	28th October	27th October
11.	Threshing and Winnowing	Manual	30th October	29th October

3.11 Brief Information of the herbicide used in the experiment

3.11.1 Oxadiargyl

Common Name: Oxadiargyl (ISO, ISOPA)

Formula: $C_{15}H_{14}C_{l2}N_2O_3$.

Chemical Group: oxadiazole

Uses: Controls broadleaf weeds, grasses, and annual sedges in citrus, potato, rice, sugarcane, sunflower, and vegetables.

Mode of Action: Inhibition of protoporphyrinogen oxidase (PPO)

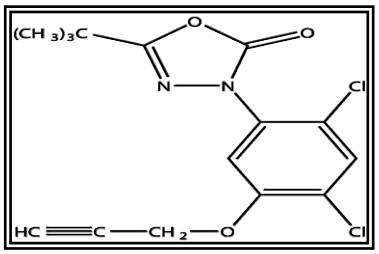
Action Group: HRAC Group E; WSSA Group 14

Toxicity: (Rat): Oral LD50 >5000 mg kg^{-1}. (Rabbit): Dermal LD50 <2000 mg kg^{-1}. (Rat): Inhalation LC50 (4 h) >5.16 mg l^{-1}

General Information:

Oxadiargyl acts as protoporphyrinogen IX oxidase inhibitor. Oxadiargyl is a pre-emergence and early post-emergence herbicide active on broad-leaved weeds. Oxadiargyl was developed for rice and sugarcane, however the product is also being evaluated in sunflower, transplanted vegetables and perennial crops. Oxadiargyl is effective in controlling nutsedge-the-swamp (*Cyperus spp*) in four doses tested and barnyardgrass (*Echinochloa colonum*) and male grass (*Ischaemum rugosum*) the three higher doses, the Oxadiargyl caused slight phytotoxicity to the crop when applied at the highest doses, the symptoms disappeared 60 days after application.

Structural Formula



3.11.2 Pretilachlor

Common Name: Pretilachlor

Formula: $C_{17}H_{26}C_lNO_2$.

Chemical Group: Chloroacetamide

Uses: For control of annual grasses and sedges in transplanted rice.

Mode of Action: Inhibition of VLCFAs (inhibition of cell divison)

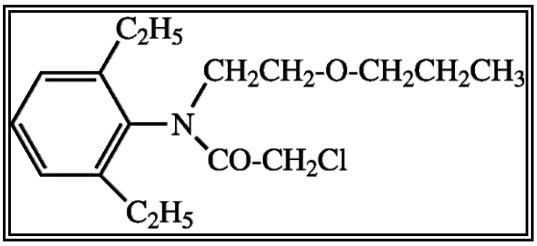
Action Group: HRAC group K3; WSSA group 15

General Information:

Pretilachlor is one of well known synthetic selective herbicide. Pretilachlor belongs to the chloroactamide class of herbicides, which inhibits growth and reduces cell division. Pretilachlor is used to control annual grasses, broad-leaved weeds and sedges in rice and works by inhibiting cell division. Pretilachlor was introduced for rice weed control at the same time, mainly to control barnyardgrass. It is selective herbicide and it is taken up readily by the hypocotyls, mesocotyls and

coleoptiles, and, to a lesser extent, by the roots of germinating weeds. Pretilachlor is effective against main annual grasses, broad-leaved weeds and sedges in transplanted and seeded rice, at 1-1.25 kg ha^{-1}. Pretilachlor + Safner (Sofit) when applied at 500 g per hectare within three DAS *i.e.*, before weed emergence, effectively controls weeds in rice nursery.

Structural Formula



3.11.3 Bensulfuron-methyl

Common Name(s): Bensulfuron-methyl (ANSI, BSI, WSSA, ISO draft); bensulfuron (ANSI, BSI, ISOE, ISOF, WSSA)

Chemical Group: Sulfonylurea

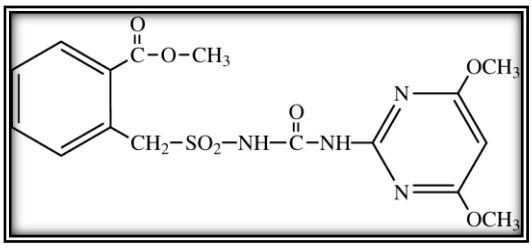
Uses: Londax* for selective control of most broadleaf and sedge weeds in rice.

Mode of Action: Inhibition of acetolactate synthase ALS (acetohydoxyacid synthase AHAS)

Action Group: HRAC Group B; WSSA Group 2

Toxicity: (Rat): Oral LD50 >5000 mg/kg. (Rabbit): Dermal LD50 >2000 mg kg^{-1}. Nonmutagenic, noncarcinogenic. Nonirritating to skin, eyes

Structural Formula:



3.11.4 Londax Power

Bensulfuron methyl 0.6% + Pretilachlor 6% GR herbicide, is a pre-emergence herbicide for weed control in rice. Bensulfuron methyl inhibition of acetolactate synthase ALS (acetohydoxyacid synthase AHAS) and Pretilachlor belongs to the chloroacetamide class of herbicides, which inhibits growth and reduces cell division. Londax Power herbicide provides effective solution for weed

control in rice by inhibiting the growth of the most important perennial and annual species of weeds namely *Echinochloa crusgalli, Echinochloa colonum* in grasses, *Cyperus iria, Cyperus difformis, Cyperus rotundus, Fimbristylis miliacea* in sedges, and *Ludwigia palviflora, Marsilea quadrifolia, Sphenoclea zeylancia, Eclipta alba, Ammania baccifera* in broad leaf weeds. Londax power herbicide is highly selective to most varieties of Indian rice. It exhibits safety margins of 5-30 folds at recommended rates. The granular formation of Londax power gives farmers an additional benefit of easy hand dispersal in the rice field and enables them to protect their crop.

3.11.5 Pyrazosulfuron-ethyl

Common Name(s): Pyrazosulfuron-ethyl (ISO, BSI)

Chemical Group: Sulfonylurea

Uses: Control weeds and sedges in direct-seeded and transplanted paddy rice.

Mode of Action: inhibition of acetolactate synthase ALS (acetohydoxyacid synthase AHAS)

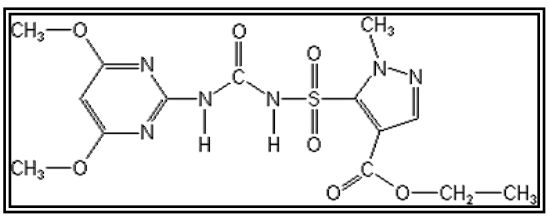
Action Group: HRAC Group B; WSSA Group 2

Toxicity: Sirius*: (Rat): Oral LD50 >5000 mg kg^{-1}; Dermal >2000 mg kg^{-1}

General Information:

Pyrazosulfuron-ethyl is selective, systemic, pre-emergence sulfonylureas herbicide mainly used to control broad-leave weeds, grasses and sedges in rice. It controls Barnyard grass; Tidalmarsh flatsedge (*Cyperus serotinus*); Jungle rice (*Echinochloa colona*). Pyrazosulfuron-ethyl has broad-spectrum activity, absorbed by roots and translocated through out plant by controlling the synthesis of amino acids. Inhibits plant amino acid synthesis - acetohydroxyacid synthase AHAS. Acts by inhibiting biosynthesis of the essential amino acids valine and isoleucine, hence stopping cell division and plant growth. It controls annual and perennial broad-leaved weeds and sedges, pre- or post-emergence in wet-sown and transplanted rice crop.

Structural Formula:



3.11.6 Bispyribac-sodium

Common Name(s): Bispyribac-sodium (BSI, ISO draft)

Formula: $C_{19}H_{17}N_4NaO_8$; $C_{19}H_{18}N_4O_8$ for the acid.

Chemical Group: Pyrimidinyl(thio)benzoate

Uses: Postemergence control of a wide range of weeds in rice fields. Velocity* for use on golf courses and sod farms. Tradewind* for use on aquatic weeds in bayous, drainage ditches, lakes, marshes, non-irrigation canals, ponds, and reservoirs.

Mode of Action: Inhibition of acetolactate synthase ALS (acetohydoxyacid synthase AHAS)

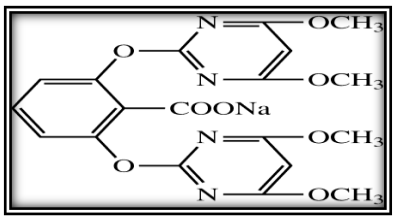
Action Group: HRAC Group B; WSSA Group 2

Toxicity: (Rat): Oral LD50 4111 mg kg^{-1} (male), 2635 mg kg^{-1} (female); Dermal LD50 >2000 mg kg^{-1}; Inhalation (4 h) LC50 >4.48 mg l^{-1}

General Information:

Bispyribac-sodium is selective, systemic post-emergence herbicide, absorbed by foliage and roots. Bispyribac-sodium control grasses, sedges and broad-leaved weeds, especially *Echinochloa* spp., in direct-seeded rice, at rates of 15-45 g/ha. The mode of action for bispyribac-sodium is to inhibit the enzyme acetolactate synthase (ALS) and the subsequent biosynthesis of essential amino acids, which in turn interferes with cell division and causes cessation of plant growth, leading to chlorosis, necrosis, and death of sensitive plants. The selectivity of bispyribac-sodium is a result of absorption, translocation, and differential metabolism. In sensitive plants, bispyribac-sodium is absorbed through the leaf surface and translocated throughout the plant. In insensitive plants, such as rice, bispyribac sodium is rapidly metabolized to non herbicidal products.

Structural Formula:



3.11.7 Azimsulfuron

Common Name(s): Azimsulfuron (BSI, pa E-ISO)

Chemical Group: sulfonylurea

Use: To control wide spectrum weeds in rice crop.

Mode of Action: Inhibition of acetolactate synthase ALS (acetohydoxyacid synthase AHAS)

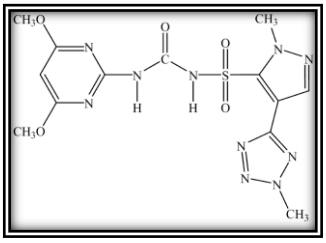
Action Group: HRAC Group B; WSSA Group 2

Toxicity: (Rat): Oral LD50 >5000 mg kg^{-1}. Dermal LD50 >2000 mg kg^{-1}. Inhalation LC50 (4 h) >5.9 mg l^{-1}

General Information:

Azimsulfuron is a sulfonyl urea compound and is a post-emergent herbicide taken up by the foliage with translocation in the xylem and phloem. It acts through inhibition of the synthesis of the branched-chain amino acids isoleucine and valine through blocking the enzyme acetolactate synthase. This stops cell division and plant growth. Azimsulfuron helps farmers control major weeds in rice including tough to control sedges like *Cyperus* spp. and *Fimbristylis miliacea* apart from *Echinochloa* spp and other broad leaf weeds and reduces their dependence on manual workers to greater extent, and enables them to experience reduced cost of cultivation. Recommended for both direct seeded and transplanted crops.

Structural Formula:



3.12 Harvesting and Threshing

Harvesting was done when crop attained maturity. Manual labourers made harvesting by using sickle. Harvested produce was left on the plot itself for sun drying for three days. After sun drying the produce was weighed plot-wise. Threshing was done by manual labourers with the help of wooden sticks. The

material threshed from each plot was kept separately and grain was separated from the chaff and straw by winnowing with the help of *supa*, after this the clean grains were weighed.

3.13 Observations recorded

3.13.1 Pre-harvest observations

Pre- harvest studies *viz*. plant height , plant population ,Dry matter accumulation , tillers, length of spike, number of spikelets, weed population, dry matter of weeds were taken in rice crop during both the years.

3.13.1.1 Plant population (No m^{-2})

Plant population was counted per square meter randomly in broadcasted rice and plant population in one m from four different rows in each plot at 15 DAS. The average plant population was worked out for each period of observation. The plant population was calculated by plant population at initial stage (15 DAS) and the total no. of tillers on later stage *i.e.* the total plant population means mother plant + number of total tillers.

3.13.1.2 Plant height (cm)

Ten randomly selected plants were marked in each plot and the plant height was measured with the help of meter scale at an interval of 15 days starting from 15, 30, 45, 60 DAS and finally at harvest. The height was measured in cm from ground level to tip from the longest leaf until the panicles emerged.

3.13.1.3 Number of tillers (No $m^{-2)}$

The total number of tillers m^{-2} were recorded from randomly selected five location in each plot leaving border rows at 30, 45,60 ¸ 90 DAS and at harvest stage.

3.13.1.4 Dry matter accumulation of rice (g $hill^{-1}$)

To obtain dry matter, five plants from each plot without root were taken carefully at 15, 30, 45, 60 DAS and at harvest. The plants were kept in oven at 60°C for 48 hours to obtain the constant dry weight. After drying, the samples were weighed and average reading was noted in g $plant^{-1}$.

3.13.1.5 Number of effective tillers (No m^{-2})

The observation on number of effective tillers was made at harvest. Ear bearing tillers were counted from each plot by using one-meter square quadrate from four different place and then number of effective tillers m^{-2} were worked out.

3.13.2 Post-harvest observations

Post harvest observations were undertaken with special care. At the time of harvesting, the tagged plants were selected from each net plot and following observations were recorded.

3.13.2.1 Panicle length (cm)

The length of panicle was taken from ten panicles selected randomly from harvested produce. It was measured from the neck-node to the tip of the apical grains. After this, average length of panicle was determined.

3.13.2.2 Number of grains $panicle^{-1}$

The ten panicles of the tagged plant were harvested separately and grains were manually removed from the panicle. The number of grains $panicle^{-1}$ was counted and the mean was calculated.

3.13.2.3 Panicle weight (g)

The panicles selected for measuring length were weighed and then mean was worked out.

3.13.2.4 Number of filled grains $panicle^{-1}$

The panicles collected for measurement of length were used to count filled grains and then average was calculated.

3.13.2.5 Test weight (g)

A random grain samples were taken from the produce of each net plot. Out of the samples, 1000 grains were counted from each net plot and same were dried in oven at 60°C to constant weight, thereafter, weight so obtained was noted as 1000-grain weight (test weight).

3.13.2.6 Grain and straw yield (q ha^{-1})

After proper sun-drying, the produce of the net plot was tied in bundles and weighed to determine the dry matter produce (grain + straw). The clean seeds obtained after threshing and winnowing from each net plot was weighed. The results were expressed on 14 percent moisture basis. The straw yield was obtained by subtracting weight of the seed yield from the total weight of the bundle and converted to t $ha^{-1.}$

3.13.2.7 Root sampling techniques and parameters

3.13.2.7.1 Sampling of the root

A representative hill was selected in the plot and cut from the base and root samples were taken with the help of core sampler. The core sampler consisted of a cylinder of 150 mm height, 6" diameter and attached to a 1000 mm long hallow shaft at the upper end which was marked at 100 mm interval. A plunger was attached with hallow shaft of the core sampler for pressing out the core sample. A 40 mm thick wooden plate and 10 kg hammer were used to push the core sampler to desired depth by hammering at the top.

For sampling, the core sampler was hammered into the soil to 100 mm depth. The core sampler was pulled out after twisting 2-3 times and again pushed to the next 100 mm depth increment, after removing the root sample into the bucket. Samples were taken until no roots were visible in the sample.

3.13.2.7.2 Root washing

After removing the soil sample, including soil and roots, it was immersed in water over night. Sodium Hexametaphosphate (5%) was added to facilitate removing. The soil attached to roots was removed by sieving to pass a 0.5 mm opening. Roots were washed manually. Clean roots were stored in bottles containing 5 per cent formalin solution.

3.13.2.7.3 Root Volume

Root volume was measured by volumetric flask (2 litre). First volumetric flask bottle was filled with water up to fixed mark on the neck of the bottle. The lower meniscus was fixed carefully with the help of the micropipette. Thereafter,

free water adhering over the roots was whipped out with the filter paper and such clean and dry roots are inserted inside the empty volumetric flask. After that measured amount of water was filled in the volumetric flask up to the previous fixed mark on the neck of the bottle. The lower meniscus was adjusted carefully as before. The net volume of roots (Vr) was determined using relation:

$Vr = Vwp – Vwpr$

Where, Vr = net root volume (cm^3)

Vwp = volume of water required to fill the empty volumetric flask

Vwpr = volume of water required to fill the volumetric flask with fresh roots

3.13.2.7.4 Root dry weight

The preserved roots were dried for 24 hrs at 60-65°C and then dry weight was determined.

3.13.3 Weed observation

3.13.3.1 Weed density (m^{-2})

The weed population of different weeds species in each plot were studied on 15, 30, 45, 60 DAS and at harvest. The weed density in each plot was recorded from four randomly selected spots by using 0.25 m^2 quadrate. Counting of weed was done according to species and total numbers of weed m^{-2} were recorded. The data, thus, obtained were transformed as wide variation existed among the treatments and expressed in number per square meter. Weed population was subjected to square root of transformation *i.e.* $\sqrt{(x+0.5)}$

3.13.3.2 Dry matter of weeds (g m^{-2})

Dry matter of weeds was recorded at 15, 30, 45, 60 DAS and at harvest. Weed present in quadrate (0.25 m^2) were uprooted carefully along with roots. The root portion was detached and shoot portion of the weed plants were oven dried at 60ºC for 48 hours. After complete oven drying the weight was recorded on electronic balance and converted into g m^{-2} by using appropriate factor. Weed dry matter of weeds was subjected to square root of transformation i.e. $\sqrt{(X + 0.5)}$

3.13.4 Computations

3.13.4.1 Harvest index (HI)

Harvest index (HI) was calculated by the following formula:

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

3.13.4.2 Sterility percentage

The number of filled and unfilled spikelets per panicle was counted from ten panicles selected randomly for measurement of panicle length and sterility percentage was computed with the following formula:

$$\text{Sterility percentage} = \frac{\text{Number of unfilled spikelets panicle}^{-1}}{\text{Total number of grains panicle}} \times 100$$

3.13.4. 3 Crop growth rate (g day^{-1} hill^{-1})

CGR denotes overall growth rate of the crop plants and measured after the fixed period of time, irrespective of the previous growth rate. The values were calculated by using the following formula as suggested by Leopold and Kridemann (1975). The unit of CGR is g day^{-1} hill^{-1}. Crop growth rate was calculated between 15-30, 30-45, 45-60, DAS and at 60 DAS -harvest.

$$\text{Crop growth rate (g day}^{-1}\text{ hill}^{-1}\text{)} = \frac{W_2-W_1}{t_2-t_1}$$

Where,

W_2-W_1= Difference in oven dry biomass at the interval

t_2-t_1 = time interval in days

3.13.4.4 Relative growth rate (RGR) (g g^{-1} day^{-1})

The RGR indicates the increase in dry weight per unit of original dry weight over any specific time interval. The values were computed between 15-30, 30-45, 45-60, DAS and at 60 DAS- harvest. The RGR was worked out with the help of following formula.

$$\text{Relative growth rate (g g}^{-1}\text{ day}^{-1}\text{)} = \frac{\ln W_2-\ln W_1}{t_2-t_1}$$

Where, $\ln W_1$ and $\ln W_2$ are the natural logarithm of total dry weight of plant at the time interval t_2 and t_1, respectively.

3.13.4.5 Weed flora composition (%)

Weed flora composition was worked out at 15, 30, 45, 60 and 75 DAS and at harvest by the formula mentioned below

$$\text{Weed flora composition} = \frac{\text{Dry wt. of a weed sp. in a community}}{\text{Dry wt. of all weed species in a community}} \times 100$$

3.13.4.26 Weed growth rate (WGR) (g day^{-1} m^{-2})

Weed growth rate was calculated during, 15- 30, 30-45, 45-60 DAS and 60 DAS-at harvest by using the formula given below:

$$\text{Weed growth rate (g day}^{-1}\text{ m}^{-2}) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W_2-W_1= Difference in oven dry biomass at the time interval

$t_2 - t_1$ = time interval in days

3.13.4.7 Relative weed density (RWD) (%)

Relative weed density was worked out at 15, 30, 45 60 DAS and at harvest. to the formula as mentioned by Mishra (1968)

$$\text{RWD (\%)} = \frac{\text{Density of that group in a community}}{\text{Density of all groups in a community}} \times 100$$

3.13.4.8 Weed control efficiency (WCE)

The weed control efficiency was calculated on the basis of reduction in dry matter production in treated plot in comparison with the control plot and expressed in percentage.

$$\text{WCE (\%)} = \frac{\text{DWC-DWT}}{\text{DWC}} \times 100$$

Where,

WCE = Weed control efficiency

DWC = Dry weight of weeds in weedy check plot

DWT = Dry weight of weeds in treated plot

3.13.4.9 Weed Index (WI %)

Weed index is defined as the reduction in yield due to the presence of weed in comparison with unweeded plot. Weed index was calculated by formula mentioned below. It is expressed in percentage.

$$WI\ (\%) = \frac{\text{Seed yield in best treatment (q ha}^{-1}\text{)} - \text{Seed yield in a treatment (Particular treatment)}}{\text{Seed yield in best treatment q ha}^{-1}} \times 100$$

Where, WI = Weed index

3.13.5 Microbiological observations

The procedure to evaluate the dehydrogenase activity of soil was described by Klien *et al*. (1971). 1 g air dried soil sample was taken in a 15 ml airtight screw capped test tube. 0.2 ml of 3% TTC solution was added in each of the tubes to saturate the soil. 0.5 ml of distill water was also added in each tubes. Gently tap the bottom of the tube to drive out all tapped oxygen. So that, a water seal was formed above the soil. No air bubbles were formed that was ensured. The tubes were incubated at 37° C for 24 hour. Then 10 ml of methanol was added. Shake it vigorously and allowed to stand for 6 hrs. Clear pink colored supernatant was withdrawn and readings were taken with a spectrophotometer. The amount of TPF formed was calculated from the standard curve drawn in the range of 10 mg to 90 mg TPF ml^{-1}.

3.13.6 Economics

Cost of cultivation for each treatment was calculated separately. Gross return (Rs. ha^{-1}) was obtained by converting the harvested produce into monetary terms at the prevailing market rate during the course of studies for every treatment. Net return was obtained by deducting cost of cultivation from the gross return. The benefit: cost ratio was calculated with the help of the following formula:

Total gross return (Rs ha^{-1}) = Grain yield (q ha^{-1}) X Price of grain (Rs ha^{-1}) + Straw yield (q ha^{-1}) X Price of Straw (Rs ha^{-1})

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

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

3.13.8 Energetics

Energy inputs were calculated and estimated in Mega Joule (MJ) ha^{-1} with reference to the standard values prescribed by *Mittal et al.* (1985). These inputs were taken to each treatment of rice crop. The standard energy coefficient for seed and straw of rice was multiplied with their respective yields and summed up to obtain total energy output. Energy use efficiency and Energy productivity were calculated as per the following formulae

$$\text{Energy use efficiency (q MJ X } 10^3) = \frac{\text{Total produce (q)}}{\text{Energy input (MJ X}10^3)}$$

$$\text{Energy productivity (kg MJ } ha^{-1}) = \frac{\text{Mean Grain Yield (kg } ha^{-1})}{\text{Total energy input, MJ}}$$

$$\text{Energy Output –Input Ratio} = \frac{\text{Energy Output (MJha}^{-1})}{\text{Input Ratio (MJha}^{-1})}$$

$$\text{Specific Energy} = \frac{\text{Energy Input (MJha}^{-1})}{\text{Grain Yield (kg ha}^{-1})}$$

3.13.9 Statistical analysis

The statistical analysis of data collected on different parameters of rice crop in both experiments was doen in strip plot design, as described by Gomez and Gomez (1984). The data recorded on weed population and their dry matter was subjected to square root transformation before analysis to normalize their distribution. Standard error of means (SEm) and critical differences (C.D.) at 5% level ware worked out for each character studied to evaluate difference between means. The analysis of variance tables (ANOVA) for two different experiments are outlined as follows (Table3.6).

Table 3.5: ANOVA table for strip plot design

Source of Variation	Degrees of freedom	Sum of Squares	Mean sum of squares	F cal	F tab	
					5%	1%
Replication	r-1	RSS	RMS	RMS /EaMS		
Main plot (A)	a-1	ASS	AMS	AMS/ EaMS		
Error (a)	(r-1) (a-1)	EaSS	EaMS			
Sub plot (B)	b-1	BSS	BMS	BMS/ EbMS		
Error (b)	(r-1) (b-1)	EbSS	EbMS			
A x B	(a-1) (b-1)	ABSS	ABMS	ABMS/ EcMS		
Error (c)	(r-1) (a-1) (b-1)	EcSS	EcMS			
Total	rab-1	TSS				

In order to compare the mean value of treatments standard error and critical values were calculated.

3.13.9.1 Standard Error of mean SEm±

a. Comparison of two horizontal strips = $\sqrt{\mathrm{EaMS/r\ x\ b}}$

b. Comparison of two vertical strips = $\sqrt{\mathrm{EbMS/r\ x\ a}}$

c. Comparison of two horizontal strips at same level of vertical strips

$$= \sqrt{\mathrm{EaMS} + (\mathrm{b} - 1)\mathrm{EcMS/r\ x\ b}}$$

d. Comparison of two vertical strip at same or different level of horizontal strips

$$= \sqrt{\mathrm{EbMS} + (\mathrm{a} - 1)\mathrm{EcMS/r\ x\ a}}$$

3.13.9.2 Standard Error of mean SEd

a. Comparison of two horizontal strips = $\sqrt{2\mathrm{EaMS/r\ x\ b}}$

b. Comparison of two vertical strips = $\sqrt{2\mathrm{EbMS/r\ x\ a}}$

c. Comparison of two horizontal strips at same level of vertical strips

$$= \sqrt{2\left(\mathrm{EaMS} + \frac{(\mathrm{b}-1)\mathrm{EcMS}}{\mathrm{r}}\ \mathrm{x\ b}\right)}$$

d. Comparison of two vertical strip at same or different level of horizontal strips=

$$=2X\sqrt{(ErMS + (a-1)EcMS/r\ x\ a)}$$

3.13.9.3 Critical difference (CD)

Comparison of two horizontal strips = SE (d) x t value at 5% error (df)

Comparison of two vertical strips = SE (d) x t value at 5% error (df)

Comparison of two horizontal strips at same level of vertical strips=

$$SE\ (d)x\ tw\ tw = \frac{taEaMS + (b-1)tcEcMS}{EaMS + (b-1)EcMS}$$

Comparison of two vertical strip at same or different level of horizontal strips=

$$SE\ (d)x\ tw\ tw = \frac{taEbMS + (a-1)tcEcMS}{EbMS + (a-1)EcMS}$$

3.13.9.4 Coefficient of variation (CV%)

$$CV\ (A) = \frac{\sqrt{EaMS}}{mean}\ x\ 100$$

$$CV\ (B) = \frac{\sqrt{EbMS}}{mean}\ x\ 100$$

$$CV\ (C) = \frac{\sqrt{EcMS}}{mean}\ x\ 100$$

Chapter – IV
RESULTS AND DISCUSSION

The field experiment entitled **"Studies on broadcast and direct line seeded rice (*Oryza sativa* L.) under different seed rate and weed management practices for alternatives of beushening (*biasi)* operation"** was conducted during *kharif* 2013 and 2014 at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.).

In this chapter, data recorded on various aspects of investigation are presented and interpretations in terms of cause and effect relationship are highlighted along with the earlier established scientific views of national and international research workers. Interpretations of only significant findings have been narrated along with the results in appropriate tables and some of them are also depicted through figures for reference.

4.1 Weather condition

The growth and yield of crop is mostly governed by the genotype, agro-management techniques and the environment to which the crop is exposed. Among the environmental factors, the prevailing weather condition such as rainfall, relative humidity, temperature, evaporation, solar radiation etc. play crucial role in the performance of crop under a particular farming situation.

Temperature, solar radiation and rainfall influence rice yield by directly affecting the physiological processes involved in grain production and indirectly through diseases and insects. In general, the temperature regimes of tropics are favorable for rice growth throughout the year.

The rainfall received during the cropping season of *Kharif* 2013 and 2014 was 1574 mm and 1029 mm, respectively which was sufficient for the growth and development of rice plant. The mean maximum temperature ranged from 25.7 ^{0}C to 21.4 ^{0}C and 27 ^{0}C to 17.6 ^{0}C during *kharif* season of 2013 and 2014, respectively which play major role for the photosynthesis and grain formation. It was higher at the time of sowing of the crop in the month of June and July and gradualy decreased thereafter. Both intensity and duration of solar radiation

influence rice yield. Solar radiation at reproductive stage has greater effect on grain yield than ripening and vegetative stages. Meteorological observatory during the crop period indicated that sun shine hours ranged from 8.6 to 0.7 and 8.3 to .5 per day during 2013 and 2014, respectively. Relative humidity throughout the crop season varied between 80 to 95 per cent at morning and 44 to 80 per cent in evening hours in both the year. The open pan evaporation mean values ranged from 8.8 to 2.1 mm day^{-1}in 2013 and 8.5 to 1.7 mm day^{-1}in 2014. Meteorological data on temperature, rainfall, and relative humidity and sunshine hours are presented in Appendix I and II and illustrated graphically in Figure 3.1 and Figure 3.2. This indicates clearly that all the weather parameters i.e. relative humidity, sunshine hours, maximum and minimum temperatures and rainfall were normal and favorable for healthy growth of rice throughout the growing season during 2013 and 2014.

Experiment No -I: Studies on broadcast rice (*Oryza sativa* L.*)* under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation

4.2 Crop observations

4.2.1 Pre-harvest observations

4.2.1.1 Plant population

Plant population per square meter was counted randomly at 15 DAS. Number of plants m^{-2} are presented in Table 4.1. It is clearly depicted from the data on plant population at 15 DAS that weed management practices did not influence the plant population significantly. However population varied significantly due to various seed rates.

Among the seeding rates, at 15 DAS, initial plant stand was influenced by different level of seed rates applied. Significantly highest plant population in both the years was recorded under120 kg ha^{-1} (S_1), while minimum number of plants (132 plants m^{-2}) was recorded in the 40 kg ha^{-1} seed rate, mainly due to lesser number of seeds as compared to 120 kg ha^{-1}. The mean plant population was 313 plants m^{-2} (S_1 120 kg ha^{-1}), followed by 80 kg ha^{-1} (236 plants m^{-2}) (S_2) and 40 kg

Table4.1: Plant population (No m^{-2}) of broadcast direct seeded rice as influenced by weed management and seed rate

Treatment	Plant population (No. m^{-2})		
	2013	2014	Mean
Weed management			
W_1 :- *Biasi* method (Farmer's practice)	226	220	226
W_2 :- Two hand weeding at 20 & 40 DAS	227	236	231
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	222	234	228
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	221	237	229
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	219	236	227
W_6 :- Weedy check	221	220	220
SEm±	4.80	6.13	2.90
CD (P = 0.05)	NS	NS	NS
Seed rate (kg ha^{-1})			
S_1 :- 120	307	320	313
S_2 :- 80	222	250	236
S_3 :- 40	139	125	132
SEm±	2.94	1.42	1.80
CD (P = 0.05)	11.53	5.58	7.08
Interaction (WM X SR)	NS	NS	NS

ha^{-1} (132 plants m^{-2}) (S_3). The population under 120 kg ha^{-1} was 137 % higher than 40 kg ha^{-1} and 33 % higher than 80 kg ha^{-1} seed rate. Interaction effect between seed rate and weed management was non-significant. Yadav *et al.* (2007) and Ravi Gopal (2008) also reported the similar result regarding the plant stand.

4.2.1.2 Plant height (cm)

The data presented in Table 4.2 revealed that different weed management practices significantly affected the plant height at different growth stages. In general, plant height increased with the advancement in age of the crop but the

maximum increase was recorded between 45 DAS to 60 DAS after the emergence, while the growth was slowed down after the 80 days after emergence.

Different seed rate did not exhibit significant impact on the plant height but in the treatment (S_3) of 40 kg ha^{-1} produced taller plants as compared to the other seed rate treatment. It was due to the low intra crop plant competition and better utilization of space and light for the growth as compared to the high seed rate where the plant population was high and intra plant competition was more.

Among the weed management practices, there was a significant variation in plant height. At 15 DAS, plant height was found non significant. However, highest plant height (21 cm) was observed under the (W_3) Pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS

At 30 DAS, maximum plant height was observed under the treatment of hand weeding twice (W_2) which was significantly superior over weedy check but was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS , and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS at 15 and 35 DAS. However, all the weed management practices produced significantly taller plants than weedy check. The lowest height was recorded under the weedy check (W_6) due to the maximum competition between the plant and weed.

At 45 and 60 DAS, significantly taller plant was recorded under treatment of *biasi* method (W_1) at par with the W_2, W_3, W_4 and W_5 treatment in both the year. Whereas, lowest height was recorded in the control plot. *Biasi* operations boost the growth by manipulating the soil environment and aeration.

Similar trend as that of 45 DAS and 60 DAS was recorded at harvest. *Biasi* method produced significantly higher plant height (105.5 cm) than weedy check which was at par with other weed management treatments. In weedy check, shorter plant was measured (99.8 cm) which is 5.7 cm smaller than the *biasi* method. Among the hand weeding and herbicide treatments no significant difference in plant height was recorded. It shows that the chemical weed control is as effective as the hand weeding and *biasi* method. The interaction effect of weed management

Table 4.2: Plant height (cm) of broadcast direct seeded rice at different duration as influenced by weed management and seed rate

Treatment	Plant height (cm)														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	19.5	22.1	20.8	31.1	34.1	32.6	60.6	64.5	62.5	75.60	80.49	78.0	105.95	105.05	105.5
W_2 :- Two hand weeding at 20 & 40 DAS	19.0	22.0	20.5	30.3	33.8	32.0	59.7	63.7	61.7	74.93	79.93	77.4	105.56	104.05	104.8
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	19.5	22.4	21.0	30.4	33.5	32.0	59.5	64.0	61.7	74.94	79.78	77.4	105.31	104.04	104.7
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	19.6	22.2	20.9	29.3	33.2	31.2	59.1	62.9	61.0	73.21	78.10	75.7	105.46	103.48	104.5
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	19.2	22.4	20.8	30.6	33.8	32.2	59.2	63.5	61.3	75.10	79.98	77.5	105.39	104.38	104.9
W_6 :- Weedy check	19.4	22.0	20.7	24.6	30.6	27.6	54.5	60.1	57.3	71.05	76.57	73.8	101.67	97.98	99.8
SEm±	0.4	0.5	0.32	1.2	0.7	0.06	1.2	0.7	0.66	0.93	0.81	0.86	0.57	1.20	0.62
CD (P = 0.05)	NS	NS	NS	3.9	2.2	1.89	3.7	2.3	2.06	2.92	2.55	2.71	1.78	3.79	1.95
Seed rate (kg ha^{-1})															
S_1 :- 120	19.3	21.6	20.4	28.5	32.5	30.5	57.6	62.7	60.2	73.11	78.14	75.6	104.08	102.48	103.3
S_2 :- 80	19.1	22.6	20.8	29.8	33.4	31.6	58.7	63.0	60.8	74.00	79.00	76.5	105.09	102.77	103.9
S_3 :- 40	19.7	22.5	21.1	29.8	33.7	31.7	59.9	63.6	61.8	75.31	80.30	77.80	105.50	104.24	104.8
SEm±	0.5	0.4	0.28	0.5	0.4	0.45	0.6	0.8	0.67	0.66	0.82	0.74	0.57	0.58	0.41
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

and different seed rate on plant height was found non significant at all the growth stages of crop.

4.2.1.3 Plant dry matter accumulation (g plant^{-1})

Data with respect to dry matter production of rice are presented in Table 4.3 dry matter of rice crop was increased with the advancement of crop age. Dry matter plant^{-1} was significantly influenced by the different weed management practices except at early growth stage.

Among weed management practices at 15 DAS, there was no significant effect on dry matter production of rice, all the weed management treatment plots produced nearly equal dry matter during both the years.

At 30 DAS, significantly higher dry matter was recorded under (W_1) *biasi* method as compared to weedy check (W_6), but it was at par with rest of the weed management treatment. Whereas, dry matter production was recorded significantly lowest under the un-weeded control (W_6).

At 45 and 60 DAS, *biasi* method was found significantly superior over the un-weeded control and it was at par with the other weed management treatments. During this period, plant accumulated highest dry matter plant^{-1}. The maximum dry matter was accumulated in plant growth under *biasi* method due to *biasi* operation, manipulated environment provides opportunity for rapid photosynthesis, uptake of nutrients and root aeration. However, dry matter production was recorded lowest under un-weeded control due to high weed crop competition for the resources.

At the harvest dry matter accumulation was maximum in *biasi* method and at par with the (W_2) two hand weeding at 20 & 40 DAS and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the years but significantly superior over the W_4, W_5 and W_6 treatment. Poor growth of plant under un-weeded control was observed. This is due to the fact that there was highest competition for nutrient, water and sunlight between the crop and weed.

Among different seed rates at different crop growth stage there was no significant effect due to variability in seed rate on dry matter accumulation at early

stage. However, after the 45 days the maximum dry matter accumulation was found in the 40 kg seed ha^{-1} due to the less plant population that gives individual plant to accumulate more dry matter by using the favorable environment and weed free situation on the weed treatment plots.

At harvest, the significantly higher dry matter was recorded under 40 kg ha^{-1} but, it was at par with the other higher seed rate of 80 kg seed ha^{-1}. It shows that the low plant population in direct seeded broadcast rice can produce the higher dry matter per plant. Mahajan *et al.* (2010) also concluded that seed rate caused significant reduction in dry matter due to high plant population per unit area.

Interaction between weed management and seed rate for plant dry matter accumulation (g $hill^{-1}$) was recorded non significant at 15, 30, 45 and 60 DAS. however, it was significant during harvest (Table 4.3a). Interaction between seed rate and weed management was significant as maximum dry matter was produced in the combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with *biasi* method. Minimum dry matter was accumulated by the weedy check with all the seed rate combination and at par with each other during both the year.

4.2.1.4 Crop growth rate (g day^{-1} $hill^{-1}$)

Data on crop growth rate (CGR), during various crop growth intervals are presented in Fig. 4.1 it is clear from the data that crop growth increased sharply up to 60 DAS and declined thereafter till harvest. Among the weed management practices, it is quite clear from the data that growth rate under *biasi* method was maximum in 45 to 60 days period. Hand weeding and other weed management practices also had higher but were next in order. The lowest CGR was recorded under the un-weeded control (W_6) throughout the crop growth period. The similar result was reported by the Reddy (1993).

Among the different seeding rate, highest CGR was observed in (S_3) 40 kg ha^{-1} seed rate and lowest CGR was recorded under the highest seed rate 120 kg ha^{-1} seed rate in all the growth stage of the plant.

4.2.1.5 Relative growth rate (g g^{-1} day^{-1})

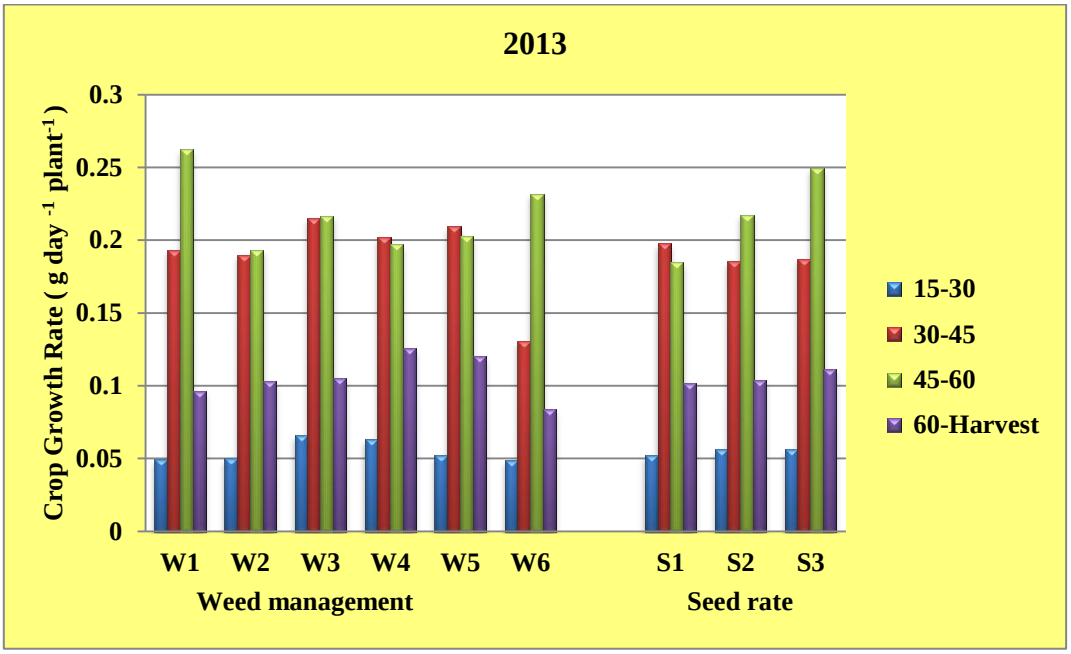
The data on relative growth rate (RGR) are presented in Fig4.2 it is obvious from the data that relative growth rate progressed up to the 30 days and after that

Table 4.3: Dry matter accumulation (g plant^{-1}) of broadcast direct seeded rice at different duration as influenced by weed management and seed rate

Treatment	Dry matter accumulation (g plant^{-1})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	0.13	0.12	0.12	0.77	0.92	0.84	4.16	4.38	4.27	6.87	7.41	7.14	8.54	8.88	8.71
W_2 :- Two hand weeding at 20 & 40 DAS	0.12	0.13	0.12	0.74	0.89	0.82	4.02	4.16	4.09	6.63	7.27	6.95	8.31	8.56	8.43
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	0.12	0.12	0.12	0.73	0.87	0.80	4.07	4.15	4.11	6.61	7.25	6.93	8.33	8.58	8.45
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.13	0.12	0.12	0.73	0.87	0.80	3.80	3.92	3.86	6.41	6.93	6.67	7.72	7.97	7.85
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	0.12	0.11	0.11	0.73	0.87	0.80	3.84	4.11	3.98	6.72	7.35	7.04	8.16	8.41	8.29
W_6 :- Weedy check	0.13	0.12	0.13	0.65	0.79	0.72	3.29	3.49	3.39	5.30	5.91	5.61	7.04	7.78	7.41
SEm±	0.01	0.01	0.01	0.02	0.02	0.02	0.13	0.17	0.11	0.31	0.30	0.30	0.09	0.11	0.09
CD (P = 0.05)	NS	NS	0.02	0.06	0.06	0.06	0.40	0.52	0.35	0.98	0.94	0.96	0.27	0.34	0.29
Seed rate (kg ha^{-1})															
S_1 :- 120	0.12	0.12	0.12	0.69	0.83	0.76	3.81	3.86	3.83	6.21	6.82	6.52	7.75	8.00	7.87
S_2 :- 80	0.12	0.11	0.12	0.71	0.86	0.79	3.83	4.06	3.95	6.52	7.09	6.81	8.00	8.39	8.20
S_3 :- 40	0.14	0.12	0.13	0.76	0.91	0.84	3.95	4.19	4.07	6.54	7.14	6.84	8.30	8.70	8.5
SEm±	0.01	0.00	0.00	0.02	0.02	0.02	0.09	0.07	0.06	0.17	0.19	0.18	0.11	0.14	0.12
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S

Table 4.3a: Interaction of weed management and seed rate on dry matter accumulation (g plant^{-1}) at harvest in broadcast direct seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**
W_1 :- *Biasi* method (Farmer's practice)	8.33	8.27	9.02	8.58	8.79	9.27	8.46	8.53	9.14
W_2 :- Two hand weeding at 20 & 40 DAS	8.12	8.53	8.27	8.37	8.78	8.52	8.24	8.66	8.39
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	8.18	8.35	8.45	8.43	8.60	8.70	8.31	8.48	8.58
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	7.27	7.97	7.93	7.52	8.22	8.18	7.39	8.09	8.06
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	7.37	8.05	9.07	7.62	8.30	9.32	7.50	8.18	9.19
W_6 :- Weedy check	7.21	6.83	7.07	7.46	7.65	8.23	7.34	7.24	7.65
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.18	0.59		0.21	0.71		0.19	0.64	
Comparison of two weed management means at the same or different level of seed rate	0.05	0.15		0.06	0.18		0.05	0.16	



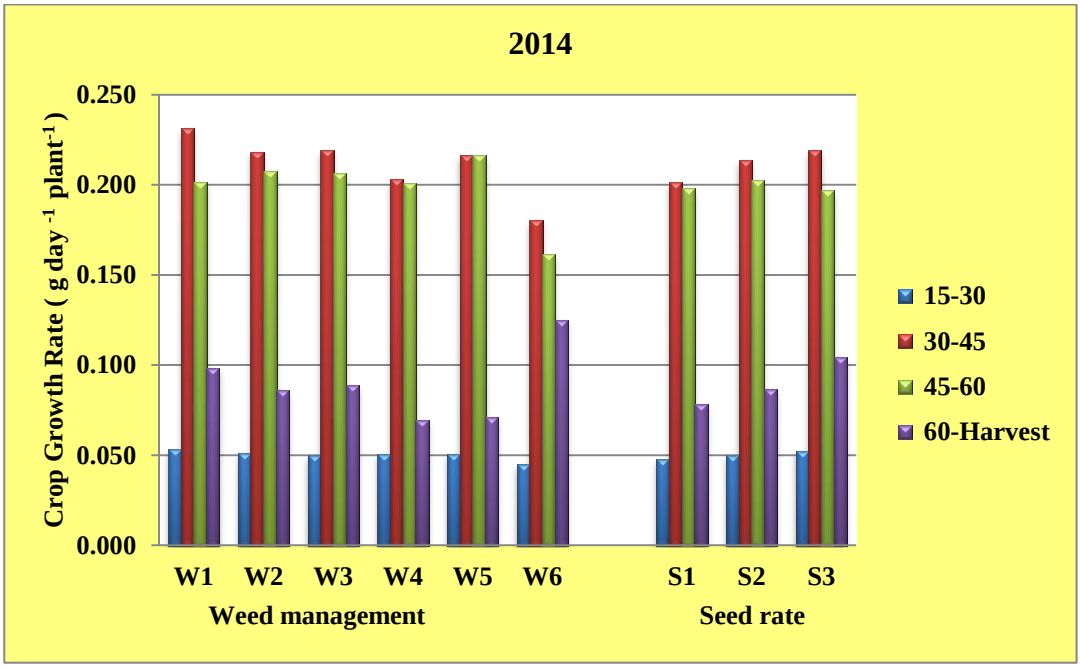
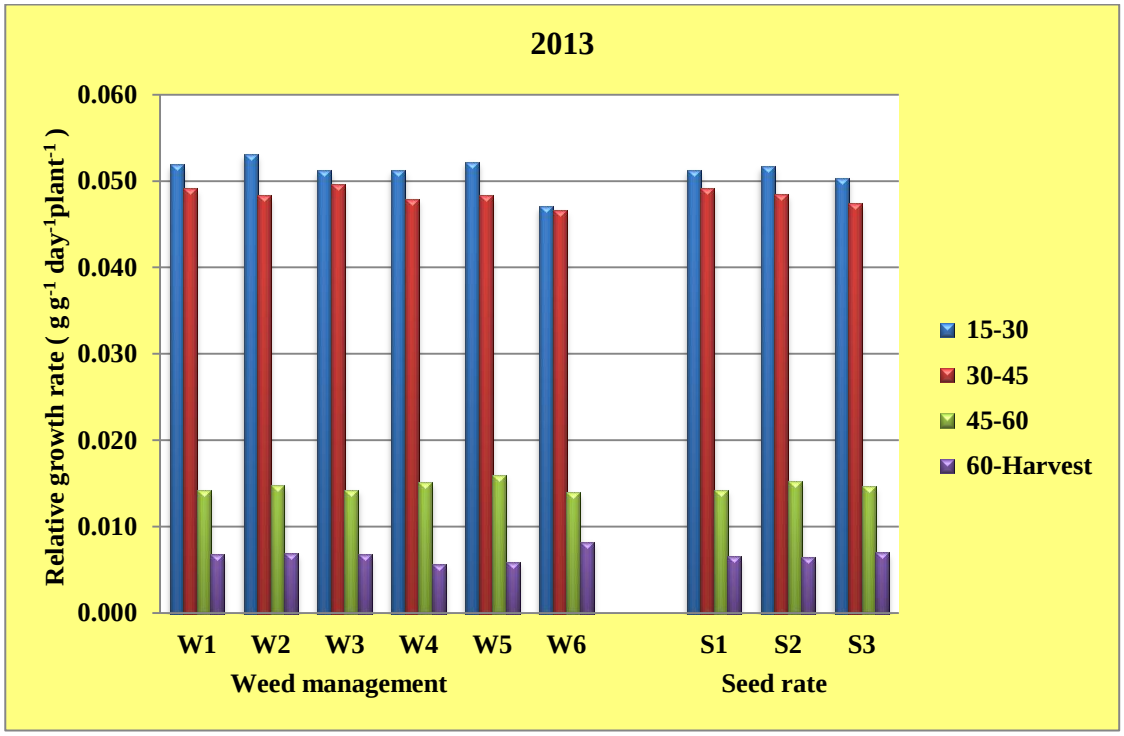


Fig 4.1: Crop Growth Rate (g day $^{-1}$ plant^{-1}) in broadcasted direct seeded rice in (2013-2014)



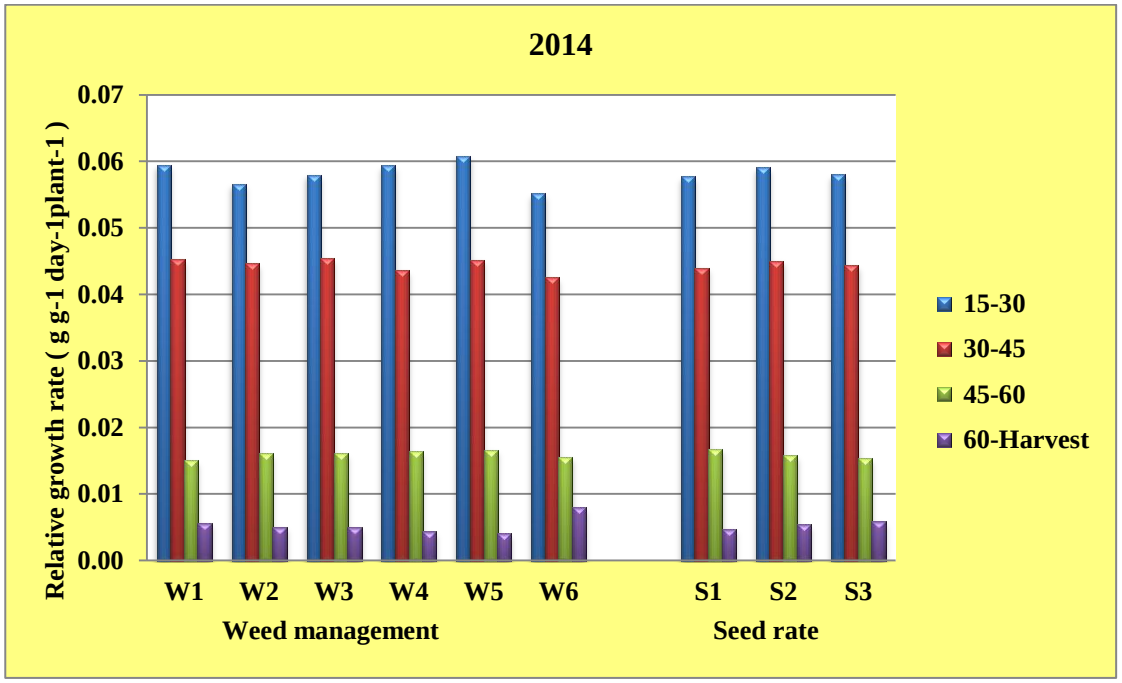


Fig 4.2: Relative Growth Rate (g g $^{-1}$ day^{-1} plant^{-1}) in broadcasted direct seeded rice (2013- 2014)

declined slightly up to the 45 days but 45 DAS onward the decline in growth was very fast. Among the weed management practices, higher relative growth rate was observed with hand weeding during the 15-30 days period in both the year. The un weeded control plot, from initial stage to harvest showed lowest value in all the period of observation.

Among the seeding rate, higher relative growth rate was observed with seeding rate of 40 kg ha^{-1} (S_3) at the harvesting stage. However, the lowest RGR was registered under seeding rate of 120 kg ha^{-1} seed rate from initial to the harvest. Similar result was also reported by Singh *et al.* (1981) and Reddy (1993).

4.2.1.6 Discussion on growth parameters

Growth parameters like plant height, plant dry matter, number of total tillers, number of effective tillers and crop growth rate were influenced significantly due to various weed management practices in direct seeded rice. The results obtained revealed that under *biasi* method, hand weeding twice and herbicidal application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS produced the taller plants. These treatments were significantly superior to untreated control. Other treatments of weed management also favored significant increase in plant height as compared to untreated control. The possible reason of higher plant height in these treatments might be due to congenial and longer weed free environment during crop growth period, provided better opportunity for overall growth and development of rice plants lead to maximum plant height. The similar finding was obtained by Mamun (2011), Khaliq *et al.* (2011),. In general, higher accumulation of dry matter of rice and crop growth rate (CGR) taken place in *biasi* method, hand weeding and sequential application of pre and post emergence application of herbicides. Due to the effect of herbicides and manual weeding on weeds and biasi method, plants receive more space, moisture, light and nutrient for their proper growth and this favored the higher dry matter accumulation of rice crop per unit area. The increasing foliage might have enhanced the photosynthesis due to which plant dry matter accumulation was higher under these treatments. This is in accordance with the findings of Reddy (1993), Singh *et al.* (1981) and Reddy (1993), Gopinath and

Kundu (2008). It was observed that irrespective of the treatments, crop growth rate (CGR) declined with advancement of crop stages. Reduction in crop growth rate with advancement of crop age might be due to the senescence of leaves and higher weed density during this period. The crop growth rate is higher at active vegetative stage of crop. Other growth parameters like total number of tillers m^{-2} and number of effective tillers m^{-2} were also influenced significantly with different weed management practices. Higher number of tillers were obtained under biasi method, application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS and hand weeding twice . Higher numbers of tillers under these treatments was due to the fact that there was more space to the crop to show their potential due to lower weed competition in terms of dry matter of weeds, which allowed crop to absorb required amount of nutrient, water and sunlight for its growth and tillering behavior. Similar result was observed by Kumar *et al.* (2008) , Khaliq *et al.* (2011) and Suria *et al.* (2011).

On the contrary the minimum values of growth parameters was recorded under weedy check, might be due to high weed infestation and competition during critical periods, which does not allow the crop to grow to their potential, resulted in less dry matter accumulation, crop growth rate, tillering as well as effective tillers m^{-2} by rice crop.

The number of tillers m^{-2} and other growth parameters at harvest did not show any significant difference over the seed rate. However, the maximum tillers was found in (S_3) 40 kg ha^{-1} seed rate followed by the 80 kg ha^{-1} and 120 kg ha^{-1}. Higher number of total tillers under the 40 kg ha^{-1} seed rate was due to the fact that there was more space and light to the crop to show their potential.

4.2.1.7 Number of total tillers (m^{-2})

The data with respect to tillers at 45, 60 DAS and harvest are presented in Table 4.4. Weed management practices significantly affect the total tillers at all the observational period. Different seed rates do not influence the tillers and found non significant during both years during all the observational period. At 45 DAS, maximum number of tillers was produced by the *biasi* method during both the year whereas, it was at par with two hand weedings at 20 and 40 DAS, (W_3) pre -

emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS during both the years of investigation. However, minimum tillers were recorded under the weedy check.

At 60 DAS, maximum number of tillers were recorded under the *biasi* method during both the year was at par with hand weeding (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS during 2013. Whereas, during 2014 all the weed management was at par and produced equal tillers.

Among weed management practices at harvest, significantly maximum number of tillers (452) was recorded under *biasi* method in both the year and at par with (W_2) two hand weedings at 20 and 40 DAS, (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS during both the year. However, lowest number of tillers was recorded in un - weeded control plot (245) over the year. On an average in *biasi* operation, 84% more tillers were produced as compared to the weedy check. Among the *biasi* method and other weed management practices the tillers ranging from 3.5 to 12 percent more tillers in *biasi* method on mean basis. As compared to the biasi method and hand weeding it was only 3.3percent more in *biasi* method. However, it was only 3.9 percent in (W_3) Pre -emergence Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS ,6.19 % (W_5) Pre-emergence (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g ha^{-1} at 25 DAS and 10% in (W_4) Pre-emergence (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS more over the chemical weed management treatments.

Thakur *et al.* (2005) also revealed that when compared between *bueshning* and *non-bueshning* treatments in broadcasted rice the more tillers in the *bueshning* as compared to the *non-bueshning* treatments were observed. Khaliq *et al.* (2011) also reported that the hand weeding and application of bispyribac gives the similar trends in regards to the tillering patterns in rice crops.

The number of tillers m^{-2} at harvest did not show any significantly difference over the seed rate. However, the maximum tillers was found in (S_3) 40 kg ha^{-1} seed followed by the 80 kg ha^{-1} and 120 kg ha^{-1}. Higher number of total tillers under the 40 kg ha^{-1} seed rate was due to the fact that there was more space and light to the crop to show their potential due to proper weed management practices and less number of plant populations in the low seed rate. In the 40 kg ha^{-1} seed rate, initially plant population was less as compared to the 120 kg ha^{-1}, seed rate gives the opportunity to produce more tillers due to less competition between the plant to plant and good weed management practices suppress the weed growth and provide the favorable environment to the plant for their maximum potential to emerge the tillers. Similarl result was found by the Gill *et al.* (2007).

4.2.1.8 Number of effective tillers (m^{-2})

Data with respect to number of effective tillers (m^{-2}) of rice at harvest is presented in Table 4.4 and it revealed that the number of effective tillers (m^{-2}) were significantly higher under weed management treatments where as non-significant in the seeds.

Among the weed management, significantly higher number of effective tillers was produced under the *biasi* method as compared to weedy check during both the years and it was at par with two hand weeding and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS during both the year whereas, treatment (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS was also at par during 2014.

Higher number of effective tillers under the *biasi* method was due to the reason that, in *biasi* method physical manipulation of soil gives the lower weed competition in terms of dry matter of weeds as well as good source sink relationship which allow crop to absorb required amount of nutrient, water and sunlight for its growth and tillering behavior. On the mean basis *biasi* method produced 99 percent more effective tillers as compared to the weedy check treatment but it was only 3.5 percent more as compared with hand weeding and 3 to 12 % with the chemical weed management. The lowest number of effective tiller m^{-2} was recorded under control (W_6) where only 207 effective tillers m^{-2} were

recorded on the mean basis. This is due to high crop weed competition for the nutrient light space and water at early growth stage due to this source sink relation badly affected the dry matter and grain formation for the crop.

Kumar *et al.* (2008) also supported that the in absence of weed control reduction in effective tillers. Khaliq *et al.* (2011) and Jaysuria *et al.* (2011) also supported that more numbers of effective tillers in the hand weeding and chemical treatment with bispyribac-sodium as post-emergence.

Among the seeding rates, the number of effective tillers m^{-2} of rice crop was recorded significantly higher under seed rate of 40 kg ha^{-1} as compared to 120 kg ha^{-1}but was comparable with 80 kg ha^{-1} seed rate. This is due to less number of seeding per meter square under 40 kg ha^{-1} seed rate with the effective weed management provide favorable environment to the source sink relation and dry matter accumulation and to show plant their full genetic potential. FAO (2007) also support that higher seed rate increases costs, population of infertile tillers starvation of nitrogen etc.

Interaction between seed rate and weed management was significant in respect to effective tillers (Table 4.4a) during both the year. Interaction between seed rate and weed management significantly produced maximum effective tillers in combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with *bias*i method and was at par with the combination of (S_1 x W_1) 120 kg seed rate ha^{-1} with *bias*i operation during 2013. Whereas, during 2014 it was found maximum under the combination of (S_2 x W_1) 80 kg seed rate ha^{-1} with *bias*i operation and at par with combination of *biasi* with 120 and 40 kg seed rate ha^{-1} and combination of 40 kg seed rate ha^{-1} with hand weeding and oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (S_1 x W_1), (S_3 x W_1), (S_3 x W_2) and (S_3 x W_3). So that it can be stated that the lower seed rate can also achieve high effective tillers subject to proper weed management. Minimum production of effective tillers were recorded under combination of (S_1 x W_6) application of 120 kg seed rate ha^{-1} with no weed control during 2013 and it was minimum under (S_2 x W_6) and (S_3 x W_6) and at par with (S_1 x W_6) during 2014.

Table4.4: Number of total and effective tillers (m^{-2}) of broadcast direct seeded rice as influenced by weed management and seed rate

Treatment	Number of total and effective tillers (m^{-2})											
	45 DAS			60 DAS			Harvest			Effective tillers m^{-2}		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management												
W_1 :- *Biasi* method (Farmer's practice)	378	414	396	396	422	409	446	459	452	407	419	413
W_2 :- Two hand weeding at 20 & 40 DAS	365	402	384	385	420	403	424	450	437	387	411	399
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	358	407	383	379	418	398	419	448	434	389	406	398
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	340	386	358	352	396	374	385	424	403	347	387	367
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	355	394	369	374	403	388	417	431	424	368	397	383
W_6 :- Weedy check	234	184	209	249	194	221	275	216	245	242	172	207
SEm±	7.50	6.57	5.51	7.34	10.67	8.04	9.47	11.32	9.37	7.95	9.62	7.54
CD (P = 0.05)	23.63	20.72	17.35	23.14	33.64	25.33	29.83	35.63	29.51	25.06	30.32	23.77
Seed rate (kg ha^{-1})												
S_1 :- 120	331	359	345	350	365	358	388	404	396	345	362	353
S_2 :- 80	337	362	349	360	379	370	389	409	399	351	366	359
S_3 :- 40	341	369	355	367	384	376	406	400	403	374	367	371
SEm±	2.88	2.28	2.05	4.18	3.99	3.37	4.87	5.89	2.31	2.64	4.23	1.97
CD (P = 0.05)	NS	NS	NS	NS	NS	13.24	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	S	NS	NS	NS	NS	NS	NS	NS	S	S	NS

Table 4.4a: Interaction of weed management and seed rate on effective tillers (m^{-2}) at harvest in broadcast direct seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**
W_1 :- *Biasi* method (Farmer's practice)	412	387	423	414	422	420	413	404	422
W_2 :- Two hand weeding at 20 & 40 DAS	373	383	403	403	417	411	388	400	409
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	372	398	397	396	399	420	384	399	408
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	328	346	367	380	384	396	354	365	381
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	351	353	400	381	404	408	366	378	404
W_6 :- Weedy check	232	240	253	176	170	170	204	205	212
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	14043	43.04		11.75	36.13		8.89	26.64	
Comparison of two weed management means at the same or different level of seed rate	4.99	15.01		4.58	13.96		3.75	13.99	

4.2.2 Post-harvest observations

4.2.2.1 Number of filled grains (panicle^{-1})

The data with respect to number of filled grains panicle^{-1} are presented in Table 4.5. Data revealed that *biasi* method treatment proved significantly superior over all the treatments. Among the weed management treatments, highest number of filled grains panicle^{-1} was recorded under *biasi* (125) and was at par with (W_2) hand weeding twice and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the years. Whereas, the lowest number of filled grains panicle^{-1} (101) was observed under the control plot. The variation between the *biasi* method and chemical weed control was very less due to the less crop-weed competition at critical period of crop growth and better weed suppression. The variation of filled grain in the experiment between the biasi method and chemical weed control varies between the 4 to 8.5 per cent only. Jay Suria *et al.* (2011) and Soni *et al.* (2012) also reported that grains panicle^{-1} was markably increased by chemical weed control over the weedy check.

Among different seed rates, it was observed that variation in numbers of filled grains panicle^{-1} varies with the variation in seed rate. More number of filled grain panicle^{-1} was observed under 40 kg seed rate ha^{-1} over 80 kg and 120 kg ha^{-1} seed rate. Ravi Gopal (2008) reported that 150 to 200 seeds m^{-2} (26 to 30 kg ha^{-1}) seed rate with good weed management condition led to highest filled grains in dry direct seeded rice. Walia *et al.* (2009) also supported that the low seed rate 37.5 to 45 kg ha^{-1} was found optimum for successful cultivation of direct seeded rice (DSR).

Interaction effect between weed management and seeding rate was found non-significant during both the years (Table 4.5a). Combination of (S_3W_1) 40 kg seed rate with *biasi* method produced higher numbers of filled grain $^{-1}$ during both the years. However, during 2013 the combination of (S_3W_2) 40 kg seed rate ha^{-1} with hand weeding twice was found at par with best combination (S_3W_1). Whereas, the combination (S_3W_2) 40 kg seed rate ha^{-1} with hand weeding twice and (S_3W_3) 40 kg seed rate ha^{-1} with pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS was also at par with (S_3W_1) during 2014.

On the basis of two years mean the combination (S_3W_1) was significantly superior over other but was found at par with the combination of (S_3W_2) 40 kg seed rate ha^{-1} with had weeding twice and (S_3W_3) 40 kg seed rate ha^{-1} with pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS . This result support that, the low seed rate with *biasi* , hand weeding and application of pre and post emergence herbicide produced equal filled grain under direct seeded rice.

4.2.2.2 Number of un-filled grains (panicle^{-1})

Data with respect to number of un-filled grains (panicle^{-1}) are presented in Table 4.5 it is clear from the data that un-filled grains were significantly influenced by different weed management practices. Significantly higher number of un-filled grains panicle^{-1} was found in weedy check. Whereas, the minimum number of un-filled grains was found in *biasi* method in both the years. However, during the year 2013, the un-filled grain was high as compared to the year 2014. It was due to the variation in climatic condition both the years. On the mean basis, 75 per cent more un-filled grains were found in un-weeded control plot as compared with *biasi* method. It was may be due to the high competition between the plants and weed present in un-weeded control plot.

Among the seed rate highest number of un-filled grains was found in high seed rate 120 kg ha^{-1} as compared to the low seed rate, but it was statistically at par with other seed rates.

4.2.2.3 Sterility per cent (%)

The data with respect to sterility per cent are presented in Table 4.5 it is clear from the data that the sterility was significantly influenced by different weed management practices and seeding rates.

Among the weed management practices, maximum sterility was present in the un-weeded control plot which was significantly superior over other treatment whereas, the minimum sterility per cent was recorded under *biasi* method followed by hand weeding. However, the mean sterility was high in 2013 as compared to the 2014 which reflects the yield during 2013. Among the chemical control method, all

Table 4.5: Number of grains panicle^{-1} and sterility percentage of broadcast direct seeded rice as influenced by weed management and seed rate

Treatment	No. of filled grains panicle^{-1}			No. of unfilled grains panicle^{-1}			Sterility (%)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management									
W_1 :- *Biasi* method (Farmer's practice)	123	126	125	18.1	14.9	16.5	14.8	11.9	13.2
W_2 :- Two hand weeding at 20 & 40 DAS	121	124	123	25.0	15.1	20.0	20.6	12.0	16.3
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	116	123	120	28.5	17.4	23.0	24.6	14.4	19.5
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	112	118	115	28.1	18.5	23.3	25.3	15.7	20.5
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	114	119	116	28.9	18.0	23.5	25.5	15.2	20.3
W_6 :- Weedy check	96	106	101	27.9	30.1	29.0	29.0	28.6	28.8
SEm±	2.32	1.53	1.68	1.40	1.47	1.23	1.22	1.22	1.02
CD (P = 0.05)	7.32	4.84	5.28	4.41	4.63	3.89	3.84	3.86	3.23
Seed rate (kg ha^{-1})									
S_1 :- 120	112	115	113	28.2	20.5	24.4	25.6	18.2	21.9
S_2 :- 80	113	117	115	25.1	18.3	21.7	22.5	15.8	19.1
S_3 :- 40	116	125	121	24.9	18.2	21.5	21.8	14.9	18.4
SEm±	1.24	2.09	1.61	1.09	1.05	0.42	1.06	.88	0.36
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	S	S	S	NS	NS	NS	NS	NS	NS

Table 4.5a: Interaction of weed management and seed rate on no. of filled grains panicle^{-1}at harvest in broadcast direct seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**
W_1 :- *Biasi* method (Farmer's practice)	114	122	130	122	122	134	118	122	132
W_2 :- Two hand weeding at 20 & 40 DAS	121	116	126	116	124	133	118	120	130
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	110	119	125	115	119	135	112	119	130
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	116	113	108	117	112	124	116	113	116
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	115	114	112	117	118	121	116	116	116
W_6 :- Weedy check	96	95	99	103	108	106	99	101	102
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	3.32	10.24		1.53	4.83		2.60	8.65	
Comparison of two weed management means at the same or different level of seed rate	1.20	3.64		2.09	8.22		0.83	2.52	

the treatments were found statistically equal. Under the un-weeded control, more sterility per cent directly influenced to the seed yield as compared to the *biasi* method. On the mean basis of two years 118 per cent more sterility was recorded in the weedy check as compared with the *Biasi* method. However, the difference in sterility per cent was very marginal between all the weed control treatments.

With respect to seed rate, higher sterility per cent was recorded under 120 kg ha^{-1} seed rate in both the year. This is due to high plant population and high competition between the rice plant for the space, light and nutrients, so that, there is no proper source to sink relationship developed in the plots having more plants and weeds. The minimum sterility per cent was recorded under 40 kg ha^{-1} seed rate.

4.2.2.4 Panicle length (cm)

Data with respect to panicle length are presented in Table 4.6 the observation of panicle length among different weed management practices revealed that it was significantly influenced by all the weed management practices. During both the years *biasi* method produced significantly higher length of panicle which was found at par with hand weeding twice (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Panicle length was longest (23.7cm) in *biasi* method followed by the hand weeding (23.5cm) and the lowest length in the control plot (21.4cm) was found on the mean basis of two year. Panicle length in *biasi* method was 10 % more long than the weedy check but there is no large difference between the *biasi* and other weed management treatments. It varied from 1 to 3% difference among the *biasi* and other treatments. Tiwari (2002) and Thura (2003) also reported that the hand weeding produced longer panicle length as compare to the chemical weed management. Thakur *et al.* (2005) also revealed that the *bueshening* gives additional advantage through more rooting, better tillering, panicle length and other yield parameter.

Among different seed rate 40 kg ha^{-1} seed rate produced higher panicle length (23.3) as compared to 80 and 120 kg ha^{-1} seed rate. However, seed rates were statistically at par during both the years.

4.2.2.5 Panicle weight (gm)

Data regarding panicle weight is presented in Table 4.6 among the different weed management practices, panicle weight was found significantly higher under *biasi* treatment but it was at par with the hand weeding twice , (W_3) pre - emergence oxadiargyl 70 g ha^{-1} fb bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} fb bispyribac Na @ 20 g ha^{-1} at 25 DAS

Whereas, the lowest panicle weight was observed under un-weeded control. However, there is no remarkable difference among the chemical weed control and weight was near to the *biasi* and hand weeding treatment which showed that the chemical weed control might be the alternatives to the *biasi* and hand weeding operation. Singh *et al.* (2005) also reported the similar result.

Among different seeding rates, plot having 40 kg ha^{-1} seed rate proved higher panicle weight as compared with the 120 kg ha^{-1} and 80 kg ha^{-1} seed rate but the data was non-significant in both the year. On the mean basis of two years low seed rate with the appropriate weed management practices can also produced the similar yield parameter as the high seed rate in broadcasted direct seeded rice.

Interaction effect between weed management practices and seeding rate was found non-significant.

4.2.2.6 Test weight (g)

The data with respect to test weight are presented in Table 4.6. Data revealed that all the weed management treatment proved significantly superior over the un-weeded control. But, the data are statistically at par in both the years. Among the weed management practices, test weight was highest in *biasi* method in both the year but it was similar and statistically at par with the hand weeding twice and chemical control of weeds. Khaliq *et al.* (2011) also supported that the application bispyribac will be the alternatives of hand weeding.

Table 4.6: Panicle length (cm) and weight (g) and Test weight (g) of broadcast direct seeded rice as influenced by weed management and seed rate

Treatment	Panicle length (cm)			Panicle weight (g)			Test weight (g)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management									
W_1 :- *Biasi* method (Farmer's practice)	23.3	24.1	23.7	3.20	3.25	3.22	28.0	28.3	28.2
W_2 :- Two hand weeding at 20 & 40 DAS	23.2	23.9	23.5	3.11	3.16	3.13	27.7	28.1	27.9
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	22.8	23.8	23.3	3.13	3.12	3.12	27.7	28.0	27.8
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	22.2	22.9	22.55	2.80	2.90	2.80	27.4	27.6	27.5
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	22.9	23.8	23.3	3.02	3.10	3.06	27.6	27.6	27.6
W_6 :- Weedy check	20.9	21.9	21.4	2.60	2.30	2.04	26.2	26.4	26.3
SEm±	0.2	0.4	0.12	0.1	0.1	0.04	0.2	0.2	0.15
CD (P = 0.05)	0.7	1.1	0.39	0.2	0.2	0.11	0.6	0.7	0.48
Seed rate (kg ha^{-1})									
S_1 :- 120	22.1	23.5	22.8	2.80	2.70	2.75	27.2	27.4	27.3
S_2 :- 80	22.2	23.5	22.9	2.81	2.83	2.82	27.2	27.5	27.4
S_3 :- 40	23.0	23.7	23.3	2.92	2.92	2.92	27.7	27.9	27.8
SEm±	0.2	0.1	0.10	0.0	0.1	0.04	0.1	0.1	0.05
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Data in Table 4.6 indicates that seeding rate was found non significant on test weight during both the years. However, maximum test weight (27.8) was observed in 40 kg ha^{-1} seed rate followed by 80 kg (27.4) and 120 kg (27.3) on the basis of two year mean. Higher seed rate could be replaced by the low seed rate as the growth parameter and yield attributes were same in all the seed rates with proper weed management.

Gill *et al.* (2007) also supported that, test weight gave the highest value at lower seed rate. Interaction effect between weed management practices and seeding rate was found non-significant.

4.2.2.7 Seed yield (q ha^{-1})

The data with respect to seed yield are presented in Table 4.7, it is clear from the data that seed yield was significantly influenced by different weed management practices.

Among different weed management practices, *biasi* method proved significantly superior over other weed management practices but at par with the (W_2) two hand weeding twice and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS during both the year. Seed yield was slightly higher in 2014 might be due to favorable climatic conditions as compared to the 2013. Among the chemical weed management treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was superior but it was at par with the other chemical control (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} fb bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) PE (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS respectivly. The minimum seed yield was found in the weedy check treatment. As compared to the weedy check plot, *biasi* method showed 261percent more yield in 2013 and 475 percent more seed yield in 2014 but it was very subsidiary increase as compared to hand weeding and chemical control method on the mean basis. It was only 2.7 per cent more as compared to hand weeding and 4.7 per cent more as compared to chemical control (W_3) pre emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS. Thakur *et al.* (2005) also reported that the *biasi* method is best as compared to the *non-biasi* method. Nagappa and Biradar

(2002) reported that among weed management practices, two hand weeding gives significantly higher yield. Walia *et al.* (2009), Hussain *et al.* (2009) and Kiran *et al.* (2010) reported that the bispyribac-sodium is the best chemical for the direct seeded rice.

With respect to different seeding rates, seed yield did not vary significantly. It showed that there is no remarkable yield difference between the high seed rate and low seed rate. However, seed yield was highest in 40 kg ha^{-1} seed rate followed by the 80 kg ha^{-1} and 120 kg ha^{-1} seed rate respectively. In respect to the mean data, the difference between the seed yield in seeding rates was very marginal. It was noticeable that the yield difference between 40 kg to 120 kg ha^{-1} was only 6 per cent. Data present in Table 4.7 reveals that with low seed rate and proper weed management, yield can be achieved as the tradition high seed rate. Same results were also observed by Ravi (2008), Yadav *et al.* (2007) and Gill *et al.* (2007) in their experimentation.

Result on yield shows that the *biasi* method is the best method in respect to the seed yield but it has several disadvantages like availability of water for *biasi* operation at right stage of crop, un-availability of labour at the time of *biasi* operation, management of fertilizer in *biasi*, cost of the human and animal energy in this method.

4.2.2.8 Straw yield (q ha^{-1})

The data on straw yield are given in Table 4.7 the straw yield significantly affected by different weed management practices. In respect to weed management practices, *biasi* method produced significantly higher straw yield, but it was found at par with treatments of two hand weeding (W_2), (W_3) PE oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS and (W_5) PE (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS respectively. The lowest straw yield was observed under un-weeded control (W_6). The minimum yield of straw in control was due to more dry matter of weed and its density, or due to the high crop-weed competition which did not allow crop to grow with their genetic potential.The straw yield was statistically at par with each other in respect to the seeding method. However, the highest straw yield was found in 40 kg ha^{-1} seed

rate followed by 80 kg and 120 kg ha^{-1} seed rate. This is due to the high plant to plant and weed competition that did not allow the high dry matter production under 120 kg seed rate.

4.2.2.9 Harvest index (%)

The data on Harvest index are given in Table 4.7. Harvest index is a measure of the productive efficiency of crop. Data of the harvest index also depicted significant response in relation to various treatments under study.

Harvest index data revealed that different weed management practices significantly influenced the harvest index values. The significantly higher harvest index value was found under *biasi* method but it was at par with other weed management practices. The lowest harvest index value was recorded under un-weeded control.

Different seeding rates did not affect harvest index significantly. However, crop sown with 40 kg ha^{-1} seed rate (S_3) recorded maximum harvest index value (42.2) followed by 80 kg (42.3) and 120 kg ha^{-1} (41.6) seed rate on mean value basis.

4.2.2.10 Discussion on yield attributes and yield

Yield attributes like number of grains $panicle^{-1}$, panicle length, panicle weight, test weight and sterility percentage as well as the grain and straw yield of direct seeded rice were influenced significantly due to combination of different weed management practices and seed rate.

Weed management played a vital role in enhancement of yield attributing characters and ultimately the yield of direct seeded rice. Increase in yield attributers like number of grains $panicle^{-1}$, panicle length, panicle weight, test weight and reduction in sterility were mainly due to reduced crop weed competition under *biasi* method, hand weeding twice and herbicidal application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS created favorable condition for crop growth, better crop efficiency for translocation of food materials to sink at reproductive stage of the crop. Thakur *et al.* (2005) also reported that the *biasi* method is best as compared to the *non-biasi* method.

Table 4.7: Seed and straw yield (q ha^{-1}) and harvest index (%) of broadcast direct seeded rice as influenced by weed management and seed rate

Treatment	Seed yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management									
W_1 :- *Biasi* method (Farmer's practice)	51.4	53.1	52.2	57.0	62.4	59.7	47.41	46.0	46.8
W_2 :- Two hand weeding at 20 & 40 DAS	49.6	52.1	50.8	55.1	61.3	58.2	47.4	45.9	46.6
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	48.3	51.6	50.0	54.3	61.4	57.8	47.1	45.5	46.3
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	45.0	47.1	46.1	51.8	60.0	55.9	46.5	44.0	45.3
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	46.1	49.5	47.8	54.3	61.3	57.8	46.0	44.6	45.3
W_6 :- Weedy check	14.2	8.9	11.5	42.9	34.2	38.6	24.5	20.6	22.5
SEm±	1.3	1.0	0.95	0.9	0.7	0.63	1.3	1.0	0.38
CD (P = 0.05)	4.1	3.3	2.10	3.0	2.1	1.98	4.2	3.3	1.20
Seed rate (kg ha^{-1})									
S_1 :- 120	41.5	42.1	41.8	51.9	55.7	53.8	42.6	40.5	41.6
S_2 :- 80	42.2	44.1	43.1	52.6	56.7	54.6	43.2	41.4	42.3
S_3 :- 40	43.7	44.9	44.3	54.4	57.8	56.1	43.0	41.5	42.2
SEm±	0.8	1.5	0.36	0.6	0.5	0.31	0.8	0.8	0.18
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Nagappa and Biradar (2002) reported that among weed management practices, two hand weeding gives significantly higher yield. Hussain *et al.* Walia *et al.* (2009), Hussain *et al.* (2009) and Kiran *et al.* (2010) reported that the bispyribac-Sodium is the best chemical for the direct seeded rice. Higher grain yield under these treatments was due to proper management of weeds at critical period and early crop growth stage resulted in higher dry matter production, high growth in terms of tiller numbers, consequently resulted in higher photosynthesis, and greater translocation of food materials to the reproductive parts of the crop resulted in superiority of yield attributing characters and ultimately higher yield. Lower weed population and higher weed control efficiency also contributed in higher grain yield due to lower crop weed competition. On the other hand, the minimum grain and straw yield in control plot is due to the less dry matter accumulation of rice, less CGR, higher weed infestation and high competition during the critical periods of crop, which did not allow the rice crop to grow to their potential, and vice versa, resulted in higher crop weed competition and less availability of space, nutrient, light and moisture to the direct seeded rice crop throughout the crop growth period especially at the time of flowering and grain development, adversely influenced the yield attributes as well as the grain yield. As regards to weed management practices the comparable harvest index was obtained under biasi method , hand weeding and herbicidal application of pre - emergence Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS which was due to higher economic yield in proportion to straw yield., whereas, in untreated control reverse trend was observed resulted in lowest harvest index of direct seeded rice.

With respect to different seeding rates, seed yield was at par in all the seeding rates shows that there is no yield difference between the high seed rate and low seed rate. In respect to the mean data, the difference between the seed yield in seeding method was very marginal. It was noticeable that the yield difference between 40 kg to 120 kg ha^{-1} was only 6 per cent. With low seed rate and proper weed management yield can be achieved equivalent to tradition high seed rate. Same result was also observed by Ravi (2008), Yadav *et al.* (2007) and Gill *et al.* (2007) in their experimentation.

Farmer needs the alternatives of *bueshening (biasi)* system like "*machine to machine production system*". Present studies involving the chemical method of weed control with the low seed rate might be the option for farmer's to replace the *biasi* method by adopting this combination. This combination is the best utilization of resources and energy in production system to achieve the high growth yield involving the less energy and cost.

4.2.2.11 Root volume (cc)

Root volume was recorded at 50 and 70 DAS are presented in Table 4.8. Weed management practices and seed rate influenced the root volume at 50 and 70 DAS in direct broadcasted rice during both the years. Among the different weed management practices root volume was recorded significantly higher under *biasi* method followed by hand weeding twice and chemical weed management at 50 DAS. During 70 DAS root volume was recorded significantly higher under *biasi* method and was found at par with hand weeding twice and application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3) during both the years. Root volume increased at faster rate up to 70 DAS and thereafter declined slowly. Similar results were also reported by Kunwar and Shrestha (1979). Root volume was recorded higher under *biasi* method due to the fact that physical manipulation of soil provide better environment for growth of roots. Whereas, among seed rates higher root volume was recorded under the 40 kg seed rate ha^{-1} followed by 80 and 120 kg seed rate ha^{-1}. Optimum population under the low seed rate 40 kg ha^{-1} with proper weed management increases the growth and development of rice crop due to proper utilization of space and other resources by the plant and ultimately root growth was higher under less plant population crop as compared to over crowded plots.

4.2.2.12 Root dry weight (g $hill^{-1}$)

Root dry weight was recorded at 50 and 70 DAS is presented in Table 4.8. At 50 DAS root dry weight was recorded maximum under biasi method due to manipulated soil environment followed by hand weeding twice and other chemical control. After that root dry weight at 70 DAS, was significantly superior under *biasi* method and was at par with hand weeding twice and application of pre-

Table 4.8: Root volume (cc) and root dry weight (g hill^{-1}) of broadcast direct seeded rice as influenced by weed management and seed rate

Treatment	Root Volume (cc)						Root dry weight (g hill^{-1})					
	50 DAS			70 DAS			50 DAS			70 DAS		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management												
W_1 :- *Biasi* method (Farmer's practice)	15.17	15.58	15.38	22.07	22.33	22.20	1.23	1.25	1.24	1.44	1.54	1.49
W_2 :- Two hand weeding at 20 & 40 DAS	14.68	15.16	14.92	21.66	22.26	21.96	1.16	1.16	1.16	1.37	1.44	1.40
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	14.24	14.61	14.43	21.34	21.65	21.48	1.15	1.15	1.15	1.34	1.37	1.34
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	13.86	14.23	14.04	20.85	21.30	21.07	1.17	1.17	1.17	1.21	1.26	1.24
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	14.14	14.50	14.32	20.84	21.21	21.02	1.16	1.15	1.	1.28	1.34	1.31
W_6 :- Weedy check	12.95	13.43	13.19	18.95	19.19	19.07	1.09	1.03	1.06	1.13	1.19	1.16
SEm±	0.08	0.08	0.07	0.23	0.22	0.22	0.04	0.05	0.08	0.03	0.03	0.03
CD (P = 0.05)	0.25	0.26	0.23	0.73	0.71	0.69	0.13	0.14	0.25	0.10	0.11	0.10
Seed rate (kg ha^{-1})												
S_1 :- 120	13.80	14.20	14.00	20.63	20.91	20.77	1.11	1.10	1.10	1.23	1.26	1.25
S_2 :- 80	14.21	14.57	14.39	20.96	21.23	21.09	1.18	1.14	1.16	1.28	1.36	1.32
S_3 :- 40	14.51	14.99	14.75	21.25	21.82	21.54	1.24	1.26	1.30	1.36	1.46	1.41
SEm±	0.07	0.05	0.06	0.10	0.16	0.12	0.03	0.03	0.03	0.02	0.03	0.02
CD (P = 0.05)	0.29	0.21	0.25	0.39	0.63	0.49	0.11	0.14	0.12	0.07	0.14	0.09
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3). Among the different seed rates significantly higher root dry weight was produced by 40 kg seed rate ha^{-1} over 120 and 80 kg seed rate ha^{-1} during both the observational stages and both the years.

4.3 Weed studies

4.3.1 Weed floral association with rice crop

The predominant weed species observed in the experimental field were *Echinochloa colona, Alternanthra triandra, Cyperus iria* and *Cynotis axillaris* are depicted in Table 4.9 and Fig. 4.3

Table 4.9: Dominant weed species observed in the experimental field

S. No.	Botanical name	Family	Vernacular name	Type of weed
1.	*Echinochloa colona*	Poaceae	Sawa	Grasses
2.	*Alternanthra triandra*	Compositae	Resham kanta	Broadleaves
3.	*Cyperus iria*	Cyperaceae	Motha	Sedges
4.	*Cyanotis axillaris*	Commelinaceae	Cynotis	Grasses

On the basis of two year mean at 15 DAS, the most pre dominating weeds in the field was *Echinochloa colona , Alternanthra triandra, , Cynotis axillaris, Cyperus iria* 74, 13,6 and 3 per cent respectively during initial stage. At 30 DAS dominating weeds was *Echinochloa colona* (66 %) and *Alternanthra triandra* (17%) on the basis of two year mean of un weeded control.

After that at 45 and 60 DAS *Echinochloa colona* and *Alternanthra triandra* was pre dominant weed followed by, *Cyanotis axillaris* and *Cyperus iria* respectively. At harvest, the major weed species, which infested in untreated control, were *Alternanthra triandra* (34 %), other weeds (23 %), *Cyanotis axillaris* (17 %), *Cyperus iria* (14 %) and minimum was *Echinochloa colona* (12 %) respectively.

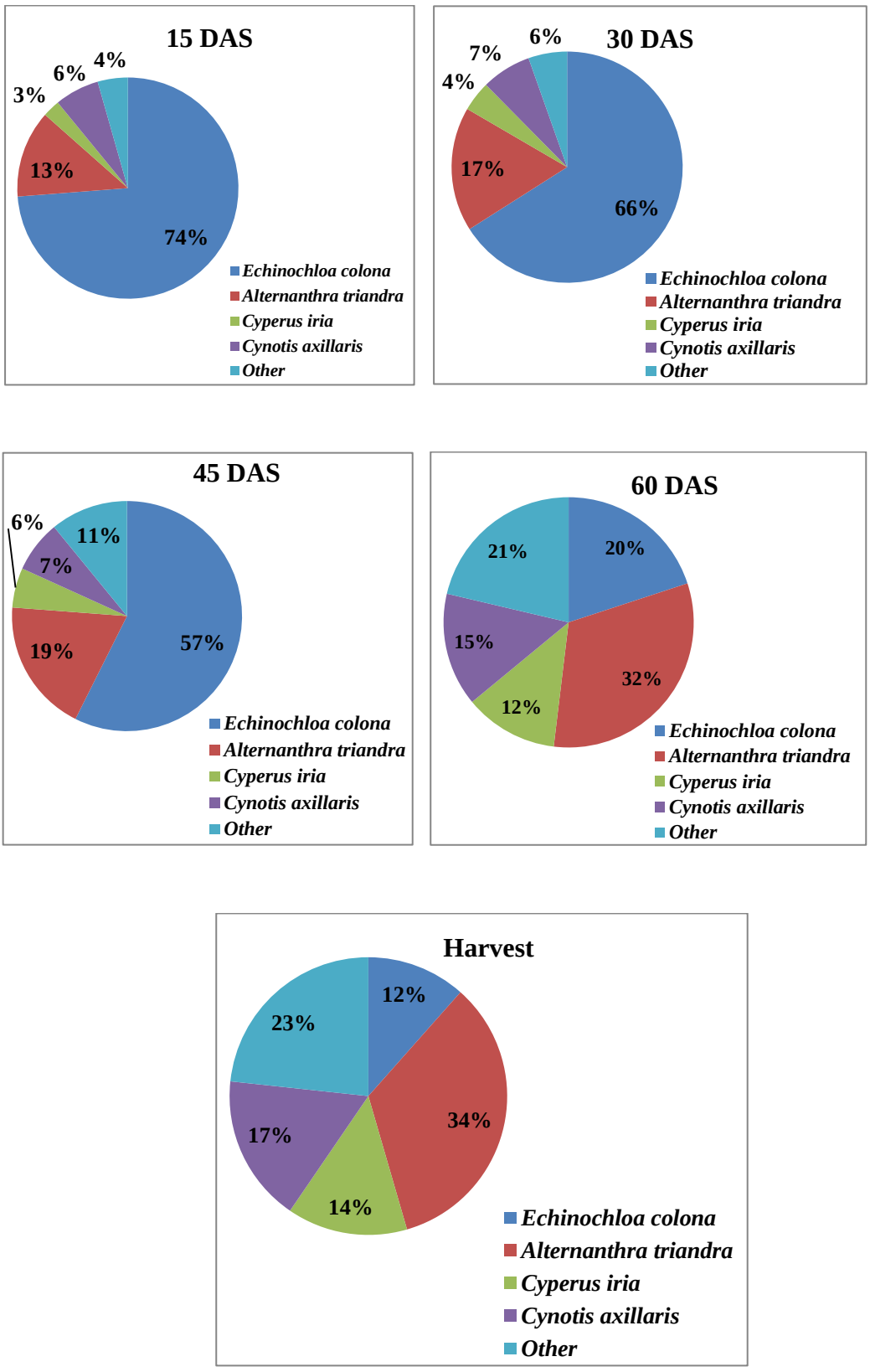


Fig 4.3: Average flora composition in un-weeded control treatment (%) in broadcasted direct seeded rice

4.3.2 Total weed density (No m^{-2})

The data on total weed density at different time interval are presented in Table 4.10 Weed management practices had remarkable effect on total weed density throughout the crop growth period. Weed management practices at 15 DAS, had significant effect on weed density. Application of pre-emergence herbicide shows the minimum weed density at early stage. However, significantly high weed density was observed under (W_1) *Biasi* method, (W_2) two hand weedings at 20 & 40 DAS and (W_6) Weedy check where no weed control was done. The lowest weed density at 15 DAS, was recorded in the (W_3) pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by the (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in both the years. The maximum weed density was found in weedy check, which was at par with the *biasi* method and hand weeding. Application of pre-emergence herbicide controlled the weed population during this period. Kiran *et al.* (2010) observed that the application of oxadiargyl 75 g ha^{-1} controlled the weeds at early stage, lowest density and dry weight with maximum weed control efficiency was found during the study. Pal *et al.* (2012) revealed that the pyrazosulfuron-ethyl was most effective to manage associated weed *spp*.

At 30 DAS, among different weed management practices, the significantly lowest weed density was recorded under the treatment of (W_3) pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with the (W_2) two hand weedings at 20 and 40 DAS, (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS. However, maximum weed density was found in *biasi* method and un-weeded control . This is due to that under the *biasi* method, *biasi* operation was done after the 30 DAS in both the years. Patra *et al.* (2006) reported that the two hand weeding recorded the minimum weed population and dry weight and highest WCE. Mahajan *et al.* (2008) and Khaliq *et al.* (2011) found that post

emergence application of bispyribac sodium 25 g ha^{-1} effectively controls the weed species in direct seeded rice.

At 45 DAS, significantly lowest weed density was observed under the treatment of two hand weeding at 20 and 40 DAS, this was at par with all other weed management practices. However the maximum weed density was recorded under the weedy check. Application of bispyribac as post-emergence after 25 DAS is as effective as the hand weeding twice and *biasi* method. Thus, it can be stated that, chemical control is the alternative of *biasi* and hand weeding method, when applied with proper dose and time.

At 60 DAS, the minimum weed density was found under the *biasi* treatment which was at par with the hand weeding and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. At harvest almost similar trend as that at 60 DAS was observed. However, at harvest the minimum weed density was recorded in *biasi* method and the difference between the *biasi*, hand weeding and chemical control was very marginal. Maximum weed density was found in control plot, infestation of weed increased with increased in time under un-weeded control up to harvest. In general, maximum weed density was observed in un-weeded control plot throughout crop growth period. Under weedy condition, weed population was maximum and competition between weed and crop was maximum which reduced the grain yield finally.

Among different seeding rates at 15 DAS, no significant effect was found but, there was slightly lower weed density recorded under (S_1) 120 kg ha^{-1} seed rate, this might be due to the high seed rate, which did not allow weeds for sufficient space, light and nutrients for profuse growth and establishment.

At 30, 45, 60 DAS and harvest, minimum weed density was recorded under the 120 kg ha^{-1} as compared to low seed rate. It was due to intra row weed was high in low seed rate treatment. But the difference between all the seed rates was marginal and statistically at par.

Table 4.10: Density of total weeds (No. m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Density of total weeds (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	9.24 (85.03)	9.74 (94.70)	9.49 (89.86)	10.30 (105.61)	10.78 (115.76)	10.54 (110.69)	3.70 (13.29)	4.06 (15.98)	3.88 (14.63)	3.96 (15.26)	4.35 (18.47)	4.15 (16.86)	4.37 (18.72)	4.36 (18.53)	4.36 (18.63)
W_2 :- Two hand weeding at 20 & 40 DAS	8.99 (80.37)	9.77 (95.65)	9.38 (88.01)	3.38 (10.99)	3.78 (13.83)	3.58 (12.41)	3.77 (13.97)	3.82 (14.15)	3.79 (14.06)	4.39 (18.91)	4.55 (20.21)	4.47 (19.56)	4.56 (20.38)	4.43 (19.16)	4.49 (19.77)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	4.09 (16.48)	4.83 (22.94)	4.46 (19.71)	3.19 (9.72)	3.80 (14.02)	3.49 (11.87)	4.11 (16.51)	4.62 (20.88)	4.36 (18.70)	4.69 (21.57)	4.69 (21.58)	4.69 (21.57)	4.98 (24.28)	4.78 (22.45)	4.88 (23.36)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	5.20 (26.71)	5.73 (32.72)	5.46 (29.71)	4.05 (15.94)	4.40 (18.90)	4.22 (17.42)	5.00 (24.67)	5.16 (26.16)	5.08 (25.42)	5.35 (28.30)	5.51 (30.01)	5.43 (29.16)	5.68 (31.98)	5.38 (28.61)	5.53 (30.29)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25	4.83 (23.46)	4.93 (23.92)	4.08 (23.69)	3.65 (12.83)	4.33 (18.31)	3.99 (15.57)	4.42 (19.18)	5.03 (24.90)	4.72 (22.04)	4.86 (23.19)	4.77 (22.29)	4.81 (22.74)	5.18 (26.43)	4.67 (21.29)	4.92 (23.86)
W_6 :- Weedy check	9.26 (86.02)	9.88 (97.25)	9.57 (91.64)	10.66 (115.37)	11.07 (122.74)	10.86 (119.06)	11.06 (121.83)	11.57 (133.51)	11.31 (127.67)	9.05 (81.54)	9.00 (80.52)	9.02 (81.03)	9.17 (83.63)	9.24 (84.83)	9.20 (84.23)
SEm±	0.21	0.26	0.18	0.06	0.15	0.9	0.16	0.07	0.07	0.09	0.08	0.06	0.07	0.07	0.04
CD (P = 0.05)	0.65	0.82	0.56	0.20	0.48	0.27	0.50	0.22	0.24	0.28	0.26	0.20	0.23	0.23	0.14
Seed rate (kg ha^{-1})															
S_1 :- 120	6.83 (51.27)	7.36 (58.96)	7.09 (55.11)	5.74 (43.48)	6.17 (47.10)	5.95 (45.29)	5.35 (35.02)	5.65 (38.72)	5.5 (36.87)	5.23 (29.72)	5.34 (30.66)	5.28 (30.19)	5.53 (32.95)	5.33 (30.46)	5.43 (31.70)
S_2 :- 80	7.02 (54.96)	7.50 (61.66)	7.26 (58.31)	5.87 (45.14)	6.43 (52.54)	6.15 (48.84)	5.22 (34.02)	5.73 (39.48)	5.47 (36.75)	5.45 (32.20)	5.55 (33.06)	5.50 (32.63)	5.66 (34.26)	5.57 (33.46)	5.61 (33.86)
S_3 :- 40	6.97 (52.80)	7.58 (62.96)	7.27 (57.80)	6.00 (46.61)	6.48 (52.14)	6.24 (49.38)	5.47 (35.69)	5.76 (39.59)	5.61 (37.64)	5.47 (32.46)	5.55 (32.82)	5.51 (32.64)	5.78 (35.49)	5.55 (33.51)	5.66 (34.50)
SEm±	0.11	0.14	0.10	0.05	0.09	0.06	0.08	0.08	0.04	0.08	0.04	.04	0.06	0.02	0.04
CD (P = 0.05)	NS	NS	NS	0.20	NS	NS	NS	NS	NS	NS	0.16	.016	NS	0.09	0.15
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

4.3.3 Species-wise weed density

Weed management practices and seed rate had remarkable effect on weed density m^{-2} throughout the crop growth period.

4.3.3.1 *Echinochloa colona* (No m^{-2})

The data on total weed density of *Echinochloa colona* at different time interval are presented in Table 4.11 among different weed management practices at 15 DAS, minimum weed density was recorded under the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* at 25 DAS. However, the maximum density of *Echinochloa colona* was found in *biasi* method which was at par with the weedy check. Application of pre-emergence herbicide effectively control the *Echinochloa colona* , similar result was also reported by the Jadhav *et al.* (2008) and Kurmi (2008).

At 30 DAS, among different weed management practices, significantly lowest weed density of *Echinochloa colona* was recorded under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment. Sequential application of pre and post-emergence herbicide controlled the weeds effectively. Due to unavailability of good rains during both the year *biasi* operation was delayed. *Biasi* opration was done after 40 DAS in 2013 and it was done at 37 DAS in 2014, as a result significantly at par weed density was found under the *biasi* and un-weeded control plots at 30 DAS.

At 45 DAS, the lowest weed density of *Echinochloa colona* was observed under the *biasi* treatment which was at par with hand weeding treatment. Among the chemical treatment application of (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was recorded less density of *Echinochloa colona*, which was at par with (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) pre-emergence (sand

mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS . As compared to the *biasi*, hand weeding and chemical control the difference is marginal among them which showed that chemical treatment was as effective as hand weeding and *biasi* method of weed control. Risi *et al.* (2004) also observed that bispyribac-sodium controls the *Echinochloa colona* effectively. Mahajan *et al.* (2008) also found that the bispyribac-sodium controls the *Echinochloa colona* efficiently as compared to other herbicides.

Result like 45 DAS was found at 60 DAS and at harvest. In *biasi* method minimum weed density was found in both the interval and in both the year which was followed by the hand weeding and chemical control method. At harvest *Echinochloa colona* was maximum under the weedy check. Mamun (1990) reported that the yield reduction due to un-weeded control condition was 68 to 100% in direct seeded rice and 16 to 48% for transplanted rice.

Among different seeding rates at 15 DAS, there was no significant effect on density of *Echinochloa colona*, but there was slightly lower density under 120 kg^{-1} (S_1) as compared to the other seeding rates. At 30, 45, 60 DAS and harvest, the data of *Echinochloa colona* shows similar trend at different interval. There was no significant effect of different seeding rate on density of *Echinochloa colona*. However, minimum weed density was recorded under 120 kg ha^{-1} seed rate which was at par with 80 kg ha^{-1} and 40 kg ha^{-1} seed rates in all the growth stage and during both the years.

Interaction between weed management and seed rate was non significant in both the year at 15, 30, 60 DAS and harvest but it was significant at 45 DAS during both the year (Table 4.11a). On the basis of two year mean significantly minimum number of *Echinochloa colona* m^{-2} was recorded in combination of (S_2 x W_2) 80 kg seed rate ha^{-1} with two hand weeding at 20 and 40 DAS as compared to other combinations but it was at par with the combinations of (S_3 x W_1) 40 kg seed rate ha^{-1} with *bias*i operation, (S_3 x W_3) 40 kg seed rate ha^{-1} with pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1}at 25 DAS. Interaction is itself explanotry that combination of low seed rate 40 ha^{-1} with *biasi* method, hand weeding and chemical control, controlled equally *Echinochloa colona*a,at 45DAS.

Table 4.11: Density of *Echinochloa colona* (No m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Density of *Echinochloa colona* (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	7.88 (61.78)	8.53 (72.63)	8.35 (67.20)	8.26 (67.67)	8.64 (74.19)	8.45 (70.93)	2.37 (5.18)	2.65 (6.56)	2.51 (5.87)	1.64 (2.23)	1.71 (2.44)	1.67 (2.33)	1.48 (1.75)	1.71 (1.94)	1.95 (1.84)
W_2 :- Two hand weeding at 20 & 40 DAS	7.63 (57.89)	8.40 (70.89)	8.01 (64.39)	2.15 (4.21)	2.49 (5.78)	2.32 (4.99)	2.54 (6.67)	2.51 (5.89)	2.52 (6.28)	1.88 (3.24)	1.72 (2.48)	1.80 (2.86)	1.63 (2.20)	1.72 (1.98)	1.67 (2.09)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	3.48 (12.15)	4.16 (16.88)	3.82 (14.51)	2.15 (4.13)	2.70 (6.89)	2.42 (5.51)	2.38 (5.33)	3.00 (8.89)	2.69 (7.11)	2.12 (4.04)	1.75 (2.59)	1.93 (3.31)	1.96 (3.40)	1.75 (1.90)	1.85 (2.65)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at	4.40 (19.06)	4.99 (24.85)	4.69 (21.96)	2.67 (6.63)	2.95 (8.22)	2.81 (7.43)	3.04 (9.04)	3.17 (9.59)	3.10 (9.31)	2.20 (4.76)	1.86 (3.05)	2.03 (3.91)	2.07 (4.26)	1.86 (2.55)	1.96 (3.41)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	4.14 (17.26)	4.24 (17.61)	4.19 (17.43)	2.30 (4.79)	3.17 (9.56)	2.73 (7.17)	2.57 (6.37)	3.32 (10.67)	2.94 (8.52)	2.18 (4.57)	1.80 (2.77)	1.99 (3.67)	2.00 (3.85)	1.80 (2.27)	1.9 (3.06)
W_6 :- Weedy check	7.94 (62.78)	8.54 (72.44)	8.24 (67.61)	8.74 (76.00)	8.91 (79.70)	8.82 (77.85)	5.89 (71.44)	8.69 (75.11)	7.29 (73.28)	4.34 (18.41)	3.77 (13.93)	4.04 (16.17)	2.99 (8.44)	3.77 (10.35)	3.38 (9.40)
SEm±	0.23	0.28	0.19	0.07	0.13	0.06	0.26	4.06	0.12	0.15	0.06	0.07	0.18	0.06	0.09
CD (P = 0.05)	0.72	0.89	0.16	0.22	0.41	0.18	0.83	1.26	0.39	0.46	0.19	0.22	0.57	0.19	0.27
Seed rate (kg ha^{-1})															
S_1 :- 120	5.82 (37.62)	6.41 (44.68)	6.11 (41.15)	4.27 (26.23)	4.65 (28.39)	4.40 (27.31)	3.66 (18.16)	3.91 (19.56)	3.78 (18.86)	2.29 (5.46)	2.06 (4.33)	2.17 (4.89)	2.00 (3.95)	2.06 (3.09)	2.03 (3.52)
S_2 :- 80	6.01 (40.35)	6.49 (46.27)	6.25 (43.31)	4.37 (27.41)	4.96 (33.02)	4.66 (30.22)	2.10 (16.43)	3.04 (19.74)	2.57 (18.08)	2.44 (6.51)	2.18 (5.14)	2.31 (5.82)	2.05 (4.06)	2.18 (3.80)	2.11 (3.93)
S_3 :- 40	5.90 (37.48)	6.53 (46.71)	6.21 (42.09)	4.40 (28.07)	4.81 (30.76)	4.60 (29.41)	3.64 (17.43)	3.86 (19.06)	3.75 (18.24)	2.46 (6.66)	2.06 (4.16)	2.26 (5.41)	2.01 (3.94)	2.06 (3.60)	2.03 (3.77)
SEm±	0.13	0.14	0.10	0.05	0.10	0.05	0.13	0.06	0.06	0.08	0.03	0.05	0.08	0.09	0.04
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	0.53	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	S	S	S	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.11a : Interaction of weed management and seed rate on density of *Echinochloa colona* (No. m^{-2}) at 45 DAS in broadcast direct seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**
W_1 :- *Biasi* method (Farmer's practice)	2.50 (5.77)	2.22 (4.44)	2.39 (5.33)	2.73 (7.00)	2.48 (5.67)	2.74 (7.00)	2.62 (6.38)	2.35 (5.06)	2.56 (6.17)
W_2 :- Two hand weeding at 20 & 40 DAS	2.92 (8.44)	2.16 (4.89)	2.54 (6.67)	2.40 (5.33)	2.73 (7.00)	2.41 (5.33)	2.66 (6.89)	2.45 (5.99)	2.47 (6.00)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	2.82 (7.56)	2.22 (4.44)	2.11 (4.00)	3.08 (9.00)	3.02 (8.67)	3.08 (9.00)	2.59 (6.50)	2.62 (6.56)	2.61 (8.28)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	3.24 (10.22)	2.94 (8.44)	2.96 (8.44)	3.08 (9.00)	3.10 (9.11)	3.34 (10.67)	3.16 (9.61)	3.02 (8.78)	3.15 (9.56)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	2.57 (6.22)	2.35 (5.33)	2.79 (7.56)	3.43 (11.33)	3.57 (12.33)	2.96 (8.33)	3.00 (8.78)	2.96 (8.83)	2.88 (7.99)
W_6 :- Weedy check	8.65 (74.33)	8.45 (71.00)	8.33 (69.00)	8.73 (75.67)	8.73 (75.67)	8.62 (74.00)	8.69 (75.00)	8.59 (73.33)	8.48 (71.50)
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.27	0.87		0.13	0.43		0.13	0.41	
Comparison of two weed management means at the same or different level of seed rate	0.11	0.33		0.04	0.12		0.05	0.16	

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

4.3.3.2 *Alternenthera triandra* (No m^{-2})

The data on weed density of *Alternenthera triandra* at different time interval are presented in Table 4.12. Maximum population of *Alternentera triandra* was recorded under the weedy check in all the growth stages and both the year of investigation. Interaction effect between weed management and seed rates was non-significant.

At 15 DAS, the minimum density of *Alternenthra triandra* was found in the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was significantly superior over all the treatments. The maximum weed density was recorded under un-weeded control and *biasi* method in both the year.

At 30 DAS, the significantly lower weed density was recorded under the treatment of hand weeding twice (W_2) which was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS. In initial stage of crop growth period hand weeding can be replaced by the pre-emergence application of oxadiargyl and pyrazosulfuron.

During the investigation at 45 DAS, significantly lowest density of *Alternentera triandra* was recorded under the *biasi* method which was significantly superior over rest of the other treatments, but at par with two hand weeding. Application of (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS was found best among the chemical treatment, which controlled the *spp* effectively as *biasi* method and hand weeding. Among the *biasi,* chemical and hand weeding methods, difference is very marginal therefore it could be stated that the chemical method is an alternative for the *biasi* method and hand weeding, subject to proper dose and time of application.

At the growth stage of 60 DAS and harvest, maximum density of *Alternenthra triandra* was found under the weedy control method. However, significantly lowest density of *Alternenthra triandra* was recorded under the *biasi* method which was marginal difference over the hand weeding and chemical control method, in both the growth period and in both the years of experimentation.

Regarding the seed rates, the marginal difference between all the seeding methods in both the year in all the crop growth stage was recorded. However, high weed density of *Alternenthra triandra* was found in 40 kg ha^{-1} seed rate as compared to high seed rate.

Interaction between seed rate and weed was significant at harvest (Table 4.12a). Whereas, it was found non significant at 15, 30, 45 and 60 DAS. Significantly minimum density of *Alternenthra triandra* m^{-2} was recorded in the combination of (S_1 x W_1) 120 kg seed rate ha^{-1} with *bias*i operation and at par with the combination of 80 and 40 kg seed rate ha^{-1} with *biasi* method (S_2 x W_2), (S_3 x W_1), 40 kg seed rate ha^{-1} with two hand weeding (S_3 x W_2) and 40 kg seed rate ha^{-1} with pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (S_3 x W_3) during 2013. However, it was minimum under the combination of (S_2 x W_1) 80kg seed rate ha^{-1} with *bias*i operation and at par with (S_1 x W_1), (S_3 x W_1), (S_3 x W_2) (S_3 x W_3) during 2014. Interaction shows that the combination of low seed rate with *biasi*, hand weeding and pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS effectively controlled the density of *Alternenthra triandra*.

4.3.3.3 *Cyperus iria* (No m^{-2})

The data on density of *Cyperus iria* at different time interval are presented in Table 4.13 among different weed management practices at 15 DAS, shows significant impact on population of *Cyperus iria*. Application of (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was found significantly superior over all other treatment. The maximum population of *Cyperus iria* was found in biasi method and hand weeding method which was at par with each other. oxadiargyl and sand mix pyrazosulfuron controlled the *Cyperus iria* at early stage of crop growth period, gives advantage over the other treatments. Jadhav *et al.* (2008) stated that the application of oxadiargyl 75 g ha^{-1} effectively control the *Cyperus iria*. Chopra and Chopra (2003) observed that the application of pyrazosulfuron @ 20 and 25 g ha^{-1} significantly reduced the density and dry weight of *Cyperus iria* and other weeds.

At 30 DAS, there was a significant impact of weed management practices on weed density. Application of (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb*

Table 4.12: Density of *Alternanthra triandra* (No. m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Density of *Alternanthra triandra* (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	3.50 (11.96)	3.36 (10.93)	3.43 (11.44)	4.55 (20.22)	4.96 (24.22)	4.75 (22.22)	1.81 (2.89)	1.89 (3.22)	1.85 (3.06)	2.13 (4.06)	2.26 (4.67)	2.19 (4.36)	2.20 (4.39)	2.24 (4.53)	2.22 (4.46)
W_2 :- Two hand weeding at 20 & 40 DAS	3.53 (12.00)	3.70 (13.22)	3.61 (12.61)	1.66 (2.33)	1.87 (3.00)	1.76 (2.67)	1.81 (2.83)	1.86 (3.00)	1.83 (2.92)	2.26 (4.67)	2.39 (5.22)	2.32 (4.94)	2.33 (5.00)	2.40 (5.28)	2.36 (5.14)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	1.40 (1.51)	1.66 (2.30)	1.53 (1.91)	1.60 (2.09)	1.85 (2.95)	1.72 (2.52)	2.07 (3.81)	2.04 (3.66)	2.0 (3.73)	2.51 (5.83)	2.57 (6.10)	2.54 (5.96)	2.70 (6.83)	2.72 (6.90)	2.71 (6.86)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1}	1.75 (2.59)	1.83 (2.86)	1.79 (2.72)	1.86 (3.03)	2.07 (3.80)	1.96 (3.41)	2.47 (5.63)	2.57 (6.15)	2.57 (5.89)	3.10 (9.13)	3.19 (9.69)	3.14 (9.41)	3.30 (10.63)	3.39 (11.02)	3.34 (10.83)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25	1.76 (2.60)	1.74 (2.54)	1.75 (2.57)	1.85 (2.97)	1.93 (3.23)	1.89 (3.10)	2.25 (4.59)	2.37 (5.09)	2.31 (4.84)	2.63 (6.44)	2.71 (6.83)	2.67 (6.64)	2.90 (7.94)	2.80 (7.39)	2.85 (7.67)
W_6 :- Weedy check	3.41 (11.30)	3.53 (12.07)	3.47 (11.69)	4.32 (18.30)	4.80 (22.74)	4.56 (20.52)	4.68 (21.44)	5.20 (26.56)	4.94 (24.00)	4.99 (24.44)	5.27 (27.33)	5.13 (25.89)	5.29 (27.56)	5.64 (31.33)	5.46 (29.44)
SEm±	0.10	0.08	0.07	0.2	0.09	0.06	0.09	0.05	0.06	0.04	0.05	0.03	0.04	0.04	0.06
CD (P = 0.05)	0.31	0.25	0.23	0.07	0.28	0.20	0.28	0.17	0.19	0.12	0.17	0.09	0.13	6.14	0.16
Seed rate (kg ha^{-1})															
S_1 :- 120	2.47 (6.42)	2.50 (6.52)	2.48 (6.47)	2.56 (7.46)	2.79 (8.98)	2.67 (8.22)	2.43 (6.49)	2.56 (7.57)	2.49 (7.03)	2.87 (8.72)	2.95 (9.41)	2.91 (9.07)	3.3 (9.92)	3.13 (10.61)	3.09 (10.27)
S_2 :- 80	2.59 (7.20)	2.66 (7.43)	2.62 (7.32)	2.73 (8.56)	2.90 (9.92)	2.81 (9.24)	2.60 (7.27)	2.70 (8.09)	3.65 (7.68)	3.00 (9.46)	3.06 (9.88)	3.03 (9.67)	3.18 (10.70)	3.22 (11.11)	3.2 (10.91)
S_3 :- 40	2.61 (7.36)	2.75 (8.01)	2.68 (7.68)	2.64 (8.45)	3.05 (11.08)	2.84 (9.76)	2.51 (6.84)	2.70 (8.17)	2.60 (7.50)	2.94 (9.10)	3.18 (10.64)	3.06 (9.87)	3.15 (10.56)	3.25 (11.50)	3.2 (11.03)
SEm±	0.05	0.03	0.05	0.05	0.08	0.05	6.08	0.06	0.07	0.04	0.02	0.02	0.03	0.02	0.03
CD (P = 0.05)	NS	0.18	NS	NS	NS	NS	NS	0.23	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.12a: Interaction of weed management and seed rate on density of *Alternanthra triandra* (No. m^{-2}) at harvest in broadcast direct seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**
W_1 :- *Biasi* method (Farmer's practice)	2.18 (3.83)	2.21 (4.42)	2.32 (4.92)	2.28 (3.83)	2.18 (4.27)	2.45 (5.50)	2.08 (3.83)	2.19 (4.34)	2.39 (5.21)
W_2 :- Two hand weeding at 20 & 40 DAS	2.20 (4.33)	2.51 (5.83)	2.30 (4.83)	2.27 (4.67)	2.51 (5.83)	2.41 (5.33)	2.23 (4.50)	2.51 (5.83)	2.36 (5.08)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	2.58 (6.20)	2.77 (7.17)	2.33 (7.11)	2.58 (6.20)	2.77 (7.17)	2.50 (7.33)	2.58 (6.20)	2.77 (7.17)	2.78 (7.22)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	3.41 (11.41)	3.33 (10.59)	3.26 (10.17)	3.41 (11.41)	3.33 (10.59)	3.44 (11.33)	3.41 (11.14)	3.33 (10.59)	3.35 (10.75)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	2.86 (7.67)	2.94 (8.17)	2.91 (8.00)	2.89 (7.83)	2.94 (8.17)	2.58 (6.17)	2.87 (7.75)	2.94 (8.17)	2.75 (7.08)
W_6 :- Weedy check	5.18 (26.33)	5.33 (28.00)	5.37 (28.33)	5.52 (30.00)	5.58 (30.67)	5.81 (33.33)	5.35 (28.17)	5.46 (29.33)	5.59 (30.33)

	2013		2014		Mean	
	SEm±	**CD (P = 0.05)**	**SEm±**	**CD (P = 0.05)**	**SEm±**	**CD (P = 0.05)**
Comparison of two seed rate means at the same level of weed management	0.07	0.22	0.22	0.66	0.05	0.17
Comparison of two weed management means at the same or different level of seed rate	0.05	0.15	0.02	0.33	0.06	0.80

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

bispyribac Na @ 20 g ha^{-1} at 25 DAS produced significantly lowest weed density. However, (W_2) hand weeding and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS were next, in order. Whereas, maximum density was recorded under the un-weeded control and *biasi* method. Kiran *et al.* (2010) observed that the application of oxadiargyl and bispyribac gave lowest density and dry weight of weeds. Dixit and Varshney (2008) also reported that pre-emergence application of pyrazosulfuron controls the *Cyperus iria*.

At 45 DAS, minimum weed population of *Cyperus iria* was found in hand weeding twice, which was nearly equal to the *biasi* method and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. The maximum population was under un-weeded control plot. Data itself explains that application of pre-emergence followed by post-emergence application herbicide is equally effective as hand weeding twice and *biasi* method.

At 60 DAS and at harvest, density of *Cyperus iria* was minimum in *biasi* method but it was very closed to the hand weeding and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment. However, the maximum population of *Cyperus iria* was found in un-weeded control plot. *Biasi* operation, hand weeding and application of oxadiargyl followed by bispyribac proved the equal control of *Cyperus iria* during both the year.

Among different seed rates, there was no significant effect of seed rate on weed density of *Cyperus iria* at all the growth stage in both the year. However, the higher population was recorded in 40 kg ha^{-1} seed rate.

Interaction between seed rate and weed management was significant at 30 DAS (Table 4.13a). Whereas, it was found non significant at 15, 45, 60 DAS and harvest. Significantly minimum density of *Cyperus iria* m^{-2} was recorded in the combination of (S_1 x W_2) 120 kg seed rate ha^{-1} with two hand weeding during both the year and at par with the combination of 120.80 and 40 kg seed rate ha^{-1} with the application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (S_1 x W_3) ,(S_2 x W_3) and (S_3 x W_3). It is quite clear from interaction that sequential application of oxadiargyl and bispyribac Na controlled the *Cyperus iria* as hand weeding.

Table 4.13: Density of *Cyperus iria* (No. m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Density of *Cyperus iria* (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	1.53 (1.90)	1.58 (2.01)	1.56 (1.96)	2.20 (4.33)	2.25 (4.60)	2.22 (4.47)	1.34 (1.33)	1.46 (1.64)	1.4 (1.49)	1.60 (2.14)	2.04 (3.70)	1.82 (2.92)	2.04 (3.72)	1.94 (3.77)	1.99 (3.75)
W_2 :- Two hand weeding at 20 & 40 DAS	1.54 (1.89)	1.59 (2.07)	1.56 (1.98)	1.22 (1.01)	1.30 (1.22)	1.26 (1.12)	1.11 (0.76)	1.25 (1.13)	1.18 (0.95)	1.70 (2.41)	2.09 (3.89)	1.89 (3.15)	2.12 (4.00)	1.62 2.87	1.87 (3.43)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	1.05 (0.61)	1.10 0.71	1.07 (0.66)	1.17 (0.86)	1.23 (1.03)	1.2 (0.95)	1.65 (2.23)	5.72 (2.46)	1.68 (2.35)	1.79 (2.72)	1.95 (3.29)	1.87 (3.01)	2.19 (4.31)	1.62 4.35	2.1 (4.33)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.21 (0.97)	1.22 1.00	1.21 (0.99)	1.44 (1.72)	1.53 (1.86)	1.51 (1.79)	1.89 (3.09)	1.92 (3.22)	1.90 (3.15)	1.94 (3.27)	2.50 (6.52)	2.22 (4.89)	2.36 (5.07)	2.16 (4.71)	2.26 (4.89)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	1.08 (0.68)	1.12 (0.77)	1.1 (0.72)	1.38 (1.42)	1.42 (1.53)	1.4 (1.48)	1.81 (2.79)	1.84 (2.90)	1.82 (2.84)	1.80 (2.74)	2.01 (3.56)	1.90 (3.15)	2.20 (4.33)	2.16 (2.83)	1.93 (3.58)
W_6 :- Weedy check	1.63 (2.16)	1.73 (2.50)	1.68 (2.33)	2.25 (4.59)	2.42 (5.37)	2.33 (4.98)	2.69 (6.76)	2.83 (7.51)	2.76 (7.13)	3.06 (8.91)	3.35 (10.74)	3.20 (9.82)	3.54 12.07	3.43 (11.76)	3.48 11.92
SEm±	0.03	0.03	0.03	0.04	0.05	0.04	0.04	0.03	0.03	0.04	0.17	0.08	0.04	0.11	0.05
CD (P = 0.05)	0.09	0.09	0.08	0.14	0.15	0.12	0.13	0.09	0.08	0.13	0.55	0.26	0.14	0.34	0.16
Seed rate (kg ha^{-1})															
S_1 :- 120	1.32 (1.28)	1.35 (1.41)	1.33 (1.35)	1.59 (2.25)	1.66 (2.52)	1.62 (2.38)	1.71 (2.75)	1.79 (3.01)	1.75 (2.88)	1.94 (3.62)	2.39 (5.51)	2.16 (4.56)	2.37 (5.47)	2.14 (5.03)	2.25 (5.25)
S_2 :- 80	1.35 (1.38)	1.37 (1.43)	1.36 (1.40)	1.62 (2.34)	1.67 (2.54)	1.64 (2.44)	1.76 (2.84)	1.82 (3.10)	1.79 (2.97)	1.96 (3.62)	2.33 (5.51)	2.14 (4.56)	2.39 (5.51)	2.20 (5.40)	2.29 (5.46)
S_3 :- 40	1.37 (1.44)	1.48 (1.69)	1.42 (1.57)	1.64 (2.39)	1.75 (2.74)	1.69 (2.57)	1.78 (2.89)	1.90 (3.32)	1.84 (3.11)	2.04 (3.86)	2.25 (4.83)	2.14 (4.34)	2.46 (5.78)	2.00 (4.71)	2.27 (5.25)
SEm±	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.03	0.02	0.03	0.07	0.15	0.02	0.10	0.05
CD (P = 0.05)	NS	NS	NS	NS	0.06	0.05	0.04	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	S	S	S	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.13a: Interaction of weed management and seed rate on density of *Cyperus iria* (No. m^{-2}) at 30 DAS in broadcast direct seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**
W_1 :- *Biasi* method (Farmer's practice)	2.16 (4.20)	2.20 (4.37)	2.22 (4.43)	2.20 (4.37)	2.26 (4.60)	2.31 (4.83)	2.18 (4.28)	2.23 (4.48)	2.26 (4.63)
W_2 :- Two hand weeding at 20 & 40 DAS	1.16 (0.63)	1.27 (1.12)	1.33 (1.28)	1.14 (0.82)	1.27 (1.12)	1.49 (1.73)	1.13 (0.73)	1.27 (1.12)	1.41 (1.15)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	1.18 (0.89)	1.15 (0.82)	1.17 (0.88)	1.21 (0.97)	1.18 (0.90)	1.31 (1.22)	1.19 (0.93)	1.16 (0.86)	1.21 (1.05)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.42 (1.52)	1.52 (1.81)	1.52 (1.83)	1.46 (1.64)	1.55 (1.89)	1.60 (2.05)	1.44 (1.58)	1.53 (1.85)	1.56 (1.94)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	1.47 (1.67)	1.34 (1.30)	1.34 (1.30)	1.47 (1.67)	1.34 (1.30)	1.46 (1.63)	1.47 (1.67)	1.34 (1.30)	1.40 (1.47)
W_6 :- Weedy check	2.25 (4.57)	2.26 (4.60)	2.26 (4.60)	2.48 (5.67)	2.43 (5.43)	2.35 (5.00)	2.37 (5.12)	2.34 (5.02)	2.30 (4.80)
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.05	0.16		0.05	0.15		0.04	0.12	
Comparison of two weed management means at the same or different level of seed rate	0.02	0.06		0.02	0.06		0.02	0.05	

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

4.3.3.4 *Cyanotis axillaris* (No m^{-2})

The data on density of *Cyanotis axillaris* at different time interval are presented in Table 4.14 in case of *Cyanotis axillaris* at 15 DAS, the minimum density of weed was found in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with (W_5)pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS. However, the maximum density of *Cyanotis axillaris* was found in the un-weeded control which was at par with the *biasi* method. Application of pre-emergence herbicides oxadiargyl and pyrazosulfuron sand mix control the *Cyanotis axillaris* effectively at early growth period. Jadhav *et al.* (2008) and Kurmi (2008) reported that the pre-emergence application of oxadiargyl and pyrazosulfuron are equally effective to control both monocot and dicot weeds.

At 30 DAS, among different weed management practices significantly lowest density of *Cyanotis axillaris* was found under the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS ,which was at par with the (W_2) two hand weeding at 20 and 40 DAS. Due to no *biasi* up to the 30 DAS weed population was high in *biasi* method. Jadhav *et al.* (2008) also reported that the pre-emergence application of oxadiargyl effectively control the weed at early stage of crop growth followed by post-emergence application of bispyribac control the late coming weeds.

At 45 DAS, minimum weed population of *Cyanotis axillaris* was under the *biasi* treatment. *Biasi* or beushening is a cultural practices of cross-plowing in the direct seeded broadcast rice after that pulling of weeds and redistribution of seedling of rice plant was done. This practice looses the soil, control weeds, improves water use efficiency, improves tillering and nutrient uptake, reduces insect pest and helps redistribute seedlings. Although *biasi* operation is labour demanding and costly operation, and labour are not available at peak time for the *biasi* operation at village. But sequential application of pre-emergence and post-emergence herbicide were equally effective as that of biasi operation which is not

labour dependent and costly as the *biasi* method. The maximum weed population of *Cyanotis axillaris* was found under the weedy check.

Similar trend continued up to at 60 and at harvest. *Biasi* method was found minimum weed density in both the interval and in both the year which was equal to hand weeding and chemical control (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS . The maximum population was found under the un-weeded control method which finally affects the seed yield. Saha *et al.* (2005), also observed that the maximum yield reduction due to weeds up to 41 per cent in direct seeded broadcasted rice as compared to hand weeding.

Among different seed rates at 15 DAS, there was non significant effect on density of *Cyanotis axillaris* but there was slightly lower weed density under 40 Kg ha^{-1} seed rate as compared to the other seeding treatments. However, minimum weed density was recorded under 120 kg ha^{-1} seed rate which was equal to 80 kg ha^{-1} and 40 kg ha^{-1} seed rates in all the growth stage in both the year. Interaction between weed management and seed rate was non significant in both the year.

4.3.3.5 Other weeds species (No m^{-2})

The data on density of other species at different time interval are presented in Table 4.15 different weed management options showed significant variation in other weed species density at all the observational stage of rice in both the year.

At 15 DAS, higher weed density was observed under the *biasi* method, two hand weeding and weedy check which were on par with each other. However, significantly lower number of other weed species was found under the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment which was at par with (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS at early growth stage of crop in both the year. At 30 DAS, sequential spray of pre and post-emergence application of herbicides effectively control the weeds, so that the minimum weed population of other weeds were found under the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment

which was at par with the other chemical and hand weeding treatments in both the year. The maximum population of other weed was found under the weedy control plot which was at par with *biasi* treatment. *Biasi* operation was done at 40 DAS in 2014 and it was done after the 37 DAS in 2014. In case of weed management options, at 45 DAS, higher number of weed were observed under weedy check (W_6). Whereas, minimum number of other weeds were observed under the treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during the 2013 and during 2014 it was in (W_2) two hand weeding twice. Very marginal difference was found in all the weed management treatmentsduring both the years except the weedy check.

During the investigation at 60 DAS, and at harvest the significantly lower number of other weed *spp*. was found in *biasi* method which was at par with two hand weeding and other chemical weed control treatments. However, the marginal difference was observed in *biasi*, hand weeding and chemical control during the advance crop growth stage. Among the chemical method of weed control, treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS ,was superior over the other chemical method. The difference between the biasi and sequential application of herbicides is very marginal so the chemical method may be the alternative of *biasi* method in respect of weed control.

Among the seeding rates in all the crop growth stage was found non-significant effect on the other weed spp. However, the minimum weeds were found in the 120 kg ha^{-1} seed rates which were nearly equal to 80 kg ha^{-1} and 40 kg ha^{-1} seed rates. It is self explanatory that the seed rates did not influence the weeds during the experimentation.

Interaction effect due to weed managements and seed rates on weed density of other weed species was non significantly at 15,30,45 60 DAS whereas it was found significant at harvest (4.15a) .Minimum density of other weeds was recorded under the combination of 120 kg seed rate ha^{-1} with *biasi* operation (S_1x W_1) during both the yeards.

Table 4.14: Density of *Cynotis axillaris* (No. m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Density of *Cynotis axillaris* (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	2.41 (5.39)	2.36 (5.07)	2.38 (5.23)	2.79 (7.39)	2.70 (6.89)	2.74 (7.14)	1.28 (1.19)	1.46 (1.62)	1.37 (1.41)	1.65 (2.24)	1.71 (2.65)	1.71 (2.45)	1.89 (3.08)	1.79 (2.69)	1.84 (2.88)
W_2 :- Two hand weeding at 20 & 40 DAS	2.30 (4.83)	2.40 (5.27)	2.35 (5.05)	1.44 (1.59)	1.49 (1.73)	1.46 (1.66)	1.24 (1.06)	1.47 (1.65)	1.35 (1.35)	1.73 (2.51)	1.89 (3.07)	1.81 (2.79)	1.99 (3.48)	1.79 (2.72)	1.89 (3.10)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	1.39 (1.46)	1.49 (1.77)	1.44 (1.61)	1.37 (1.41)	1.37 (1.41)	1.37 (1.41)	1.67 (2.31)	1.79 (2.69)	1.73 (2.50)	1.81 (2.79)	1.87 (3.00)	1.84 (2.90)	2.08 (3.84)	1.82 (2.83)	1.95 (3.34)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.76 (2.65)	1.70 (2.46)	1.73 (2.56)	1.73 (2.52)	1.78 (2.67)	1.75 (2.59)	1.94 (3.30)	1.93 (3.23)	1.93 (3.26)	2.24 (4.54)	2.04 (3.68)	2.14 (4.11)	2.47 (5.63)	1.90 (3.12)	2.18 (4.38)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	1.49 (1.74)	1.43 (1.57)	1.46 (1.65)	1.48 (1.72)	1.54 (1.89)	1.51 (1.81)	1.75 (2.58)	1.80 (2.76)	1.77 (2.67)	1.89 (3.08)	1.87 (3.02)	1.88 (3.05)	2.13 (4.04)	1.81 (2.77)	1.97 (3.41)
W_6 :- Weedy check	2.50 (5.78)	3.78 (6.17)	2.54 (5.97)	2.87 (7.78)	3.03 (8.67)	2.95 (8.22)	3.00 (8.52)	3.26 (10.11)	3.13 (9.31)	3.59 (12.44)	3.43 (11.30)	3.51 (11.87)	4.11 (16.44)	3.69 (13.11)	3.90 (14.78)
SEm±	0.05	0.08	0.03	0.09	0.07	0.07	0.04	0.03	0.03	0.04	0.02	0.02	0.03	0.02	0.02
CD (P = 0.05)	0.15	0.17	0.11	0.27	0.21	0.23	0.13	0.11	0.10	0.13	0.07	0.07	0.11	0.07	0.07
Seed rate (kg ha^{-1})															
S_1 :- 120	2.04 (3.93)	2.03 (3.86)	2.03 (3.90)	1.98 (3.92)	1.99 (3.91)	1.98 (3.91)	1.74 (2.87)	1.95 (3.68)	1.84 (3.27)	2.09 (4.26)	2.08 (4.14)	2.08 (4.20)	2.40 (5.76)	2.10 (4.41)	2.25 (5.08)
S_2 :- 80	1.93 (3.48)	2.00 (3.73)	1.96 (3.61)	1.89 (3.55)	1.95 (3.76)	1.92 (3.65)	1.75 (2.96)	1.95 (3.65)	1.85 (3.31)	2.14 (4.61)	2.14 (4.45)	2.14 (4.53)	2.44 (6.10)	2.12 (4.44)	2.28 (5.27)
S_3 :- 40	1.95 (3.51)	1.95 (3.56)	1.95 (3.53)	1.97 (3.74)	2.01 (3.96)	1.99 (3.85)	1.95 (3.64)	1.96 (3.71)	1.95 (3.68)	2.23 (4.94)	2.21 (4.76)	2.22 (4.85)	2.50 (6.40)	2.18 (4.78)	2.34 (5.59)
SEm±	0.04	0.05	0.04	0.03	6.01	0.01	0.06	0.03	0.04	0.03	0.03	0.01	0.02	0.02	0.01
CD (P = 0.05)	NS	NS	NS	NS	0.11	0.05	NS	NS	NS	NS	NS	NS	0.06	0.06	0.05
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.15: Density of other weeds (No. m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Density of other weeds (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	1.98 (4.00)	2.13 (4.06)	2.05 (4.03)	2.48 (6.00)	2.52 (5.87)	2.5 (5.93)	1.78 (2.70)	1.85 (2.93)	1.81 (2.81)	2.25 (4.59)	2.34 (5.01)	2.29 (4.80)	2.49 (5.78)	2.57 (6.10)	2.53 (5.94)
W_2 :- Two hand weeding at 20 & 40 DAS	2.06 (3.77)	2.16 (4.20)	2.11 (3.98)	1.52 (1.85)	1.60 (2.09)	1.56 (1.97)	1.77 (2.65)	1.72 (2.48)	1.74 (2.56)	2.54 (6.08)	2.46 (5.56)	2.5 (5.82)	2.48 (5.70)	2.70 (6.81)	2.59 (6.26)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	1.01 (0.74)	1.33 (1.29)	1.17 (1.01)	1.25 (1.22)	1.45 (1.74)	1.35 (1.48)	1.00 (2.83)	1.90 (3.18)	1.85 (3.01)	2.58 (6.19)	2.65 (6.60)	2.61 (6.39)	2.53 (5.91)	2.65 (6.96)	2.59 (6.44)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at	1.35 (1.44)	1.38 (1.54)	1.36 (1.49)	1.57 (2.04)	1.67 (2.35)	1.62 (2.19)	2.02 (3.61)	2.10 (3.98)	2.05 (3.80)	2.64 (6.60)	2.75 (7.07)	2.69 (6.84)	2.62 (6.39)	2.70 (7.70)	2.66 (7.04)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	1.25 (1.18)	1.34 (1.44)	1.29 (1.31)	1.54 (1.93)	1.60 (2.09)	1.57 (2.01)	1.80 (2.85)	1.98 (3.48)	1.89 (3.17)	2.61 (6.35)	2.57 (6.11)	2.59 (6.23)	2.57 (6.26)	2.65 (6.53)	2.61 (6.40)
W_6 :- Weedy check	2.10 (4.01)	2.13 (4.07)	2.11 (4.04)	2.64 (6.51)	2.59 (6.27)	2.61 (6.39)	3.76 (13.67)	3.83 (14.22)	3.79 (13.94)	4.22 (17.33)	4.21 (17.22)	4.21 (17.28)	4.43 (19.11)	4.39 (18.78)	4.41 (18.94)
SEm±	0.15	0.08	0.10	0.12	0.07	0.08	0.10	0.06	0.08	0.10	0.07	0.06	0.09	0.17	0.07
CD (P = 0.05)	0.49	0.26	0.32	0.39	0.23	0.27	0.33	0.19	0.24	0.31	0.21	0.20	0.28	0.54	0.22
Seed rate (kg ha^{-1})															
S_1 :- 120	1.50 (2.01)	1.66 (2.49)	1.58 (2.25)	1.71 (2.64)	1.89 (3.30)	1.8 (2.97)	2.17 (4.75)	2.21 (4.90)	2.19 (4.83)	2.76 (7.67)	2.71 (7.27)	2.73 (7.47)	2.80 (7.86)	2.73 (7.82)	2.76 (7.84)
S_2 :- 80	1.60 (2.55)	1.74 (2.80)	1.67 (2.68)	1.79 (3.28)	1.86 (3.31)	1.82 (3.29)	2.08 (4.51)	2.18 (4.91)	2.13 (4.71)	2.85 (8.01)	2.86 (8.09)	2.85 (8.05)	2.80 (7.90)	3.04 (9.20)	2.92 (8.55)
S_3 :- 40	1.78 (3.01)	1.84 (3.00)	1.81 (3.01)	1.99 (3.86)	1.89 (3.60)	1.94 (3.73)	2.21 (4.89)	2.31 (5.33)	2.26 (5.11)	2.81 (7.89)	2.92 (8.43)	2.86 (8.16)	2.96 (8.81)	3.06 (9.42)	3.01 (9.11)
SEm±	0.08	0.06	0.07	0.06	0.03	0.04	0.06	0.06	0.06	0.10	0.03	0.05	0.04	0.06	0.02
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.12	NS	NS	0.03	0.09
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x} + 0.5$

Table 4.15a: Interaction of weed management and seed rate on density of other weeds (No. m^{-2}) at harvest in broadcast direct seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**
W_1 :- *Biasi* method (Farmer's practice)	2.22 (4.44)	2.59 (6.22)	2.67 (6.67)	2.52 (5.87)	2.60 (6.27)	2.58 (6.17)	2.37 (5.16)	2.60 (6.24)	2.63 (6.42)
W_2 :- Two hand weeding at 20 & 40 DAS	2.39 (5.21)	2.39 (5.23)	2.65 (6.67)	2.64 (6.50)	2.76 (7.12)	2.70 (6.80)	2.52 (5.86)	2.57 (6.18)	2.68 (6.73)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	2.50 (2.77)	2.46 (5.53)	2.63 (6.43)	2.68 (7.56)	2.78 (7.56)	2.48 (5.78)	2.59 (6.66)	2.62 (6.54)	2.56 (6.11)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	2.69 (6.73)	2.58 (6.21)	2.58 (6.21)	2.63 (6.67)	3.12 (9.44)	3.35 (11.00)	2.16 (4.70)	2.85 (7.83)	2.97 (8.61)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	2.61 (6.33)	2.32 (4.89)	2.79 (7.56)	2.61 (6.33)	2.64 (6.50)	2.70 (6.77)	2.61 (6.33)	2.48 (5.69)	2.74 (7.16)
W_6 :- Weedy check	4.38 (18.67)	4.45 (19.33)	4.45 (19.33)	4.30 (18.00)	4.34 (18.33)	4.53 (20.00)	4.34 (18.33)	4.40 (18.83)	4.49 (19.67)
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.13	0.40		0.21	0.64		0.12	0.35	
Comparison of two weed management means at the same or different level of seed rate	0.05	0.14		0.08	0.25		0.04	0.13	

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

4.3.4 Total weed dry weight (g m^{-2})

The data on total weed dry matter accumulation at different time interval are presented in Table 4.16 reveals that weed management practices proved significant effect on total dry matter accumulation of weeds. In general, the increased density of weeds enhanced dry matter accumulation of weeds per unit area. Among different weed management practices at 15 DAS, significantly lowest weed dry weight was found under the pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3) in year 2013 but was at par with W_5 and W_4.Whereas, it was lower in (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS during 2014. However, all pre-emergence application of herbicide (W_3, W_4 and W_5) equally influenced the dry matter of weeds during both the year. However, maximum dry matter was found in (W_6) weedy check method which was at par with *biasi* method (W_1) and hand weeding (W_2).

Statistical analysis of data on different weed management practices revealed that at 30 DAS, minimum dry weight of weed was found under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment which was at par with the hand weeding twice (W_2). Sequential application of oxadiargyl and pyrazosulfuron followed by bispyribac are as effective as hand weeding . However, due to delayed *biasi* operation, weed dry weight was high in *biasi* method during this stage. *Biasi* operation was done at 45 DAS in 2013 and 37 DAS in 2014 looking to the sufficient precipitation for the *biasi* operation. Whereas, the *biasi* operation perform superior in later stage of crop growth, and produced the minimum dry matter after the 45 DAS up to the harvest. Chandra *et al.* (1998) found that the lowest weed density and dry weight was achieved by manual weeding at 25 and 40 DAS.

At 45 DAS, significantly lower weed dry weight was recorded under (W_1) *biasi* method which was at par with hand weeding twice. Among the chemical weed management (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was found superior over the other chemical control treatment. However, *biasi* method was statistically superior over the chemical control in both

the year, but difference was marginal in total dry weight after the 45 DAS to harvest in respect to *biasi* method and hand weeding twice. Although the maximum weed dry weight was found in weedy check (W_6) up to the harvest. Weedy check plot was found full of weeds, which reduces the growth of rice plant and grain yield. Venkateswarlu (1999) concluded tht *beushening* suppresses weeds, leads root pruning and incorporates weeds and excess rice seedlings as green manure for the standing crops. Jadhav *et al.* (2008), Khaliq *et al.* (2011) reveals that the application of bispyribac-Na as post-emergence controls the weed effectively. Mamun *et al.* (2011) founds that herbicides of pyrazosulfuron ethyl and oxadiargyl group control weeds above 80% using recommended dose. Accordingly it can be concluded that sequential application of pre and post-emergence application may be the alternative of *biasi* method.

Similar result like 45 DAS was found in 60 DAS and up to harvesting stage, significantly weed dry weight was recorded under the *biasi* method which was at par with the hand weeding treatment. During investigation, marginal difference was noted in the *biasi* method, hand weeding and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS at both the stage and both the year. However, at harvest maximum weed dry weight was found in weedy check method which explains that, if weeding is not done in the direct seeded rice it will reduce the grain yield up to the 68 to 100 percent (Mamun ,1990).

Among different seed rates there was no significant effect on dry weight at all the crop growth stage in both the years. However, at 60 DAS and harvest minimum weed dry weight was found in 120 kg ha^{-1} seed rate followed by 80 kg ha^{-1} and 40 kg ha^{-1} seed rate. Rao *et al.* (2007) found that increased seeding rates of crop suppress weed growth and reduces grain yield losses from weed competition. However, it is not necessary to use high seeding rates to suppress weeds in DSR, if effective herbicides are used. Interaction between the weed control method and seed rates was found significantly at par at all the growth stage in both the years.

Table 4.16: Dry matter of total weeds (g m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Dry matter of total weeds (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	4.45 (19.93)	4.81 (23.54)	4.63 (21.74)	10.88 (118.01)	11.55 (133.34)	11.21 (125.67)	4.94 (24.54)	5.35 (28.59)	5.15 (26.56)	5.20 (26.92)	5.69 (35.32)	5.44 (31.12)	7.56 (57.33)	7.75 (59.88)	7.65 (58.60)
W_2 :- Two hand weeding at 20 & 40 DAS	4.08 (16.53)	4.88 (23.47)	4.48 (20.00)	3.31 (10.61)	3.72 (13.47)	3.51 (12.04)	5.19 (26.89)	5.85 (30.92)	5.54 (28.90)	6.12 (37.56)	6.89 (40.50)	6.25 (39.03)	7.92 (63.49)	8.07 (65.09)	7.13 (64.29)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	2.11 (4.04)	2.54 (6.07)	2.32 (5.05)	3.19 (9.69)	3.56 (12.23)	3.37 (10.96)	6.03 (36.50)	6.84 (46.64)	6.43 (41.57)	6.73 (45.01)	7.05 (49.57)	6.89 (47.29)	8.76 (76.56)	8.95 (79.99)	8.85 (78.28)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	2.43 (5.58)	2.97 (8.46)	2.07 (7.02)	3.89 (14.63)	4.20 (17.23)	4.04 (15.93)	7.16 (50.93)	7.38 (54.08)	7.37 (52.50)	7.87 (61.64)	8.24 (67.57)	8.07 (64.60)	10.33 (106.74)	10.31 (106.35)	10.32 (106.54)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25	2.18 (4.35)	2.41 (5.50)	2.29 (4.92)	3.49 (11.67)	3.77 (13.78)	3.63 (12.72)	6.35 (40.03)	7.38 (54.13)	6.86 (47.08)	7.38 (55.19)	7.27 (52.67)	7.32 (53.93)	9.20 (84.48)	8.87 (78.53)	9.03 (81.50)
W_6 :- Weedy check	4.75 (22.58)	5.09 (25.75)	4.92 (24.17)	11.50 (132.01)	12.12 (5.09)	11.81 (139.86)	16.80 (282.02)	17.76 (308.64)	17.28 (295.33)	17.76 (315.02)	18.07 (326.34)	17.91 (320.68)	20.36 (414.56)	21.20 (449.55)	20.78 (432.06)
SEm±	0.13	0.13	0.09	0.09	0.27	0.17	0.15	0.18	0.13	0.4	0.13	0.14	0.11	0.14	0.08
CD (P = 0.05)	0.42	0.44	0.29	0.29	0.85	0.53	0.47	0.56	0.41	0.66	0.4	0.44	0.34	0.45	0.26
Seed rate (kg ha^{-1})															
S_1 :- 120	3.22 (11.40)	3.73 (15.03)	3.47 (13.21)	5.88 (46.95)	6.24 (51.99)	6.07 (49.47)	7.63 (75.39)	8.04 (81.72)	7.83 (78.55)	8.25 (86.35)	8.56 (89.93)	8.40 (88.14)	10.49 (130.24)	10.49 (130.57)	10.49 (130.40)
S_2 :- 80	3.35 (12.37)	3.74 (15.25)	3.54 (13.81)	6.02 (49.23)	6.34 (57.92)	6.28 (53.58)	7.58 (74.52)	8.45 (88.65)	8.04 (81.59)	8.65 (92.85)	8.89 (96.88)	8.77 (94.86)	10.71 (134.20)	11.03 (143.88)	10.87 (139.04)
S_3 :- 40	3.44 (12.74)	3.87 (16.12)	3.66 (14.43)	6.22 (52.13)	6.68 (58.96)	6.45 (55.55)	8.03 (80.54)	8.56 (91.13)	8.29 (85.83)	8.64 (91.47)	9.04 (99.18)	8.84 (95.33)	10.89 (137.13)	11.03 (145.25)	10.97 (141.19)
SEm±	0.06	0.06	0.04	0.05	0.11	0.06	0.19	0.13	0.14	0.14	0.04	0.07	0.12	0.14	0.12
CD (P = 0.05)	NS	NS	NS	0.21	NS	NS	NS	NS	NS	NS	5.16	NS	NS	0.54	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

4.3.5 Species-wise weed dry matter (g m^{-2})

4.3.5.1 *Echinochloa colona* (g m^{-2})

The data on weed dry weight of *Echinochloa colona* at different time interval are presented in Table 4.17 among different weed management practices at 15 DAS, the maximum dry weight of *Echinochloa colona* was recorded under weedy check method which was at par with *biasi* and hand weeding. However, application of pre-emergence herbicides oxadiargyl and pyrazosulfuron controls the *Echinochloa colona* effectively. Similar result was also found by Saini (2003) and Chopra and Chopra (2003).

At 30 DAS, significantly lower weed dry weight was observed in two hand weeding (W_2). However, it was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment. Whereas, the maximum dry matter was found in un-weeded controls plot.

During the 45, 60 DAS and at harvest, similar trend was recorded, where minimum dry weight production of *Echinochloa colona* was recorded under *biasi* method (W_1), which was significantly superior over rest of the treatments, but it was at par with hand weeding twice (W_2) followed by (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS , (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatments. However, the maximum dry weight of *Echinochloa colona* was in un-weeded control plot.

Among different seed rate, at all the growth period in both the year, minimum weed dry matter of *Echinochloa colona* was recorded under 120 kg ha^{-1} which was significantly lower over rest of seed rates but nearly equal to 80 kg ha^{-1} and 40 kg ha^{-1} seed rates. Phuving *et al.* (2005) concluded that, seeding rate was inversely correlated to weed interference. However, Rao *et al.* (2007) reveals that it is not necessary to use high seed rates to suppress weeds in DSR.

Table 4.17: Dry matter of *Echinochloa colona* (g m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Dry matter of *Echinochloa colona* (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
V_1 :- *Biasi* method (Farmer's practice)	3.76 (14.56)	3.92 (16.24)	3.08 (15.40)	9.11 (82.77)	3.54 (90.79)	6.32 (86.78)	4.08 (16.80)	4.36 (19.06)	4.22 (17.93)	2.24 (5.03)	2.32 (5.15)	2.28 (5.09)	2.41 (5.76)	2.50 (5.90)	2.45 (5.83)
V_2 :- Two hand weeding at 20 & 40 DAS	1.86 (11.74)	3.91 (15.11)	7.33 (13.42)	2.32 (5.02)	2.67 (6.74)	2.49 (5.88)	4.29 (18.78)	4.66 (21.59)	4.47 (20.19)	2.85 (9.03)	2.43 (5.70)	2.64 (7.36)	2.62 (6.48)	2.51 (6.06)	2.56 (6.27)
V_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 2	2.06 (3.07)	2.33 (5.02)	2.09 (4.05)	2.45 (5.51)	2.71 (6.87)	2.58 (6.19)	4.43 (20.18)	5.29 (27.92)	4.86 (24.05)	3.14 (9.52)	2.75 (7.79)	2.94 (8.66)	2.87 (7.88)	2.72 (7.23)	2.79 (7.56)
V_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.93 (4.01)	2.72 (7.03)	2.39 (5.52)	2.91 (7.98)	3.22 (9.92)	3.06 (8.95)	5.38 (28.68)	5.43 (28.99)	5.40 (28.84)	3.16 (9.56)	2.86 (7.87)	3.01 (8.71)	3.06 (8.89)	2.42 (5.85)	2.74 (7.37)
V_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25	4.01 (3.38)	2.16 (4.41)	2.04 (3.90)	2.53 (5.93)	2.86 (7.73)	2.69 (6.83)	4.71 (22.01)	5.74 (32.65)	5.22 (27.33)	3.39 (15.09)	2.65 (7.81)	3.52 (11.45)	2.89 (7.94)	2.91 (8.72)	2.9 (8.33)
V_6 :- Weedy check	4.53 (16.25)	4.24 (17.90)	4.17 (17.08)	9.68 (93.53)	5.89 (98.95)	7.78 (96.24)	13.43 (180.11)	13.71 (187.78)	13.57 (183.94)	11.12 (123.27)	10.41 (108.46)	10.76 (115.87)	8.53 (72.58)	9.44 (89.72)	8.98 (81.15)
SEm±	0.17	0.14	0.13	0.09	0.32	0.13	0.13	0.17	0.14	0.42	0.4	0.29	0.16	0.30	0.19
CD (P = 0.05)	0.53	0.43	0.40	0.30	0.72	0.41	0.59	0.55	0.45	1.33	0.65	0.90	0.51	0.94	0.60
Seed rate (kg ha^{-1})															
S_1 :- 120	2.74 (8.33)	3.20 (10.81)	2.97 (9.57)	4.69 (32.05)	4.91 (33.64)	4.80 (32.85)	5.97 (47.24)	6.21 (48.33)	6.09 (47.79)	4.09 (26.00)	3.84 (21.96)	3.96 (23.98)	3.75 (19.29)	3.62 (18.93)	3.68 (19.11)
S_2 :- 80	2.86 (9.08)	3.14 (10.69)	3.00 (9.89)	4.82 (33.27)	5.32 (39.65)	2.07 (36.46)	5.90 (45.77)	6.70 (54.88)	6.3 (50.32)	4.37 (30.61)	3.84 (24.91)	4.10 (27.76)	3.76 (18.11)	3.37 (22.14)	3.14 (20.13)
S_3 :- 40	2.93 (9.09)	3.30 (11.35)	3.11 (10.22)	4.99 (35.04)	5.21 (37.21)	5.1 (36.13)	6.30 (50.27)	6.68 (55.79)	6.49 (53.03)	4.49 (29.14)	4.03 (24.51)	4.26 (26.83)	3.68 (17.36)	3.90 (20.67)	3.79 (19.02)
SEm±	0.08	0.08	0.05	0.05	0.08	0.05	0.24	0.13	0.63	0.20	0.22	.20	0.14	0.20	.15
CD (P = 0.05)	NS	NS	NS	0.18	0.31	0.21	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	S	S	NS	S	S	S	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

4.3.5.2 *Alternenthera triandra* (g m^{-2})

The data on dry weight of *Alternenthera triandra* at different time interval are presented in Table 4.18 among different weed management practices, at 15 DAS, pre-emergence application of herbicides produced significant impact on weed dry weight of *Alternenthra triandra.* Minimum dry weight of *Alternenthra triandra* was recoeded under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with (W_5) pre-emergence (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. However, the maximum dry weight of *Alternenthra triandra* was found in weedy check, during 2013, and it was maximum in hand weeding twice in year 2014. Whereas *biasi* method, hand weeding and weedy check produced equal dry matter at 15 DAS, this was due to no weed control practices were done at 15 DAS.

At 30 DAS, among different weed management practices, minimum dry weight of *Alternenthra triandra* was recorded under sequential application of pre-emergence oxadiargyl and post-emergence application of bispyribac Na at 25 DAS (W_3) which was significantly superior over rest of the treatment, but it was at par with (W_2) two hand weeding, (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment. However, the maximum infestation of *spp*. was in *biasi* method and weedy check during this stage.

During 45 DAS, two hand weeding at 20 and 40 DAS (W_2) produced lowest weed dry weight, which was significantly lower than other, but it was found at par with *biasi* method (W_1). Among the herbicide application, treatments (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS produced the minimum dry weight of *Alternenthra triandra* which was nearly equal to the hand weeding and *biasi* method. Jadhav *et al.* (2008) also supported that application of pre-emergence oxadiargyl effectively controls the weeds at

early stage of crop growth followed by post-emergence application of bispyribac-Na control the new coming weeds.

At 60 DAS and at harvest, the lowest weed dry weight was observed under the treatment *biasi* method and found significantly superior over other treatment but, it was at par with (W_2) two hand weeding in both the year and both the interval. However, the maximum dry weight of weed was recorded under the un-weeded control (W_6) . Treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS was very near to the hand weeding and *biasi* method in respect to dry weight of *Alternenthra triandra* . Kiran (2010) observed that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} gave lowest density and dry weight of weeds with maximum weed control efficiency.

Among different seeding rates at both the year and different growth stages there was no remarkable difference between the high seed rate and low seed rate in respect to dry weight of *Alternenthra triandra*. However, the minimum dry weight was recorded under the 120 kg ha^{-1} seed rate followed by 80 kg ha^{-1} and 40 kg ha^{-1} seed rates.

Interaction between the weed management and seed rates was found non-significant during 15, 30, 45 and 60 DAS both the year of investigation but it shows significant at harvest during both the year (Table 4.18a). Significantly, minimum dry weight of *Alternenthra triandra* m^{-2} was recorded in the combination of (S_1 x W_1) 120 kg seed rate ha^{-1} with *biasi* method and was at par with the *biasi* and 80 and 40 kg $^{-1}$ seed rate. Among chemical control method minimum density of *Alternenthra triandra* was recorded under the combination of (S_3 x W_3) 40 kg seed rate ha^{-1} with the application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and at par with same herbicide application with 120 and 80 kg ha^{-1} (S_2 x W_3) and (S_1 x W_3).

Table 4.18: Dry matter of *Alternanthra triandra* (g m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Dry matter of *Alternanthra triandra* (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	149 (1.81)	1.74 (2.55)	1.59 (2.18)	4.51 (19.89)	5.16 (26.45)	4.83 (23.17)	1.62 (2.20)	1.82 (2.93)	1.72 (2.57)	2.81 (7.49)	3.06 (8.93)	2.93 (8.21)	4.48 (20.03)	4.58 (20.89)	4.53 (20.46)
W_2 :- Two hand weeding at 20 & 40 DAS	1.39 (1.42)	2.19 (4.44)	1.79 (2.93)	1.54 (1.98)	1.74 (2.58)	1.64 (2.28)	1.57 (2.03)	1.65 (2.29)	1.61 (2.16)	3.03 (8.84)	3.22 (9.94)	3.12 (9.39)	4.80 (23.15)	4.97 (24.59)	4.88 (23.87)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	0.91 (0.35)	0.95 (0.42)	0.93 (0.38)	1.47 (1.71)	1.71 (2.48)	1.59 (2.10)	2.04 (3.68)	2.01 (3.57)	2.02 (3.63)	3.43 (11.34)	3.57 (11.82)	3.47 (11.58)	5.60 (31.20)	5.67 (31.95)	5.63 (31.58)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1}	1.04 (0.60)	0.97 (0.44)	1.00 (0.52)	1.72 (2.54)	1.91 (3.22)	1.81 (2.88)	2.43 (5.46)	2.52 (5.90)	2.47 (5.68)	4.27 (17.84)	4.41 (19.01)	4.37 (18.42)	6.97 (48.57)	7.17 (51.36)	7.07 (49.97)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	0.91 (0.33)	0.94 (0.39)	0.92 (0.36)	1.70 (2.45)	1.77 (2.65)	1.73 (2.55)	2.21 (4.43)	2.31 (4.88)	2.26 (4.65)	3.64 (12.78)	3.74 (13.55)	3.69 (13.16)	6.03 (36.21)	5.81 (33.59)	5.92 (34.90)
W_6 :- Weedy check	1.75 (2.60)	1.93 (3.26)	1.84 (2.93)	4.17 (17.15)	4.72 (22.27)	4.44 (19.71)	6.18 (38.00)	6.87 (46.88)	6.52 (42.44)	8.34 (69.38)	9.07 (80.85)	8.67 (75.11)	11.74 (139.22)	12.65 (160.50)	12.19 (149.86)
SEm±	0.04	0.11	0.06	0.09	0.12	0.09	0.13	0.11	0.12	0.11	0.09	0.09	0.23	0.17	0.61
CD (P = 0.05)	0.13	0.34	0.18	0.27	0.37	0.27	0.41	0.34	0.36	0.33	0.30	0.29	0.73	0.54	8.73
Seed rate (kg ha^{-1})															
S_1 :- 120	1.21 (1.07)	1.39 (1.68)	1.3 (1.38)	2.45 (7.05)	2.73 (9.04)	2.59 (8.04)	2.59 (8.81)	2.78 (10.78)	2.68 (9.79)	4.15 (20.37)	4.35 (23.05)	4.25 (21.71)	6.43 (47.30)	6.67 (51.47)	6.55 (49.38)
S_2 :- 80	1.24 (1.14)	1.47 (1.97)	1.35 (1.56)	2.55 (7.67)	2.75 (9.15)	2.65 (8.41)	2.75 (9.76)	2.90 (11.11)	2.82 (10.43)	4.35 (22.15)	4.49 (23.75)	4.42 (22.95)	6.72 (51.3))	6.84 (53.97)	6.78 (52.63)
S_3 :- 40	1.30 (1.34)	1.50 (2.09)	1.4 (1.72)	2.35 (8.14)	3.02 (11.64)	2.78 (9.89)	2.68 (9.33)	2.91 (11.34)	2.79 (10.33)	4.27 (921.32)	4.65 (25.26)	4.45 (23.29)	6.66 (50.59)	6.92 (56.01)	6.79 (53.30)
SEm±	0.03	0.02	0.02	0.06	0.10	0.07	0.07	0.06	0.06	0.06	0.05	0.04	0.07	0.07	0.07
CD (P = 0.05)	NS	0.08	NS	NS	NS	NS	NS	NS	NS	NS	0.20	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.18a: Interaction of weed management and seed rate on dry matter of *Alternanthra triandra* (g m^{-2}) at harvest in broadcast direct seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**
W_1 :- *Biasi* method (Farmer's practice)	4.20 (17.25)	4.51 (20.38)	4.75 (22.46)	4.28 (17.88)	4.44 (19.70)	5.02 (25.08)	4.24 (17.56)	4.47 (20.04)	4.88 (23.77)
W_2 :- Two hand weeding at 20 & 40 DAS	4.48 (19.83)	5.19 (27.08)	4.73 (22.54)	4.71 (21.92)	5.19 (27.08)	5.01 (24.77)	4.60 (20.88)	5.19 (27.08)	4.87 (23.65)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	5.71 (32.38)	5.73 (32.58)	5.35 (28.64)	5.84 (33.72)	5.73 (32.58)	5.45 (29.55)	5.40 (29.10)	5.73 (32.58)	5.78 (33.05)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	7.14 (50.92)	6.95 (48.08)	6.82 (46.71)	7.37 (54.03)	6.95 (48.08)	7.20 (51.97)	7.25 (52.48)	6.95 (48.08)	7.01 (49.34)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	5.92 (34.81)	6.12 (37.36)	6.06 (36.47)	5.98 (35.42)	6.12 (37.36)	5.32 (28.01)	5.95 (35.11)	6.12 (37.36)	5.69 (32.24)
W_6 :- Weedy check	11.47 (132.33)	11.85 (142.33)	11.90 (143.00)	12.23 (150.00)	12.59 (159.00)	13.12 (172.50)	11.85 (141.17)	12.22 (150.67)	12.51 (157.75)

	2013		2014		Mean	
	SEm±	**CD (P = 0.05)**	**SEm±**	**CD (P = 0.05)**	**SEm±**	**CD (P = 0.05)**
Comparison of two seed rate means at the same level of weed management	0.16	0.51	0.17	0.53	0.14	0.45
Comparison of two weed management means at the same or different level of seed rate	0.09	0.28	0.07	0.23	0.08	0.23

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

4.3.5.3 *Cyperus iria* (g m^{-2})

Data on dry weight of *Cyperus iria* at different time interval are presented in Table 4.19 weed management practices had remarkable effect on dry weight of *Cyperus iria* through-out the crop growth period in both the year. Weed management practices at 15 DAS, due to application of pre-emergence in the W_3, W_4 and W_5 had significant effect on dry weight of *Cyperus iria* at early growth period. However, minimum dry weight was recorded under the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment which was significantly superior over other treatment and next was (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. However, the maximum dry weight of *Cyperus iria* was recorded in weedy check (W_6) which was nearly equal to hand weeding (W_2) and *biasi* method (W_1).

At 30 DAS, there was a significant impact of sequential application of pre and post-emergence herbicides on dry weight of *Cyperus iria.* Treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was recorded minimum dry weight which was at par with hand weeding (W_2) (W_4) and (W_5). Among the herbicides treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was produced less dry matter as compared to other chemical control method, but it was at par with other treatments (W_4) and (W_5). However, Maximum dry matter was recorded under the un-weeded control plot.

Due to the *biasi* operation at 60 DAS and at harvest, dry weight of *Cyperus iria* was minimum in *biasi* method which was statistically superior over all the treatment, but it was at par with the (W_2) two hand weeding. Among the chemical treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was recorded the minimum dry weight and it was nearly equal to biasi method and hand weeding treatment. However, maximum dry weight of *Cyperus iria* was recorded under the un-weeded control plot. At harvest un-weeded control plot produced 4.79 q ha^{-1} dry weight of *Cyperus iria.* Whereas *biasi* method

produced 0.77 q ha^{-1} dry matter and difference between the dry matter of un-weeded control and *biasi* method was very vast. Un-weeded control produced 83% more dry matter which reflects on the yield of un weeded control plot. Whereas grain yield was 72% more in *biasi* method as compared to weedy condition.

Among different seed rates, there was no significant effect of seed rates on dry weight of *Cyperus iria* at all the growth period in both the year. However, the high dry weight was recorded in 40 kg ha^{-1} seed rate which was marginal high as compared to other seed rates. However, at the harvest dry weight of *Cyperus iria* was 1.46, 1.49 and 1.45 q ha^{-1} ,respectively from high seed rate to low seed rates. However, very marginal difference between high seed rate and low seed rate was noticed in respect to dry matter production of *Cyperus iria* and difference was less than 1% among all the seed rates in respect to dry weight production of *Cyperus iria* at harvest.

Interaction between the weed management and seed rates was found non-significant during 15, 45 , 60 DAS and harvest in both the year of investigation but it was significant at 30 DAS during both the year (Table 4.19a) significantly minimum dry weight of *Cyperus iria* m^{-2} was recorded in the combination of (S_2 x W_3) 80 kg seed rate ha^{-1} with application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS dring both the year and at par with the combination of 120 and 40 kg seed rate ha^{-1} with application of oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (S_1 x W_3), (S_3 x W_3) and the combination of (S_2 x W_5), (S_3 x W_5) application of 80 and 40 kg seed rate ha^{-1} with pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS during both the year. However, combination of (S_3 x W_6) 40 kg seed rate ha^{-1} with weedy check produced maximum dry weight of *Cyperus iria* was at par with the un weeded control plot with high seed rate 80 and 120 kg ha^{-1} during both the year.

4.3.5.4 *Cyanotis axillaris* (g m^{-2})

The data on dry weight of *Cyanotis axillaris* at different time interval are presented in Table 4.20, data revealed that weed management practices proved significantly superior over the un-weeded control at all the growth period in both

Table 4.19: Dry matter of *Cyperus iria* (g m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Dry matter of *Cyperus iria* (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	1.12 (0.75)	1.16 (0.84)	1.14 (0.80)	1.51 (1.78)	1.65 (2.23)	1.58 (2.00)	1.36 (1.38)	1.52 (1.85)	1.44 (1.61)	1.79 (2.85)	2.33 (4.99)	2.06 (3.92)	2.74 (7.31)	2.93 (8.17)	2.83 (7.74)
W_2 :- Two hand weeding at 20 & 40 DAS	1.08 (0.68)	1.11 (0.75)	1.09 (0.72)	1.08 (0.68)	1.16 (0.87)	1.12 (0.77)	1.13 (0.81)	1.27 (1.18)	1.20 (1.00)	1.86 (3.02)	2.33 (4.92)	2.09 (3.97)	2.73 (7.11)	2.27 (5.38)	2.50 (6.24)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	0.78 (0.11)	0.79 (0.13)	0.78 (0.12)	0.95 (0.40)	0.99 (0.48)	0.97 (0.44)	1.88 (3.07)	1.96 (3.36)	1.92 (3.21)	2.24 (4.53)	2.45 (5.51)	2.34 (5.02)	2.93 (8.16)	3.04 (9.86)	2.98 (9.01)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.84 (0.20)	0.84 (0.21)	0.84 (0.21)	1.11 (0.73)	1.15 (0.82)	1.13 (0.78)	2.03 (3.63)	2.10 (3.93)	2.06 (3.78)	2.52 (5.88)	3.15 (9.58)	2.83 (7.73)	3.22 (9.95)	3.27 (10.35)	3.24 (10.15)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25	0.82 (0.17)	0.83 (0.19)	0.82 (0.18)	1.06 (0.62)	1.08 (0.68)	1.07 (0.65)	2.01 (3.57)	2.05 (3.71)	2.03 (3.64)	2.22 (4.45)	2.50 (5.76)	2.36 (5.11)	2.91 (8.02)	2.42 (5.51)	2.66 (6.77)
W_6 :- Weedy check	1.17 (0.88)	1.27 (1.11)	1.22 0.99	2.18 (4.33)	2.41 (5.38)	2.29 (4.86)	3.84 (14.31)	4.12 (16.54)	3.98 (15.42)	5.15 (26.14)	5.70 (32.03)	5.42 (29.09)	6.79 (45.70)	7.10 (50.12)	6.94 (47.91)
SEm±	0.03	0.03	0.06	0.10	0.07	0.08	0.11	0.06	0.08	0.02	0.09	0.08	0.14	0.20	0.10
CD (P = 0.05)	0.09	0.11	0.19	0.30	0.23	0.26	0.33	0.19	0.25	0.21	0.29	0.28	0.43	0.65	0.30
Seed rate (kg ha^{-1})															
S_1 :- 120	0.96 (0.44)	0.98 (0.50)	0.97 (0.47)	1.29 (1.36)	1.41 (1.82)	1.35 (1.59)	2.01 (4.39)	2.14 (5.05)	2.07 (4.72)	2.60 (7.86)	3.11 (10.65)	2.85 (9.25)	3.51 (14.32)	3.49 (14.60)	3.43 (14.46)
S_2 :- 80	0.97 (0.47)	0.99 (0.51)	0.98 (0.49)	1.32 (1.45)	1.36 (1.58)	1.34 (1.51)	2.04 (4.47)	2.15 (5.01)	2.09 (4.74)	2.60 (7.61)	3.11 (10.76)	2.85 (9.18)	3.52 (14.18)	3.59 (15.69)	3.55 (14.93)
S_3 :- 40	0.98 (0.49)	1.03 (0.61)	1.00 (0.55)	1.33 (1.47)	1.45 (1.83)	1.39 (1.65)	2.07 (4.52)	2.22 (5.21)	2.14 (4.87)	2.69 (7.96)	3.00 (9.98)	2.84 (8.97)	3.62 (14.63)	3.45 (14.40)	3.53 (14.52)
SEm±	0.01	0.01	0.01	0.01	0.03	0.04	0.02	0.04	0.03	0.04	0.06	0.07	0.04	0.20	0.05
CD (P = 0.05)	NS	NS	NS	NS	0.11	NS	0.09	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	S	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.19a: Interaction of weed management and seed rate on dry matter of *Cyperus iria* (g m^{-2}) at 30 DAS in broadcast direct seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**
W_1 :- *Biasi* method (Farmer's practice)	1.48 (1.71)	1.51 (1.81)	1.52 (1.83)	1.69 (2.39)	1.54 (1.88)	1.70 (2.42)	1.59 (2.05)	1.53 (1.84)	1.61 (2.12)
W_2 :- Two hand weeding at 20 & 40 DAS	0.96 (0.42)	1.12 (0.76)	1.16 (0.85)	1.06 (0.62)	1.12 (0.76)	1.31 (1.22)	1.01 (0.52)	1.12 (0.76)	1.23 (1.03)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	0.95 (0.41)	0.94 (0.38)	0.96 (0.42)	0.97 (0.44)	0.97 (0.44)	1.03 (0.56)	0.96 (0.42)	0.95 (0.41)	0.99 (0.49)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.07 (0.65)	1.13 (0.78)	1.12 (0.76)	1.13 (0.79)	1.14 (0.81)	1.17 (0.86)	1.10 (0.72)	1.14 (0.80)	1.14 (0.81)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	1.11 (0.73)	1.04 (0.58)	1.03 (0.56)	1.11 (0.73)	1.04 (0.52)	1.11 (0.73)	1.11 (0.73)	1.04 (0.58)	1.07 (0.65)
W_6 :- Weedy check	2.17 (4.25)	2.18 (4.37)	2.18 (4.37)	2.52 (5.97)	2.34 (5.02)	2.37 (5.17)	2.34 (5.11)	2.26 (4.70)	2.28 (4.77)
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.04	0.11		0.07	0.21		0.09	0.23	
Comparison of two weed management means at the same or different level of seed rate	0.03	0.10		0.04	0.14		0.26	0.12	

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

the year. At 15 DAS, the minimum dry weight of *Cyanotis axillaris* was recorded under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. However, the maximum dry matter was found under the weed check in year 2013 but it was maximum in (W_1) *biasi* method during year 2014. Although at 15 DAS *biasi* method, two hand weeding and, weedy check produced the equal dry matter of *Cynotis axillaris* due to no weed management done in this period. Data itself explains that application of pre-emergence herbicide is effective against the *Cynotis axillaris*. Similar result was revealed by the Jadhav *et al.* (2008) and Kurmi (2008).

During 30 DAS, among different weed management practices, significantly low dry matter of *Cyanotis axillaris* was recorded under two hand weeding at 20 and 40 DAS in year 2013. However, it was minimum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in year 2014. Although all the weed management practices was found at par with each other during this period. So we can say that the combination of pre and post-emergence with proper dose and time of application is equally effective as hand weeding twice.

At 45 DAS significantly low dry matter of *Cyanotis axillaris* was recorded under two hand weeding method during 2013 and it was at par with *biasi* method. However, it was vice-versa in year 2014 which was at par with the hand weeding method. Among the chemical control method, (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was recorded the less dry weight in both the year which was at par with (W5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS.

During advancement of crop growth period at 60 DAS and at harvest significantly lowest dry weight was recorded under the *biasi* method which was at par with hand weeding twice and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment. At harvest, un-weeded control

method produced maximum dry matter of *Cyanotis axillaris* (6.0 q ha^{-1}). However, it was 0.27 q ha^{-1}in *biasi* method, 0.74 q ha^{-1} in hand weeding and 0.81 q ha^{-1} in W_3 respectively. Difference between the weedy check and *biasi* method in respect to dry matter production of *Cyanotis axillaris* was very high.

Among different seed rates at 15 DAS, there was no significant effect on dry weight of *Cyanotis axillaris* but it was slightly lower under 40 kg ha^{-1}. At 30, 45, 60 DAS and at harvest, minimum weed dry weight was recorded under 120 kg ha^{-1} seed rate which was equal to 80 kg ha^{-1} and 40 kg ha^{-1} seed rates in all the growth stage in both the year. Interaction between the weed management and seed rates of dry weight of *Cyanotis axillaris* was found non-significant at both the year and all the growth stages.

4.3.5.5 Other weed species (g m^{-2})

Data on weed dry weight of other species at different time interval are presented in Table 4.21 during 2013 and 2014, weed management practices caused significant variation in dry weight of other weed species.

Among different weed management practices at 15 DAS, significantly lower dry weight of other weeds was obtained under the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS which was at par with (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year.

At 30 DAS, among different weed management practices, significantly lowest dry matter was recorded under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS whereas, hand weeding twice was nearly equal to the (W_3) treatment. At 45 DAS, lowest weed dry weight was recorded under the *biasi* operation which was at par with the two hand weeding. Among the chemical method of weed control minimum dry weight was recorded under the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS.

However, difference between the *biasi* method, hand weeding and W_3 was very marginal in respect to dry weight of the weeds.

Similar results like 45 DAS continued at 60 DAS and at harvest. In *biasi* method, minimum dry weight of other weed species was recorded in both the years and interval followed by hand weeding and chemical control method. During this period, maximum dry weight was recorded under un-weeded control plot. At harvest, un-weeded control plot produced 9.25 q ha^{-1} dry matter, which was 82 per cent more over the *biasi* method and 73 per cent more over the hand weeding. However, chemical control method also produced very less quantity of dry matter at harvest. It was only 2.20, 2.63 and 2.29 q ha^{-1} respectively in (W_3) pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS , (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS treatment.

Among different seed rates in respect to dry matter production of other weed species at 15, 30, 45, 60 DAS and at harvest, data revealed that, there was equal effect of seed rates on other weed species. However, the lower weed dry matter was recorded under 120 kg ha^{-1} as compared to other seeding rates treatment, seed rate 80 kg ha^{-1} and 40 kg ha^{-1} was next, in order. Interaction between the weed management and seed rates was found non-significant in all the growth period and both the year.

Interaction between the weed management and seed rates was found non-significant during 15, 30, 45 and 60 DAS during both the year of investigation but it was significant at harvest during both the years (Table 4.21a) .Significantly minimum dry weight of other weeds m^{-2} was recorded in the combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with *biasi* method during both the year and it was at par with the combination of different seed rate (40 80 and 120 kg ha^{-1}) and two hand weeding and application of oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year (S_1, S_2 and S_3 x W_2) (S_1, S_2 and S_3 x W_3 during 2013 and S_1, and S_3 x W_3 during 2014).

Table 4.20: Dry matter of *Cyanotis axillaris* (g m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Dry matter of *Cynotis axillaris* (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	1.38 (1.41)	1.71 (2.45)	1.54 (1.93)	2.74 (7.15)	2.78 (7.33)	2.76 (7.24)	1.31 (1.27)	1.53 (1.86)	1.42 (1.56)	2.24 (4.55)	2.53 (6.01)	2.38 (5.28)	2.79 (7.33)	2.70 (6.80)	2.74 (7.06)
W_2 :- Two hand weeding at 20 & 40 DAS	1.36 (1.35)	1.44 (1.64)	1.41 (1.49)	1.16 (0.88)	1.19 (0.93)	1.17 (0.91)	1.30 (1.21)	1.58 (2.01)	1.44 (1.61)	2.40 (5.30)	2.69 (6.77)	2.54 (6.04)	2.95 (8.26)	2.66 (6.64)	2.80 (7.45)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	0.86 (0.24)	0.90 (0.32)	0.88 (0.28)	1.20 (0.96)	1.16 (0.87)	1.18 (0.92)	1.90 (3.17)	2.13 (4.06)	2.01 (3.61)	2.49 (5.77)	2.56 (6.05)	2.52 (5.91)	3.11 (9.18)	2.75 (7.08)	2.93 (8.13)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.50 (0.50)	1.03 (0.58)	1.01 (0.54)	1.42 (1.66)	1.20 (1.15)	1.31 (1.41)	2.34 (5.01)	2.44 (5.47)	2.39 (5.24)	3.50 (12.13)	3.26 (10.11)	3.38 (11.12)	4.03 (15.75)	3.18 (9.64)	3.60 (12.69)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25	0.88 (0.28)	0.88 (0.27)	0.88 (0.28)	1.19 (0.97)	1.11 (0.79)	1.15 (0.88)	2.08 (3.84)	2.23 (4.52)	2.15 (4.18)	2.59 (6.24)	2.63 (6.44)	2.61 (6.34)	3.23 (9.99)	2.76 (7.17)	2.99 (8.58)
W_6 :- Weedy check	1.44 (1.58)	1.56 (1.94)	1.5 (1.76)	3.30 (10.41)	3.80 (13.99)	12.20	4.03 (15.87)	4.53 (20.09)	4.28 (17.98)	6.44 (41.18)	6.46 (41.62)	6.45 (41.40)	8.12 (65.61)	7.84 (55.49)	7.98 (60.55)
SEm±	0.04	0.07	0.03	0.16	0.17	0.09	0.09	0.08	0.08	0.13	0.15	0.13	0.14	0.12	0.12
CD (P = 0.05)	0.15	0.21	0.10	0.50	0.54	0.28	0.27	0.25	0.25	0.42	0.48	0.42	0.44	0.38	0.39
Seed rate (kg ha^{-1})															
S_1 :- 120	1.17 (0.95)	1.28 (1.26)	1.22 (1.11)	1.81 (3.90)	1.67 (4.17)	1.87 (4.03)	2.08 (4.59)	2.40 (6.35)	2.24 (5.47)	3.26 (12.50)	3.25 (11.92)	3.25 (12.21)	3.49 (18.16)	3.13 (15.12)	3.51 (16.64)
S_2 :- 80	1.14 (0.86)	1.25 (1.18)	1.19 (1.02)	1.78 (3.47)	1.87 (4.18)	1.82 (3.83)	2.08 (4.82)	2.39 (6.28)	2.23 (5.55)	3.25 (12.29)	3.35 (12.74)	3.3 (12.52)	4.03 (19.53)	3.55 (15.04)	3.79 (17.29)
S_3 :- 40	1.15 (0.88)	1.24 (1.15)	1.19 (1.01)	1.85 (3.65)	1.89 (4.19)	1.81 (3.92)	2.32 (5.77)	2.24 (6.36)	2.37 (6.07)	3.34 (12.80)	3.47 (13.84)	3.41 (13.32)	4.14 (20.37)	3.68 (16.25)	3.91 (18.31)
SEm±	0.01	6.02	0.02	0.03	0.01	0.02	0.07	0.04	0.18	0.04	0.05	0.02	0.04	0.03	0.03
CD (P = 0.05)	NS	NS	NS	NS	0.05	NS	NS	NS	NS	NS	NS	0.06	0.15	0.12	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.21: Dry matter of other weeds (g m^{-2}) at different duration as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Dry matter of other weeds (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	1.32 (1.39)	1.40 (1.47)	1.36 (1.43)	2.55 (6.42)	2.64 (6.55)	2.59 (6.49)	1.83 (2.89)	1.83 (2.89)	1.13 (2.89)	2.72 (7.00)	3.25 (10.24)	2.98 (8.62)	4.15 (16.90)	4.31 (18.12)	4.23 (17.51)
W_2 :- Two hand weeding at 20 & 40 DAS	1.35 (1.34)	1.42 (1.54)	1.38 (1.44)	1.57 (2.05)	1.67 (2.35)	1.62 (2.20)	2.11 (4.05)	2.06 (3.85)	2.08 (3.95)	3.40 (9.88)	3.69 (13.17)	3.54 (11.53)	4.33 (18.49)	4.79 (22.43)	4.56 (20.46)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	0.88 (0.11)	0.23 (0.18)	0.85 (0.15)	1.20 (1.11)	1.37 (1.53)	1.28 (1.32)	2.59 (6.40)	3.84 (7.73)	2.71 (7.07)	3.76 (13.85)	4.29 (18.40)	4.02 (16.13)	4.53 (20.15)	4.77 (23.87)	4.65 (22.01)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.87 (0.20)	0.84 (0.21)	0.85 (0.20)	1.47 (1.72)	1.60 (2.11)	1.53 (1.92)	2.92 (8.15)	3.18 (9.80)	3.05 (8.98)	4.04 (16.23)	4.61 (21.00)	4.32 (18.62)	4.69 (23.57)	5.07 (29.15)	4.98 (26.36)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25	0.82 (0.18)	0.85 (0.24)	0.83 (0.21)	1.45 (1.69)	1.54 (1.92)	1.49 (1.81)	2.55 (6.19)	2.94 (8.37)	2.74 (7.28)	4.12 (16.65)	4.42 (19.11)	4.27 (17.88)	4.73 (22.30)	4.90 (23.53)	4.81 (22.92)
W_6 :- Weedy check	1.32 (1.24)	1.43 (1.55)	1.37 (1.39)	2.65 (6.59)	2.75 (7.11)	2.7 (6.85)	5.83 (33.73)	6.15 (37.36)	5.99 (35.54)	7.43 (55.04)	7.94 (63.38)	7.68 (59.21)	9.58 (91.45)	9.70 (93.72)	9.64 (92.58)
SEm±	0.08	0.05	0.05	0.12	0.07	0.07	0.16	0.14	0.13	0.28	0.21	0.23	0.18	0.36	0.16
CD (P = 0.05)	0.25	0.16	0.15	0.36	0.23	0.24	0.49	0.44	0.42	0.88	0.64	0.72	0.57	1.14	0.52
Seed rate (kg ha^{-1})															
S_1 :- 120	1.03 (0.54)	1.09 (0.77)	1.06 (0.65)	1.69 (2.59)	1.88 (3.32)	1.78 (2.96)	3.00 (10.35)	3.12 (11.21)	3.06 (10.78)	6.18 (19.40)	4.51 (22.35)	4.34 (20.87)	5.28 (31.17)	5.10 (30.45)	5.19 (30.81)
S_2 :- 80	1.10 (0.78)	1.14 (0.90)	1.12 (0.84)	1.19 (3.37)	1.84 (3.36)	1.81 (3.37)	2.84 (9.71)	3.07 (11.37)	2.95 (10.54)	4.31 (19.99)	4.76 (24.72)	4.53 (22.36)	5.26 (31.08)	5.83 (37.03)	5.54 (34.06)
S_3 :- 40	1.15 (0.91)	1.16 (0.92)	1.15 (0.92)	1.96 (3.83)	2.07 (4.10)	2.01 (3.97)	3.07 (10.65)	3.31 (12.42)	3.19 (11.53)	4.25 (19.93)	4.06 (25.59)	4.55 (22.76)	5.57 (34.18)	5.83 (37.92)	5.70 (36.05)
SEm±	0.04	0.01	0.02	0.06	0.07	0.06	0.11	0.09	0.09	0.15	0.05	0.07	0.07	0.13	0.06
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.21	NS	NS	0.53	0.23
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.21a: Interaction of weed management and seed rate on dry matter of other weeds (g m^{-2}) at harvest in broadcast direct seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**	**S_1-120**	**S_2-80**	**S_3-40**
W_1 :- *Biasi* method (Farmer's practice)	4.67 (18.02)	4.48 (11.18)	4.46 (19.51)	4.32 (17.29)	4.41 (19.00)	4.31 (18.08)	4.49 (18.15)	4.44 (18.59)	4.39 (18.80)
W_2 :- Two hand weeding at 20 & 40 DAS	4.19 (17.04)	4.17 (16.95)	4.65 (21.47)	4.66 (21.18)	4.94 (23.86)	4.77 (22.24)	4.42 (19.11)	4.55 (20.41)	4.71 (21.85)
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	4.48 (19.70)	4.39 (18.86)	4.73 (21.88)	4.75 (25.07)	5.09 (26.58)	4.46 (19.96)	4.61 (22.38)	4.74 (22.73)	4.59 (20.92)
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	5.03 (24.85)	4.81 (22.71)	4.83 (23.16)	2.86 (10.22)	6.02 (36.36)	6.35 (40.87)	3.94 (17.54)	5.41 (29.54)	5.59 (32.01)
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	4.82 (22.73)	4.24 (17.47)	5.14 (26.71)	4.82 (22.75)	4.89 (23.47)	4.98 (24.37)	4.82 (22.74)	4.56 (20.47)	5.06 (25.54)
W_6 :- Weedy check	9.48 (89.69)	9.63 (92.33)	9.63 (92.33)	9.30 (86.22)	9.66 (92.93)	10.12 (102.00)	9.39 (87.95)	9.65 (92.63)	9.88 (97.17)
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.25	0.77		0.42	1.29		0.24	0.72	
Comparison of two weed management means at the same or different level of seed rate	0.09	0.29		0.17	0.52		0.09	0.27	

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

4.3.6 Weed control efficiency (%)

Weed control efficiency (WCE) at 15, 30, 45, 60 DAS and at harvest is calculated and presented in Table 4.22. At 15 DAS, among different weed management practices, weed control efficiency was recorded maximum under W_3 pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS (80.79%). Data shows that the application of pre-emergence herbicides effectively controlled the weed at early stage of weed growth period. Whereas, among different seeding rates, maximum weed control efficiency was recorded under the (S_2), 80 kg ha^{-1} seed rate which was statistically equal to the (S_1), 120 kg ha^{-1} and (S_3) 40 kg ha^{-1}.

Weed control efficiency at 30 DAS shows that the maximum weed control was under the treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with the (W_2) two hand weeding and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS treatment. Application of pre-emergence and post-emergence herbicides controlled weeds efficiently, and it was superior over the hand weeding. Walia *et al.* (2009) reported that weeds in DSR can be controlled effectively with the integration of post-emergence application of bispyribac with pre-emergence application. Singh and Namdeo (2004) found that hand weeding 20 and 40 days after sowing showed 72 per cent weed control efficiency.

Weed control efficiency at 45 DAS was maximum in biasi method which was at par with the two hand weeding in both the years. Difference between the biasi method, hand weeding and chemical control was very marginal, as compared to the biasi method difference between (W_1) *biasi* method and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, treatment was only 5.6 per cent and with (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS,treatment it was only 7.59 per cent. The WCE was 91.06 per cent in *biasi* method and 90.20 per cent in hand weeding and 85.95 per cent in the W_3 treatment. Saha *et al.* (1999) concluded that hand weeding twice at 25 and 40 DAS controls weed most effectively in DSR followed by *beueshning* method. Rao and Ratnum (2010) reported that bispyribac Sodium

30 g ha^{-1} reduced weed growth with higher weed control efficiency (WCE) of 74 per cent.

Among weed management options at 60 DAS and at harvest, weed control efficiency recorded under *biasi* method was maximum which was at par with the two hand weeding. However, it was very marginally higher with the chemical control method. Data itself clarifying that, sequential application of oxadiargyl and bispyribac Na gave same WCE as *biasi* method and hand weeding. The difference between the *biasi* method and chemical control method (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in regards to WCE was only 5.30 per cent and with (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS it was only 6.3 per cent. However, the minimum weed control efficiency was recorded under the treatment (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in both the years and all the growth period of rice.

Among different seeding rates weed control efficiency was at par throughout the crop growth period in both the year. Whereas, the maximum weed control efficiency was recorded under the 120 kg ha^{-1} seed rate at 60 DAS and at harvesting. The interaction between the weed management and seed rates were found non-significant at all the growth period in both the years.

4.3.7 Weed index (%)

The data on weed index are present in Table 4.23 with regards to the different weed management practices, it was noted that maximum weed index was recorded under un-weeded control plot (77.81) (loss of yield as compared to *biasi* method) and minimum weed index was recorded under hand weeding twice in both the year. Among the hand weeding (W_2) and (W_3) PE oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS weed index was very closed and was 2.67 and 4.36 on mean basis which showed that the application of pre emergence along with post emergence might be the alternative of hand weeding twice and *biasi* method. However, the maximum yield was found under the *biasi* treatment, and as compared to the *biasi* treatment, reduction on yield in hand weeding was only 2.67 per cent and in W_3 it was only 4.36 per cent. Among different seeding rates,

Table 4.22: Weed control efficiency (%) at different duration of broadcast direct seeded rice as influenced by weed management and seed rate

Treatment	Weed Control Efficiency (%)														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	-1.45	0.29	-0.58	9.98	6.45	8.22	91.33	90.79	91.06	91.49	89.21	90.35	86.27	86.71	86.49
W_2 :- Two hand weeding at 20 & 40 DAS	19.19	4.65	11.92	91.97	90.44	91.21	90.46	89.94	90.20	88.13	87.59	87.86	84.73	85.56	85.15
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	80.79	75.68	78.24	92.63	91.28	91.96	87.07	84.84	85.95	85.69	84.83	85.26	81.58	82.23	81.90
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	73.55	66.16	69.86	88.89	87.78	88.34	81.89	82.45	82.17	80.39	79.28	79.83	74.33	76.32	75.32
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	79.05	77.12	78.08	91.12	90.29	90.70	85.81	82.47	84.14	82.56	83.82	83.19	79.58	82.48	81.03
W_6 :- Weedy check	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEm±	3.02	4.25		0.67	2.01		0.55	0.61		1.02	0.51		0.60	0.62	
CD (P = 0.05)	9.50	13.38		2.12	6.33		1.72	1.94		3.21	1.61		1.88	1.94	
Seed rate (kg ha^{-1})															
S_1 :- 120	39.37	33.59	36.48	60.17	58.23	59.20	72.99	72.06	72.52	72.29	70.86	71.57	68.32	69.01	68.66
S_2 :- 80	56.52	51.60	54.06	64.28	65.61	64.95	73.19	71.62	72.40	71.02	71.03	71.03	67.89	68.71	68.30
S_3 :- 40	29.67	26.76	28.22	62.84	59.28	61.06	72.11	71.57	71.84	70.82	70.47	70.64	67.05	68.93	67.99
SEm±	8.14	7.14	7.06	0.63	1.99	0.81	0.90	0.38	0.54	0.38	0.44	0.37	0.44	0.48	0.29
CD (P = 0.05)	31.94	28.04	NS	2.48	7.81	3.17	3.53	1.49	NS	1.48	1.71	NS	1.75	1.90	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.23: Weed index (%) of broadcast direct seeded rice as influenced by weed management and seed rate

Treatment	Weed index (%)		
	2013	2014	Mean
Weed management			
W_1 :- *Biasi* method (Farmer's practice)	0.00	0.00	0.00
W_2 :- Two hand weeding at 20 & 40 DAS	3.46	1.87	2.67
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	5.98	2.73	4.36
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	12.46	11.21	11.83
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	10.34	6.71	8.53
W_6 :- Weedy check	72.32	83.29	77.81
SEm±	--	--	--
CD (P = 0.05)	--	--	--
Seed rate (kg ha^{-1})			
S_1 :- 120	4.94	6.08	5.51
S_2 :- 80	3.42	1.60	2.51
S_3 :- 40	0.00	0.00	0.00
SEm±	--	--	--
CD (P = 0.05)	--	--	--

minimum weed index was recorded under 40 kg ha^{-1} followed by 80 kg ha^{-1} and maximum index was in 120 kg ha^{-1} seed rate

4.3.8 Relative weed density (%)

Periodical relative weed density of different weed species was calculated at 15, 30, 45, 60 DAS and at harvest on the basis of two year mean and presented in Fig. 4.4, 4.5 and 4.6

4.3.8.1 Relative weed density (%) at 15 DAS

At 15 DAS data indicated that the maximum relative weed density was noticed by *Echinochloa colona* among the all species. Higher relative weed density of *Echinochloa colona* was found under the *biasi* method followed by two hand weeding. Among different seeding rates, the RWD was found minimum under the 40 kg ha^{-1} and maximum under the 80 kg ha^{-1} seed rate.

Among different weed management, RWD of *Alternanthra triandra* was found minimum under (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS. However, it was maximum in *biasi* method at this stage. Among different seed rates it was maximum in 40 kg ha^{-1} seed rate and minimum in 120 kg ha^{-1} seed rate. RWD of *Cynotis axilliaris* was recorded maximum under the (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. whereas ,it was minimum in (W_2) two hand weedings at 20 & 40 DAS two hand weeding.

Among different weed management practices, RWD of other weed species was found minimum under (W_6) Weedy check and it was maximum in (W_3) pre emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment.

4.3.8.2 Relative weed density (%) at 30 DAS

Among different species maximum relative weed density was recorded through *Echinochloa colona* followed by *Alternanthra triandra*. The maximum relative weed density of *Echinochloa colona* was recorded under the (W_2) two hand weeding followed by the (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS However, it was maximum under (W_6) Weedy check. Among the seed rate RWD

was maximum under the 80 kg ha^{-1} seed rate and it was minimum in 40 kg ha^{-1} seed rate.

Among different weed management practices, the RWD of *Alternanthra triandra* was found minimum under weed check (W_6). Whereas, maximum relative weed density was recorded under (W_2) two hand weeding at 20 and 40 DAS. Among the chemical control method it was minimum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and maximum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Among different seed rate it was found minimum under the 40 kg ha^{-1} seed rate and maximum in 80 kg ha^{-1} seed rate.

RWD at 30 DAS of *Cyperus iria* and *Cynotis axilliaris* was found maximum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and minimum in (W_1) *biasi* method. However, among the seed rate it was maximum in 40 kg ha^{-1} seed rate.

Among different weed management practices, the RWD of other weed species was found minimum under *biasi* method. Whereas, it was maximum in (W_2) two hand weedings at 20 & 40 DAS. The maximum relative weed density of other weed species was recorded maximum under the 40 kg ha^{-1} seed rate and it was minimum in 80 kg ha^{-1} seed rate.

4.3.8.3 Relative weed density (%) at 45 DAS

Among different weed species highest RWD was recorded under *Echinochloa colona.* RWD of *Echinochloa colona* was maximum in (W_6) weedy check whereas, it was minimum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Application 40 kg ha^{-1} seed rate recorded minimum RDW of *Echinochloa colona* at 45 DAS.

RWD of *Alternandra triandra* at 45 DAS among different weed management was recorded minimum in (W_6) weedy check and it was maximum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Relative density of *Alternanthra triandra* among different

seed rate was recorded minimum in 120 kg ha^{-1}. However, it was maximum in 80 kg ha^{-1} seed rate.

Among different weed management option, the RWD of *Cyperus iria* was found minimum under (W_6) weedy check method. Whereas, maximum RWD was recorded under (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS. Chemical control method produced nearly equal RWD of *Alternandra triandra* at this stage. Application of 40 kg ha^{-1} seed rate recorded maximum relative density of *Cyperus iria*.

Minimum RWD of *Cyanotis axilliaris* was under (W_1). However, it was maximum in (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS. Among chemical control method relative density of *Cyanotis axillairis* was newly equal in all the treatments. Whereas, among different seeding rate, the RWD was found minimum under the (S_1) 120 kg ha^{-1} seed rate and maximum was recorded under (S_3) 40 kg ha^{-1}.

Relative weed density of *Cyanotis axilliaris* was recorded maximum under (W4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and it was minimum in (W_6) weedy check followed by (W_1) *Biasi* method (Farmer's practice) and (W_2) two hand weedings at 20 & 40 DAS. Among seed rate relative density of *Cyanotis axilliaris* was maximum in (S_3) 40 kg ha^{-1} and minimum in (S_1) 120 kg ha^{-1} seed rate.

Due to various weed management option, maximum relative density of other weeds was observed under (W_1) *biasi* method and it was maximum in (W_6) weedy check. Although, chemical control method recorded nearly equal relative density of other weeds. Among seed rate it was minimum in (S_2) 80 kg ha^{-1} and maximum in (S_3) 40 kg ha^{-1} seed rate.

4.3.8.4 Relative weed density (%) at 60 DAS

Later on during 60 DAS relative weed density of other weeds was highest among the different weed species. Relative density of *Echinochloa colona* was maximum in (W_6) weedy check. Whereas it was minimum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1}

at 25 DAS. Among different seed rate RWD of *Echinochloa colona* was nearly equal and marginal difference in high to low seed rates was recorded.

Among different weed management practices, RWD of *Alternanthra triandra* was found minimum in (W_2) two hand weeding and it was recorded maximum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Although, the relative density was nearly equal to all the weed management option. Application of high to low seed rate produced nearly equal relative density of *Alternanthra triandra* whereas, it was maximum in (S_3) 40 kg ha^{-1} and minimum in (S_1) 120 kg ha^{-1} seed rates.

Relative density of *Cyperus iria* was recorded maximum under (W_1) *biasi* method and it was minimum in (W_6) weedy check. Among seed rate, it was maximum in (S_2) 120 kg ha^{-1} and minimum in (S_3) 40 kg ha^{-1} seed rate but it was nearly equal in all the seeding method.

Due to various weed management practices, maximum relative weed density of *Cyanotis axilliaris* was recorded under (W_6) weedy check and it was minimum in (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS although the difference in relative density of *Cyanotis axilliaris* was very marginal among the weed management practices. Relative density of *Cyanotis axilliaris* did not show very big difference among the different seed rate.

Among different weed management practices, RWD of other weed was maximum under (W_2) two hand weeding whereas it was minimum in (W_6) weedy check method. Different seed rates did not show any significant difference in RWD and it was almost equal in other weeds at 60 DAS.

4.3.8.5 Relative weed density (%)at harvest

Maximum relative weed density was recorded by other weeds followed by *Alternanthra triandra, Cyperus iria, Cyanotis axilliaris* and *Echinochloa colona* in descending order at harvest. The maximum relative density of *Echinochloa colona* was recorded under (W_6) weedy checks and it was minimum

in (W_1) *biasi* method among seed rate it was minimum in (S_2) 120 kg ha^{-1} and maximum in (S_3) 40 kg ha^{-1} seed rates.

Relative weed density of *Alternanthra triandra* was recorded maximum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Whereas, it was minimum in (W_1) *biasi* method. Among seed rates RWD was maximum in (S_2) 80 kg ha^{-1} and minimum in (S_3) 40 kg ha^{-1}.

Due to various weed management option, maximum relative density of *Cyperus iria* was under (W_1) *biasi* method and it was minimum in (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS. Application of high to low seed rate does not influence the relative density of *Cyperus iria* at harvest and it was almost equal in 120, 80 and 40 kg ha^{-1} seed rate.

Relative density of *Cyanotis axilliaris* at harvest was recorded maximum under (W_1) weedy check whereas, it was minimum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS chemical control methods showed almost equal relative density of *Cynotis axilliaris*. However, among the seed rates relative density was maximum in (S_3) 40 kg ha^{-1} and minimum in (S_2) 80 kg ha^{-1} seed rate at harvest.

At harvest, relative density of other weeds was maximum in (W_1) *biasi* method which was almost equal to (W_2) two hand weeding. However, it was minimum in (W_6) weedy check method. Among chemical methods it was highest in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Application of (S_3) 40 kg ha^{-1} seed rate recorded maximum relative density of other weeds. Whereas, it was minimum in (S_1) 120 kg ha^{-1} seed rate.

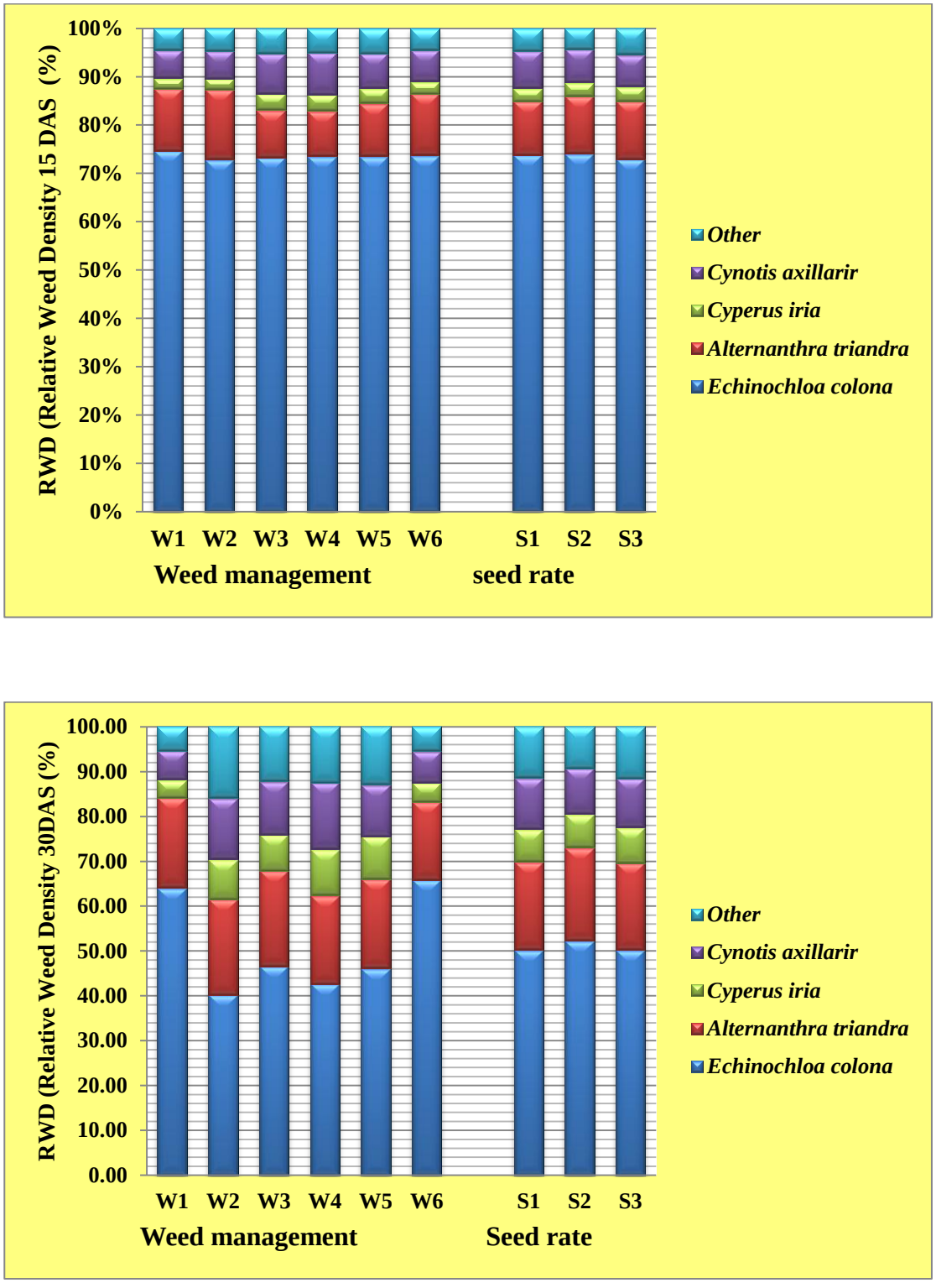


Fig. 4.4: Species wise relative weed density (%) at 15 & 30 DAS as influenced by weed management and seed rate in broadcasted direct seeded rice

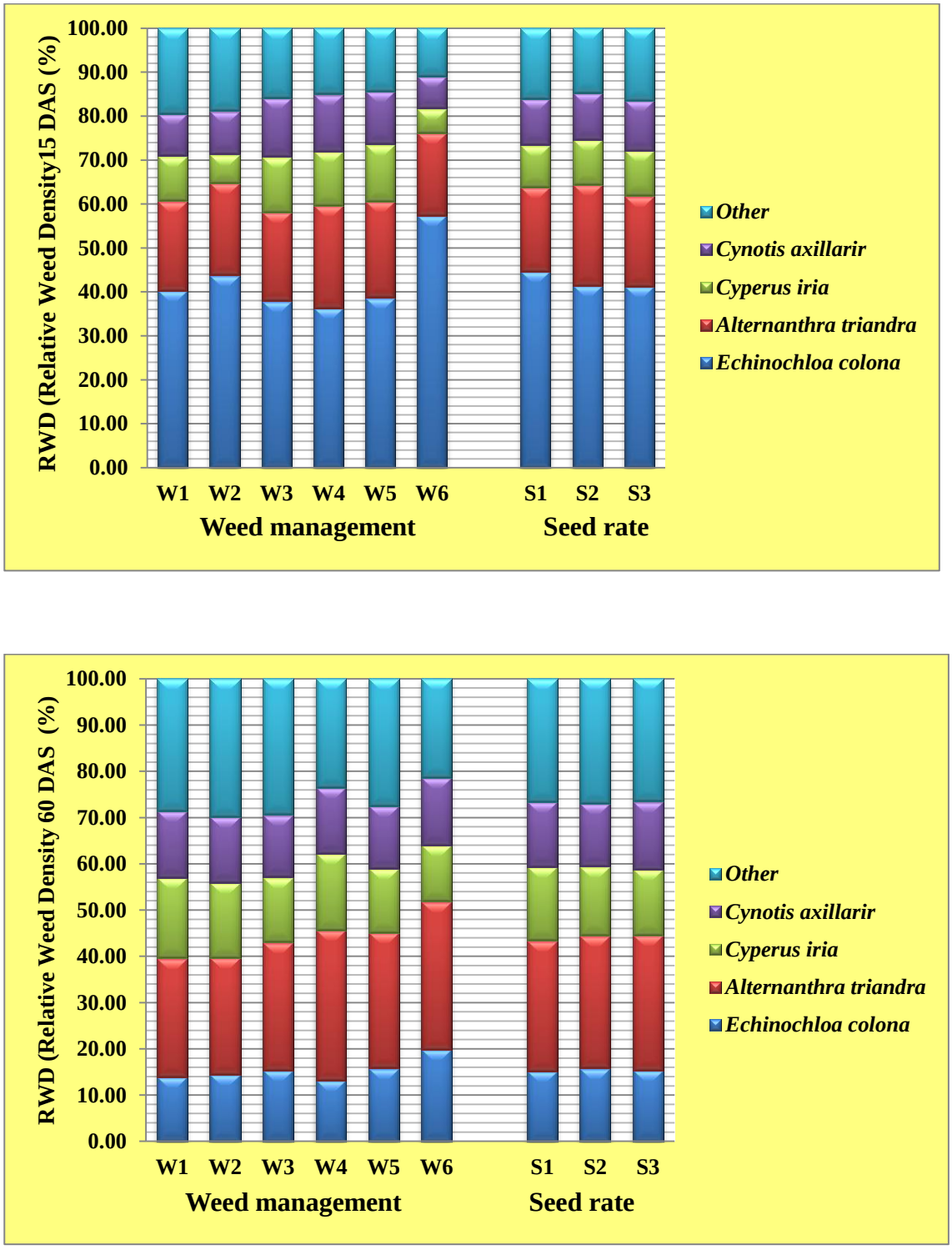


Fig 4.5: Species wise relative weed density (%) at 45 & 60 DAS as influenced by weed management and seed rate in broadcasted direct seeded rice

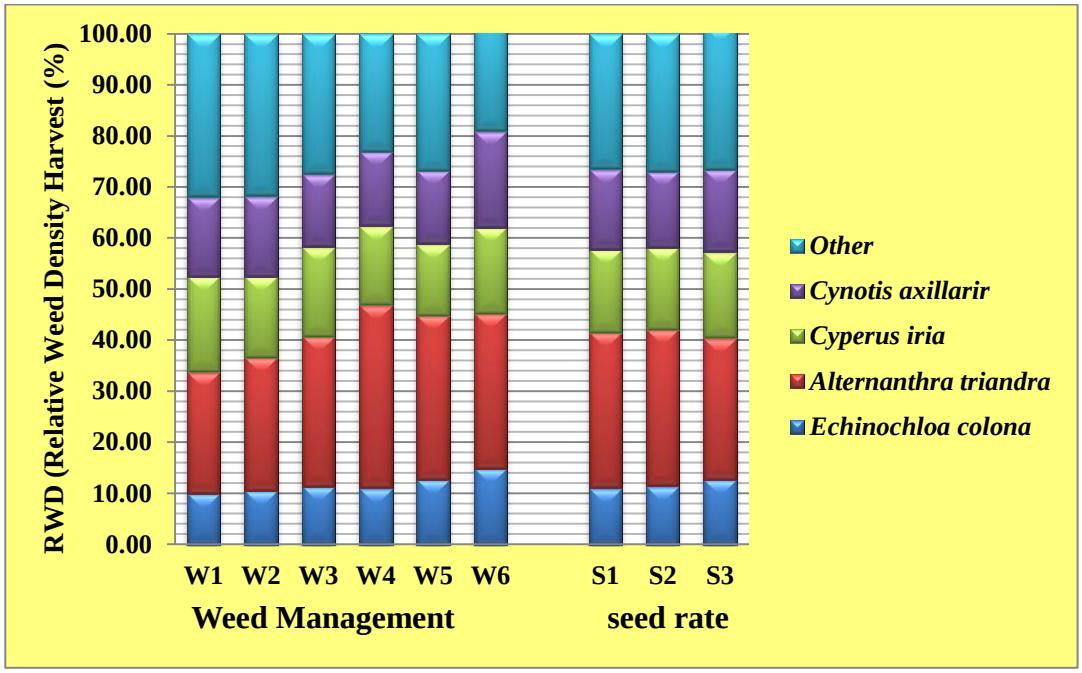


Fig. 4.6 : Species wise relative weed density (%) at harvest as influenced by weed management and seed rate in broadcasted direct seeded rice

4.3.9 Weed growth rate (g day^{-1}m^{-1})

Weed growth rate (WGR) during various crop growth intervals are presented in Fig. 4.7 Weed growth rate showed differential response due to different weed management and seed rate options at various time intervals. Weed growth was maximum in (W_6) weedy check in all the observational stages in weed management practices.

At 15 to 30 DAS the lowest weed growth rate (WGR) was observed under (W_2) due to hand weeding at 20 DAS. However, it was maximum in (W_6) weedy check and newly equal to (W_1) *biasi* method due to no weed control in both the situation during this period. Among chemical control method WGR was minimum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Among seed rate weed growth was minimum in high seed rate (S_1) 120 kg ha^{-1} due to the high plant population of rice crop restrict the growth of weed.

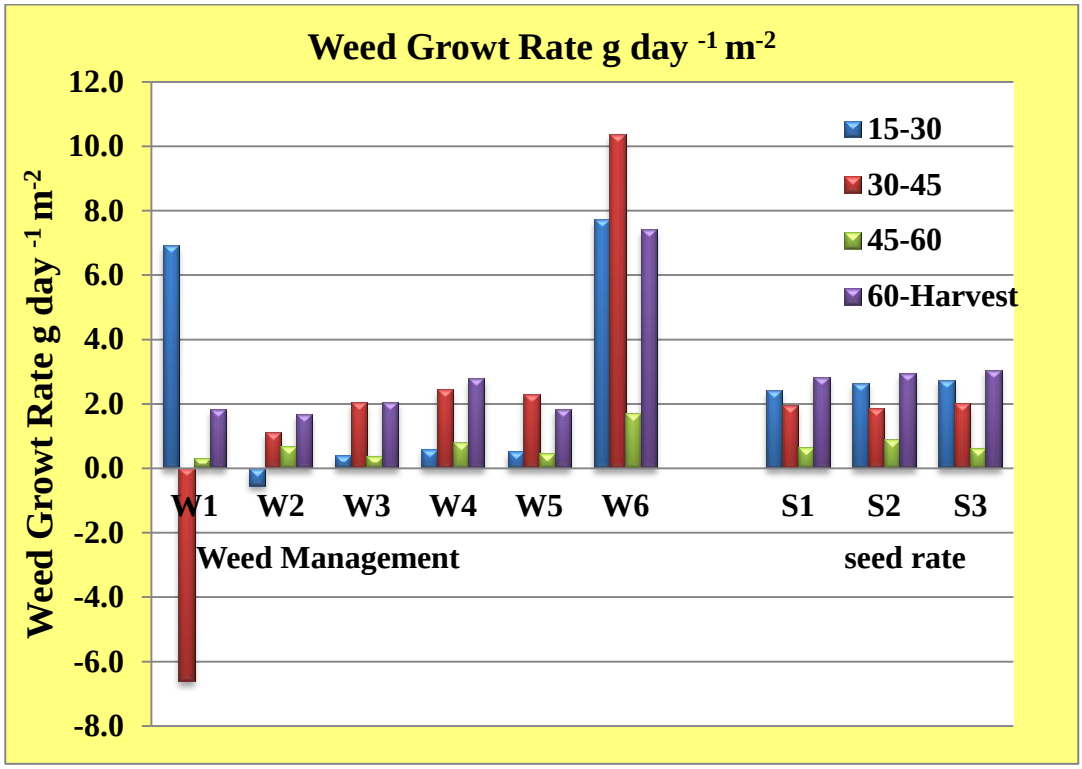


Fig 4.7: Weed growth rate at different time interval as influenced by weed management and seed rate in broadcasted direct seeded rice (mean of 2013-2014)

During 30 to 45 DAS, growth rate of weeds were maximum and it was low in (W_2) *biasi* method due to *biasi* operation during this period and next was (W_2) two hand weeding. Weed growth rate of chemical control method was slightly high as compared to *biasi* and hand weeding, but it was significantly low as compared to the weedy check. Difference in weed growth rate in regards to high to low seed rate weed growth shows very marginal difference at period.

Declined weed growth was observed during 45 to 60 DAS and it was minimum in (W_1) *biasi* method followed by (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS. Among seed rate weed growth showed similar trends in seed rate ranging from 120 to 40 kg ha^{-1} seed rate. During the 60 to harvest, nearly equal weed growth rate was observed under the (W_2) two hand weeding, (W_1) *biasi* method and (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS.

However, significantly higher weed growth was observed under the weedy check. Application of (S_1) 120 kg ha^{-1} seed rate recorded minimum weed growth rate but it was very marginal with (S_2) 80 kg ha^{-1} and (S_3) 40 kg ha^{-1}. This might be due to better growth of rice plant in 40 kg ha^{-1} seed rate and suppress the growth of weed.

4.3.10 Discussion on weed studies

Weeds, being a serious negative factor in crop production are responsible for reduction on yield of rice and weed management is considered as a positive factor in trapping the production potential. Among the major problem involved in management of rice for high economic yield, weed management is one of the most important constraints. The extent of yield reduction of rice due to weeds has been estimated from 15-95% (Gogai *et al.* 1996). Weed not only cause quantative, but also hampers the quality of produce due to competition. Weed flora of the experimental site were, *Echinochloa colona*, *Ischaemum rugosum* in grasses, *Alternanthra triandra* and *Cyanotis axillaris* among broad leaf and *Cyperus iria* from sedges.

Among the weed management practices highest weed density, and weed dry weight were observed in untreated control throughout the growth period of crop due to absence of weed management practices throughout the rice growth period. Saha *et al*. (2005 a), observed that the maximum yield reduction due to weeds were 41 per cent in direct dry seeded rice. Among weed management practices, weed dry matter production was significantly highest in untreated control which was due to absence of suitable weed management practices. Weeds grow naturally and contributed the maximum weed density and their dry matter. Mamun (1990), suggested that weed growth reduced the grain yield by 68-100% for direct seeded rice, 16-48% for transplant rice.

Biasi method of weed control was found best among the all management practices. Minimum weed density and dry matter was recorded under the *biasi* method. *Beushening* (*Biasi*) is a traditional cultural practice of cross-plowing the dry-seeded (broadcast) standing crop of rice 25-35 day after seeding when 15-20 cm of rain water gets impounded in rice fields, followed by laddering and seedling

redistribution. This practice loosens the soil, controls weeds, improves water-use efficiency, improves tillering and nutrient uptake, reduces insect pests, and helps redistribute seedlings. Under *biasi* method weed was controlled by the cross-plowing after that *chalai* operation was done. In *chalai* operation weeds were uprooted and crop plants are rearranged. Due to the manipulation of soil and pruning of roots, rice plant get better opportunity for growth and development and crop weed competition was minimum. Better growth and development of rice plant suppressed the luxurious growth of weeds and one hand weeding reduce the population of weed. Due to this fact weed population and dry matter of weeds was minimum under *biasi* treatment. Saha *et al*. (1999), concluded that hand weeding twice at 25 + 40 DAS controlled weeds most effectively in direct seeded lowland rice followed by *beushening* (25 DAS) + hand weeding (HW) at 40 DAS

Manual weeding was found next among the weed management practices during both the year. Due to manual weeding at 20 and 40 DAS significantly reduced the density and dry matter production of weeds. Manual weeding at 20 DAS control the first flush of weeds whereas weeding at 40 DAS removes the late coming weeds in the field. Two hand weeding completely removes weed during the critical period of rice weed competition. Due to this reason density and dry matter of weeds was found minimum under this treatment. Nagappa and Biradar (2002) reported that among the weed management practices, two hand weeding at 20 and 40 days produced significantly higher yield over the un weeded check and density and dry matter of weed was minimum under manual weeding. Patra *et al*. (2006) reported that two hand-weeding at 20 and 40 DAS recorded the minimum weed population and dry weight and the highest weed control efficiency at 60 DAT and at harvest. El-Desoki (2003) found that two hand weeding at 20 and 40 DAT was very effective in controlling rice weed growth and increasing the yield

Application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS and pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS was best among the chemical control and was found at par with hand weeding and *biasi* method. Application of pre emergence of oxadiargyl and pyrazosulfuron controlled the first flush of weeds during initial

stage after that application of post emergence herbicide bispyribac Na effectively controlled the late coming weeds. This combination restricted the weed growth and emergence during the critical period of crop weed competition due to this fact growth and development of rice plant was better and produced high yield attributes and grain yield. Jadhav *et al*. (2008) stated that pre-emergence application of oxadiargyl 75 g ha^{-1} effectively control the weeds at early stage of crop growth followed by post-emergence application of bispyribac-Na 30 g ha^{-1} control the late coming weeds. Kiran *et al*. (2010) observed that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} gave lowest density and dry weight of weeds with maximum weed control efficiency. Al-Mamun *et al*. (2011) found that herbicides of pyrazosulfuron ethyl and oxadiazon group control weeds above 80% using recommended dose.

The maximum weed control efficiency was under *biasi* and hand weeding twice might be due to less weed density and production of dry matter by weed in the treated plot. Nevse *et al*. (2010) reported that under the various weed management practices hand weeding twice (20 and 40 DAS) exhibited 95% weed control efficiency in direct seeded rice. Singh and Namdeo (2004) found that hand weeding (20 and 40 days after sowing) showed 72 per cent weed control efficiency. Thakur *et al*.(2005) revealed that when compared between *bueshening* and *non- bueshening* treatments of wet seeding, the *bueshening* had given additional advantage by increased yield through more rooting, better tillering, more panicle density and better HI and weed control efficiency. Weed control efficiency was marginally equal in sequential application of pre and post emergence herbicide due to fact that effective control of weeds by the herbicide weeds density and weed dry matter was less in chemical treated plot. Hussain *et al*. (2008) conducted an experiment to manage the weeds in direct seed rice and concluded that the herbicides nominee gold 100SC (bispyribac sodium) proved as the best herbicides with 90.5 percent weed control efficiency.

Weed index indicated that reduction in yield due to weed competition as compare to the maximum attained seed yield. The maximum weed index under untreated control was due to the fact that there was minimum seed yield.

Application of pre and post emergence herbicide showed minimum weed index due to reason there was maximum grain yield and minimum dry weight due to less density of weed. Due to the reason pre emergence controlled the initial weeds and post emergence controls the late coming weeds contributed good source and sink relation ultimately converted in high grain as well as straw yield as compared to untreated plot. Weed growth rate and weed index are directly related to the dry matter of weeds. Since, there was minimum dry matter of weeds under sequential application of pre and post emergence of oxadiargyl and bispyribac Na, all the parameters were the minimum and weed control efficiency was thr maximum. High weed growth rate was in unweeded control plot due to natural growth of weeds in un treated plot. Weed growth rate was low in chemical control plot due to effictiveness of herbicides and capicity to control the weed and restrict the growth of weeds in treated plot.

4.7.11 Dehydrogenase activity (µg TPF h^{-1} g^{-1}) soil

Soil dehydrogenase activity is considered as a valuable parameter for assessing the impact of herbicide treatments on the soil microbial biomass and can also be used as an indicator of the microbiological redox system.

The dehydrogenase activity (DHA) was measured at 0, 30, 60, and at harvest stages during both the years (Table 4.24). The DHA was influenced significantly due to different weed management practices at 30, 60 DAS and at harvest during both the years. However dehydrogenase activity did not significantly influenced by the seed rate during both the year.

There was no significant variation in dehydrogenase activity among treatments prior to herbicide application. Whereas it was observed that all the herbicides significantly inhibited the DHA after their application. The result was supported with the finding of Sebiomo *et al*. (2011) who observed that the application of herbicides to the soils led to a significant drop in dehydrogenase activity with respect to untreated control soil samples. It can also be observed that, compared to weedy check and hand weeding twice all the herbicide treatments recorded significantly higher dehydrogenase activity. This might be due to the

greater availability of carbon source for the growth and activity of micro-organisms. The result is in close agreement with the findings of Rao *et al*. (2012).

At 30 DAS all the herbicides treatment significantly reduced dehydrogenase activity over *biasi* method, hand weeding and weedy check. The effect of pre and post emergence herbicide on soil microbial activity was observed in this stage. The lowest dehydrogenase activity was observed in (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year. However, dehydrogenase activity was increased in weedy check, *biasi* and hand weeding. *Biasi* method was found superior over two hand weeding in dehydrogenase activity. In soil at 30 DAS, it might be due to soil manipulation at 20 DAS by hand weeding which would increase the aeration support microbes for better growth.

At 60 DAS the harmful effect of different herbicide treatment narrowed down. In this stage maximum DHA was found in weedy check followed by *biasi* and hand weeding. Among herbicide treatment significantly minimum dehydrogenase activity was found in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year. Brzeziñska (2006) observed a significant correlation between the dehydrogenase activity of soil and biomass of soil bacteria. Jezierska-Tys and Frac (2008) reported that dehydrogenase activity was also linked with the total fungal population.

At harvest all the treatment were at par which showed that, by reaching to this stage all the herbicides degraded and there residues become non toxic to the microbial activities. This indicated that the different combination of pre emergence herbicide with bispyribac -Na had no adverse impact on soil health and was found to be environmentally safe.

Table 4.24: Dehydrogenase activity (µg TPF h^{-1} g^{-1}) of rhizosphere soil at different growth stages as influenced by weed management and seed rate in broadcast direct seeded rice

Treatment	Dehydrogenase activity (µg TPF h^{-1} g^{-1} soil)											
	0DAS			30 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management												
W_1 :- *Biasi* method (Farmer's practice)	31.47	37.06	34.26	48.39	50.88	49.64	71.90	75.26	73.58	34.14	34.17	34.15
W_2 :- Two hand weeding at 20 & 40 DAS	31.24	36.85	34.04	49.50	49.75	49.63	72.74	74.96	73.85	35.04	35.07	35.05
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	31.17	36.99	34.08	18.71	21.82	20.27	13.04	13.78	13.41	33.93	34.53	34.23
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	30.97	36.48	33.73	13.39	14.90	14.14	18.22	19.92	19.07	34.10	34.78	34.44
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	31.04	36.76	33.90	14.97	17.04	16.00	22.90	24.84	23.87	34.37	34.80	34.58
W_6 :- Weedy check	31.19	38.69	34.89	54.12	56.63	55.37	79.12	78.93	79.02	35.06	36.66	35.86
SEm±	0.42	0.41	.35	0.34	0.78	0.44	0.31	0.46	0.26	0.21	0.34	0.21
CD (P = 0.05)	NS	NS	1.09	1.06	2.47	1.38	0.97	1.46	0.82	0.66	1.07	0.65
Seed rate (kg ha^{-1})												
S_1 :- 120	29.89	36.93	33.41	32.82	34.79	33.80	45.62	46.65	46.14	34.26	35.05	44.15
S_2 :- 80	30.68	37.17	33.92	33.24	35.19	34.21	45.78	46.83	46.30	34.62	35.29	44.33
S_3 :- 40	30.69	37.32	34.00	33.49	35.53	34.51	45.92	46.76	46.34	34.94	35.66	44.26
SEm±	0.30	0.16	0.15	0.17	0.16	0.08	0.08	0.21	0.10	0.19	0.23	0.21
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.4 Economics

The data with respect to cost of cultivation, gross return, net return and benefit cost are presented in Table 4.25 and 4.26

The details about cost of cultivation of rice and treatment cost are presented in Appendix III to IX for 2013 and 2014, respectively.

During the investigation harvesting was done manually. But now-a-days farmers are harvesting their crop through harvester to save time, minimize the cost and solution of labour dependency in large area of Chhattisgarh. Therefore to understand the difference between manual weeding and harvester hypothetically additional information is also presented here on economics. By calculating the data on economics involving low seed rate, sowing with machine, chemical method of weed control and harvesting through harvester *"the machine to machine production system"* will give the information about alternative rice production system for the Chhattisgarh. To calculate the cost of cultivation labour rate of MNREGA during 2013 & 2014 and C.G. Government procurement rate of produce are considered to calculate the economics.

The data on economics of direct seeded broadcasted rice reveals that the maximum cost of cultivation (₹ 32412) was found in hand weeding twice followed by *biasi* method (₹ 30912). Among the chemical weed management, it was ranging from ₹ 27070 to 27196 on mean basis. However, comparison between costs of cultivation in chemical control method with *biasi* method, the difference was approximately ₹ 3600 ha^{-1} higher in *biasi* system.

The mainly difference between the manual harvesting and harvesting through combine harvester was ₹ 2239 ha on the basis of two year mean. Cost of cultivation is high in manual harvesting system. Harvesting through harvester gives chance to establishing next crop timely by reducing the harvesting time and provide the solution for short fall in labour during the peak time period in the village.

Data on gross income and net income through manual harvesting reveals that the higher gross income (₹ 92252) and net income (₹ 61341) was found in

biasi method which was at par with hand weeding (W_2) and chemical control method (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS respectively. The minimum gross income and net income was found under the weedy checks. During the year 2014, net income was found negative which showed that the weed infestation was highly influenced the yield of the plot. Regarding the net income among the *biasi* method, hand weeding and chemical control method, highest net income was in *biasi* method in both the year but it was followed by W_3 and hand weeding twice. Data itself supports that, the chemical control method might be the alternative for the *biasi* method as the difference between both the treatments was ₹ 306 only in respect to net income.

Comparison between the manual harvesting and harvesting through harvester, difference in respect to net income was ₹ 2238 ha higher in harvesting through harvester. So that we can conclude that the higher net income can be achieved by adopting the *"machine to machine rice production system".* Among the seed rates cost of cultivation, gross income and net income does not show any critical difference in both the year.

Data on B : C. ratio revealed that the maximum B:C ratio, income from per rupee invested was in the treatment (W_3) PE oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS followed by (W_5) pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and (W_1) *biasi* method in both the year as well as in both the harvesting system. The lowest B:C ratio (0.09) was found in un-weeded control treatment, it was negative in year 2014 in both the harvesting situation. The maximum B:C ratio (2.25) through chemical control itself explained that the combination of low seed rate and weed management through chemical method is the best replacement of *biasi* method in the present studies. Among the seed rate, highest B : C ratio was found in 40 Kg seed rate ha^{-1} followed by the 80 Kg and 120 Kg ha^{-1} seed rate. Difference between the B : C ratio in regards to the manual and harvester harvesting was 0.23 which is big difference in respect to the rice production system. The difference between the *biasi* treatment and (W_3) chemical control in regards to B:C ratio was 0.26 more in W_3 chemical control method .

Table 4.25: Effect of different weed management practices and seed rate on total cost (₹ ha^{-1}) gross income and net income (₹ ha^{-1}) in broadcast direct seeded rice

Treatment	Total Cost (₹ha^{-1}) Manual Harvesting			Total Cost (₹ ha^{-1}) Through Harvester			Gross Income (₹ ha^{-1})			Net Income through Manual (₹ ha^{-1})			Net Income through Harvester (₹ ha^{-1})		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1 :- *Biasi* method (Farmer's practice)	29556	32267	30912	27938	29408	28673	90735	93770	92252	61178	61503	61341	62796	64362	63579
W_2 :- Two hand weeding at 20 & 40 DAS	30456	34367	32412	28838	31508	30173	87364	92059	89711	56908	57692	57300	58526	60551	59538
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	25840	28551	27196	24222	25692	24957	85156	91306	88231	59316	62755	61035	60934	65613	63274
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	26974	29685	28330	25356	26826	26091	79413	83745	81579	52439	54060	53250	54057	56919	55488
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	25714	28425	27070	24096	25566	24831	81459	87814	84637	55745	59389	57567	57363	62248	59806
W_6 :- Weedy check	20160	22343	21252	21688	23158	22423	27760	18052	22906	7599	-4291	1654	6071	-5106	482
SEm±							2148	1673	845	2148	1673.1	845	2148.0	1673	846
CD (P = 0.05)							6768	5271	2663	6768	5271.6	2663	6768.0	5271	2663
Seed rate (kg ha^{-1})															
S_1 :- 120	27050	30233	28642	25957	27987	26972	73657	75087	74372	46606	44854	45730	47700	47100	47400
S_2 :- 80	26450	28553	27502	25357	26307	25832	74823	78497	76660	48372	49944	49158	49466	52191	50828
S_3 :- 40	25850	29033	27442	24757	26787	25772	77464	79789	78627	51614	50756	51185	52708	53002	52855
SEm±							1371.2	2396.5	606	1371.2	2396.5	606	1371.2	2396.5	606
CD (P = 0.05)							NS	NS	NS	NS	NS	NS	NS	9408.3	NS
Interaction (WM X SR)							NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.26: Effect of different weed management practices and seed rate on B: C ratio in broadcast direct seeded rice

Treatment	B : C (Through Manual)			B : C (Through Harvester)		
	2013	2014	Mean	2013	2014	Mean
Weed management						
W_1 :- *Biasi* method (Farmer's practice)	2.07	1.91	1.99	2.21	2.13	2.17
W_2 :- Two hand weeding at 20 & 40 DAS	1.87	1.68	1.77	2.00	1.87	1.93
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	2.30	2.21	2.25	2.47	2.49	2.48
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.95	1.82	1.88	2.09	2.06	2.07
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	2.17	2.09	2.13	2.33	2.36	2.35
W_6 :- Weedy check	0.38	-0.19	0.09	0.28	-0.22	0.03
SEm±	0.09	0.06	0.03	0.08	0.08	0.04
CD (P = 0.05)	0.28	0.19	0.10	0.25	0.26	0.12
Seed rate (kg ha^{-1})						
S_1 :- 120	1.66	1.41	1.53	1.76	1.59	1.67
S_2 :- 80	1.78	1.67	1.73	1.89	1.88	1.88
S_3 :- 40	1.93	1.68	1.80	2.05	1.88	1.96
SEm±	0.05	0.08	0.02	0.05	0.09	0.02
CD (P = 0.05)	0.20	0.31	0.01	0.20	0.34	0.08
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS

Kumar *et al.* (2002) also concluded that the maximum net return and B:C ratio was recorded in broadcasting biasi system. Ahmed *et al.* (2000) revealed the herbicidal weed control method offer an advantage to save labour and money. Hussain *et al.* (2008) concluded that the application of bispyribac sodium gives the highest economics as compared to the *biasi* and other method of weed control in direct seeded rice. Rathore *et al.* (2004) also supports the more B:C ratio in direct seeded rice. Kiran *et al.* (2010) recorded that the sequential application of herbicides gives the maximum net return and B: C ratios.

4.5 Energetics

The relation between agriculture and energy is very close. Agricultural sector itself is an energy user and energy supplier in the form of bio-energy (Alam *et al*., 2005). It uses large quantities of locally available non-commercial energies, such as seed, farmyard manure and animate energy, and commercial energies directly and indirectly in the form of electricity, diesel fuel, chemical fertilizers, plant protections, irrigation water and farm machinery (Kizilaslan, 2009). The increased use of inputs such as fertilizer, irrigation water, diesel, plant protection chemicals, electricity etc. demands more energy in the form of human, animal and machinery.

The energy requirements for broadcast direct seeded rice cultivation under different treatments method using labour, seed, fertilizer, herbicides etc. were estimated on the basis of standard energy coefficients (Mittal and Dhawan, 1988). Output energy was estimated with seed and straw yields with standard energy coefficients. Fixed energy inputs and variable energy inputs of seed and weed management are presented in appendix XVIII to XXI. The standard energy coefficient for seed and straw of rice was multiplied with their respective yields and summed to obtain energy use efficiency, energy productivity. During the investigation crop was harvested manually but for the presentation and to understand the energy status of combine harvester on rice production system hypothetically calculation was also done if harvester is used to harvest the crop. Data with respect to total input energy MJ, total output energy MJ and output-input energy ratio is presented in Table 4.27 and 4.28

Energy inputs required to the different treatments of weed management and seed rates were estimated. Input energy was highest in *biasi* method followed by the hand weeding. However, the weed management through herbicides shows low input energy as compared to the *biasi* method and hand weeding. The input energy was high in combine harvester due to the use of heavy machine and high consumption of diesel as compared to manual harvesting system. However, the minimum energy required in weedy check method due to less labour required for harvesting and processing the produce.

Maximum output energy was recorded under the *biasi* method which was statistically superior over all the treatments in both the year. Although, minimum output energy was recorded under the weedy check. Due to weedy condition yield was very low in weedy check which reflects on output energy. As compared to the *biasi* method output energy was 59 per cent less in un-weeded control condition. This situation clearly indicates that the weeds are the major factor in production system. Energy was consumed by weed for their growth and development in place of rice plant. During the investigation seed rate does not influence the output energy and almost similar output energy was produced by the 120, 80 and 40 kg ha^{-1} seed rate. However, the maximum output was produced by the 40 kg ha^{-1} seed rate followed by the 80 and 120 kg ha^{-1} seed rate.

To evaluate the performance of production system, output energy to input energy ratio and energy productivity (i.e. yield to input energy ratio) in crop production systems have been used (Mohammadi *et al*., 2010; Unakitan et al., 2010). The energy input output analysis is usually made to measure the energy efficiency. This analysis will determine how efficiently the energy is used. Establishing the functional forms between energy inputs and output for agricultural crops are very useful in terms of determining elasticity of different energy inputs on yield (Turhan *et al*., 2008).

Maximum energy output input ratio was observed in *biasi* method (12.4) in 2013 and during 2014, it was maximum in W_3 (13.5) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS. However, the minimum output-input energy was produced by weedy check. Output-input ratio was almost 52 per

cent less in weedy check as compared to the *biasi*, hand weeding and chemical control. High output-input ratio in chemical control method supported the combination of herbicides and low seed rate might be the alternative of *biasi* and hand weeding method in broadcasting direct seeded rice.

Energy output-input ratio was less in combine harvester method of harvesting as compared to the manual weeding, difference was only 5.5 to 6.5 per cent between the manual and combine harvester. However, difference was not very much in manual and harvester harvesting system, but in harvester timely harvesting of crop provides chance for timely sowing of next crop. Harvester may be the solution of labour crisis during the peak time of harvesting at village. Harvester saves the time of threshing and winnowing and other operation which required more energy in rice production system, this energy may be used for the next crop and other activity related to agriculture for high efficiency.

Efficiency is defined as the ability to produce the outputs with a minimum resource level required (Sherman, 1988). In production, efficiency is a normative measure and is defined as the ratio of weighted sum of outputs to inputs or as the actual output to the optimal output ratio. Efficient use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living (Singh *et al*., 2002). Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living (Kizilaslan, 2009).

Efficient use of energy resources in agriculture is one of the principal requirements for sustainable agricultural productions. Therefore, energy saving has been a crucial issue for sustainable development in agricultural systems. Development of energy efficient agricultural systems with low input energy compared to the output of food.

The maximum energy use efficiency (9.1) was recorded in *biasi* system in 2013, however, it was maximum in W_3 (10.0) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS during the 2013. All other weed

management practices produced almost equal efficiency except the weedy check method which produced the minimum efficiency in both the year. However, efficiency of chemical control W_3 was maximum on mean basis of two years. Difference between the *biasi,* hand weeding and chemical control in respect to energy use efficincy was not very huge in respect to produce biological yield (q MJ ha^{-1}) by the unit input energy which supports chemical control might be the alternative of *biasi* and hand weeding in broadcasting direct seeded rice production system.

Efficiency of harvesting through harvester was less as compared to the manual harvesting but the difference was very marginal in both the years. However, harvester reduces the human energy in rice production system and promotes the timely operation.

Energy productivity is an important indicator for more efficient use of energy although higher energy productivity does not mean in general, more economic feasibility (Mohammadi *et al*., 2010). Energy productivity (kg MJ ha^{-1}) was recorded maximum in W_3 pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS treatment which was at par with *biasi* method and hand weeding and other chemical control method in both the year during the investigation. However, the energy productivity was higher in combine harvester as compared to the manual harvesting. High energy productivity in combine harvester reveals the production of more yields per hectare by the expenditure of input energy, although the output input ratio and energy use efficiency was high in manual harvesting method.

This result supports the “machine to machine rice production system” in broadcasted direct seeded rice production system. *Biasi* method can be substituted by the combination of sowing by machine with low seed rate, application of herbicide and harvesting through the combine harvester for the double cropping system in Chhattisgarh. Timely operation by the involvement of machine in production system gives chance for the timely sowing of next crop.

Table 4.27: Effect of different weed management practices and seed rate on total in put energy, total output energy and energy output-input ratio in broadcast direct seeded rice

Treatment	Total input energy ha^{-1} (MJ X10^3) 2013 & 2014	Total input energy ha^{-1} (MJ X10^3) 2013 & 2014	Total output energy ha^{-1} (MJ X10^3)			Energy Output - input ratio Manual			Energy Output - input ratio Harvester		
	Manual	Harvester	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management											
W_1 :- *Biasi* method (Farmer's practice)	12.2	12.8	149.8	155.6	152.7	12.4	12.9	12.6	11.7	12.1	11.9
W_2 :- Two hand weeding at 20 & 40 DAS	11.9	12.6	141.7	153.2	147.5	12.0	12.9	12.5	11.3	12.2	11.7
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	11.3	12.0	138.9	152.6	145.8	12.3	13.5	12.9	11.6	12.7	12.1
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	11.4	12.1	130.9	144.3	137.6	11.5	12.7	12.1	10.8	11.9	11.4
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	11.4	12.0	135.6	149.4	142.5	12.0	13.2	12.6	11.3	12.4	11.9
W_6 :- Weedy check	11.0	12.0	74.5	55.8	65.2	6.8	5.1	6.0	6.2	4.7	5.5
SEm±			2.0	1.1	1.02	0.2	0.1	0.09	0.2	0.1	0.08
CD (P = 0.05)			6.3	3.6	3.22	0.6	0.3	0.08	0.5	0.3	0.26
Seed rate (kg ha^{-1})											
S_1 :- 120	12.1	12.9	125.9	131.6	128.7	10.4	10.8	10.6	9.8	10.2	10.0
S_2 :- 80	11.5	12.3	127.7	135.7	131.7	11.1	11.7	11.4	10.4	11.0	10.7
S_3 :- 40	10.9	11.7	132.2	138.2	135.2	12.1	12.6	12.3	11.3	11.8	11.5
SEm±			1.1	1.8	0.77	0.1	0.2	0.07	0.1	0.2	0.26
CD (P = 0.05)			4.3	7.1	3.02	0.4	0.6	0.27	0.3	0.7	2.58
Interaction (WM X SR)			NS	NS	NS	NS	NS	NS	NS	NS	NS

Table4.28: Effect of different weed management practices and seed rate on Energy use efficiency and Energy productivity in broadcast direct seeded rice

Treatment	Energy Use Efficiency (q MJ X10^3)						Energy Productivity (kg MJ ha^{-1})					
	Manual			Harvester			Manual			Harvester		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management												
W_1 :- *Biasi* method (Farmer's practice)	9.2	9.5	9.3	8.6	9.0	8.8	0.42	0.44	0.43	0.41	0.46	0.43
W_2 :- Two hand weeding at 20 & 40 DAS	8.8	9.6	9.2	8.3	9.0	8.7	0.42	0.44	0.43	0.41	0.46	0.44
W_3 :- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	9.1	10.0	9.6	8.6	9.4	9.0	0.43	0.46	0.44	0.43	0.48	0.45
W_4 :- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	8.5	9.4	9.0	8.0	8.9	8.4	0.40	0.41	0.40	0.39	0.43	0.41
W_5 :- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	8.9	9.8	9.3	8.4	9.2	8.8	0.41	0.44	0.42	0.41	0.46	0.43
W_6 :- Weedy check	5.2	4.0	4.6	4.8	3.6	4.2	0.13	0.08	0.11	0.07	0.08	0.08
SEm±	0.12	0.1	0.07	0.1	0.1	0.06	0.01	0.01	0.00	0.01	0.01	0.00
CD (P = 0.05)	0.39	0.2	0.21	0.4	0.2	0.19	0.04	0.03	0.01	0.03	0.03	0.01
Seed rate (kg ha^{-1})												
S_1 :- 120	7.7	8.1	7.9	7.2	7.6	7.4	0.34	0.35	0.34	0.33	0.36	0.34
S_2 :- 80	8.2	8.7	8.5	7.7	8.2	8.0	0.36	0.38	0.37	0.36	0.40	0.38
S_3 :- 40	8.0	9.4	9.2	8.4	8.8	8.6	0.40	0.41	0.40	0.38	0.42	0.40
SEm±	0.06	0.1	0.05	0.1	0.1	0.05	0.01	0.01	0.00	0.01	0.01	0.00
CD (P = 0.05)	0.25	0.4	0.20	0.2	0.4	0.19	NS	NS	0.01	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Experiment II: Direct line seeded rice

Studies on direct line seeded rice (*Oryza sativa L.*) under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation

4.6 Crop observation

4.6.1 Pre-harvest observations

4.6.1.1 Plant population (No. m^{-2})

Plant population at 15 DAS was computed and presented in Table 4.29 plant population varied significantly due to seed rate ranging from 80 to 40 kg ha^{-1} but weed management did not influence the plant population significantly. Among weed management practices maximum plant population was recorded under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment which was marginally over other weed management treatment. Weed management practices does not influence the plant population significantly.

Plant population at 15 DAS influenced significantly by the different level of seed rates ranging from 80 to 40 kg ha^{-1}. Significantly higher number of plant population in both the years was recorded in 80 kg ha^{-1} (S_1). However, the lowest number of plants was recorded under 40 kg ha^{-1} seed rate in both the years. Mean plant population was 228, 159 and 120 plant m^{-2}, respectively in 80, 60 and 40 kg ha^{-1} seed rate. Data on number of plant population reveals that 44 and 90 percent more plant population in 80 kg ha^{-1} seed rate as compared to 60 and 40 kg seed rate ha^{-1}. Interaction between weed management and seed rate was found non significant during both the years.

4.6.1.2 Plant height (cm)

Plant height of rice was measured at 15, 30, 45, 60 DAS and at harvest and are presented in Table 4.30. In general, plant height increased with advancement of crop age and higher magnitude of increase was observed between the 45 and 60 DAS, while growth was slowed down after 80 days after emergence. Seed rate, did not show any significant variation on plant height at all the stages of observation in both the years. However, the taller plant was observed in 40 kg ha^{-1} seed rate in all

Table4.29: Plant population (No. m^{-2}) of direct line seeded rice as influenced by weed management and seed rate

Treatment	Plant population (No. m^{-2})		
	2013	2014	Mean
Weed management			
W_1:- Two hand weeding	166	168	167
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	167	171	169
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	168	174	171
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	167	173	170
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	166	173	169
W_6:- Weedy check	166	174	170
SEm±	3.00	4.00	2.93
CD (P = 0.05)	NS	NS	NS
Seed rate (kg ha^{-1})			
S_1 :- 80	226	232	229
S_2 :- 60	157	161	159
S_3 :- 40	119	122	120
SEm±	7.08	12.39	9.67
CD (P = 0.05)	27.78	48.66	37.95
Interaction (WM X SR)	NS	NS	NS

the crop growth stages in both the years. It was due to better utilization of space and light for the growth and development of plant.

With reference to weed management, significant difference in plant height was noticed at all the observational stages except 15 DAS during both the years. At 15 DAS, plant height was non-significant in all weed management practices and produced equal plant height.

At 30 DAS, significantly taller plant was observed in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment over the control plot and it was at par with (W_4) pre-emergence (pretilachlor + bensulfuron

) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. The shortest height was recorded under the weedy check (W_6) due to initial competition between plants and weed.

At 45 and 60 DAS, significantly taller plant was recorded under two hand weeding (W_1) which was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} applied at 15 and 35 DAS at 45 DAS stage. Whereas at 60 DAS it was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20 g ha^{-1} at 15 and 35 DAS on the basis of two year mean. However, the shortest height of plant was recorded in weedy check. At harvest, two hand weeding recorded taller plant (106.01 cm) which was significantly superior over the weedy check (97.31 cm) and it was at par with all other weed management treatments. When the interaction between weed management and seed rate was studied it was found that the effect was statistically non-significant at all the stages of observation.

4.6.1.3 Plant dry matter accumulation (g $plant^{-1}$)

Data with respect to dry matter production of rice are presented in Table 4.31. Dry matter of rice crop increased with the advancement of crop age. Dry matter $plant^{-1}$ was significantly influenced by the different weed management practices except at early growth stage.

Among weed management practices at 15 DAS, data revealed that there was no significant effect on dry matter production of rice all the weed management practices produced equal dry matter in both the years. At 30 DAS, dry matter production was statistically significant. Maximum dry matter was produced by the (W_3) pre -emergence oxadiargyl 70 g ha-1 *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS but it was at par with (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. However, lowest dry matter production was recorded under the weedy check (W_6).

Table 4.30: Plant height (cm) of direct line seeded rice at different duration as influenced by weed management and seed rate

Treatment	Plant height (cm)														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	24.22	24.54	24.38	41.54	40.38	40.96	64.74	66.40	65.57	84.76	86.00	85.38	106.38	105.63	106.01
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	24.05	24.05	24.05	40.71	40.52	40.61	62.95	63.79	63.37	80.43	84.81	82.62	103.60	103.64	103.62
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	24.12	24.00	24.06	44.50	43.00	43.75	64.43	65.99	65.21	83.13	86.24	84.68	105.87	104.22	105.04
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	23.74	23.40	23.57	43.44	42.80	43.12	63.14	64.25	63.69	82.30	83.70	83.00	104.63	103.55	104.09
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	24.10	23.85	23.97	41.72	40.76	41.24	63.56	64.90	64.23	83.09	84.66	83.87	104.36	103.59	103.98
W_6:- Weedy check	24.19	23.85	24.02	41.40	38.13	39.77	60.05	60.41	60.23	76.11	80.63	78.37	98.24	96.38	97.31
SEm±	0.48	0.47	.46	0.74	0.98	.55	0.84	1.15	.62	1.16	1.11	.72	0.75	1.51	0.90
CD (P = 0.05)	NS	NS	NS	2.33	3.10	1.74	2.65	3.62	1.94	3.64	3.51	2.27	2.36	4.76	2.83
Seed rate (kg ha^{-1})															
S_1 :- 80	23.42	23.04	23.23	42.19	40.48	41.33	62.72	63.63	63.18	80.91	84.44	82.68	103.61	102.03	102.82
S_2 :- 60	24.29	24.32	24.05	42.12	41.06	41.59	63.24	65.06	64.15	82.28	84.01	83.14	103.98	103.43	103.50
S_3 :- 40	24.51	24.67	24.59	42.34	41.25	41.79	63.47	64.17	63.82	81.72	84.57	83.14	103.96	103.44	103.71
SEm±	0.46	0.45	.45	0.56	0.78	.50	0.35	0.51	.39	1.33	1.54	1.36	0.58	0.79	.63
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

At 45 DAS, treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was found significantly superior over the un-weeded control. At this stage, chemical control with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS produced maximum dry matter accumulation and it was at par with the other weed management treatments (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. At this stage, plant produced maximum dry matter accumulation $plant^{-1}$ throughout the crop growth period. However, dry matter production was recorded lowest under un-weeded control due to high weed crop competition for the resources.

During the 60 DAS, maximum dry matter accumulation $hill^{-1}$ was produced by the two hand weeding at 20 and 40 DAS which was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Plant accumulate maximum dry matter between 45 to 60 DAS which was the active growth period. At harvest, it was maximum in two hand weeding method and at par with the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS , (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. The poor growth of plant in the weedy check is due to the fact that there was maximum competition for nutrient, water and sunlight between the crop and weed.

Dry matter accumulation up to 45 DAS was found non significant due to different seed rates. However, after the 45 days the maximum dry matter accumulation was found in the 40 kg seed ha^{-1} due to this, the less plant population gives individual plant to grow more dry matter under the favorable environment and weed free situation. Mahajan *et al.* (2010) also concluded that high seed rate caused significant reduction in dry matter due to high plant population per unit area. Interaction between weed management and seed rate for plant dry matter accumulation (g $plant^{-1}$) was recorded non significant up to the 45 DAS. However, it was significant during 60 DAS and harvest (Table 4.31a and 4.31b). Interaction between seed rate and weed management was significant as maximum dry matter

was produced under the combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with two hand weeding at 20 and 40 DAS as compared to other combinations during both the years and was at par with the combinations of (S_2 x W_1) 60 kg seed rate ha^{-1} with two hand weeding and (S_2 x W_3) 60 kg seed rate ha^{-1} with pre -emergence application of oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the years. However, minimum dry matter was produced by the combination of (S_3 x W_6) application of 80 kg seed rate ha^{-1} with weedy check in both the years. Comparison of same level of weed management with different seed rate showed that, comparatively more dry matter was accumulated under 40 kg ha^{-1} seed rate and was at par with 60 and 80 kg ha^{-1} seed rate in all the weed management practices. At harvest during 2013 dry matter production with the combination of (S_3 x W_4) application of 40 kg ha^{-1} seed rate with pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was found significaltly superior among all the combination.Whereas, it was maximun under the combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with two hand weeding at 20 and 40 DAS during 2014. Minimum dry matter was produced by the combination of (S_3 x W_6) application of 80 kg seed rate ha^{-1} with weedy check in both the years. On the basis of two year mean, maximum production of dry matter was recorded under the combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with two hand weeding at 20 and 40 DAS which was nearly equal to the 40 kg seed rate ha^{-1} along with pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS

4.6.1.4 Crop growth rate (g day^{-1} $plant^{-1}$)

Crop growth rate (CGR) of rice pant was observed at 15-30,30-45, 45-60 and 60- harvest and presented in Fig 4.8 . Crop growth rate g day^{-1} $plant^{-1}$ was sharply increased up to 60 DAS and declined thereafter till harvest in both the years. Crop growth rate was influenced significantly due to different weed management practices during 15-30, 30-45 and 45-60 DAS in both the years of investigation but after that from 60 - harvest the crop growth did not differ significantly with weed management practices. It is quite clear from the data that the weed management through chemical control (W_3) pre -emergence oxadiargyl

Table 4.31: Dry matter accumulation (g plant^{-1}) of direct line seeded rice at different duration as influenced by weed management and seed rate

Treatment	Dry matter accumulation (g plant^{-1})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	0.16	0.17	0.17	0.91	0.85	0.88	3.80	3.70	3.75	7.74	8.58	8.16	9.18	9.89	9.54
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	0.17	0.17	0.17	0.92	0.87	0.89	3.77	3.67	3.72	6.66	7.46	7.06	8.21	8.71	8.46
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.17	0.17	0.17	1.16	1.14	1.15	4.38	4.00	4.19	7.63	8.46	8.05	9.08	9.63	9.36
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.15	0.16	0.15	1.10	1.09	1.09	4.13	3.81	3.97	7.08	7.83	7.46	8.96	9.46	9.21
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	0.16	0.16	0.16	0.93	0.81	0.87	4.07	3.92	4.00	7.11	7.86	7.49	8.91	9.44	9.18
W_6:- Weedy check	0.17	0.16	0.16	0.89	0.76	0.83	2.85	2.75	2.80	6.33	7.08	6.71	7.59	8.05	7.82
SEm±	0.01	0.01	0.01	0.04	0.04	0.03	0.09	0.09	0.09	0.16	0.14	0.15	0.13	0.14	0.13
CD (P = 0.05)	0.02	0.02	0.02	0.12	0.14	0.09	0.28	0.28	0.28	0.50	0.45	0.47	0.40	0.43	0.41
Seed rate (kg ha^{-1})															
S_1 :- 80	0.16	0.16	0.16	0.94	0.90	0.92	3.91	3.73	3.82	6.68	7.43	7.05	8.20	8.70	8.45
S_2 :- 60	0.16	0.17	0.16	1.00	0.93	0.97	3.79	3.58	3.68	7.05	7.81	7.43	8.60	9.08	8.84
S_3 :- 40	0.16	0.16	0.16	1.01	0.93	0.97	3.81	3.62	3.71	7.56	8.40	7.98	9.17	9.81	9.49
SEm±	0.00	0.01	0.02	0.04	0.04	0.04	0.14	0.14	0.14	0.11	0.15	0.12	0.12	0.11	0.11
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.41	0.57	0.49	0.46	0.44	0.44
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	NS	S	S	S

Table 4.31a: Interaction of weed management and seed rate on dry matter accumulation (g plant^{-1}) at 60 DAS in direct line seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**
W_1:- Two hand weeding	7.18	7.73	8.30	7.93	8.48	9.33	7.56	8.11	8.82
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	6.55	6.98	6.46	7.33	7.83	7.21	6.94	7.41	6.84
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	7.29	7.34	8.27	8.04	8.09	9.25	7.67	7.72	8.76
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	6.49	6.93	7.83	7.24	7.68	8.58	6.86	7.31	8.21
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	6.75	7.08	7.50	7.50	7.83	8.25	7.13	7.45	7.88
W_6:- Weedy check	5.80	6.21	6.99	6.55	6.96	7.74	6.17	6.58	7.37
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.35	1.07		0.35	1.08		0.35	1.07	
Comparison of two weed management means at the same or different level of seed rate	0.11	0.34		0.11	0.32		0.11	0.33	

Table 4.31b: Interaction of weed management and seed rate on dry matter accumulation (g plant^{-1}) at harvest in direct line seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**
W_1:- Two hand weeding	8.75	9.02	9.77	9.25	9.52	10.90	9.00	9.27	10.33
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	8.00	8.39	8.23	8.50	8.89	8.73	8.25	8.64	8.48
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	8.93	9.10	9.20	9.43	9.60	9.87	9.18	9.35	9.53
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	8.02	8.72	10.16	8.52	9.22	10.66	8.27	8.97	10.41
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	8.12	8.80	9.82	8.62	9.30	10.39	8.37	9.05	10.11
W_6:- Weedy check	7.37	7.58	7.82	7.87	7.97	8.32	7.62	7.78	8.07
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.21	0.68		0.21	0.68		0.21	0.66	
Comparison of two weed management means at the same or different level of seed rate	0.07	0.20		0.07	0.21		0.07	0.20	

70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and at par with (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS showed maximum growth rate during 15-30 and 30-45 days period after that 45-60 DAS, it was maximum in two hand weeding method. After that, crop growth period from 60 to harvest, was non significant during both the years in direct seeded line sown crop during the experimentation. The lowest CGR was recorded under the weedy check (W_6) throughout the crop growth period.

Different seed rates did not influence crop growth significantly in both the years throughout the crop growth period. However, highest CGR was observed in (S_3) 40 kg ha^{-1} seed rate and lowest CGR was recorded under the highest seed rate of 120 kg ha^{-1} in all the growth stages of the plant. Interaction between the seed rate and weed management was non significant in both the years.

4.6.1.5 Relative growth rate (g g^{-1} day^{-1})

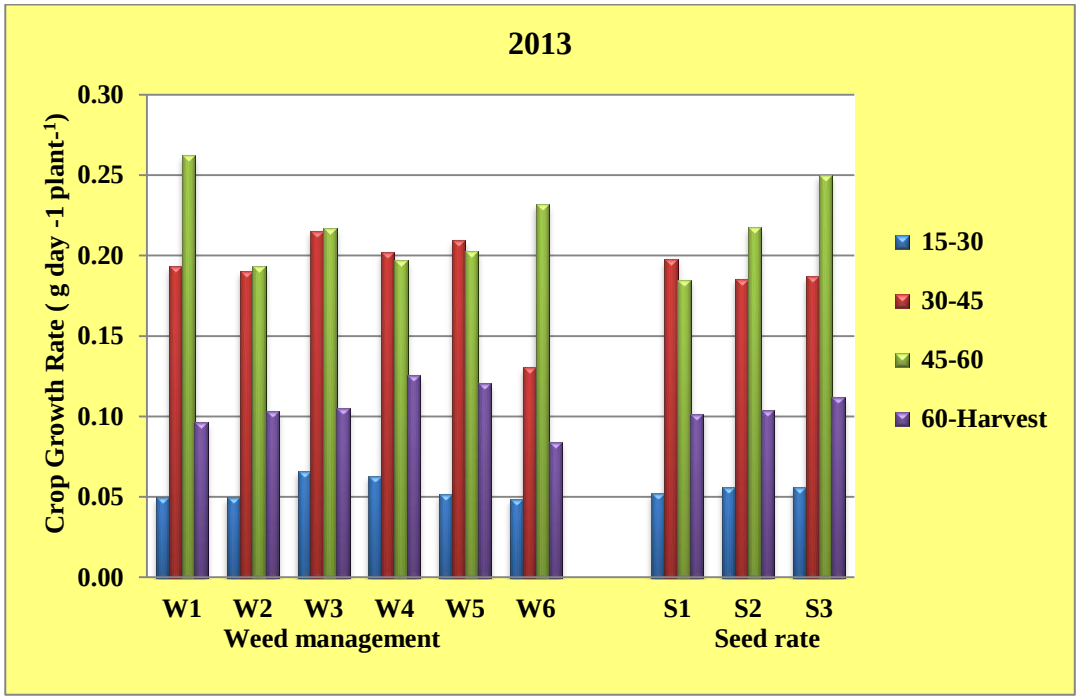
Relative growth rate (RGR) of rice plant was observed at 15-30,30-45, 45-60 and 60- harvest and presented in Fig 4.9. Relative growth rate (g g^{-1} day^{-1}) showed decreasing trend up to harvest. In general, RGR did not differ greatly at different intervals. It is clear from the data that relative growth rate progressed up to the 30 days and after that slightly declined up to the 45 days asfet that subsequently decline in growth is very fast. As regard to weed management option , significant variation in relative growth rate was recorded during 15-30, 30-45 and 45-60 DAS in both the year of investigation but after that from 60 - harvest the crop growth did not differ significantly with weed management practices. Among the weed management practices, higher relative growth rate was observed with hand weeding during the 15-30 days period in both the years. At 30-45 DAS, it was maximum in (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS after that 45 to 60 DAS maximum RGR was observed in weedy check. During 60 DAS to harvest, it was non significant in both the year. However, it was maximum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment.

Different seed rate treatments did not show significant difference in relative growth rate in both the years but it was higher in 40 kg ha^{-1} seed in all the growth period except 30-15 DAS. However, the lowest RGR was registered under seeding rate of 120 kg ha^{-1} seed rate from initial to the harvest period of crop growth. It is also reported by Singh *et al.* (1981) and Reddy (1993). Interaction between the seed rate and weed management was non significant in both the years.

4.6.1.6 Discussion on growth parameters

Growth parameters like plant height, plant dry matter, number of total tillers, number of effective tillers and crop growth rate were influenced significantly due to various weed management practices in direct line seeded rice. The results obtained revealed that under *biasi* method, hand weeding twice and herbicidal application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS produced higher plant height. These treatments were significantly superior over untreated control. Other treatments of weed management also favored significant increase in plant height as compared to untreated control. The possible reason of higher plant height in these treatments might be due to congenial and longer weed free environment during crop growth period, provided better opportunity for overall growth and development of rice plants lead to maximum plant height. The similar finding was obtained by Mamun (2011), Khaliq *et al.* (2011). The maximum plant height and dry matter accumulation was due to fact that due to low plant population and sufficient availability of moisture , light ,development of high photosynthesis activity and supply of photosynthates to growing area leading to enlargement and development of meristematic tissues at growing point. This causes faster growth of growing points, ultimately the plant height and dry matter accumulation.

In general, higher accumulation of dry matter of rice and crop growth rate (CGR) took place in hand weeding and sequential application of pre and post emergence application of herbicides. Due to the effect of weed management, plants received more space, moisture, light and nutrient for their proper growth and development, this might be the reason that higher dry matter accumulation of rice crop per unit area. Higher foliage under weed management might have enhanced



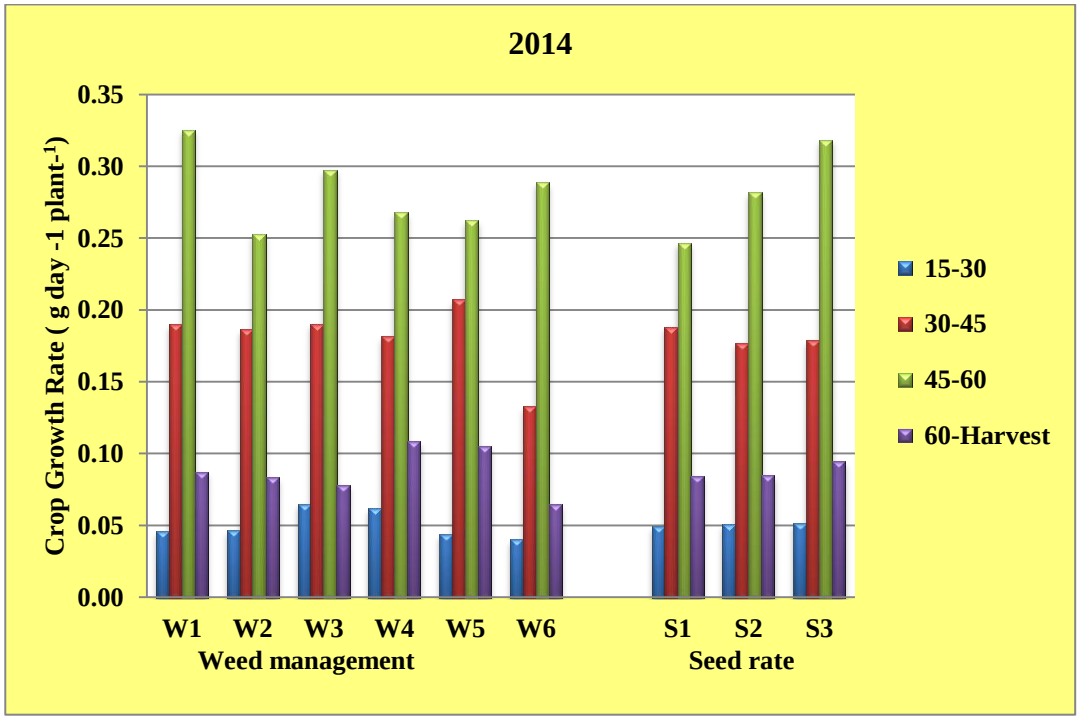
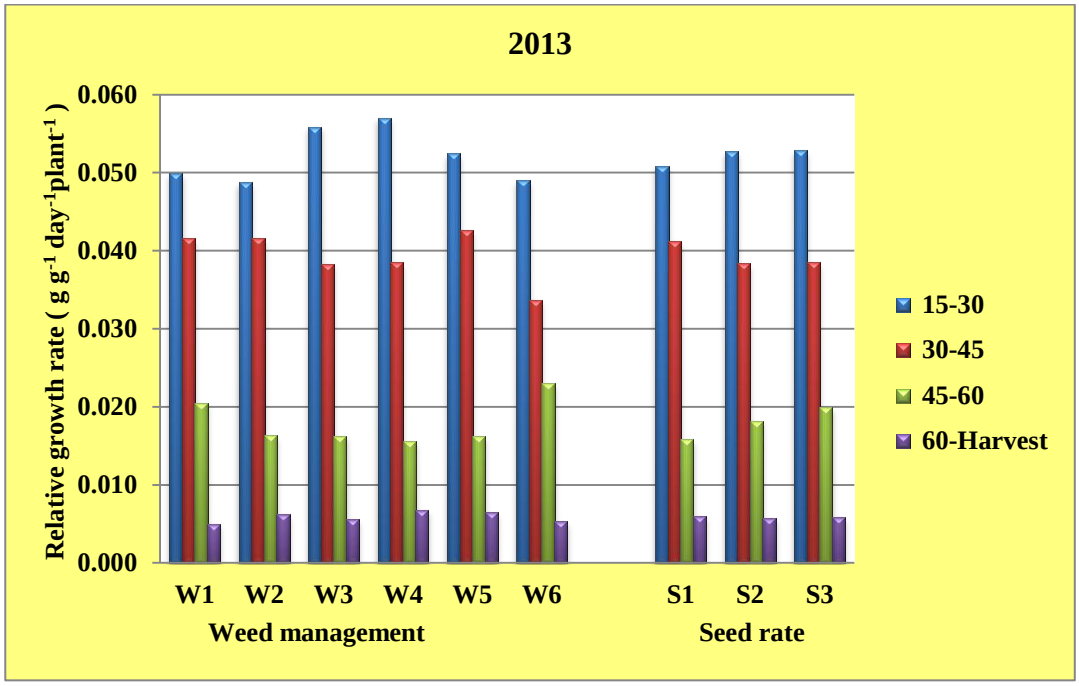


Fig 4.8: Crop Growth Rate (g day $^{-1}$ plant^{-1}) in direct line seeded rice (2013-2014)



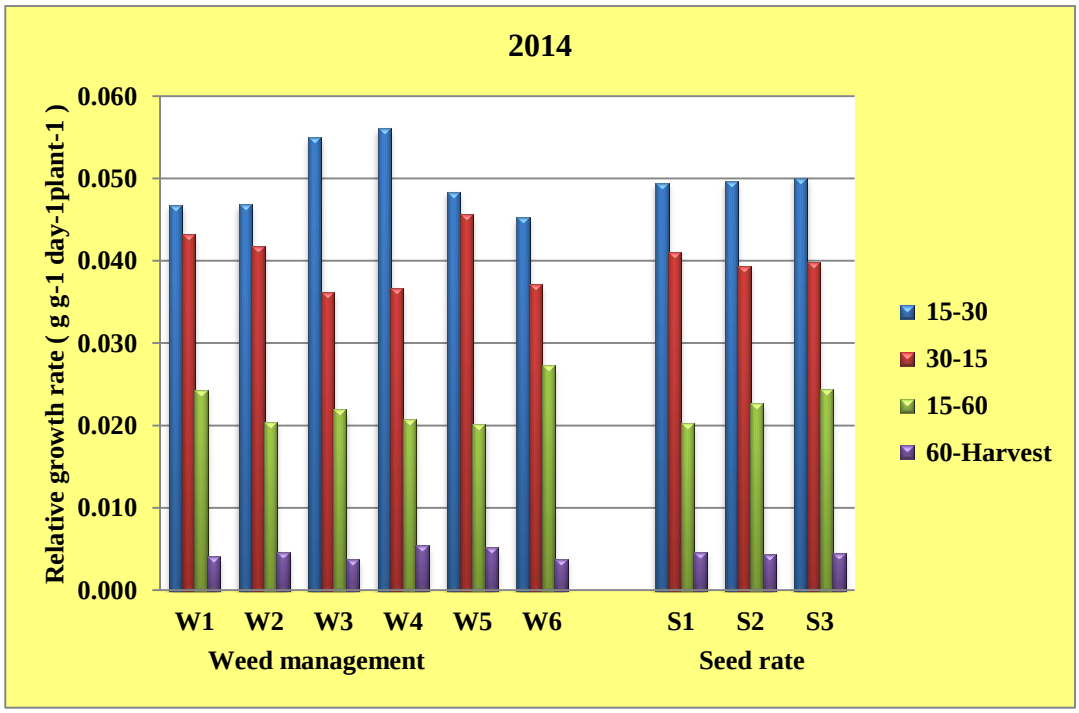


Fig 4.9: Relative Growth Rate (g g $^{-1}$ day^{-1}plant^{-1}) in direct line seeded rice (2013-2014)

photosynthesis produced higher dry matter accumulation. The highest dry matter accumulation under hand weeding and pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS due to reduction in crowding effect of weed populations. This is in accordance with the findings of Reddy (1993), Singh *et al.* (1981) and Reddy (1993).

It was observed that irrespective of the treatments, crop growth rate (CGR) declined with advancement of crop stages. Reduction in crop growth rate with advancement of crop age might be due to the senescence of leaves and higher weed density during this period. The crop growth rate is higher at active vegetative stage of crop.

The increase in crop growth up to 60 DAS was due to fact that after 60 DAS source sink relationship was occurred and translocation of photosynthates from vegetative to reproductive parts which decreases the vegetative growth and increased the reproductive growth. Other growth parameter like total number of tillers m^{-2} and number of effective tillers m^{-2} were also influenced significantly with different weed management practices. Higher number of tillers were obtained under hand weeding and , application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS . Higher numbers of tillers under these treatments was due to the fact that there was more space for the crop to show their genetic potential due to less crop -weed competition for the resources. Similar result was observed by Kumar *et al.* (2008) , Khaliq *et al.* (2011) and jaysuria *et al.* (2011).

On the contrary, the minimum values of growth parameters was recorded under weedy check, might be due to high weed infestation and competition during critical periods, which did not allow the crop to grow to their potential, resulted in less dry matter accumulation, crop growth rate, tillering as well as effective tillers by rice crop.

The number of tillers m^{-2} and other growth parameters at harvest did not show any significant difference over the seed rates. However, the maximum tillers were found in (S_3) 40 kg ha^{-1} seed followed by the 80 kg ha^{-1} and 120 kg ha^{-1}. Higher number of total tillers under the 40 kg ha^{-1} seed rate was due to the fact that

there was more space and light for the crop to show their genetic potential. Other parameters like plant height and dry matter accumulation, was also comparatively higher under 40 kg ha^{-1} seed rate as compared to other seed rates due to better utilization of light, moisture, space and nutrients by the rice plant for their growth and development.

4.6.1.7 Number of total tillers (m^{-2})

Data with respect to total tillers at 45, 60 DAS and at harvest are presented in Table 4.32. Weed management practices significantly affected the total tillers at 45, 60 DAS and at harvest. At 45 and 60 DAS, maximum number of tillers was recorded in two hand weeding at 20 and 40 DAS which was significantly superior over weedy check.

Among weed management practices at harvest, maximum number of total tillers (476) was found in two hand weedings which was at par with the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in both the years. However, the lowest number of total tillers (223) was recorded under the weedy check which reflects on the grain yield. On the basis of two year mean, hand weeding produced 113 per cent more tillers as compared to the weedy check. Difference between hand weeding and chemical control was very marginal in respect to number of tillers, it was ranging from 1.2 to 14 percent. However, 1.2 per cent more tillers in hand weeding as compared to the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment showed that sequential application of pre and post-emergence herbicides are effective to control the weeds and might be the alternative of manual weeding.

Different seed rates did not show significant difference in number of tillers both the year at 45, 60 and at harvest. However, the maximum tillers were recorded in (S_3) 40 Kg ha^{-1} seed rate. Higher number of total tillers under the 40 Kg ha^{-1} seed rate was due to the fact that more space and light was utilized by the widely spaced plant population which gives the opportunity to produce more tillers due to less initial competition between the plants.

Interaction between seed rate and weed management was found non significant at 45 and 60 DAS whereas, it was significant at harvest in respect to

total tillers (Table 4.32a) during both the years. Interaction between seed rate and weed management significantly produced maximum total tillers in combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with two hand weeding at 20 and 40 DAS as compared to other combinations during both the years. Comparison of different seed rates with same level of weed management of two hand weeding reveals that 60 and 40 kg ha^{-1} seed rate was at par with each other. Whereas, in chemical control of (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS showed that all the seed rates from 80 to 60 kg ha^{-1} was similar in production of total tillers. However, minimum total tiller was recorded under combination of (S_2 x W_6) 60 kg seed rate ha^{-1} with weedy check during both the years. Interaction of total tiller is self explanatory that, low seed rate and high seed rate produced equal tillers in combination of hand weeding or chemical control.

4.6.1.8 Number of effective tillers (m^{-2})

The data on number of effective tillers (m^{-2}) of rice at harvest are presented in Table 4.32. Weed management practices significantly influenced number of effective tillers (m^{-2}) of rice crop at harvest, whereas, non-significant due to different seed rates.

Among the weed management, highest number of effective tillers of rice was found in two hands weeding in both the years which was at par with (W_3) pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. However, the minimum number of effective tillers was produced by the weedy check (183). Result is self explanatory that applicaton of pre and post emergence herbicides may be the alternative of manual weeding.

On the mean basis of two years it was concluded that two hand weeding at 20 and 40 DAS produced 56 per cent more effective tillers as compared to the weedy check but it was ranging only 1.6 to 10 per cent more as compared with chemical weed management. Difference between hand weeding and (W_3) pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in respect to effective tillers was only 1.6 per cent which showed that chemical control is an alternative of manual weeding. The lowest number of effective tiller m^{-2} was recorded under control (W_6) only 183 effective tillers m^{-2} was recorded on the

mean basis of two year, might be due to high crop - weed competition for the nutrient, light, space and water at early growth stage, finally source and sink relation would not be established which badly affected the dry matter accumulation and grain formation. Nagappa and Biradar (2002) reported that among the weed management practices, two hand weeding at 20 and 40 days produced significantly higher yield (5872 kg ha^{-1}) over the unweeded check (3698 kg ha^{-1}). Pal *et al.* (2002) reported that the hand weeding, application of ethoxysulfuron @ 0.02 kg ha^{-1} + anilofos @ 0.375 kg ha^{-1} and oxadiargyl @ 0.1 kg ha^{-1} resulted in higher yield and less weed growth compared to other treatment. Kumar *et al.* (2008) also supported that due to absence of weed control reduction in effective tillers was observed. Khaliq *et al.* (2011) and Jaysuria *et al.* (2011) also supports that more numbers of effective tillers in the hand weeding and with bispyribac-sodium as post-emergence was recorded during investigation.

Among the seed rates, number of effective tillers m^{-2} of rice crop was recorded non significant in direct line seeded rice. However, 40 kg ha^{-1} produced higher effective tillers but it was statistically at par with the 60 kg ha^{-1} and 80 kg seed ha^{-1} respectively. Higher effective tillers under 40 kg seed rate ha^{-1} is due to less number of seedlings per meter square with effective weed management provides favorable environment to develop source sink relation and higher dry matter accumulation in plants . Yadav *et al*. (2007) observed that the crop stand and tillers was higher in direct-drilled plots with 50 kg seed ha^{-1}. FAO (2007) also supported that higher seed rate increases costs, population of infertile tillers and incidence of plant hoppers etc. and also suffer from nitrogen shortages.

Interaction between seed rate and weed management was significant in respect to effective tillers (Table 4.32b) during both the years. Interaction between seed rate and weed management significantly produced maximum effective tillers in combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with two hand weeding at 20 and 40 DAS as compared to other combinations during both the years and was at par with the combinations of (S_2 x W_1) 60 kg seed rate ha^{-1} with two hand weeding and (S_2 x W_3) 60 kg seed rate ha^{-1} with pre -emergence application of oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. During 2013 and 2014 effective tillers was similar in all the combinations of seed rates ranging from 80 to 40 kg

Table 4.32: Number of total and effective tillers (m^{-2}) of direct line seeded rice as influenced by weed management and seed rate

Treatment	Number of tillers (m^{-2})											
	45 DAS			60 DAS			Harvest			Effective tillers m^{-2}		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management												
W_1:- Two hand weeding	396	428	412	421	460	440	468	484	476	407	424	415
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	334	365	350	364	398	381	394	420	407	362	382	372
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	385	422	403	410	453	431	460	478	470	398	418	408
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	377	401	393	407	433	420	437	457	447	379	399	389
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	382	407	394	410	437	423	442	462	452	382	402	392
W_6:- Weedy check	158	182	170	196	209	202	210	237	223	177	189	183
SEm±	6.86	7.43	6.83	6.95	6.96	6.39	7.00	6.55	6.52	9.53	10.53	9.53
CD (P = 0.05)	21.61	23.43	21.53	21.90	22.93	20.14	22.05	20.66	20.53	30.01	31.25	20.01
Seed rate (kg ha^{-1})												
S_1 :- 80	341	368	355	367	398	382	399	424	411	346	365	355
S_2 :- 60	335	364	349	366	396	381	399	420	409	351	371	361
S_3 :- 40	340	370	358	371	398	386	407	425	416	356	372	364
SEm±	4.35	2.54	3.32	4.05	2.06	2.89	3.86	2.43	3.13	6.42	6.82	6.42
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	S	S	S	S	S	S

Table 4.32a: Interaction of weed management and seed rate on total tillers (m^{-2}) at harvest in direct line seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**
W_1:- Two hand weeding	449	468	487	469	482	500	459	475	493
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	387	397	397	426	417	417	406	407	407
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	456	465	460	476	485	474	466	475	467
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	444	442	424	464	462	444	454	452	434
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	440	425	461	460	445	481	450	435	471
W_6:- Weedy check	220	198	212	250	228	232	235	213	222
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	7.96	25.30		7.85	23.88		7.66	23.85	
Comparison of two weed management means at the same or different level of seed rate	3.12	9.56		3.12	9.51		3.01	9.20	

Table 4.32b: Interaction of weed management and seed rate on effective tillers (m^{-2}) at harvest in direct line seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**
W_1:- Two hand weeding	392	404	416	412	424	436	402	414	426
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	344	383	359	364	403	379	354	393	369
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	394	407	393	414	427	413	404	417	403
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	395	383	360	415	403	380	405	393	370
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	377	373	396	397	393	416	387	383	406
W_6:- Weedy check	165	154	188	185	174	208	175	164	198
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	13.60	43.09		12.60	42.09		13.60	43.09	
Comparison of two weed management means at the same or different level of seed rate	4.78	14.53		4.70	13.53		4.78	14.53	

ha^{-1} and all the weed management practices. So that it can be stated that the lower seed rate can also achieve high effective tillers subject to proper weed management. Minimum production of effective tillers were recorded under combination of (S_2 x W_6) application of 60 kg seed rate ha^{-1} with no weed control and at par with 80 and 40 kg ha^{-1} seed rate at same level of weedy check.

4.6.2 Post-harvest observations

4.6.2.1 Number of filled grains (panicle^{-1})

The data with respect to number of filled grains panicle^{-1} are presented in Table 4.33. Data revealed that hand weeding treatment proved significantly superior over weedy check. Among the weed management treatments, highest number of filled grains panicle^{-1} (131.49) was recorded under two hand weeding at 20 and 40 DAS in both the year which was at par with all the chemical control methods. Whereas, the lowest number of filled grains panicle^{-1} (107.86) was observed under the control plot. The difference between the hand weeding and chemical weed control in respect to filled grains was very marginal, due to the less crop-weed competition at critical period of crop growth and better weed suppression by the herbicides. Difference between hand weeding and chemical weed control was only 1 to 4 per cent in respect to filled grains per panicle whereas, it was 22 percent more as compared to weedy check on the mean data basis. Jay Suria *et al.* (2011) and Soni *et al.* (2012) also reported that grains panicle^{-1} was markedly increased by chemical weed control over the weedy check. Nagappa and Biradar (2002) reported that among the weed management practices, two hands weeding at 20 and 40 days produced significantly higher yield and yield attributes over the un weeded check. Khaliq *et al*. (2011) stated that, manual weeding also accounted for maximum panicle length (18.57 cm), grains per panicle (117), 1000-grain weight (18.52 g), number of grains per panicle (116.66) and was at par with post emergence application of bispyribac sodium. Saha and Rao (2012) reported that higher number of panicles m^{-2} and grains panicle^{-1} were recorded at the application rate 30-35 g a.i. ha^{-1} of azimsulfuron over other treatments.

Among different seed rates, it was observed that numbers of filled grains panicle^{-1} were recorded non-significant. Whereas, the maximum number of filled

grains panicle^{-1} were found under the 40 kg seed rate ha^{-1} which was at par with the 80 kg and 120 Kg ha^{-1} seed rate. Ravi (2008) reported that 150 to 200 seeds m^{-2} (26 to 30 kg ha^{-1}) seed rate with good weed management condition led to highest filled grains in dry direct seeded rice. Walia *et al.* (2009) also supported that the low seed rate 37.5 to 45 Kg ha^{-1} was found optimum for successful cultivation of direct seeded rice (DSR). Interaction effect between weed management and seeding rate was found non-significant.

4.6.2.2 Number of un-filled grains (panicle^{-1})

Data with respect to unfilled grain are presented in Table 4.33. It is clear from the data that un-filled grains were significantly influenced by different weed management practices and it was non significant in respect to different seed rates. Maximum number of un-filled grains panicle^{-1} was found in weedy check treatment. Whereas, the minimum number of un-filled grains were found in two hand weeding in both the years which was nearly equal to the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. However, during the year 2013, the un-filled grain was high as compared to the year 2014. It was due to the climatic condition variation in both the year. Weedy check plots produced 62 percent more unfilled grains as compared to hand weeding might be due to the competition between the plants and weed present in un-weeded control plot.

Among the seed rate statistically non significant effect was found in number of un-filled grains during both the years. However, it was high in 80 kg ha^{-1} seed rate as compared to the low seed rate 40 kg ha^{-1}. This is due to low growth rate and weak source to sink relationship in high seed rate. Weed management and seed rate did not interact significantly in respect to number of un-filled grains panicle^{-1}.

4.6.2.3 Sterility per cent (%)

The data with respect to sterility per cent are presented in Table 4.33. It is clear from the data that the sterility was significantly influenced by different weed management practices. Among the weed management practices, maximum sterility

was present in the un-weeded control plot which was significantly superior over other treatment, and the minimum sterility per cent was recorded in the two hand weeding followed by the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} applied at 15 and 35 DAS. However, the sterility was high in 2013 as compared to the 2014. Under the un-weeded control, higher sterility per cent directly influenced the seed yield of weedy check plot. On the mean basis of two years 100 per cent higher sterility was present in the weedy check plot as compared to the hand weeding. Whereas, the difference in sterility per cent was very marginal between hand weeding and chemical control method.

With respect to seed rate, the significantly highest sterility per cent (20.04) was recorded in 80 kg ha^{-1} seed rate in both the year. This is due to high plant population, competition between the crop plants and weeds for space, light and nutrients was very high, so that there was weak source to sink relationship developed ultimately high sterility per cent was produced by the weedy plot. However, the minimum sterility per cent (16.52) was recorded under 40 kg ha^{-1} seed rate. Weed management and seed rate did not interact significantly in respect to sterility percent.

4.6.2.4 Panicle length (cm)

Data with respect to panicle length is presented in Table 4.34. The observation of panicle length among different weed management practices revealed that it was significantly influenced by the weed management practices. During 2013 and 2014 maximum length (24.07 cm) of panicle was recorded in (W_1) two hands weeding at 20 and 40 DAS over the weedy check and (W_2) bispyribac-Na @25 g ha^{-1} at 20DAS treatment although it was at par with W_3, W_4 and W_5 treatment. However, smallest (21.74 cm) panicle length was recorded in un-weeded condition due to high crop weed competition and low growth and development of rice plant weedy check.

Panicle length in hand weeding was 10 per cent more longer than the weedy check treatment but there is marginal difference between the hand weeding and other chemical control weed management were ranged between 1 to 5 per cent

Table 4.33: Number of grains panicle^{-1} and sterility percentage of direct line seeded rice as influenced by weed management and seed rate

Treatment	No. of filled grains panicle^{-1}			No. of unfilled grains panicle^{-1}			Sterility (%)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management									
W_1:- Two hand weeding	131.49	141.94	131.49	23.17	12.25	17.71	17.65	7.94	12.80
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	129.71	136.11	129.71	31.40	12.39	21.89	24.60	8.34	8.34
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	130.20	139.00	130.20	29.79	11.41	20.60	23.25	7.50	7.59
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	126.28	135.56	126.28	34.39	15.33	24.86	27.82	10.16	10.16
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	128.12	136.11	128.12	31.71	14.67	23.19	24.93	9.73	9.73
W_6:- Weedy check	107.86	105.28	107.86	36.70	20.67	28.68	34.85	16.41	25.63
SEm±	2.95	2.69	2.23	1.63	0.57	0.93	1.21	0.47	0.70
CD (P = 0.05)	9.29	8.48	7.04	5.14	1.80	2.94	3.80	1.47	2.19
Seed rate (kg ha^{-1})									
S_1 :- 80	123.67	129.81	123.67	32.76	14.44	23.60	27.36	10.01	18.69
S_2 :- 60	119.15	134.67	119.15	32.10	15.01	23.55	27.29	10.03	18.66
S_3 :- 40	134.01	137.03	134.01	28.72	13.92	21.32	21.90	9.22	15.56
SEm±	2.91	1.71	1.30	2.07	0.37	0.89	2.20	0.47	0.96
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS

only. Difference between two best treatment hand weeding and (W_3) pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was only 1.0 per cent proved that application of pre and post emergence herbicide may be the alternative to manual weeding. Tiwari (2002) and Thura (2003) also reported that the hand weeding produced longer panicle length as compared to the chemical weed management. Kiran *et al.* (2010) stated that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} or penoxsulam 75 g ha^{-1} was as effective as hand weeding twice in improving growth, yield attributes and yield of rice.

In respect to different seed rates, no significant effect on panicle length was observed. However, panicle length under 40 kg ha^{-1}(23.6 cm) is slightly higher than other treatments and lowest panicle length was recorded under 60 kg ha^{-1} on mean basis of two years.

Interaction between the seed rate and weed management was non significant in both the years in respect to panicle length. Gill *et al.* (2007) also supported that, contrary to effective tillers, the panicle length, grains $panicle^{-1}$ and 1000-grains weight gave the highest values at lower seed rate (50 kg ha^{-1}) which were significantly higher than 100 and 150 kg ha^{-1}, respectively.

4.6.2.5 Panicle weight (gm)

Data regarding panicle weights are presented in Table 4.34. The panicle weight at different weed management practices in direct seeded line sown rice crop was found significantly superior over the weedy check and (W_2) bispyribac-Na @25 g ha^{-1} at 20 DAS treatment. However, maximum panicle weight was recorded under two hand weeding (W_1) which was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS treatments. Whereas, lowest panicle weight was observed under un-weeded control plot.

There is no makeable difference among the chemical weed control method and manual weeding in respect to panicle weight which proves that chemical weed

control might be the alternatives of hand weeding. Singh *et al.* (2005) also reported the similar result. Walia *et al.* (2009), found that integration of post-emergence (25-30 DAS) application of bispyribac 25 gha^{-1} or azimsulfuron 20 g ha^{-1} with pre-emergence application gives higher yield parameters and yield.

Among different seed rates, plot having 40 kg ha^{-1} seed rate produced higher panicle weight as compared with the 60 kg ha^{-1} and 80 kg ha^{-1} seed rate but the data was non-significant in both the years. On the mean basis we can say that the low seed rate with the appropriate weed management practices can also produce the similar yield parameter as the high seed rate. Interaction effect between weed management practices and seeding rate was found non-significant.

4.6.2.6 Test weight (g)

The data with respect to test weight are presented in Table4.34. Data revealed that weed management practices proved significantly superior over the weedy check (27.61). However, all weed management treatments are at par with each other in both the year. Among the weed management practices, test weight was highest in (W_1) two hand weeding (29.23) but it was similar and statistically at par with chemical control methods in both the year. Data is self explanatory that the chemical control with proper dose of herbicide may be the replacement of hand weeding operation. Khaliq *et al.* (2011) also support that the application of bispyribac will be the alternatives of hand weeding.

Test weight of direct seeded line sown rice was found non significant in both the year during experimentation. However, maximum test weight (28.97) was observed in 40 kg ha^{-1} seed rate. Almost similar test weight was observed in different seed rate ranging from 80 to 40 kg ha^{-1} .So that we can interpret that higher seed rate can be replaced by the low seed rate with the combination of pre and post emergence herbicides as the growth parameter supports in this experiment. Gill *et al.* (2007) also support that, test weight gave the highest value at lower seed rate. Interaction effect between weed management practices and seeding rate was found non-significant.

Table 4.34: Panicle length (cm) and weight (g) and Test weight (g) of direct line seeded rice as influenced by weed management and seed rate

Treatment	Panicle length (cm)			Panicle weight (g)			Test weight (g)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management									
W_1:- Two hand weeding	23.94	24.21	24.07	3.36	3.17	3.26	29.57	28.89	29.23
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	23.25	22.02	22.64	2.91	2.84	2.93	28.56	29.67	29.11
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	23.93	23.72	23.83	3.21	3.04	3.13	29.56	29.67	29.61
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	23.39	22.60	23.00	3.08	2.91	3.00	28.67	29.22	28.94
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	23.55	23.33	23.44	3.12	2.99	3.06	28.89	28.22	28.56
W_6:- Weedy check	22.40	21.09	21.74	2.62	2.53	2.58	27.44	27.58	27.61
SEm±	0.18	0.53	0.23	0.12	0.09	0.07	0.41	0.41	0.24
CD (P = 0.05)	0.56	1.66	0.73	0.37	0.30	0.21	1.28	1.29	0.76
Seed rate (kg ha^{-1})									
S_1 :- 80	23.40	22.47	22.93	2.89	2.94	2.91	28.44	28.72	28.58
S_2 :- 60	23.40	22.24	22.82	3.04	2.90	2.97	28.94	29.00	28.97
S_3 :- 40	23.40	23.77	23.60	3.22	2.97	3.09	28.95	29.00	28.98
SEm±	0.11	0.30	0.17	0.07	0.10	0.07	0.24	0.42	0.28
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.6.2.7 Seed yield (q ha^{-1})

The data with respect to seed yield are presented in Table 4.35. It is clear from the data that seed yield was significantly influenced by different weed management practices.

Among different weed management practices, two hand weeding (W_1) at 20 and 40 DAS method was significantly superior over weedy check during both the years. However, it was at par with the chemical control method (W_3) pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. During 2014 similar result was found but treatment (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was also at par with the manual weeding. Seed yield was slightly higher in 2014 due to climatic condition as compared to the 2013. Hand weeding twice produced 258 percent more grain yield as compared to the weedy check treatment. However, difference between the hand weeding and best chemical control method (W_3) application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was only two percent shows that chemical control method with proper dose and time may be the alternative of manual weeding in direct seeded rice line sown rice. Among the chemical control method, difference was very marginal in respect to grain yield, it was only 2 to 5 per cent gives better choice to farmer for the alternative combination of herbicides as per the availability of chemical in the market. Nagappa and Biradar (2002) reported that among weed management practices, two hand weeding gives significantly higher yield. Walia *et al.* (2009), Hussain *et al.* (2009) and Kiran *et al.* (2010) reported that the bispyribac-sodium is the best chemical for the direct seeded rice. Kiran *et al.* (2010) stated that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} was as effective as hand weeding twice in improving growth, yield attributes and yield of rice. Higher grain yield under these treatments was due to the weed managed at critical period and early crop growth, higher dry matter production, high growth in terms of tiller numbers, which resulted in higher production of photosynthates, which acts as a source and greater translocation food of materials to the reproductive part resulted in superiority of yield attributing characters and

ultimately high yield. Contrarily, the poor growth of plant as well as development of yield attributing characters in weedy check might be due to less moisture, nutrient, space and light available at the time of flowering and grain development adversely influenced the grain yield. The lower grain yield under weedy check may be due to the high weed interference and less number of effective tillers.

Grain yield of direct seeded line sown rice was at par in all the seed rates ranging from 40 to 80 kg ha^{-1}, it shows that there is no yield difference between the high seed rate and low seed rate. However, seed yield was highest in 40 kg ha^{-1} seed rate followed by the 60 kg ha^{-1} and 80 kg ha^{-1} seed rate. Difference between the low seed rate and high seed rate was marginal and was only 5.0 percent proves that combination of low seed rate with proper weed management can be the alternative of high seed rate of rice cultivation broadly adopted by the farmers of Chhattisgarh. Same result was also observed by the Ravi (2008), Yadav *et al.* (2007) and Gill *et al.* (2007) in their experimentation.

4.6.2.8 Straw yield (q ha^{-1})

The data on straw yield are presented in Table 4.35. Significantly superior straw yield was recorded in weed management treatments over weedy check in both the year. However, it was maximum in two hand weeding which was at par with all other chemical control methods. Among chemical control method straw yield was recorded maximum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par to all the weed managment treatments. Minimum straw yield was recorded in weedy check due to more dry matter of weed and its density in the plot, high crop-weed competition which does not allow crop to growth with their genetic potential.

The straw yield was statistically at par with each other in respect to the different seed rates. However, the highest straw yield was found in the 40 kg ha^{-1} seed rate followed by the 60 and 80 kg ha^{-1} seed rate. This is due to the high plant to plant and weed competition does not allow the high dry matter production. Interaction effect between seed rate and weed management was found non significant.

4.6.2.9 Harvest index (%)

The data on harvest index are given in Table 4.35. Harvest index is a measure of the productive efficiency of crop. Harvest index data revealed that different weed management practices significantly influenced the harvest index values. Higher harvest index value was recorded under two hand weeding during both the year. However , lowest weed index was recorded under the weedy check .

Different seeding rates did not affect harvest index significantly. However, crop sown with 40 kg ha^{-1} seed rate (S_3) recorded maximum harvest index value (43.32) followed by rest of the seed rates on mean value basis. Interaction effect between seed rate and weed management was found non significant in respect to harvest index.

4.6.2.10 Discussion on yield attributes and yield

Yield attributes like number of grains $panicle^{-1}$, panicle length, panicle weight, test weight sterility percentage the grain and straw yield of direct seeded rice were influenced significantly due to combination of different weed management practices and seed rate.

Weed management played a vital role in enhancement of yield attributing characters and ultimately the yield of direct line seeded rice. Increase in yield attributes like number of grains $panicle^{-1}$, panicle length, panicle weight, test weight and reduction in sterility were mainly due to less crop weed competition under hand hand weeding twice and sequential application of pre and post emergence herbicide created favorable condition for crop growth and development of rice plant. Due to this, translocation of food materials from source to sink at reproductive stage was enhanced. The capacity of plants to produce seed yield depends not only on the size of photosynthetic system, it's efficiency and length of time for which it is active but also on translocation of dry matter into economic sink. The final built up of yield is cumulative function of dry matter into economic sink this may be the reason for higher seed yield. Higher seed yield under hand weeding twice and application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} was due to the weed management at critical crop - weed competition period and better early growth of rice plant. Higher photosynthates

Table 4.35: Grain and straw yield (q ha^{-1}) and harvest index (%) of direct line seeded rice as influenced by weed management and seed rate

Treatment	Seed yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management									
W_1:- Two hand weeding	51.57	53.65	52.61	62.89	68.79	65.84	45.22	43..84	44.53
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	45.41	49.50	47.45	57.42	65.15	59.78	44.51	43.17	43.84
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	50.31	52.93	51.62	62.08	69.81	65.94	44.77	43.40	44.09
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	47.85	50.91	49.38	59.69	64.75	63.13	43.83	44.04	43.93
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	49.40	51.64	50.52	61.50	67.07	63.38	45.20	43.48	44.34
W_6:- Weedy check	15.59	13.78	14.69	28.86	26.76	27.81	35.04	33.16	34.10
SEm±	0.98	1.29	.73	2.37	2.03	1.74	1.13	1.35	0.77
CD (P = 0.05)	3.09	4.07	2.31	7.48	6.41	5.48	3.57	4.24	2.43
Seed rate (kg ha^{-1})									
S_1 :- 80	42.62	44.67	43.84	54.67	58.96	56.81	42.99	42.16	42.26
S_2 :- 60	42.05	45.24	43.64	56.31	59.39	57.85	42.08	41.46	41.86
S_3 :- 40	45.40	46.43	45.92	55.24	61.31	58.28	44.21	42.40	43.30
SEm±	1.36	0.71	0.49	1.48	1.57	.75	0.47	0.55	0.32
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS

and greater translocation of food material to the productive parts increase the grain filling and weight of the grain. Lower weed population and high weed control efficiency also resulted in higher seed yield. Increase in plant height and dry matter support to increase yield attributes *viz* number of filled grain plant^{-1}, no of panicle plant^{-1} higher nutrient uptake which lead to significant increase in yield of rice plant. Nagappa and Biradar (2002) reported that among weed management practices, two hand weeding gives significantly higher yield. Whereas, Walia *et al.* (2009), Hussain *et al.* (2009) and Kiran *et al.* (2010) reported that the bispyribac-sodium is the best chemical for the direct seeded rice.

Contrarily, the poor growth of plants as well as development of yield attributing characters in weedy check might be due to less moisture, nutrient, space and light availability at the time of flowering and grain development adversely influenced the seed yield. The minimum grain and straw yield in control plot is due to the less dry matter accumulation of rice, less CGR, higher weed infestation and high competition during the critical periods of crop, which does not allow the rice crop to grow to their potential, and vice versa, resulted in higher crop weed competition and less availability of space, nutrient, light and moisture to the direct seeded rice crop throughout the crop growth period especially at the time of flowering and grain development, adversely influenced the yield attributes as well as the grain yield. There was negative correlation between weed dry weight and density of weed in case of weedy check.

The higher straw yield in above treatments might be due to lesser weeds during crop growth period and get higher yield attributes and grain yield which leads to higher straw yield. While, in weedy check reverse trend was observed and therefore, the lowest Stover yield was noted under this treatment.

As regards to weed management practices the comparable harvest index was obtained under hand weeding and herbicidal application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS which was due to higher economic yield in proportion to straw yield., whereas, in untreated control reverse trend was observed resulted in lowest harvest index of direct seeded rice.

With respect to different seeding rates, seed yield was at par in all the seeding rates it shows that there is no yield difference between the high seed rate and low seed rate. In respect to the mean data the difference between the seed yield in seeding method it was very marginal. It was noticeable that , difference between low seed rate 40 kg ha^{-1} and high seed rates 60 and 40 kg ha^{-1} in respect to panicle weight it was only 4 to 5 percent whereas, it was only 7 to 10 per cent in filled grain which shows non significant effect on seed rates. However, yield difference between 40 kg to 80 kg ha^{-1} was only 4.5 per cent and it was 5 per cent only between 40 and 60 kg ha^{-1} and was non significant effect. So that it can be concluded that, with low seed rate and proper weed management yield can be achieved equivalent to tradition high seed rate. Same result was also observed by the Ravi Gopal (2008), Yadav *et al.* (2007) and Gill *et al.* (2007) in their experimentation.

Farmer needs rice production system like *Rabi* crops as "*machine to machine production system*". Present studies involving the chemical method of weed control with the low seed rate may be the option for farmer's to replace the traditional rice cultivation. This combination is the best utilization of resources and energy in production system to active the high growth yield involving the less energy and cost.

4.6.2.11 Root volume (cc)

Root volume was recorded at 50 and 70 DAS are presented in Table 4.36. Weed management practices and seed rate influenced the root volume at 50 and 70 DAS in direct line seeded rice during both the years. Among the different weed management practices root volume was recorded significantly higher under hand weeding twice followed by chemical weed management at 50 DAS. During 70 DAS root volume was recorded significantly higher under hand weeding 20 and 40 DAS and was found at par with application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3) and azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (W_5) during both the years.Whereas, among seed rates higher root volume was recorded under the 40 kg seed rate ha^{-1} followed by 60 and 80 kg seed rate ha^{-1}. Optimum population under the low seed

rate 40 kg ha^{-1} with proper weed management increased the growth and development of rice crop due to proper utilization of space and other resources by the plant and ultimately root growth was higher under less plant population crop as compared to over crowded plots.

4.6.2.12 Root dry weight (g $hill^{-1}$)

Root dry weight was recorded at 50 and 70 DAS are presented in Table 4.8. At 50 DAS root dry weight was recorded maximum under hand weeding twice and followed by other chemical control methods. After that root dry weight at 70 DAS, was significantly superior under two hand weeding at 20 and 40 DAS and was at par with application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3) and appilication of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (W_5) during both the years. Among different seed rates significantly higher root dry weight was produced by 40 kg seed rate ha^{-1} over 120 and 80 kg seed rate ha^{-1} during both the observational stage and both the years might be due to optimam plant population provided the rice plant proper space and weed management reduced the crop weed compitation for light, nutreants and water.

4.7 Weed studies

4.7.1 Weed floral association with rice crop

The predominant weed species observed in the experimental field were *Echinochloa colona, Alternanthra triandra, Cyperus iria* and *Cynotis axillaris* are depicted in table 4.37

Table 4.37: Dominant weed species observed in the experimental field

S. No.	Botanical name	Family	Vernacular name	Type of weed
1.	*Echinochloa colona*	Poaceae	Sawa	Grasses
2.	*Alternanthra triandra*	Compositae	Resham kanta	Broadleaves
3.	*Cyperus iria*	Cyperaceae	Motha	Sedges
4.	*Cyanotis axillaris*	Commelinaceae	Cynotis	Grasses

Table 4.36: Root volume (cc) and root dry weight (g hill^{-1}) of direct line seeded rice as influenced by weed management and seed rate

Treatment	Root Volume (cc)						Root dry weight (g hill^{-1})					
	50 DAS			70 DAS			50 DAS			70 DAS		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management												
W_1:- Two hand weeding	15.06	15.27	15.16	22.22	22.48	22.27	1.26	1.29	1.26	1.40	1.45	1.42
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	13.52	14.21	13.86	20.69	20.81	21.47	1.18	1.16	1.17	1.25	1.32	1.28
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	14.77	14.98	14.85	21.71	21.97	21.68	1.16	1.19	1.17	1.37	1.38	1.37
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	13.73	14.32	14.02	20.85	21.11	21.07	1.15	1.18	1.16	1.26	1.28	1.27
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	14.14	14.64	14.39	21.74	21.86	21.58	1.18	1.16	1.17	1.34	1.36	1.35
W_6:- Weedy check	13.10	13.51	13.31	19.13	19.77	19.16	1.09	1.11	1.1	1.18	1.19	1.18
SEm±	0.09	0.12	0.09	0.16	0.19	0.25	0.02	0.02	.03	0.04	0.03	.04
CD (P = 0.05)	0.29	0.39	0.29	0.52	0.62	0.72	0.07	0.07	.09	0.12	0.09	.12
Seed rate (kg ha^{-1})												
S_1 :- 80	13.75	14.15	13.95	20.60	20.77	20.76	1.18	1.15	1.16	1.26	1.27	1.26
S_2 :- 60	14.09	14.62	14.35	21.02	21.18	21.13	1.24	1.19	1.21	1.33	1.34	1.33
S_3 :- 40	14.30	14.94	14.62	21.55	22.05	21.68	1.30	1.21	1.25	1.35	1.40	1.37
SEm±	0.06	0.04	0.05	0.10	0.07	0.11	0.03	0.02	.03	0.02	0.03	0.04
CD (P = 0.05)	0.25	0.15	0.19	0.40	0.27	0.44	0.12	0.06	.08	0.08	0.10	0.11
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

On the basis of two year mean at 15 DAS, the most pre dominating weeds in the field was *Alternanthra triandra, Echinochloa colona, Cyanotis axillaris* at 31, 26 to 25 per cent respectively, during initial stage. After that at 30, 45 and 60 DAS *Alternanthra triandra* was pre dominant weed followed by *Echinochloa colona, Cyanotis axillaris* and *Cyperus iria* respectively. At harvest, the major weed species, which infested in untreated control, were *Cyanotis axillaris* (31 %), *Alternanthra triandra* (27 %), other weeds (24 %), *Cyperus iria* (11 %) and minimum was *Echinochloa colona* (7 %).

4.7.2 Total weed Density (No m^{-2})

Data on total weed density at different time interval are presented in Table 4.38. Weed management practices had remarkable effect on total weed density throughout the crop growth period. Weed management practices at 15 DAS, had significant effect on weed density. Application of pre-emergence herbicide showed the minimum weed density at early stage. However, significantly high weed density was observed under (W_6) weedy check, (W_1) two hand weeding at 20 and 40 DAS, (W_2) bispyribac-Na @25 g ha^{-1} at 20DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS where no weed control was done at early stage. Whereas, minimum total weed density at 15 DAS was recorded under W_3 and W_4 due to the application of pre emergence herbicide oxadiargyl 70 g ha^{-1} and pretilachlor + bensulfuron 660 g ha^{-1} as pre emergence. Application of pre emergence herbicide controls first flush of weed and give advantage of growth and development of rice plant. Dubey *et al*. (2005) also noted that application of acetachlor + bensulfuron-methyl @ 250 g ha^{-1} resulted in broad spectrum weed control and recorded the lowest weed population and weed dry weight. Kurmi (2008) reported that pretilachlor , (750 or 1250 g ha^{-1}) was effective against dicot weeds. Kiran *et al*. (2010) observed that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} gave lowest density and dry weight of weeds with maximum weed control efficiency.

At 30 DAS among different weed management practices, significantly lowest weed density was recorded under (W_1) two hand weeding in both the year. However, maximum total weed density during this period was under weedy check.

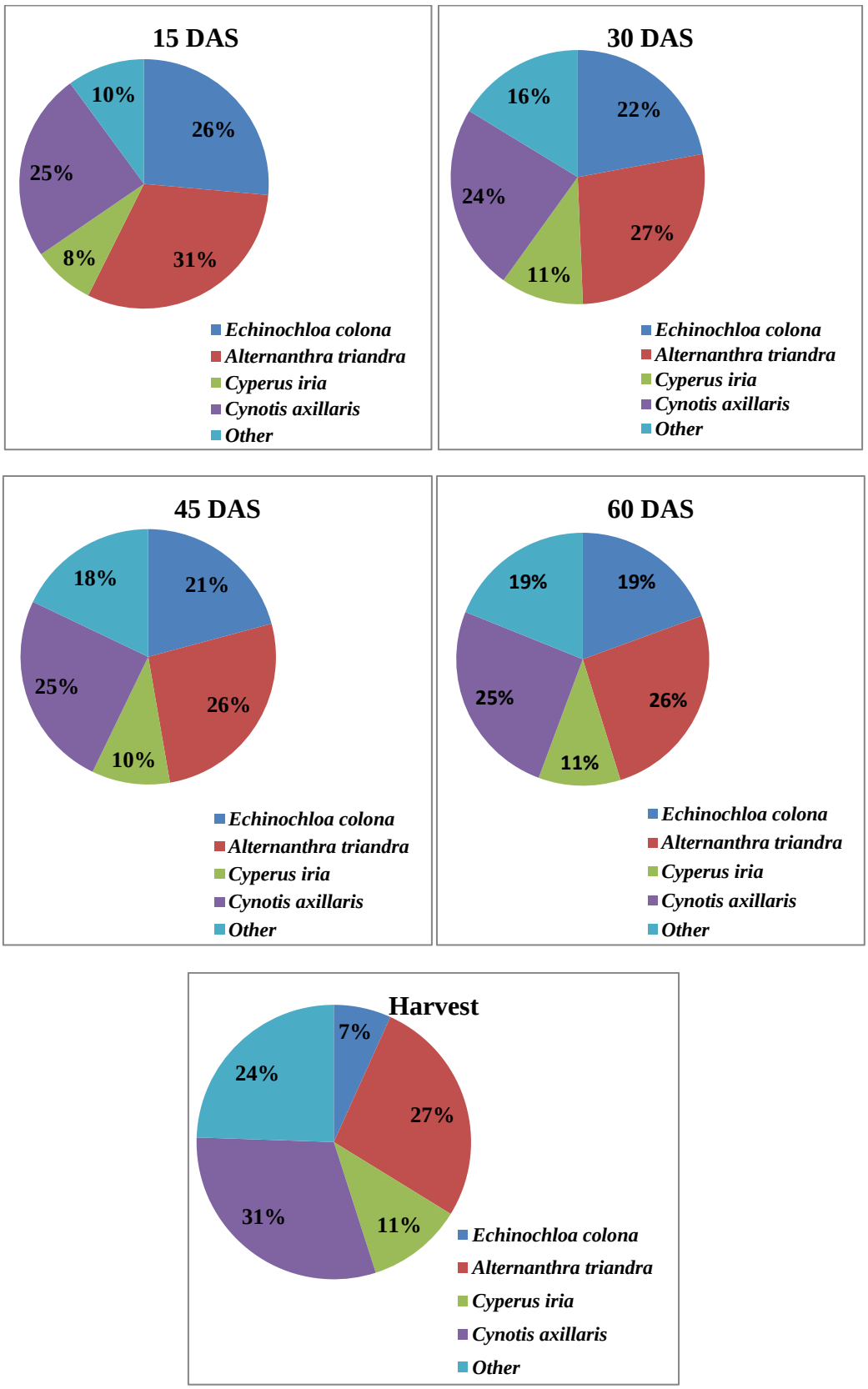


Fig 4.10: Average flora composition in un-weeded control treatment (%) in direct line seeded rice.

All the chemical weed control method was nearly equal to the hand weeding and was at par with each other due to application of bispyribac at 20 and 25 DAS and azimsulfuron at 15 DAS as post and early post application. Combinations of pre and post emergence herbicide are as effective as manual weeding. Similar result was also reported by Patra *et al.* (2006) that two hand weeding recorded the minimum weed population and dry weight and highest WCE. Mahajan *et al.* (2008) and Khaliq *et al.* (2011) found that post-emergence application of bispyribac sodium 25 g ha^{-1} effectively controls the weed species in direct seeded rice. Saha and Rao (2012) reported that azimsulfuron at 35 g a.i. ha^{-1} applied 18 DAT was found to be the most effective (weed control efficiency 98.5%) in controlling the complex weed flora and produced comparable grain yield (5.93 t ha^{-1}) with weed free check thereby realizing an increase of 91 per cent yield over weedy check.

At 45 DAS, significantly lowest weed density was observed under the treatment of two hand weeding at 20 and 40 DAS and it was at nearly equal with other chemical control method except (W_2) bispyribac-Na @25 g ha^{-1} at 20 DAS. It means application of bispyribac alone as post emergence was not enough to control the weeds for longer period. Thus, it can be stated that, chemical control is the alternative of hand weeding method, when applied in sequence with proper dose and time.

At 60 DAS, significantly minimum total weed density was found under hand weeding twice and was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. At harvest, almost similar trend as that at 60 DAS was observed. Hand weeding and chemical control showed very marginal difference in regards to total weed density at harvest. Maximum weed density was found in control plot, infestation of weed increase with increase in time under un-weeded control up to harvest. In general, maximum weed density was observed in un-weeded control plot throughout crop growth period. Under weedy condition, weed population was maximum and competition between weed and crop was maximum which reduced the grain yield finally.

Table 4.38: Density of total weeds (No. m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

Treatment	Density of total weeds (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	4.70 (21.67)	4.69 (21.56)	4.70 (21.61)	2.70 (6.87)	2.68 (6.74)	2.69 (6.80)	2.30 (4.87)	2.35 (5.07)	2.33 (4.97)	3.10 (9.19)	3.26 (10.15)	3.18 (9.67)	3.12 (9.29)	3.30 (10.45)	3.21 (9.85)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	4.80 (22.68)	4.56 (20.52)	4.68 (21.6)	3.12 (9.26)	3.01 (8.76)	3.07 (9.10)	3.59 (12.47)	3.86 (14.48)	3.73 (13.47)	4.33 (18.30)	4.63 (21.07)	4.48 (19.68)	4.25 (17.69)	4.40 (18.97)	4.33 (18.33)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	2.65 (6.60)	2.44 (5.68)	2.55 (6.14)	3.15 (9.48)	3.00 (8.64)	3.08 (9.06)	2.56 (6.12)	2.52 (5.86)	2.54 (5.99)	3.31 (10.50)	3.30 (10.48)	3.31 (10.49)	3.22 (10.03)	3.22 (9.95)	3.22 (9.99)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	3.01 (8.90)	2.68 (7.31)	2.85 (8.10)	3.18 (9.64)	3.04 (8.91)	3.11 (9.27)	2.93 (8.26)	2.67 (6.77)	2.80 (7.51)	3.98 (15.43)	4.19 (17.20)	4.09 (16.31)	3.80 (14.04)	4.19 (17.05)	4.00 (15.54)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	4.82 (22.83)	4.71 (21.68)	4.77 (22.25)	3.08 (9.07)	2.80 (7.41)	2.94 (8.24)	2.74 (7.10)	2.55 (6.02)	2.65 (6.55)	3.46 (11.59)	3.46 (11.51)	3.46 (11.55)	3.45 (11.53)	3.37 (10.93)	3.41 (11.23)
W_6:- Weedy check	5.52 (30.26)	5.08 (25.59)	5.30 (27.92)	6.33 (6.33)	5.66 (31.54)	6.00 (35.55)	6.67 (44.03)	6.22 (38.22)	6.45 (41.12)	7.09 (49.80)	6.63 (43.51)	6.86 (46.65)	6.74 (44.92)	6.49 (41.77)	6.62 (43.34)
SEm±	0.10	0.13	0.10	0.08	0.09	0.05	0.11	0.12	0.05	0.08	0.09	0.06	0.09	0.05	0.05
CD (P = 0.05)	0.30	0.41	0.33	0.24	0.28	0.15	0.36	0.37	0.14	0.24	0.28	0.17	0.28	0.17	0.16
Seed rate (kg ha^{-1})															
S_1 :- 80	4.08 (17.20)	3.92 (15.56)	4.00 (16.38)	3.52 (13.56)	3.24 (11.03)	3.38 (12.29)	3.41 (13.39)	3.40 (12.70)	3.41 (13.04)	4.32 (20.06)	4.29 (19.17)	4.31 (19.17)	4.38 (20.19)	4.38 (20.16)	4.38 (20.17)
S_2 :- 60	4.18 (18.24)	4.05 (17.06)	4.12 (17.65)	3.58 (14.07)	3.38 (11.98)	3.48 (13.02)	3.41 (13.41)	3.34 (12.68)	3.38 (13.04)	4.35 (20.18)	4.31 (19.52)	4.33 (19.52)	4.08 (17.73)	4.14 (17.81)	4.11 (17.77)
S_3 :- 40	4.49 (21.03)	4.20 (18.54)	4.35 (19.78)	6.68 (14.31)	3.48 (12.02)	5.08 (13.66)	3.58 (14.62)	3.34 (12.88)	3.46 (13.75)	3.97 (17.16)	4.13 (18.25)	4.05 (18.25)	3.83 (15.84)	3.97 (16.59)	3.90 (16.21)
SEm±	0.10	0.07	0.08	0.06	0.06	0.05	0.07	0.05	0.05	0.05	0.08	0.06	0.03	0.03	0.01
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Amon different seed rates at early stage minimum density of total weeds was recorded under 80 kg seed rate ha^{-1} which was found non significant. Aftre that , at 60 DAS and harvest total weed density was recorded under 40 kg ha^{-1} seed rate was found non significant during both the year. Interaction between seed rate and weed management was non significant during both the yeas and all the observational stage.

4.7.3 Species-wise weed density

Weed management practices and seed rate had remarkable effect on weed density m^{-2} throughout the crop growth period.

4.7.3.1 *Echinochloa colona* (No m^{-2})

The data on total weed density of *Echinochloa colona* at different time interval are presented in Table 4.39. Among different weed management practices at 15 DAS, significantly minimum weed density was recorded under the (W_3) pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and at par with (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyriba Na @ 20 g ha^{-1} at 25 DAS. However, the maximum but statistically at par density of *Echinochloa colona* was found in (W_1) two hand weeding (W_2) bispyribac-Na @25 g ha^{-1} at 20 DAS, (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS and (W_6) weedy check, where no weed management was done during this period. Application of pre-emergence herbicide effectively control the *Echinochloa colona* and similar result was also reported by the Jadhav *et al.* (2008) and Kurmi (2008).

At 30 DAS, among different weed management practices, significantly lowest weed density of *Echinochloa colona* was found under (W_1) two hand weeding and it was equal to other chemical weed control method. Among chemical control method, minimum density of *Echinochloa colona* was found under (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS followed by (W_2) bispyribac-Na @25 g ha^{-1} at 20 DAS at 30 DAS.

At 45 DAS, lowest weed density of *Echinochloa colona* was observed under two hand weeding. However, among chemical weed control, density of

Echinochloa colona was minimum under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and was at par with hand weeding. During this period, density of *Echinochloa colona* was almost equal in all the weed management treatments except weedy check. Risi *et al.* (2004) also observed that bispyribac-sodium controls the *Echinochloa colona* effectively. Mahajan *et al.* (2008) also found that the bispyribac-sodium controls the *spp* efficiently as compared to other herbicides. Walia *et al.* (2012) reported that integration of post emergence application (30 DAS) of bispyribac (25 and 30 g ha^{-1}) or azimsulfuron (20 g ha^{-1}) with pre-emergence application of pendimethalin 0.75 kg ha^{-1}, pretilachlor 0.5 kg ha^{-1} and thiobencarb 1.25 kg ha^{-1} provided effective control of weeds and produced significantly higher grain yield than unweeded treatment

Similar result like 45 DAS was found at 60 DAS and at harvest. Minimum density of *Echinochloa colona* was recorded under hand weeding twice and it was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Wheareas, *Echinochloa colona* was maximum under the weedy check. Mamun (1990) reported that the yield reduction due to un-weeded control condition was 68 to 100 percent in direct seeded rice and 16 to 48 percent for transplanted rice.

Among different seeding rates at 15, 30 and 45 DAS, there was no significant effect on density of *Echinochloa colona*, but there was slightly lower density under 80 kg^{-1} (S_3) as compared to the other seeding rates. However, minimum weed density was recorded under 40 kg ha^{-1} seed rate at harvest due to superior growth and development of rice plant did not allow the luxuries growth of *Echinochloa colona*. Interaction between weed management and seed rate was non significant in both the year at 15, 30, 45 and 60 DAS but it was significant at harvest during both the year (Table 4.39a). Significantly minimum number of *Echinochloa colona* m^{-2} was recorded in combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with two hand weeding at 20 and 40 DAS as compared to other combinations, but it was at par with the combinations of (S_1 x W_3) 40 kg seed rate ha^{-1} with pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during 2013,

Table 4.39: Density of *Echinochloa colona* (No. m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

Treatment	Density of *Echinochloa colona* (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	2.49 (5.97)	2.77 (7.16)	2.63 (6.56)	1.18 (0.89)	1.20 (.96)	1.19 (.92)	1.21 (0.99)	1.10 (0.75)	1.16 (0.87)	1.42 (1.63)	1.49 (1.75)	1.46 (1.69)	1.01 (.56)	1.01 (.53)	1.01 (0.54)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	2.60 (6.58)	2.78 (7.24)	2.69 (6.91)	1.39 (1.44)	1.43 (1.68)	1.41 (1.56)	1.70 (2.42)	1.96 (3.35)	1.83 (2.88)	1.80 (2.74)	2.15 (4.15)	1.98 (3.44)	1.60 (1.41)	1.62 (2.14)	1.61 (1.77)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.20 (0.96)	1.22 (1.01)	1.21 (0.98)	1.41 (1.50)	1.44 (1.74)	1.43 (1.62)	1.19 (0.95)	1.27 (1.85)	1.23 (1.02)	1.54 (1.88)	1.65 (2.30)	1.60 (2.09)	1.11 (0.73)	1.04 (0.74)	1.08 (0.73)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.26 (1.10)	1.28 (1.18)	1.27 (1.14)	1.49 (1.73)	1.50 (1.83)	1.50 (1.49)	1.32 (1.27)	1.34 (3.11)	1.33 (2.19)	1.73 (2.51)	2.14 (4.11)	1.94 (3.31)	1.27 (1.11)	1.60 (2.21)	1.44 (1.66)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	2.75 (7.12)	2.86 (7.68)	2.81 (7.4)	1.30 (1.18)	1.37 (1.44)	1.34 (1.31)	1.34 (1.31)	1.27 (2.15)	1.31 (1.73)	1.60 (2.09)	1.83 (2.93)	1.72 (2.51)	1.12 (0.74)	1.18 (0.93)	1.15 (0.83)
W_6:- Weedy check	2.85 (7.64)	2.75 (7.11)	2.80 (7.37)	2.87 (7.72)	2.90 (7.98)	2.89 (7.85)	2.98 (8.22)	3.26 (8.90)	3.12 (8.56)	3.13 (9.28)	3.05 (8.83)	3.09 (9.05)	1.87 (3.00)	1.67 (2.33)	1.77 (2.66)
SEm±	0.09	0.06	0.05	0.03	0.09	0.05	0.05	0.08	0.05	0.07	0.06	0.06	0.05	0.10	0.06
CD (P = 0.05)	0.28	0.19	0.17	0.10	0.13	0.15	0.17	0.26	0.15	0.23	0.20	0.18	0.16	0.30	0.18
Seed rate (kg ha^{-1})															
S_1 :- 80	2.18 (4.83)	2.22 (5.02)	2.20 (4.92)	1.62 (2.47)	1.53 (2.19)	1.58 (2.33)	1.61 (2.54)	1.64 (2.65)	1.63 (2.59)	1.89 (3.43)	2.12 (4.21)	2.01 (3.82)	1.37 (1.48)	1.40 (1.64)	1.39 (1.56)
S_2 :- 60	2.20 (4.88)	2.34 (5.46)	2.27 (5.17)	1.60 (2.42)	1.69 (2.73)	1.65 (2.56)	1.66 (2.65)	1.60 (2.80)	1.63 (2.72)	1.86 (3.34)	2.10 (4.16)	1.98 (3.75)	1.29 (1.24)	1.39 (1.56)	1.34 (1.4)
S_3 :- 40	2.20 (4.97)	2.75 (5.21)	2.48 (5.09)	1.50 (2.35)	1.70 (2.90)	1.60 (2.60)	1.58 (2.39)	1.70 (2.89)	1.64 (2.64)	1.85 (3.29)	1.95 (3.67)	1.90 (3.48)	1.21 (1.07)	1.27 (1.24)	1.24 (1.15)
SEm±	0.09	0.04	0.03	0.03	0.06	0.03	0.04	0.04	0.03	0.05	0.04	0.02	0.01	0.03	0.02
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.13	NS	NS	0.10	0.04	0.11	0.06
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.39a: Interaction of weed management and seed rate on density of *Echinochloa colona* (No. m^{-2}) at harvest in direct line seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**
W_1:- Two hand weeding	1.26 (1.08)	0.91 (0.33)	0.96 (0.27)	1.15 (.83)	0.91 (0.33)	0.96 (0.42)	1.20 (0.96)	0.91 (0.33)	0.92 (0.34)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	1.56 (1.97)	1.41 (1.53)	1.12 (0.74)	1.71 (2.45)	1.61 (2.10)	1.54 (1.89)	1.64 (2.21)	1.51 (1.81)	1.33 (1.32)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.15 (0.82)	1.11 (0.73)	1.06 (0.63)	0.92 (0.44)	1.14 (0.89)	1.06 (0.89)	1.03 (0.63)	1.12 (0.81)	1.06 (0.76)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.26 (1.08)	1.26 (1.10)	1.28 (1.13)	1.50 (2.07)	1.67 (2.33)	1.64 (2.22)	1.38 (1.58)	1.47 (1.72)	1.46 (1.68)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	1.11 (.73)	1.10 (0.72)	1.13 (0.78)	1.24 (1.05)	1.24 (1.05)	1.07 (0.69)	1.17 (0.89)	1.17 (0.89)	1.10 (0.74)
W_6:- Weedy check	1.91 (3.17)	1.87 (3.00)	1.82 (2.83)	1.87 (3.00)	1.78 (2.67)	1.35 (1.33)	1.89 (3.08)	1.82 (2.84)	1.59 (2.08)
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.10	0.40		0.15	0.46		0.08	0.24	
Comparison of two weed management means at the same or different level of seed rate	0.05	0.12		0.06	0.17		0.03	0.09	

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

whereas, it was at par with the combination of (S_1 x W_3) 40 kg seed rate ha^{-1} with pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (S_1 x W_5) 40 kg ha^{-1} with azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Combination of 40 kg ha^{-1} seed rate with two hand weeding, application of pre and post emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac and azimsulfuron 35 g ha^{-1} *fb* bispyribac was found to be the best combination against the *Echinochloa colona*.

4.7.3.2 *Alternenthera triandra* (No m^{-2})

The data on weed density of *Alternenthera triandra* at different time interval are presented in Table 4.40. Maximum population of *Alternentera triandra* was recorded under the weedy check in all the growth stages and both the year of investigation.

At 15 DAS, significantly minimum density of *Alternenthra triandra* was found in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and was at par with (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Maximum weed density was recorded under un-weeded control and nearly equal to other weed management treatments except W_3 and W_4 where pre emergence herbicide was applied. Application of oxadiargyl and combination of pretilachlor + bensulfuron controls *Alternenthra triandra* effectively at early stage.

At 30 DAS, on the basis of two year mean lower weed density of *Alternenthra triandra* was recorded under hand weeding twice (W_1) which was at par with other all other chemical weed management practices. Yadav *et al*. (2009) reported that hand weeding twice completely removed all the categories of weeds including sedges. Prakash *et al*. (2013) reported that pretilachlor 50 EC @0.75 kg *a.i*.ha^{-1} at 3-5 DAT registered significantly lowest weed density. Whereas, Khaliq *et al*. (2011 a) stated that post emergence application of bispyribac sodium gave more than 80% reduction in weed density and weed dry weight over control.

During the investigation at 45 DAS, significantly lowest density of *Alternentera triandra* was recorded under hand weeding twice and at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5)

azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. However, maximum weed density was recorded in weedy check. Difference between chemical and hand weeding methods, difference is very marginal therefore it can be stated that the chemical method is an alternative for the manual weeding, subject to proper dose and time of application.

At the growth stage of 60 DAS and harvest, maximum density of *Alternenthra triandra* was found under the weedy check method. However, significantly lowest density of *Alternenthra triandra* was recorded under hand weeding. Among chemical control (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS was superior over other chemical control method.

Regarding the seed rates, the marginal and non significant difference between all the seeding rates in both the years was observed. However, high weed density of *Alternenthra triandra* was found in 40 kg ha^{-1} seed rate at 15 and 30 DAS as compared to other seed rates. During harvest it was minimum in 40 kg ha^{-1} seed rat and was found non significant during both the years.

Interaction between seed rate and weed was significant at harvest (Table 4.40a). Whereas, it was found non significant at 15, 30, 45 and 60 DAS. Significantly minimum density of *Alternenthra triandra* m^{-2} was recorded in the combination of (S_3 x W_3) 40 kg seed rate ha^{-1} with the application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year.This combinatoon shows that low seed rate with sequeantial applicaton of pre and post emergence herbicide can control the weeds effectivly. Comparison of same level of weed management with different seed rates showes that minimum density under 40 kg ha^{-1} in all the weed management practices during both the years.

4.7.3.3 *Cyperus iria* (No m^{-2})

The data on density of *Cyperus iria* at different time interval are presented in Table 4.41. Among different weed management practices at 15 DAS, shows significant impact on population of *Cyperus iria*. Application of (W_3) pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was found

Table 4.40: Density of *Alternanthra triandra* (No. m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

Treatment	Density of *Alternanthra triandra* (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	2.87 (7.72)	2.87 (7.73)	2.87 (7.72)	1.57 (2.01)	1.51 (1.81)	1.54 (1.91)	1.26 (1.18)	1.31 (1.25)	1.29 (1.21)	1.54 (1.93)	1.59 (2.08)	1.57 (2.00)	1.69 (2.37)	1.61 (2.15)	1.65 (2.26)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	2.82 (7.59)	2.64 (6.85)	2.73 (7.22)	1.55 (1.94)	1.64 (2.22)	1.60 (2.08)	1.85 (3.06)	1.74 (2.61)	1.80 (2.84)	1.92 (3.26)	2.00 (3.56)	1.96 (3.41)	1.94 (3.28)	1.93 (3.26)	1.94 (3.27)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.56 (1.98)	1.20 (1.33)	1.38 (1.65)	1.77 (5.65)	1.44 (1.66)	1.61 (2.15)	1.44 (1.78)	1.35 (1.38)	1.40 (1.58)	1.65 (2.27)	1.53 (1.89)	1.59 (2.08)	1.66 (2.32)	1.55 (1.98)	1.61 (2.15)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.65 (2.26)	1.12 (1.19)	1.39 (1.72)	1.77 (2.64)	1.47 (1.78)	1.62 (2.21)	1.44 (1.73)	1.74 (1.33)	1.59 (1.53)	1.87 (3.04)	1.60 (2.54)	1.74 (2.79)	1.95 (3.39)	1.90 (2.57)	1.93 (2.98)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	2.98 (8.39)	3.00 (8.56)	2.99 (8.47)	1.76 (2.64)	1.42 (1.63)	1.59 (2.13)	1.48 (2.02)	1.35 (1.44)	1.42 (1.70)	1.68 (2.39)	1.56 (1.98)	1.62 (2.18)	1.71 (2.46)	1.54 (2.00)	1.63 (2.23)
W_6:- Weedy check	2.99 (8.48)	3.05 (8.81)	3.02 (8.64)	3.30 (10.39)	3.08 (9.00)	2.36 (9.69)	3.43 (11.26)	3.32 (10.50)	3.38 (10.88)	3.71 (13.35)	3.33 (10.67)	3.52 (12.01)	3.83 (14.00)	3.39 (11.06)	3.61 (12.53)
SEm±	0.07	0.10	0.05	0.07	0.08	0.04	0.10	0.06	0.07	0.07	0.09	0.06	0.09	0.08	0.07
CD (P = 0.05)	0.21	0.33	0.17	0.22	0.25	0.14	0.33	0.20	0.21	0.23	0.27	0.18	0.30	0.27	0.23
Seed rate (kg ha^{-1})															
S_1 :- 80	2.35 (5.46)	2.19 (5.39)	2.27 (5.42)	1.90 (3.54)	1.71 (2.74)	1.81 (3.13)	1.76 (3.21)	1.83 (3.35)	1.80 (3.28)	2.17 (4.76)	2.03 (4.10)	2.10 (4.43)	2.22 (5.08)	2.07 (4.17)	2.15 (4.62)
S_2 :- 60	2.53 (6.26)	2.47 (6.18)	2.50 (6.22)	1.93 (3.60)	1.74 (2.95)	1.84 (3.27)	1.97 (3.26)	1.74 (3.13)	1.86 (3.19)	2.16 (4.70)	1.97 (3.86)	2.07 (4.28)	2.12 (4.50)	1.97 (3.79)	2.05 (4.14)
S_3 :- 40	2.55 (6.50)	2.28 (5.67)	2.42 (6.08)	2.04 (4.02)	1.83 (3.35)	1.94 (3.68)	1.96 (4.04)	1.64 (2.77)	1.80 (3.40)	1.85 (3.65)	1.87 (3.45)	1.86 (2.36)	2.05 (4.34)	1.84 (3.52)	1.95 (3.93)
SEm±	0.07	0.13	0.04	0.03	0.06	0.03	0.07	0.04	0.02	0.04	0.07	0.05	0.03	0.04	0.02
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.40a: Interaction of weed management and seed rate on density of *Alternanthra triandra* (No. m^{-2}) at harvest in direct line seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**
W_1:- Two hand weeding	1.78 (2.67)	1.64 (2.22)	1.64 (2.22)	1.84 (2.89)	1.64 (2.22)	1.35 (1.33)	1.81 (2.78)	1.64 (2.22)	1.50 (1.78)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	2.00 (3.50)	2.04 (3.67)	1.78 (2.67)	2.04 (3.6)	1.92 (3.22)	1.84 (2.89)	2.02 (3.58)	1.98 (3.45)	1.81 (2.78)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.85 (2.95)	1.64 (2.22)	1.50 (1.78)	1.78 (2.67)	1.64 (2.22)	1.24 (1.05)	1.82 (2.81)	1.64 (2.22)	1.37 (1.41)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.92 (3.39)	1.97 (3.39)	1.97 (3.40)	1.91 (3.17)	1.78 (2.78)	1.50 (1.78)	1.92 (3.28)	1.87 (3.08)	1.73 (2.59)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	1.85 (2.95)	1.78 (2.67)	1.50 (1.78)	1.50 (1.78)	1.50 (1.78)	1.64 (2.22)	1.67 (2.36)	1.64 (2.22)	1.57 (2.00)
W_6:- Weedy check	3.93 (15.00)	3.65 (12.83)	3.83 (14.17)	3.37 (10.83)	3.32 (10.50)	3.50 (11.83)	3.65 (12.92)	3.48 (11.67)	3.66 (13.00)
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	**0.09**	**0.28**		**0.10**	**0.31**		0.06	0.20	
Comparison of two weed management means at the same or different level of seed rate	**0.04**	**0.13**		**0.04**	**0.12**		0.03	0.09	

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

significantly superior over other treatment and at par with (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. However, nearly equal and more number of *Cyperus iria* was recorded in hand weeding , weedy check and treatment where pre emergence was not applied (W_2 and W_5). Jadhav *et al.* (2008) stated that the application of oxadiargyl 75 g ha^{-1} effectively control the *Cyperus iria*. Application of oxadiargyl and combination of pretilachlor and bensulfuron controls *Cyperus iria* in early stage of crop growth period, gives advantage over the other treatments.

At 30 DAS, there was a significant impact of weed management practices on weed density of *Cyperus iria*. All the chemical weed management and hand weeding showed effect on density of *Cyperus iria* at this stage. However, significantly low density of *Cyperus iria* was recorded in hand weeding twice. Among the chemical control methods on the basis of two year mean, minimum weed density was in (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was nealry equal with other chemical control treatments

At 45 DAS, of *Cyperus iria* was significantly low in hand weeding twice. On the basis of two year mean, minimum and nearly equal density of *Cyperus iria* was under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and at par with and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Data itself explains that application of pre-emergence followed by post-emergence application herbicide is equally effective as hand weeding twice. The maximum population was under un-weeded control plot.

At 60 DAS and at harvest, density of *Cyperus iria* was minimum in hand weeding twice. Among chemical control, application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS effectively control the *Cyperus iria* during both the year.

Among different seed rates, there was no significant effect of seed rate on density of *Cyperus iria* at all the growth stage in both the year. However, the higher population was recorded in 40 kg ha^{-1} at 15, 30 and 45 DAS on thebasis of two year mean. Afterthat, at 60 DAS andharvest it was maximum in 80 kg ha^{-1}

Table 4.41: Density of *Cyperus iria* (No. m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

Treatment	Density of *Cyperus iria* (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	1.60 (2.11)	1.53 (1.89)	1.57 (2.00)	1.15 (0.88)	1.15 (0.85)	1.15 (0.86)	1.07 (0.69)	1.15 (0.92)	1.11 (0.80)	1.36 (1.29)	1.40 (1.48)	1.38 (1.38)	1.34 (1.34)	1.44 (1.61)	1.39 (1.97)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	1.59 (2.07)	1.52 (1.85)	1.56 (1.96)	1.36 (1.43)	1.31 (1.22)	1.34 (1.32)	1.36 (1.43)	1.55 (1.94)	1.46 (1.68)	1.81 (2.79)	1.81 (2.80)	91.41 (2.8)	1.75 (2.60)	1.87 (3.04)	1.81 (2.82)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.08 (0.73)	0.98 (0.48)	1.03 (0.60)	1.32 (1.29)	1.35 (1.37)	1.34 (1.33)	1.32 (1.20)	1.24 (.95)	1.28 (1.13)	1.48 (1.74)	1.54 (1.93)	1.51 (1.83)	1.51 (1.89)	1.62 (2.18)	1.57 (2.03)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.19 (0.97)	0.48 (0.68)	0.84 (0.82)	1.26 (1.18)	1.30 (1.33)	1.28 (1.25)	1.21 (0.98)	1.41 (1.50)	1.31 (1.24)	1.79 (2.50)	1.67 (2.36)	1.73 (2.43)	1.67 (2.34)	1.64 (2.22)	1.66 (2.28)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	1.48 (2.07)	1.08 (1.78)	1.28 (1.92)	1.21 (1.03)	1.41 (1.20)	1.31 (1.14)	1.21 (1.21)	1.26 (1.0)	1.24 (1.01)	1.59 (1.89)	1.53 (1.93)	1.56 (1.91)	1.52 (1.86)	1.54 (1.93)	1.53 (1.89)
W_6:- Weedy check	1.64 (2.22)	1.50 (2.28)	1.57 (2.25)	2.18 (4.29)	1.91 (3.14)	2.05 (3.71)	2.29 (4.75)	1.97 (3.40)	2.13 (4.0)	2.36 (5.11)	2.27 (4.67)	2.32 (4.89)	2.30 (5.20)	2.34 (4.97)	2.32 (5.08)
SEm±	0.11	0.05	0.06	0.10	0.04	0.06	0.08	0.07	0.06	0.06	0.05	0.02	0.09	0.06	0.06
CD (P = 0.05)	0.33	0.15	0.20	0.33	0.14	0.19	0.24	0.22	0.20	0.18	0.17	0.07	0.29	0.10	0.17
Seed rate (kg ha^{-1})															
S_1 :- 80	1.42 (1.69)	1.30 (1.24)	1.36 (1.46)	1.35 (1.48)	1.33 (1.8)	1.34 (1.34)	1.34 (1.44)	1.40 (1.54)	1.37 (1.49)	1.87 (3.14)	1.70 (2.48)	1.79 (2.81)	1.78 (2.77)	1.90 (3.16)	1.84 (2.96)
S_2 :- 60	1.34 (1.45)	1.35 (1.42)	1.35 (1.43)	1.46 (1.90)	1.45 (1.67)	1.46 (1.78)	1.43 (1.76)	1.41 (1.56)	1.42 (1.66)	1.78 (2.79)	1.74 (2.62)	1.76 (2.70)	1.68 (2.41)	1.71 (2.56)	1.70 (2.48)
S_3 :- 40	1.33 (1.95)	1.49 (1.82)	1.41 (1.88)	1.43 (1.68)	1.43 (1.62)	1.43 (1.65)	1.47 (1.89)	1.49 (1.89)	1.48 (1.89)	1.57 (2.16)	1.68 (2.48)	1.63 (2.32)	1.59 (2.25)	1.62 (2.26)	1.61 (2.25)
SEm±	0.06	0.04	0.02	0.08	0.06	0.04	0.06	0.03	0.03	0.05	4.00	0.12	0.04	0.05	0.03
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.14	0.21	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

seed rate which was found non significant. Interaction between weed management and seed rate for density of *Cyperus iria* m^{-2} was found non-significant at all the growth stage in both the year.

4.7.3.4 *Cyanotis axillaris* (No m^{-2})

The data on density of *Cyanotis axillaris* at different time interval are presented in Table 4.42. In case of *Cyaotis axillaris* at 15 DAS in year 2013, minimum density of weed was found in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS whearas, it was minimum in (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during 2014. However, the density of *Cyanotis axillaris* was more in un-weeded control which was nearly equal to other treatments (W_1, W_2 and W_5) where no weed management was done at early stage. Prakash *et al*. (2013) reported that pretilachlor controls weed at early stage. Kiran *et al*. (2010) reported that sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} gave lowest density and dry weight of weeds with maximum weed control efficiency.

At 30 DAS, among different weed management practices, significantly lowest density of *Cyanotis axillaris* was found under manual weeding and at par with (W_2) bispyribac-Na @ 25 g ha^{-1} at 20 DAS. All the chemical control method was effective against the *Cyanotis axillaris* during this period . Yadav *et al*. (2009) reported that hand weeding twice completely removed all the categories of weeds. Jadhav *et al.* (2008) also reported that the pre-emergence application of oxadiargyl effectively control the weed at early stage of crop growth followed by post-emergence application of bispyribac control the late coming weeds.

At 45 DAS, minimum weed population of *Cyanotis axillaris* was under two hand weeding and it was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS , (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS . Result is self explaining that there was no critical difference between manual weeding and chemical weeding in relation to weed control. However, hand weeding is costly as well as time consuming and labour demanding operation. Now a days labour is not

available at peak time period for hand weeding operation at villages of Chhattisgarh. But sequential application of pre and post-emergence herbicide are equally effective as manual weeding which saves time and cost of rice production. Maximum weed population of *Cyanotis axillaris* was found under the weedy check which reflect on the yield.

At 60 DAS significantly lover density of *Cyanotis axillaris* was recorded in hand weeding twice during 2013 and it was minimum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during 2014. Application of bispyribac as post emergence after pre emergance effectivly contros the *Cyanotis axillaris* in both the experimentation year. However, heavy infestation of *Cyanotis axillaris* was recorded in weedy check due to no weed management ultimately it affects the yield of rice. Saha *et al.* (2005) also observed that the maximum yield reduction due to weeds up to 41 per cent in direct seeded broadcasted rice as compared to hand weeding.

At harvest, mean data of two year shows, that minimum density of *Cyanotis axillaris* was in sequential application of oxadiargyl followed by bispyribac which was nearly equal to hand weeding and application azimsulfuron as early post and bispyribac Na as late post emergence. Among different seed rates, there was non significant effect on density of *Cynotis axillaris* during both the year. Whereas, it was minimum in 80 kg seed rat ha^{-1} at early stage but it was minimum in 80 kg seed rat ha^{-1} during harvest.

Interaction between weed management and seed rate was found non significant during 15, 30, 45 and 60 DAS. Whereas, as it was significant during harvest (Table 4.42a).

Significantly minimum density of *Cyanotis axillaris* m^{-2} was recorded in the combination of (S_3 x W_3) 40 kg seed rate ha^{-1} with the application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year.This combinaton showed that low seed rate with sequential applicaton of pre and post emergence herbicide can control the weeds effectively. Comprasion of same level of weed management with different seed rates show that minimum density under 40 kg ha^{-1} in all the weed management practices during

Table 4.42: Density of *Cyanotis axillaris* (No. m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

Treatment	Density of *Cyanotis axillaris* (No. m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	2.25 (4.59)	1.89 (3.44)	2.07 (4.01)	1.53 (1.91)	1.50 (1.78)	1.52 (1.84)	1.18 (1.00)	1.30 (1.18)	1.24 (1.09)	1.77 (2.65)	1.85 (2.17)	1.81 (2.41)	1.96 (2.95)	1.95 (3.33)	1.96 (3.14)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	2.42 (5.41)	2.00 (3.54)	2.21 (4.47)	1.72 (2.52)	1.54 (1.91)	1.63 (2.21)	1.85 (3.11)	2.04 (3.96)	1.95 (3.53)	2.40 (5.43)	2.45 (6.07)	2.43 (5.75)	2.48 (5.72)	2.41 (5.39)	2.45 (5.55)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.43 (1.59)	1.42 (1.52)	1.43 (1.55)	1.84 (2.82)	1.67 (2.31)	1.76 (2.56)	1.30 (1.33)	1.39 (1.44)	1.35 (1.38)	1.74 (2.52)	1.67 (2.33)	1.71 (2.43)	1.78 (2.72)	1.59 (2.08)	1.69 (2.40)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.44 (1.61)	1.33 (1.30)	1.39 (1.45)	1.85 (2.94)	1.74 (2.56)	1.80 (2.75)	1.35 (1.34)	1.41 (1.56)	1.38 (1.45)	2.01 (3.70)	2.18 (4.59)	2.10 (4.14)	1.84 (3.91)	2.38 (5.21)	2.11 (4.56)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	2.32 (4.93)	1.96 (3.37)	2.14 (4.15)	1.82 (2.84)	1.42 (1.63)	1.62 (2.23)	1.45 (1.63)	1.37 (1.26)	1.41 (1.44)	1.75 (2.61)	1.75 (2.61)	1.75 (2.61)	2.08 (3.85)	1.83 (3.19)	1.96 (3.53)
W_6:- Weedy check	3.46 (8.95)	2.23 (4.57)	2.85 (6.76)	3.47 (9.46)	2.70 (6.83)	3.09 (8.14)	3.50 (11.77)	3.30 (8.72)	3.40 (10.24)	3.60 (12.52)	3.42 (3.42)	3.51 (11.85)	3.70 (12.26)	3.59 (12.44)	3.65 (12.85)
SEm±	0.06	0.03	0.02	0.08	0.06	0.05	0.13	0.10	0.10	0.08	0.15	0.09	0.05	0.08	0.04
CD (P = 0.05)	0.20	0.10	0.07	0.26	0.20	0.17	0.40	0.36	0.32	0.24	0.49	0.30	0.16	0.26	0.12
Seed rate (kg ha^{-1})															
S_1 :- 80	2.21 (4.41)	1.84 (3.10)	2.03 (3.75)	2.01 (3.90)	1.71 (2.62)	1.86 (3.26)	1.80 (3.75)	1.77 (3.02)	1.79 (3.38)	2.25 (5.09)	2.29 (5.20)	2.27 (5.14)	2.45 (5.97)	2.50 (6.25)	2.48 (6.11)
S_2 :- 60	2.24 (5.54)	1.82 (2.89)	2.03 (4.21)	2.03 (4.05)	1.75 (2.78)	1.89 (3.41)	1.77 (3.48)	1.78 (3.05)	1.78 (3.26)	2.28 (5.26)	2.22 (4.89)	2.25 (5.07)	2.27 (5.23)	2.26 (5.19)	2.27 (5.26)
S_3 :- 40	2.22 (4.64)	1.80 (2.88)	2.01 (3.76)	2.10 (4.39)	1.82 (3.11)	1.96 (3.75)	1.75 (3.62)	1.70 (2.99)	1.73 (1.72)	2.10 (4.38)	2.14 (4.77)	2.12 (4.57)	2.14 (4.51)	2.11 (4.37)	2.13 (4.44)
SEm±	0.07	0.03	0.01	0.04	0.04	0.02	0.04	0.09	0.05	0.09	0.16	0.11	0.04	0.08	0.04
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.14	0.33	0.14
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.42a: Interaction of weed management and seed rate on density of *Cyanotis axillaris* (No. m^{-2}) at harvest in direct line seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**
W_1:- Two hand weeding	2.00 (3.50)	1.81 (2.78)	1.75 (2.57)	1.91 (3.17)	2.04 (3.67)	1.91 (3.17)	1.96 (3.33)	1.93 (3.22)	1.83 (2.87)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	2.86 (7.67)	2.27 (4.67)	2.31 (4.83)	2.77 (7.17)	2.37 (5.17)	2.08 (3.83)	2.81 (7.42)	2.32 (4.92)	2.19 (4.33)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.91 (3.17)	1.78 (2.78)	1.64 (2.22)	1.78 (2.67)	1.64 (2.22)	1.35 (1.33)	1.85 (2.92)	1.71 (2.50)	1.50 (1.78)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.89 (3.11)	1.78 (2.67)	1.86 (2.96)	2.34 (4.97)	2.46 (5.67)	2.34 (5.00)	2.12 (4.04)	2.12 (4.17)	2.10 (3.98)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	2.23 (4.50)	2.16 (4.17)	1.84 (2.89)	2.27 (4.67)	1.58 (2.67)	1.64 (2.22)	2.25 (4.58)	1.87 (3.42)	1.74 (2.56)
W_6:- Weedy check	3.79 (13.89)	3.85 (14.33)	3.47 (11.56)	3.92 (14.89)	3.50 (11.78)	3.34 (10.67)	3.86 (14.39)	3.67 (13.06)	3.41 (11.11)
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.09	0.28		0.17	0.54		0.10	0.30	
Comparison of two weed management means at the same or different level of seed rate	0.03	0.09		0.05	0.15		0.03	0.09	

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

both the year. However, mean of two year reveals that maximum density of *Cyanotis axillaris* was recorded under the combination of 80 kg ha^{-1} with the weedy check and at par with other combinaton of seed rates 60 and 80 kg ha^{-1}.

4.7.3.5 Other weeds species (No m^{-2})

The data on density of other species at different time interval are presented in Table 4.43. Different weed management options showed significant variation in other weed species density at all the observational stage of rice in both the years.

At 30 DAS, significantly minimum weed density of other weeds was recorded under two hand weeding which was at par with all chemical control method during both the year. Whereas, maximum weed density of other weeds was observed in weedy check.

At 45 DAS, significantly higher number of other weeds were observed under weedy check (W_6). Whereas, minimum number of other weeds were observed under hand weeding twice and was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Difference between, manual and chemical control was very marginal show that herbicides are as effective as hand weeding teice.

During the investigation at 60 DAS and at harvest, significantly lower number of other weed *spp*. was found in two hand weeding which was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and at par with (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. The difference between the hand weeding and sequential application of herbicides is marginal so that, chemical method may be the alternative of manual weeding method in respect of weed control. Density of other weed *spp* was significantly very high in weedy check and plot was found full of weeds. Significantly more number of weeds in control plot hampered the growth and development of rice crop, ultimately yield was very poor during both the years.

Table 4.43: Density of other weeds (No. m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

	Density of other weeds (No. m^{-2})											
	30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management												
W_1:- Two hand weeding	1.28 (1.18)	1.31 (1.29)	1.30 (1.23)	1.21 (1.00)	1.20 (0.96)	1.21 (0.98)	1.46 (1.68)	1.54 (1.93)	1.50 (1.80)	1.54 (2.07)	1.82 (2.83)	1.68 (2.45)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	1.54 (1.93)	1.45 (1.64)	1.50 (1.78)	1.70 (2.44)	1.75 (2.61)	1.73 (2.52)	2.06 (4.09)	2.21 (4.49)	2.14 (4.29)	2.26 (4.67)	2.29 (5.14)	2.28 (4.90)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.24 (1.15)	1.40 (1.55)	1.32 (1.35)	1.11 (0.77)	1.16 (0.86)	1.14 (0.81)	1.59 (2.07)	1.58 (2.04)	1.59 (2.05)	1.69 (2.37)	1.86 (2.97)	1.78 (2.67)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.26 (1.11)	1.28 (1.33)	1.27 (1.22)	1.39 (1.44)	1.18 (0.92)	1.29 (1.18)	1.97 (3.41)	2.02 (3.59)	2.00 (3.5)	2.17 (4.30)	2.30 (4.84)	2.24 (4.57)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	1.34 (1.37)	1.40 (1.48)	1.37 (1.42)	1.23 (1.11)	1.26 (1.09)	1.25 (1.10)	1.70 (2.42)	1.59 (2.07)	1.65 (2.24)	1.71 (2.61)	1.85 (2.96)	1.78 (2.78)
W_6:- Weedy check	2.75 (7.08)	2.23 (4.50)	2.49 (5.79)	2.92 (8.03)	2.64 (6.70)	2.78 ()	3.17 (9.54)	2.90 (8.09)	3.04 (8.81)	3.21 (9.83)	3.37 (10.96)	3.29 (10.39)
SEm±	0.01	0.12	0.08	0.07	0.07	0.05	0.09	0.09	0.08	0.05	0.10	0.06
CD (P = 0.05)	0.30	0.37	0.25	0.23	0.22	0.15	0.28	0.29	0.24	0.14	0.31	0.19
Seed rate (kg ha^{-1})												
S_1 :- 80	1.62 (2.38)	1.55 (2.03)	1.59 (2.20)	1.66 (2.68)	1.55 (2.34)	1.61 (2.51)	1.97 (3.71)	1.87 (3.18)	1.92 (3.44)	2.25 (4.89)	2.19 (4.93)	2.22 (4.91)
S_2 :- 60	1.57 (2.30)	1.53 (2.02)	1.55 (2.16)	1.52 (2.26)	1.50 (2.08)	1.51 (2.17)	2.08 (4.17)	2.04 (4.04)	2.06 (4.10)	2.10 (4.35)	2.23 (4.71)	2.17 (4.53)
S_3 :- 40	1.51 (2.23)	1.46 (1.85)	1.49 (2.04)	1.59 (2.46)	1.54 (2.14)	1.57 (2.30)	1.93 (3.73)	2.01 (3.88)	1.97 (3.80)	1.97 (3.97)	2.32 (5.20)	2.15 (4.44)
SEm±	0.05	0.04	0.04	0.04	0.04	0.04	0.12	0.07	0.09	0.05	0.07	0.04
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Among the seeding rates in all the crop growth stage was found non-significant effect on the other weed spp. However, the minimum weeds were found in the 40 kg ha^{-1} seed which was non significant. So, it is self explanatory that the seed rates did not influence the weeds during the experimentation. Interaction effect due to weed managements and seed rates on weed density of other weed species was non significantly at all the growth stages in both the years.

4.7.4 Total weed dry weight (g m^{-2})

The data on total weed dry matter accumulation at different time interval are presented in Table 4.44 reveals that weed management practices provided significant effect on total dry matter accumulation of weeds. In general, the increased density of weeds enhanced dry matter accumulation of weeds per unit area.

Among different weed management practices at 15 DAS, significantly lowest weed dry weight was found under the application of (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and at par with (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year.

Pre-emergence application of herbicide (W_3 and W_4) equally influenced the dry matter of weeds during both the year. However, maximum dry matter was found in (W_6) weedy check method which was at par with (W_1) two hand weeding at 20 and 40 DAS, (W_2) bispyribac-Na @25 g ha^{-1} at 20DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS where no weed management was done.

Statistical analysis of data on different weed management practices revealed that at 30 DAS, significantly lowest dry weight of total weed was recorded under two hand weeding due to manual weeding at 20 DAS. Among the herbicide application minimum dry weight on the basis of two years mean was found under (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS due to application of azimsulfuron at 15 DAS and it was at par with all the other herbicide treatments (W_2,W_3 and W_4) . Result itself explains that sequential

application of pre and post emergence herbicide and early post herbicides controls weed effectively in this stage and it was nearly equal to the hand weeding. Chandra *et al.* (1998) found that the lowest weed density and dry weight was achieved by manual weeding at 25 and 40 DAS. Park *et al.* (2005) reported that bispyribac – Na as post-emergence herbicide control annual and perennial grasses, sedges and broadleaf weeds. Whereas the combination of pre and post emergence herbicides and manual weeding controls weed significantly in rice field (Singh *et al*., 2005 b).

At 45 DAS, maximum total dry weight of weed was found in weedy check (W_6). Weedy check plot was found full of weeds, which reduces the growth of rice plant and grain yield. However, significantly minimum total dry weight of weeds was observed under two hand weeding and at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. So that it can be concluded that bispyribac controls weeds effectively up to the 45 DAS and later on. Jadhav *et al.* (2008), Khaliq *et al.* (2011) reveals that the application of bispyribac-Na as post-emergence control the weed effectively. Yadav *et al*. (2008) reported that azimsulfuron 25-30 g ha^{-1} at 15 DAS stage provided 93-99 per cent control of weeds.

Similar result like 45 DAS was found in 60 DAS and up to harvesting stage, significantly lowest dry weight of total weeds was recorded under two hand weeding and it was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. However, at 60 DAS and harvest maximum weed dry weight was found in weedy check method which explains that, if weeding is not done in the direct line seeded rice it will reduce the grain yield up to the 68 to 100%.

Among different seed rates there was no significant effect on dry weight at all the crop growth stage in both the years. Whereas, at early growth stage of crop minimum dry weight of total weeds was recorded under 80 kg ha^{-1} seed rates. However, at 60 DAS and harvest, minimum weed dry weight was found in 40 kg

Table 4.44: Dry matter of total weeds (g m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

Treatment	Dry matter of total weeds (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	2.42 (5.42)	2.38 (5.20)	2.40 (5.31)	2.92 (8.05)	2.84 (7.64)	2.88 (7.84)	3.48 (11.76)	3.43 (11.38)	3.46 (6.25)	4.84 (23.34)	5.11 (25.80)	4.98 (24.52)	5.37 (28.94)	5.12 (25.89)	5.26 (27.41)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	2.48 (5.72)	2.34 (5.05)	2.41 (5.38)	3.28 (10.35)	3.24 (10.23)	3.26 (10.29)	5.01 (24.76)	5.04 (25.39)	5.03 (25.07)	6.69 (44.37)	7.40 (54.56)	7.05 (49.46)	7.17 (52.78)	6.92 (6.92)	7.08 (50.22)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.41 (1.51)	1.29 (1.19)	1.35 (1.35)	3.30 (10.45)	3.16 (9.65)	3.23 (10.05)	3.68 (13.45)	3.87 (14.81)	3.78 (14.13)	5.22 (26.24)	5.29 (27.75)	5.26 (27.29)	5.24 (25.12)	4.97 (4.97)	5.13 (26.29)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.45 (1.60)	1.26 (1.20)	1.36 (1.40)	3.33 (10.63)	3.21 (10.01)	3.27 (10.32)	3.95 (3.95)	4.09 (16.38)	4.02 (4.02)	6.24 (38.61)	6.80 (6.80)	6.52 (42.27)	6.09 (36.85)	6.67 (24.46)	6.40 (40.51)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	2.54 (6.02)	2.47 (5.66)	2.51 (5.84)	3.22 (9.97)	2.99 (8.45)	3.11 (9.25)	3.96 (15.31)	3.87 (14.55)	3.92 (14.93)	5.48 (29.77)	5.60 (31.13)	5.54 (30.45)	5.89 (35.45)	5.25 (44.17)	5.62 (31.41)
W_6:- Weedy check	2.80 (7.43)	2.61 (6.43)	2.71 (6.93)	6.76 (45.31)	6.23 (38.39)	6.50 (41.85)	9.54 (90.64)	9.21 (84.61)	9.38 (87.62)	11.24 (126.55)	10.77 (115.48)	11.01 (121.01)	12.13 (147.62)	10.28 (27.38)	11.26 (126.57)
SEm±	0.07	0.07	0.07	0.09	0.13	0.07	0.18	0.19	0.15	0.21	0.16	0.15	022	0.11	0.12
CD (P = 0.05)	0.22	0.23	0.21	0.29	0.40	0.24	0.57	59.00	0.48	0.66	0.50	0.48	0.69	0.35	0.34
Seed rate (kg ha^{-1})															
S_1 :- 80	2.12 (4.31)	2.00 (3.95)	2.06 (4.13)	3.70 (15.27)	3.45 (12.78)	3.58 (14.02)	4.78 (27.26)	4.85 (26.61)	4.82 (26.93)	6.78 (50.31)	6.92 (50.92)	6.85 (50.61)	7.61 (63.74)	6.88 (50.74)	7.27 (57.24)
S_2 :- 60	2.19 (4.63)	2.12 (4.29)	2.16 (4.46)	3.82 (16.05)	3.64 (14.11)	3.73 (15.08)	4.93 (28.16)	4.98 (28.25)	4.96 (28.20)	6.84 (51.22)	6.97 (51.93)	6.91 (51.57)	6.93 (54.19)	6.51 (44.90)	6.77 (49.59)
S_3 :- 40	2.24 (4.91)	2.06 (4.12)	2.15 (4.51)	3.88 (16.07)	3.75 (15.34)	3.82 (15.70)	5.10 (30.15)	4.93 (28.65)	5.02 (29.4)	6.23 (43.21)	6.59 (47.78)	6.41 (45.49)	6.41 (46.94)	6.22 (41.81)	6.34 (44.38)
SEm±	0.03	0.02	0.02	0.07	0.08	0.70	0.14	0.08	0.09	0.13	0.10	0.11	.09	0.04	0.12
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

ha^{-1} seed rate which was non significant. Rao *et al.* (2007) found that increased seeding rates of crop suppress weed growth and reduces grain yield losses from weed competition. However, it is not necessary to use high seeding rates to suppress weeds in DSR, if effective herbicides are used. Interaction between the weed control method and seed rates was found statistically at par at all the growth stage in both the years.

4.7.5 Species-wise weed dry matter

4.7.5.1 *Echinochloa colona* (g m^{-2})

Data on weed dry weight of *Echinochloa colona* at different time interval are presented in Table 4.45. Among different weed management practices at 15 DAS, the maximum dry weight of *Echinochloa colona* was found in weedy check and was at par with (W_1) two hand weeding at 20 and 40 DAS ,(W_2) bispyribac-Na @25 g ha^{-1} at 20DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. However, application of pre-emergence herbicides oxadiargyl and combination of pretilachlor + bensulfuron controls the *Echinochloa colona* effectively. Similar result was also found by Saini (2003) and Chopra and Chopra (2003).

At 30 DAS, significantly lower weed dry weight of *Echinochloa colona* was observed in hand weeding twice which was nearly equal to all other weed management practices through herbicides. Whereas, significantly maximum dry matter was found in un-weeded controls plot.

At 45 DAS minimum weed was recorded under manual weeding and was at par with application of pre -emergence oxadiargyl followed by bispyribac Na and application of early post as azimsulfuron followed by bispyribac Na on the basis of two year mean. Whereas, at 60 DAS and at harvest, similar trend was recorded, where minimum dry weight production of *Echinochloa colona* was recorded under two hand weeding and maximum dry weight was recorded in weedy check. At harvest, among different weed management treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and at par with and

Table 4.45: Dry matter of *Echinochloa colona* (g m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

Treatment	Dry matter of *Echinochloa colona* (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	1.37 (1.45)	1.40 (1.47)	1.39 (1.46)	1.35 (1.32)	1.36 (1.41)	1.36 (1.36)	1.76 (2.64)	2.07 (3.95)	1.92 (3.29)	2.79 (8.16)	2.94 (8.23)	2.87 (8.19)	1.58 (2.20)	1.58 (2.11)	1.58 (2.15)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	1.43 (1.57)	1.42 (1.53)	1.43 (1.55)	1.65 (2.21)	1.70 (2.62)	1.68 (2.41)	2.65 (6.65)	2.64 (7.30)	2.65 (6.97)	3.74 (13.48)	4.53 (14.25)	4.14 (13.86)	2.38 (5.42)	2.94 (8.21)	2.66 (6.81)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.86 (0.23)	0.84 (0.21)	0.85 (0.22)	1.66 (2.25)	1.68 (2.61)	1.67 (2.43)	1.70 (2.59)	2.55 (6.92)	2.13 (4.75)	3.11 (9.23)	3.29 (10.74)	3.20 (9.98)	1.83 (2.88)	1.54 (2.79)	1.69 (2.83)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.88 (0.23)	0.86 (0.24)	0.87 (0.23)	1.75 (2.57)	1.76 (2.71)	1.76 (2.64)	1.98 (3.52)	2.80 (7.71)	2.39 (5.61)	3.57 (3.29)	4.44 (4.50)	4.01 (3.89)	2.22 (4.45)	2.93 (8.90)	2.58 (6.67)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	1.49 (0.28)	1.47 (1.69)	1.48 (0.99)	1.51 (1.79)	1.60 (2.18)	1.56 (1.98)	2.01 (3.59)	2.54 (6.27)	2.28 (4.93)	3.29 (6.25)	3.68 (7.05)	3.49 (6.65)	1.85 (2.92)	2.00 (3.69)	1.93 (3.30)
W_6:- Weedy check	1.59 (1.74)	1.47 (1.55)	1.53 (1.64)	3.49 (11.70)	3.57 (12.32)	3.53 (12.01)	4.87 (23.28)	5.70 (32.15)	5.29 (27.71)	6.25 (39.45)	6.37 (40.25)	6.31 (39.82)	3.54 (12.43)	3.11 (10.06)	3.33 (11.24)
SEm±	0.06	0.04	0.04	0.04	0.11	0.06	0.10	0.02	0.13	0.25	0.14	0.17	0.12	0.26	0.15
CD (P = 0.05)	0.18	0.13	0.14	0.13	0.36	0.18	0.32	0.64	0.40	0.80	0.44	0.53	0.36	0.81	0.47
Seed rate (kg ha^{-1})															
S_1 :- 80	1.25 (1.16)	1.23 (1.10)	1.24 (1.13)	1.92 (3.71)	1.79 (3.26)	1.86 (3.48)	2.47 (6.97)	2.84 (9.24)	2.66 (8.10)	3.87 (16.07)	4.35 (2035)	4.11 (18.21)	2.44 (5.87)	2.46 (6.62)	2.45 (6.24)
S_2 :- 60	1.27 (1.21)	1.25 (1.13)	1.26 (1.17)	1.90 (3.64)	2.03 (4.22)	1.97 (3.93)	2.57 (7.30)	3.17 (11.19)	2.87 (9.24)	3.84 (16.30)	4.33 (19.55)	4.09 (17.92)	2.21 (4.95)	2.42 (6.03)	2.32 (5.49)
S_3 :- 40	1.29 (1.30)	1.24 (1.11)	1.27 (1.20)	1.88 (3.57)	2.02 (4.45)	1.95 (4.10)	2.45 (6.86)	3.15 (11.72)	2.80 (9.29)	3.67 (14.37)	4.12 (18.35)	3.90 (16.36)	2.07 (4.33)	2.17 (4.92)	2.12 (4.62)
SEm±	0.16	0.06	0.02	0.03	0.33	0.04	0.24	0.57	0.10	0.67	0.33	0.06	0.06	0.32	0.04
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

(W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS was found best regarding dry weight of *Echinochloa colona.*

Among different seed rate, at 15,30 and 45 DAS both the year, minimum weed dry matter of *Echinochloa colona* was recorded under 80 Kg ha^{-1} which was significantly at par with other seed rates and proved non significant effect of seed rate on dry weight of *Echinochloa colona.* Howver, it was minimum during 60 and harvest in 40 kg ha^{-1} seed rate and was non significant with other seed rates during both the years. Phuving *et al.* (2005), concluded that, seeding rate was inversely correlated to weed interference. However, Rao *et al.* (2007) reveals that it is not necessary to use high seed rates to suppress weeds in DSR.

4.7.5.2 *Alternenthera triandra* (g m^{-2})

The data on dry weight of *Alternenthera triandra* at different time interval are presented in Table 4.46. Among different weed management practices, at 15 DAS, pre-emergence application of herbicides produced significant impact on weed dry weight of *Alternenthra triandra.* Statistically equal dry weight of *Alternenthra triandra* was recoeded under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. However, the maximum dry weight of *Alternenthra triandra* was observed where no weed management practice was applied during initial stage, almost nearly equal dry matter of *Alternenthra triandra* was recorded in weedy check (W_6), hand weeding (W_1) and post emergence (W_2) and (W_5) due to no weed control practices done before 15 DAS.

At 30 DAS, all the weed management practices were imposed and result showed that manual weeding and sequential application of pre - post and early post was equally effective on dry matter production of *Alternenthra triandra*. Whereas, significantly heavy infestation and dry matter of *Alternenthra triandra* was recorded in weedy check where no weed management was adopted up to the harvest.

Effect of manual as well as chemical control was observed up to the 45 DAS, sequential application of herbicide controlled weeds effectively and was as effective as hand weeding. On the basis of two year mean, minimum dry matter of *Alternenthra triandra* at 45 DAS was in hand weeding twice and it was at par with all the chemical control method except (W_2) bispyribac-Na @25 g ha^{-1} at 20 DAS. Result indicated that application of post emergence bispyribac-Na was not sufficient to control weeds for long time for all the weed *spp* during both the experimental year. Jadhav *et al.* (2008) also supports that application of pre-emergence oxadiargyl effectively control the weeds at early stage of crop growth followed by post-emergence application of bispyribac-Na control the new coming weeds.

At 60 DAS and at harvest, lowest dry weight of *Alternenthra triandra* was recorded in hand weeding twice, and it was at par with sequential application of oxadiargyl, pretilachlor + bensulfuron and azimsulfuron followed by bispyribac-Na at 20 DAS. At harvest significantly higher dry weight of *Alternenthra triandra* was recorded in weedy check . In weedy check since initial stage to harvest plenty of weeds were observed and it affects the growth and development of rice plant. Weeds were more competitive for all the resources which reflects on yield of weedy plots. Kiran (2010) observed that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} gave lowest density and dry weight of weeds with maximum weed control efficiency.

Among different seeding rates at both the year and different growth stages there was no remarkable difference between the high seed rate and low seed rate in respect to dry weight of *Alternenthra triandra* was recorded it was found non significant in all the observational stage except harvesting.

Interaction between the weed management and seed rates was found non-significant during 15, 30, 45 and 60 DAS in both the years of investigation but was significant at harvest during both the years (4.46a). Significantly minimum dry weight of *Alternenthra triandra* m^{-2} was recorded in the combination of (S_3 x W_3) 40 kg seed rate ha^{-1} with the application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year and it was at par with

Table 4.46: Dry matter of *Alternanthra triandra* (g m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

Treatment	Dry matter of *Alternanthra triandra* (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	1.66 (2.28)	1.66 (2.29)	1.66 (2.28)	1.73 (2.63)	1.67 (2.35)	1.70 (2.49)	1.78 (2.91)	1.83 (2.92)	1.81 (2.91)	2.46 (5.73)	2.57 (6.25)	2.52 (2.39)	2.65 (6.68)	2.49 (5.91)	2.57 (6.29)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	1.63 (2.22)	1.57 (2.06)	1.60 (2.14)	1.74 (2.60)	1.82 (2.86)	1.78 (2.73)	2.67 (6.99)	2.48 (5.87)	2.58 (6.43)	3.14 (9.65)	3.28 (10.44)	3.21 (6.69)	3.08 (9.01)	3.20 (8.73)	3.14 (8.87)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.08 (0.69)	0.94 (0.43)	1.01 (0.56)	1.98 (3.45)	1.57 (2.06)	1.78 (2.75)	2.02 (2.02)	1.86 (3.08)	1.94 (3.65)	2.64 (6.65)	2.44 (5.64)	2.54 (6.14)	2.60 (6.44)	2.38 (5.43)	2.49 (5.93)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.08 (0.67)	0.89 (0.41)	0.99 (0.54)	1.99 (3.51)	1.62 (2.28)	1.81 (2.89)	2.09 (2.09)	1.85 (3.00)	1.97 (3.49)	3.03 (8.87)	2.81 (7.56)	2.92 (8.21)	3.10 (9.30)	2.70 (7.10)	2.90 (8.20)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	1.72 (2.53)	1.74 (1.74)	1.73 (2.55)	1.98 (3.47)	1.56 (2.07)	1.77 (2.77)	2.23 (4.61)	1.87 (3.28)	2.05 (3.72)	2.70 (7.02)	2.49 (5.83)	2.60 (6.42)	2.68 (6.84)	2.37 (5.29)	2.53 (6.06)
W_6:- Weedy check	1.70 (2.43)	2.99 (1.84)	2.35 (2.71)	3.69 (13.12)	3.52 (11.91)	2.63 (12.51)	5.23 (26.96)	4.95 (24.70)	5.09 (25.83)	6.25 (38.20)	5.69 (32.07)	5.97 (35.13)	6.31 (39.49)	5.53 (30.19)	5.92 (34.84)
SEm±	0.05	0.07	0.05	0.09	0.10	0.06	0.17	0.11	0.11	0.12	0.16	0.11	0.18	0.15	0.14
CD (P = 0.05)	0.14	0.23	0.15	0.27	0.32	0.20	0.55	0.36	0.35	0.38	0.50	0.33	0.56	0.46	0.44
Seed rate (kg ha^{-1})															
S_1 :- 80	1.41 (1.60)	1.38 (1.68)	1.40 (1.68)	2.14 (4.66)	1.90 (3.59)	2.02 (1.65)	2.85 (9.55)	2.31 (6.32)	2.58 (7.93)	3.56 (13.81)	3.34 (12.20)	3.45 (13.00)	3.57 (14.18)	3.29 (11.41)	3.43 (12.79)
S_2 :- 60	1.52 (1.88)	1.52 (1.99)	1.52 (1.93)	2.17 (4.70)	1.94 (3.82)	2.06 (4.26)	2.58 (7.56)	2.50 (7.17)	2.54 (7.36)	3.54 (13.73)	3.24 (11.33)	3.39 (12.53)	3.40 (12.60)	3.09 (10.27)	3.25 (11.43)
S_3 :- 40	1.52 (1.93)	1.42 (1.71)	1.47 (1.82)	2.26 (5.03)	2.04 (4.36)	2.15 (4.69)	2.58 (7.73)	2.61 (7.62)	2.60 (7.67)	3.01 (10.86)	3.06 (10.37)	3.04 (10.61)	3.24 (12.10)	2.88 (9.64)	3.06 (10.87)
SEm±	0.03	0.04	0.01	0.03	0.07	0.03	0.09	0.07	0.03	0.08	0.12	0.09	0.06	0.07	0.05
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	023	026	0.20
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.46a: Interaction of weed management and seed rate on dry matter of *Alternanthra triandra* (g m^{-2}) at harvest in direct line seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**
W_1:- Two hand weeding	2.83 (7.51)	2.57 (6.27)	2.56 (6.25)	2.90 (7.90)	2.55 (6.18)	2.03 (3.64)	2.86 (7.71)	2.56 (6.23)	2.30 (4.95)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	3.18 (9.60)	3.26 (10.10)	2.80 (7.33)	3.24 (10.03)	3.00 (8.59)	2.83 (7.56)	3.21 (9.82)	3.13 (9.35)	2.81 (7.44)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	2.94 (8.22)	2.58 (6.30)	2.28 (4.79)	2.79 (7.30)	2.54 (6.09)	1.81 (2.89)	2.87 (7.76)	2.56 (6.20)	2.05 (3.84)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	3.03 (9.22)	3.13 (9.32)	3.13 (9.35)	3.02 (8.65)	2.81 (7.81)	2.28 (4.84)	3.03 (8.94)	2.97 (8.56)	2.71 (7.10)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	2.94 (8.22)	2.81 (7.38)	2.30 (4.93)	2.28 (4.84)	2.28 (4.84)	2.55 (6.18)	2.61 (6.53)	2.54 (6.11)	2.42 (5.56)
W_6:- Weedy check	6.53 (42.33)	6.05 (36.20)	6.35 (39.95)	5.49 (29.75)	5.34 (28.08)	5.74 (32.75)	6.01 (36.04)	5.70 (32.14)	6.04 (36.35)
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.16	0.50		0.18	0.55		0.12	0.39	
Comparison of two weed management means at the same or different level of seed rate	0.07	0.23		0.07	0.21		0.06	0.18	

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

combination of (S_3 x W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS during 2013.Minimum dry weight of weed under combination of low seed rate with application of pre and post emergence showed that it may be the alternative of high seed rate and manual weeding.

4.7.5.3 *Cyperus iria* (g m^{-2})

Data on dry weight of *Cyperus iria* at different time interval are presented in Table 4.47. Weed management practices had remarkable effect on dry weight of *Cyperus iria* through-out the crop growth period in both the years. Weed management practices at 15 DAS, due to application of pre-emergence in the W_3 and W_4 had significant effect on dry weight of *Cyperus iria* at early growth period. However, significantly minimum dry weight of *Cyperus iria* was recorded under the (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and was at par with pre-emergence application of pretilachlor + bensulfuron 660 g ha^{-1} followed by bispyribac Na @ 20 g ha^{-1} at 25 DAS. However, maximum dry weight of *Cyperus iria* was recorded in weedy check (W_6) which was similar to hand weeding twice (W_1), (W_2) bispyribac-Na @25 g ha^{-1} at 20DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS .

At 30 DAS, there was a significant impact of sequential application of pre and post-emergence herbicides on dry weight of *Cyperus iria.* Treatment (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS produced minimum dry weight of *Cyperus iria* and was found statistically at par with all other weed management in this stage. However, maximum dry matter was recorded under the un-weeded control plot.

At 45 DAS, minimum dry weight of *Cyperus iria* was recorded in hand weeding twice and was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS.

At harvest, dry weight of *Cyperus iria* was minimum in hand weeding twice (28.3 kg ha^{-1}) whereas, it was maximum in weedy check (92.5 kg ha^{-1}). Among, chemical control method, it was minimum in (W_5) azimsulfuron 35 g ha^{-1}

fb bispyribac Na 20g ha^{-1} at 15 and 35 DAS (39.2 kg ha^{-1}) and at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (37.1 kg ha^{-1}). Difference between the dry matter of *Cyperus iria* in un-weeded control and manual method was very vast. It was 70 per cent more dry matter in control plot as compared to hand weeding and it was nearly 60 and 57 per cent as compared to chemical control (W_5 and W_3), respectively. Difference between hand weeding and chemical control in regards to dry matter of *Cyperus iria* was very marginal. Un-weeded control produced 70 per cent more dry matter which reflects on the yield of un weeded control plot.

Among different seed rates, there was no significant effect of seed rates on dry weight of *Cyperus iria* at all the growth period in both the year. However, the high dry weight was recorded in 80 Kg ha^{-1} seed rate which was marginal as compared to other seed rates. However, very marginal difference between high seed rate and low seed rate was noticed in respect to dry matter production of *Cyperus iria* and difference was less than 1% among all the seed rates in respect to dry weight production of *Cyperus iria* at harvest.

Interaction between the weed management and seed rates was found non-significant during 15, 30, 45 and 60 DAS in both the year of investigation but it shows significant at harvest during both the years (4.47a). During 2013, significantly low dry weight of *Cyperus iria* m^{-2} was recorded in the combination of (S_3 x W_3) 40 kg seed rate ha^{-1} with the application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Whereas, it was minimum under the combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with two hand weeding and at par with the combination of (S_3 x W_5) 40 kg seed rate ha^{-1} with azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Minimum dry weight of weed under combination of low seed rate with application of pre and post emergence prove that it is as effective as the manual weeding with high seed rate like traditional rice cultivation in Chhattisgarh.

Table 4.47: Dry matter of *Cyperus iria* (g m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

Treatment	Dry matter of *Cyperus iria* (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	1.02 (0.56)	1.00 (0.50)	1.01 (.53)	1.11 (0.77)	1.70 (0.72)	1.41 (0.74)	1.13 (0.83)	1.22 (1.13)	1.18 (0.98)	1.54 (1.96)	1.71 (2.46)	1.63 (2.21)	1.30 (2.58)	1.88 (3.08)	1.59 (2.83)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	1.02 (0.54)	0.99 (0.48)	1.01 (.51)	1.30 (1.27)	1.24 (1.05)	1.27 (1.16)	1.48 (1.81)	1.69 (2.42)	1.59 (2.11)	2.25 (4.57)	2.27 (4.69)	2.26 (4.63)	2.32 (4.98)	2.51 (5.94)	2.42 (5.46)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.82 (0.18)	0.79 (0.13)	0.81 (.15)	1.28 (1.18)	1.27 (1.12)	1.28 (1.15)	1.43 (1.61)	1.33 (1.30)	1.38 (1.45)	1.80 (2.80)	1.91 (3.25)	1.86 (3.02)	1.98 (3.65)	2.14 (4.20)	2.06 (3.92)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.86 (0.24)	0.83 (0.19)	0.85 (0.21)	1.26 (1.15)	1.28 (1.14)	1.27 (1.14)	1.31 (1.23)	1.53 (1.89)	1.42 (1.56)	2.21 (4.52)	2.07 (3.91)	2.14 (4.08)	2.23 (4.60)	2.17 (4.31)	2.20 (4.45)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	0.54 (0.54)	0.98 (0.47)	0.76 (0.50)	1.17 (0.93)	1.23 (1.06)	1.20 (0.99)	1.31 (1.31)	1.35 (1.35)	1.33 (1.33)	1.95 (3.38)	1.88 (3.24)	1.92 (3.31)	2.00 (3.65)	2.04 (3.78)	2.02 (3.71)
W_6:- Weedy check	1.04 (0.59)	1.06 (0.64)	1.05 (0.61)	2.08 (3.91)	1.77 (2.63)	1.93 (3.27)	2.56 (6.05)	2.17 (1.36)	2.37 (5.05)	2.98 (8.44)	2.88 (7.83)	2.93 (8.13)	3.13 (9.37)	3.18 (9.68)	3.16 (9.25)
SEm±	0.04	0.02	0.03	0.10	0.04	0.06	0.09	0.08	0.07	0.09	0.07	0.04	0.14	0.09	0.08
CD (P = 0.05)	0.13	0.07	0.09	0.32	0.13	0.18	0.29	0.25	0.23	0.28	0.22	0.13	0.43	0.28	0.26
Seed rate (kg ha^{-1})															
S_1 :- 80	0.96 (0.45)	0.90 (0.39)	0.93 (0.39)	1.29 (1.30)	1.33 (1.31)	1.31 (1.30)	1.45 (1.83)	1.51 (1.92)	1.48 (1.87)	2.29 (5.01)	2.10 (4.12)	2.20 (4.56)	2.38 (5.41)	2.55 (6.14)	2.47 (5.77)
S_2 :- 60	0.93 (0.38)	0.93 (0.38)	0.93 (0.38)	1.44 (1.80)	1.29 (1.23)	1.37 (1.51)	1.56 (2.22)	1.52 (1.92)	1.54 (2.07)	2.15 (4.37)	2.17 (4.41)	2.16 (4.39)	2.22 (4.65)	2.27 (5.00)	2.25 (4.82)
S_3 :- 40	0.99 (0.50)	0.99 (0.50)	0.99 (0.50)	1.37 (1.51)	1.31 (1.32)	1.34 (1.41)	1.60 (2.37)	1.61 (2.33)	1.61 (2.35)	1.93 (3.46)	2.09 (4.15)	2.01 (3.80)	2.10 (4.35)	2.14 (4.36)	2.12 (4.35)
SEm±	0.02	0.02	0.01	0.08	0.04	0.04	0.06	0.06	0.04	0.07	0.05	0.04	0.06	0.08	0.05
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.30	0.19
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

Table 4.47a: Interaction of weed management and seed rate on dry matter of *Cyperus iria* (g m^{-2}) at harvest in direct line seeded rice

Treatment	Seed rate (kg ha^{-1})								
	2013			2014			Mean		
Weed management	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**	**S_1-80**	**S_2-60**	**S_3-40**
W_1:- Two hand weeding	2.00 (3.57)	1.66 (2.25)	1.54 (1.19)	2.13 (4.09)	1.75 (2.58)	1.75 (2.58)	2.07 (3.83)	1.71 (2.42)	1.64 (2.24)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	2.57 (6.13)	2.31 (4.83)	2.09 (3.97)	2.91 (7.99)	2.43 (5.44)	2.20 (4.39)	2.74 (7.06)	2.37 (5.14)	2.15 (4.18)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	2.38 (5.16)	2.13 (4.16)	1.42 (1.61)	2.42 (5.38)	2.00 (3.61)	2.00 (3.61)	2.40 (5.27)	2.07 (3.89)	1.71 (2.6)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	2.23 (4.71)	2.10 (4.04)	2.35 (5.05)	2.38 (5.18)	2.18 (4.40)	1.95 (3.36)	2.31 (4.94)	2.14 (4.22)	2.15 (4.20)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	1.93 (3.38)	2.17 (4.29)	1.90 (3.26)	2.38 (5.18)	1.98 (3.57)	1.75 (2.58)	2.16 (4.28)	2.07 (3.93)	1.83 (2.92)
W_6:- Weedy check	3.16 (9.49)	2.94 (7.30)	3.27 (10.31)	3.08 (9.00)	3.30 (1).40	3.18 (9.63)	3.12 (9.25)	3.12 (9.35)	3.23 (9.97)
	2013			**2014**			**Mean**		
	SEm±	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**		**SEm±**	**CD (P = 0.05)**	
Comparison of two seed rate means at the same level of weed management	0.13	0.41		0.15	0.47				
Comparison of two weed management means at the same or different level of seed rate	0.06	0.18		0.05	0.14				

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

4.7.5.4 *Cyanotis axillaris* (g m^{-2})

The data on dry weight of *Cyanotis axillaris* at different time interval are presented in Table 4.48. Data revealed that weed management practices proved significantly superior over the un-weeded control at all the growth period in both the year. At 15 DAS, the minimum dry weight of *Cyanotis axillaris* was recorded under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS . However, the maximum dry matter was found under the weedy check in both the years. Data itself explains that application of pre-emergence herbicide is effective against the *Cyanotis axillaris*. Similar result was revealed by the Jadhav *et al.* (2008) and Kurmi (2008)

During 30 DAS, among different weed management practices, significantly low dry matter of *Cyanotis axillaris* was recorded under the two hand weeding at 20 and 40 DAS in both the year and was at par with all the weed management practices through chemical control. At 30 DAS, application of pre, post and early post are as effective as manual weeding in regards to dry weight of *Cyanotis axillaris*. So we can conclude that combination of pre and post-emergence with proper dose and time of application is equally effective as hand weeding twice.

At 45 DAS, significantly low dry matter of *Cyanotis axillaris* was recorded under hand weeding twice at 20 and 40 DAS which was at par with application of pre - emergence oxadiargyl and combination of pretilachlor + bensulfuron followed by bispyribac Na at 25 DAS.

During advancement of crop growth period at 60 DAS and at harvest, significantly lowest dry weight of *Cyanotis axillaris* was recorded under (W_3) pre - emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS at harvest. However, it was maximum in weedy check and produced 3.94 q dry matter ha^{-1} and two hand weeding recorded only .71 q dry matter ha^{-1}. Difference between hand weeding and weedy check was very high. It was 270 percent more dry matter in control plot. Difference is self explanatory that, if weed management is not adopted in direct line seeded rice, weeds will totally hamper the growth,

Table 4.48: Dry matter of *Cyanotis axillaris* (g m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

Treatment	Dry matter of *Cynotis axillaris* (g m^{-2})														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	1.28 (1.14)	1.19 (0.94)	1.24 (1.04)	1.28 (1.23)	131.00 (1.23)	66.14 (1.23)	1.26 (1.22)	1.41 (1.49)	1.34 (1.35)	2.04 (3.73)	2.22 (4.47)	2.13 (4.1)	2.62 (6.41)	2.87 (7.79)	2.75 (7.1)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	1.37 (1.39)	1.21 (0.98)	1.29 (1.18)	1.39 (1.45)	134.00 (1.33)	67.70 (1.39)	2.00 (3.70)	2.21 (4.76)	2.11 (4.23)	2.81 (7.61)	2.96 (9.18)	2.89 (8.39)	3.62 (12.76)	3.54 (12.29)	3.58 (12.52)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.95 (0.40)	0.96 (0.42)	0.96 (0.41)	1.50 (1.82)	1.45 (1.63)	1.48 (1.72)	1.39 (1.61)	1.51 (1.82)	1.45 (1.71)	2.00 (3.58)	1.99 (3.53)	2.00 (3.55)	2.52 (5.98)	2.28 (4.80)	2.40 (5.39)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	0.95 (0.40)	0.96 (0.35)	0.96 (0.37)	1.50 (1.80)	1.51 (1.83)	1.51 (1.81)	1.87 (3.34)	1.54 (1.97)	1.71 (2.65)	2.34 (5.30)	2.64 (7.11)	2.49 (6.20)	2.62 (6.44)	3.53 (12.14)	3.08 (9.29)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	1.31 (1.21)	1.19 (0.93)	1.25 (1.07)	1.49 (1.81)	1.24 (1.10)	1.37 (1.45)	1.54 (1.90)	1.44 (1.58)	1.49 (1.74)	2.01 (3.61)	2.09 (3.96)	2.05 (3.78)	2.98 (8.49)	2.64 (7.32)	2.81 (7.90)
W_6:- Weedy check	1.68 (2.34)	1.32 (1.25)	1.50 (1.29)	2.56 (6.23)	2.32 (4.99)	2.44 (5.61)	3.81 (14.08)	3.41 (11.14)	3.61 (12.61)	4.28 (18.02)	4.19 (17.06)	4.24 (17.54)	5.47 (29.44)	5.44 (29.32)	5.46 (29.40)
SEm±	0.02	0.02	0.02	0.09	0.09	0.07	0.18	0.13	0.12	0.11	0.20	0.13	0.08	0.14	0.07
CD (P = 0.05)	0.08	0.06	0.06	0.27	0.27	0.23	0.58	0.39	0.37	0.35	0.64	0.40	0.27	0.46	0.23
Seed rate (kg ha^{-1})															
S_1 :- 80	1.24 (1.11)	1.14 (0.84)	1.19 (0.97)	1.62 (2.30)	1.49 (1.98)	1.56 (2.18)	2.01 (4.43)	1.95 (3.80)	1.98 (4.11)	2.62 (7.22)	2.76 (7.85)	2.69 (7.53)	3.55 (13.23)	3.71 (14.53)	3.63 (13.88)
S_2 :- 60	1.26 (1.16)	1.13 (0.79)	1.20 (0.97)	1.61 (2.41)	1.51 (1.94)	1.56 (2.17)	1.94 (4.17)	1.95 (3.85)	1.95 (4.01)	2.67 (7.48)	2.69 (7.38)	2.68 (7.43)	3.28 (11.59)	3.34 (12.19)	3.31 (11.89)
S_3 :- 40	1.26 (1.17)	1.13 (0.80)	1.20 (0.99)	1.63 (2.38)	1.58 (2.22)	1.61 (2.30)	1.99 (4.33)	1.86 (3.73)	1.93 (4.03)	2.45 (6.23)	2.60 (7.43)	2.53 (6.83)	3.08 (9.96)	3.10 (10.17)	3.09 (10.06)
SEm±	0.01	0.02	0.01	0.02	0.02	0.01	0.04	0.11	0.06	0.10	0.19	0.14	0.06	0.14	0.06
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	.22	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

development and yield of rice crop. Difference between hand weeding and chemical control was marginal.

Among different seed rates, there was no significant effect on dry weight of *Cyanotis axillaris.* All the seed rate showed equal effect on dry matter production during both the year of experimentation. Interaction between the weed management and seed rates of dry weight of *Cyanotis axillaris* was found non-significant in both the year and all the growth stages.

4.7.5.5 Other weed species (g m^{-2})

Data on weed dry weight of other species at different time interval are presented in Table 4.49. During 2013 and 2014, weed management practices caused significant variation in dry weight of other weed species.

At 30 DAS, among different weed management practices, significantly lowest dry matter was recorded under (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with all other weed management practices in both the year except (W_2) bispyribac-Na @25 g ha^{-1} at 20 DAS in 2013.However, maximum dry matter was in weedy check. Difference between the hand weeding and chemical control was very marginal in respect to dry weight of other weeds in both the years.

At 45 DAS, lowest dry weight of other weeds was recorded under (W_4) pre-emergence application of pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in 2013 but it was minimum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and at par with two hand weeing , (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} fb bispyribac Na 20g ha^{-1} at 15 and 35 DAS during 2014. During this period all the weed management practices were found at par except (W_2) bispyribac-Na @25 g ha^{-1} at 20 DAS. Applicaton of bispyribac-Na alone as post emergence is not sufficient to control the weeds effectively for long time.

At 60 DAS and at harvest, significantly lower dry matter of other weed was recorded under hand weeding twice and was at par with (W_3) pre -emergence

Table 4.49: Dry matter of other weeds (g m^{-2}) at different duration as influenced by weed management and seed rate in direct line seeded rice

	Dry matter of other weeds (g m^{-2})											
	30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management												
W_1:- Two hand weeding	1.61 (2.10)	1.55 (1.94)	1.58 (2.02)	2.14 (4.16)	1.50 (1.79)	1.82 (2.97)	2.02 (3.76)	2.18 (4.40)	2.10 (4.08)	2.32 (5.03)	2.73 (7.06)	2.53 (6.04)
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	1.80 (2.82)	1.60 (2.36)	1.70 (2.59)	2.42 (5.60)	2.32 (5.03)	2.37 (2.37)	2.95 (9.07)	3.22 (10.15)	3.09 (9.61)	3.44 (11.51)	3.46 (12.50)	3.45 (12.00)
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.44 (1.74)	1.61 (2.23)	1.53 (1.98)	1.90 (3.42)	1.47 (1.69)	1.69 (2.55)	2.23 (4.58)	2.23 (4.59)	2.23 (4.58)	2.51 (5.90)	2.77 (7.24)	2.64 (6.57)
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	1.43 (1.61)	1.51 (2.05)	1.47 (1.83)	1.87 (3.16)	1.49 (1.81)	1.68 (2.48)	2.82 (7.52)	2.92 (8.07)	2.87 (7.79)	3.31 (10.78)	3.49 (11.72)	3.40 (11.25)
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	1.54 (1.54)	1.61 (2.13)	1.58 (2.06)	2.02 (3.89)	1.60 (2.06)	1.81 (2.97)	2.40 (5.31)	2.25 (4.63)	2.33 (2.33)	2.53 (6.47)	2.75 (7.19)	2.64 (6.83)
W_6:- Weedy check	3.29 (3.29)	2.64 (6.53)	2.97 (8.44)	4.54 (20.20)	3.59 (13.0)	4.07 (16.63)	4.68 (21.41)	4.29 (18.37)	4.49 (4.49)	5.01 (24.68)	5.21 (26.89)	5.11 (25.78)
SEm±	0.10	0.13	0.09	0.15	0.11	0.09	0.15	0.14	0.12	0.07	0.16	0.12
CD (P = 0.05)	0.33	0.42	0.30	0.47	0.33	0.30	0.46	0.44	0.38	0.22	0.49	0.38
Seed rate (kg ha^{-1})												
S_1 :- 80	1.91 (3.57)	1.82 (3.00)	1.87 (1.86)	2.58 (7.04)	2.03 (4.55)	2.31 (5.71)	2.81 (8.20)	2.68 (7.14)	2.75 (7.67)	3.43 (12.20)	3.30 (12.03)	3.37 (12.11)
S_2 :- 60	1.89 (3.51)	1.77 (2.89)	1.83 (3.2)	2.55 (6.90)	1.96 (4.11)	2.26 (5.50)	3.00 (9.34)	2.96 (9.20)	2.98 (9.27)	3.17 (10.83)	3.38 (11.51)	3.28 (11.17)
S_3 :- 40	1.74 (3.22)	1.71 (1.71)	1.73 (1.79)	2.33 (2.33)	2.00 (4.02)	2.17 (2.17)	2.74 (2.74)	2.91 (8.77)	2.83 (8.52)	2.97 (9.16)	3.52 (12.72)	3.25 (10.94)
SEm±	0.09	0.06	0.06	0.12	0.06	0.08	0.18	0.11	0.14	0.08	0.11	0.08
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The figure in parenthesis indicate the original values, DAS =Days after sowing, Transformation= $\sqrt{x + 0.5}$

oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. However, higher dry matter of other weeds was observed in weedy check and it produced 2.57 q ha^{-1} dry matter on mean basis of two year. Whereas, hand weeding, (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS produced .604 , .657 and .683 q ha^{-1} dry matter of other weeds respectively . Difference between hand weeding and weedy check was significantly high it was 76 per cent high in weedy check method. Whereas, difference between hand weeding and chemical control, it was found 8 and 11 per cent high dry matter in W_3 and W_5 on the basis of two year mean.

Among different seed rates, in respect to dry matter production of other weed species at 15, 30, 45, 60 DAS and at harvest, data revealed that, there was equal effect of seed rates on other weed species. However, the less weed dry matter was recorded under 80 kg ha^{-1} as compared to other seeding rates. Different seed rate 80 , 60 and 40 kg ha^{-1} produced 1.21,1.11 and 1.09 q ha^{-1} dry matter of other weeds, respectively. Which show nearly equal and non significant difference on dry matter production. Interaction between the weed management and seed rates was found non-significant in all the growth period and both the year.

4.7.6 Weed control efficiency (%)

Weed control efficiency (WCE) at 15, 30, 45, 60 DAS and at harvest are calculated and presented in Table 4.50.

At 15 DAS, among different weed management practices, weed control efficiency was recorded maximum under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in 2013 which was at par with (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. However, statisticaly higher weed control efficiency was recorded under (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during 2014. Result proved that the, applications of pre-emergence herbicides oxadiargyl 70 g ha^{-1} and pretilachlor +

bensulfuron @ 660 g ha^{-1} effectively controlled the weeds and provide better growth condition to the rice crop. Whereas, among different seeding rates, maximum weed control efficiency was recorded under the (S_1), 80 kg ha^{-1} seed rate which was statistically equal to (S_2), 60 kg ha^{-1} and (S_3) 40 kg ha^{-1}.

Weed control efficiency at 30 DAS, recorded significantly superior under hand weeding twice (W_1) due to first hand weeding at 20 DAS. Whereas, among herbicide treatment it was maximum under (W_5) azimsulfuron 35 g ha-1 *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS in both the years and it was at par with all the weed management practices. El-Desoki (2003) found that two hand weeding at 20 and 40 DAT was very effective in controlling rice weed growth and increasing the yield. Singh and Namdeo (2004) found that hand weeding (20 and 40 days after sowing) showed 72 per cent weed control efficiency. Yadav *et al*. (2008) reported that azimsulfuron 25-30 g ha^{-1} at 15 DAT stage provided 93-99 per cent control of broadleaf weeds and was better than pretilachlor (85%). Saha and Rao (2012) reported that azimsulfuron at 35 g a.i. ha^{-1} applied 18 DAT was found to be the most effective (weed control efficiency 98.5%) in controlling the complex weed flora and produced comparable grain yield (5.93 t ha^{-1})with weed free check thereby realizing an increase of 91 per cent yield over weedy check.

Weed control efficiency at 45 DAS was significantly superior in two hand weeding at 20 and 40 DAS (87.09 and 86.43 per cent respectively) and was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS in both the years. Walia *et al*. (2009) reported that weeds in DSR can be controlled effectively with the integration of post-emergence (25–30 DAS) application of bispyribac 25 g ha^{-1} or azimsulfuron 20 g ha^{-1} with pre-emergence herbicide. Whereas, Rao and Ratnam (2010) reported that bispyribac Sodium 30 g ha^{-1} reduced weed growth with higher weed control efficiency (WCE) of 74 per cent.

Among weed management options at 60 DAS and at harvest, weed control efficiency recorded maximum under two hand weeding at 20 and 40 DAS which was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g

Table 4.50: Weed control efficiency (%) at different duration of direct line seeded rice as influenced by weed management and seed rate

Treatment	Weed Control Efficiency (%)														
	15 DAS			30 DAS			45 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	25.99	16.28	21.14	81.99	79.86	80.93	87.09	86.43	86.76	81.60	77.57	79.58	80.45	75.43	77.94
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	21.68	17.52	19.60	77.17	73.06	75.12	72.67	69.65	71.16	64.17	52.87	58.52	64.79	54.64	59.72
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	79.02	79.04	79.03	76.62	74.82	75.72	85.09	82.29	83.69	78.49	75.93	77.21	79.20	76.69	77.95
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	77.64	81.32	79.48	76.37	73.51	74.94	83.09	80.30	81.70	69.14	60.28	64.71	72.70	57.84	65.27
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	17.66	9.18	13.42	77.99	77.68	77.83	83.12	82.60	82.86	76.18	72.85	74.51	75.93	74.01	74.97
W_6:- Weedy check	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEm±	1.98	2.95	1.85	1.13	1.81	0.87	1.52	1.73	1.28	1.49	1.64	1.20	1.54	1.01	0.97
CD (P = 0.05)	6.23	9.30	5.83	3.56	5.72	2.75	4.78	5.45	4.05	4.71	5.16	3.78	4.85	3.19	3.05
Seed rate (kg ha^{-1})															
S_1 :- 80	37.87	35.12	36.50	67.01	63.26	65.13	69.36	65.48	68.43	61.58	54.84	58.21	59.62	57.23	58.42
S_2 :- 60	34.03	32.84	33.43	65.85	62.29	64.07	68.39	66.08	67.24	60.34	55.18	57.76	62.00	54.84	58.42
S_3 :- 40	39.10	33.71	36.40	62.21	63.91	63.06	67.79	69.08	67.42	62.87	59.73	61.30	64.92	57.24	61.08
SEm±	2.62	10.14	5.63	1.32	1.46	1.09	1.02	1.31	0.70	0.97	0.31	0.51	0.80	1.58	0.70
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.22	NS	3.15	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Data is itself clarifying that, sequential application of oxadiargyl ,azimsulfuron and bispyribac Na gives same WCE as two hand weeding and difference between hand weeding and chemical control was less than two percent .

Among different seeding rates, weed control efficiency was at par throughout the crop growth period in both the year. Interaction between the weed management and seed rates was found non-significant at all the growth period in both the years.

4.7.7 Weed index (%)

The data on weed index are present in Table 4.51 with regards to the different weed management practices, it was noted that maximum weed index was recorded under un-weeded control plot (73.34) (loss of yield as compared to hand weedingmethod).

Table 4.51: Weed index (%) of direct line seeded rice as influenced by weed management and seed rate

Treatment	Weed index (%)		
	2013	**2014**	**Mean**
Weed management			
W_1:- Two hand weeding	-	-	-
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	11.95	7.19	9.57
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	2.45	1.34	1.90
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	7.23	5.12	6.17
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	4.22	3.76	3.99
W_6:- Weedy check	69.8	74.32	73.34
SEm±	-	-	-
CD (P = 0.05)	-	-	-
Seed rate (kg ha^{-1})			
S_1 :- 80	6.12	3.79	4.96
S_2 :- 60	7.39	2.63	5.01
S_3 :- 40	-	-	-
SEm±	-	-	-
CD (P = 0.05)	-	-	-
Interaction (WM X SR)	-	-	-

However, minimum weed index was recorded under (W_3) (1.90 %)pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by the (W_5) (3.99 %) azimsulfuron 35 g ha-1 *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS, both the treatments was very closed in respect to weed index. Data itself explanatory that chemical control methods are very close to hand weeding, loss of yield as compared to hand weeding was very marginal so that chemical control may be the better option for the farmers. Among different seed rates weed index was very marginal it was 4.96 per cent and 5.01 per cent as compared to the 40 kg ha^{-1}

4.7.8 Relative weed density (%)

Periodical relative weed density of different weed species was calculated at 15, 30, 45, 60 DAS and at harvest on the basis of two year mean and presented in Fig 4.11, 4.12 and 4.13.

4.7.8.1 Relative weed density (%) at 15 DAS

At 15 DAS data indicated that maximum relative weeds density was noticed by *Echinochloa colona* among all the species. Weed management practice had remarkable effect on relative weed density. Minimum relative weed density of *Echinochloa colona* was found under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS where pre emergence herbicide was applied. However,almost similar and high relaive weed density was observed in W_1,W_2 , W_5 and W_6. Among different seeding rates, RWD of *Echinochloa colona* was found minimum under the 80 kg seed rate ha^{-1} and almost equal with other seed rates.

Among different weed management, RWD of *Alternanthra triandra* was found minimum under (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by (W_3) pre -emergence oxadiargyl 70 g ha-1 *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS . However, it was maximum in two hand weeding. Among different seed rates it was maximum in 60 kg ha^{-1} seed rate and minimum in 80 kg ha^{-1} seed rate.

RWD of *Cynotis axilliaris* was minimum in hand weeding and was very close to (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. However, it was maximum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS.Wheresa, seed rate does not show any critical difference in RWD of *Cynotis axilliaris.* Relative weed density of *Cyperus iria* was recorded minimum under weedy check.

4.7.8.2 Relative weed density (%) at 30 DAS

Among different species maximum relative weed density was recorded through *Cyanotis axilliaris* and *Alternanthra triandra* at 30 DAS. Maximum relative weed density of *Echinochloa colona* was recorded under (W_6) weedy check whereas it was minimum under two hand weeding (W_1) . Other weed management had similar effect on relative weed density of *Echinochloa colona.* During this period relative weed density of *Echinochloa colona* was found non significant in regard to different seed rates.

Among different weed management practices, RWD of *Alternanthra triandra* was recorded nearly equal relative density among all the weed management practices. Whereas, it was maximum in two hand weeding. Among different seed rate it was found minimum under the 80 kg ha^{-1} seed rate and maximum in 60 kg ha^{-1} seed rate.

RWD at 30 DAS of *Cyperus iria* and *Cynotis axilliaris* was found minimum in weedy check. However, it was maximum in (W_2) bispyribac-Na @25 g ha^{-1} at 20DAS in case of *Cyperus iria* and was maximum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in *Cynotis axilliaris.* Seed rates does not show any critical difference in relative weed density of *Cyperus iria* and *Cyanotis axilliaris* at 30 DAS.

Among different weed management practices, RWD of other weed species was found minimum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and it was maximum under (W_2) bispyribac-Na @25 g ha^{-1} at 20DAS. Relative weed density of other weed species was recorded maximum under the 60 kg ha^{-1} seed rate and it was minimum in 40 kg ha^{-1} seed rate.

4.7.8.3 Relative weed density (%) at 45 DAS

Relative weed density of *Echinochloa colona* was found maximum in (W_6) weedy check whereas, it was minimum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Application 40 kg ha^{-1} seed rate recorded minimum RDW of *Echinochloa colona* at 45 DAS.

RWD of *Alternandra triandra* at 45 DAS among different weed management was recorded minimum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and it was maximum in (W_6) weedy check. Relative density of *Alternanthra triandra* among different seed rate was recorded minimum in 80 kg ha^{-1}. However, it was maximum in 40 kg ha^{-1} seed rate but it was non significant and found nearly equal in all the seed rates.

Among different weed management options, the RWD of *Cyperus iria* was found minimum under (W6) weedy check method. Whereas, maximum RWD was recorded under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. All the chemical control method produced nearly equal RWD of *Alternandra triandra* at this stage except (W_2) bispyribac-Na @25 g ha^{-1} at 20DAS . Seed rate does not show any critical difference in relative density of *Cyperus iria*.

Minimum RWD of *Cynotis axilliaris* was under (W_1) two hand weeding. However, it was maximum in (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Whereas, among different seeding rate, the RWD was found minimum under the (S_1) 80 kg ha^{-1} seed rate and maximum was recorded under (S_3) 40 kg ha^{-1}.

Due to various weed management option, maximum relative density of other weeds was observed under (W_1) two hand weeding and it was maximum in (W3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Among different seed rate it was minimum in (S_1) 80 kg ha^{-1} and maximum in (S_3) 40 kg ha^{-1} seed rate.

4.7.8.4 Relative weed density (%) at 60 DAS

Later on during 60 DAS relative weed density of other weeds was highest among the different weed species. Relative density of *Echinochloa colona* was maximum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS .Whereas it was minimum in (W_1) two hand weeding at 20 and 40 DAS. Among different seed rate RWD of *Echinochloa colona* was nearly equal and marginal difference in high to low seed rates was recorded.

Among different weed management practices, RWD of *Alternanthra triandra* was found minimum in (W_2) bispyribac-Na @25 g ha^{-1} at 20DAS and was maximum in (W_6) weedy check .Although, the relative density was nearly equal to all the weed management options. Among different seeding rate, RWD was found minimum under the (S_3) 40 kg ha^{-1} seed rate and maximum was recorded under (S_2) 60 kg ha^{-1}.

Relative density of *Cyperus iria* was recorded maximum under (W_1) *biasi* method and it was minimum in (W_6) weedy check. Among seed rate it was maximum in (S_2) 120 kg ha^{-1} and minimum in (S_3) 40 kg ha^{-1} seed rate but it was newly equal in all the seeding method.

Due to various weed management practices, maximum relative weed density of *Cyanotis axilliaris* was recorded under (W6) weedy check and it was minimum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Seed rate does not show any critical difference in relativ weed density of *Cynotis axilliaris.*

Among different weed management practices, RWD of other weed was minimum under (W_1) two hand weeding whereas it was maximum in (W_2) bispyribac-Na @25 g ha^{-1} at 20DAS. Among different seeding rate, RWD of other weed was found minimum under the (S_1) 80 kg ha^{-1} seed rate and maximum was recorded under (S_2) 60 kg ha^{-1}.

4.7.8.5 Relative weed density (%) at harvest

At harvest minimum relative weed density was recorded under *Echinochloa colona* among all the weed *spp*. The maximum relative density of *Echinochloa colona* was recorded under (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS it was minimum in (W_6) two hand weeding . Among seed rate it was minimum in (S_1) 80 kg ha^{-1} and maximum in (S_3) 40 kg ha^{-1} seed rates.

Relative weed density of *Alternanthra triandra* was recorded maximum in weedy check. Whereas, it was minimum in (W_2) bispyribac-Na @25 g ha^{-1} at 20DAS. Seed rate did not show any critical difference in relative weed density of *Alternanthra triandra* at 60 DAS.

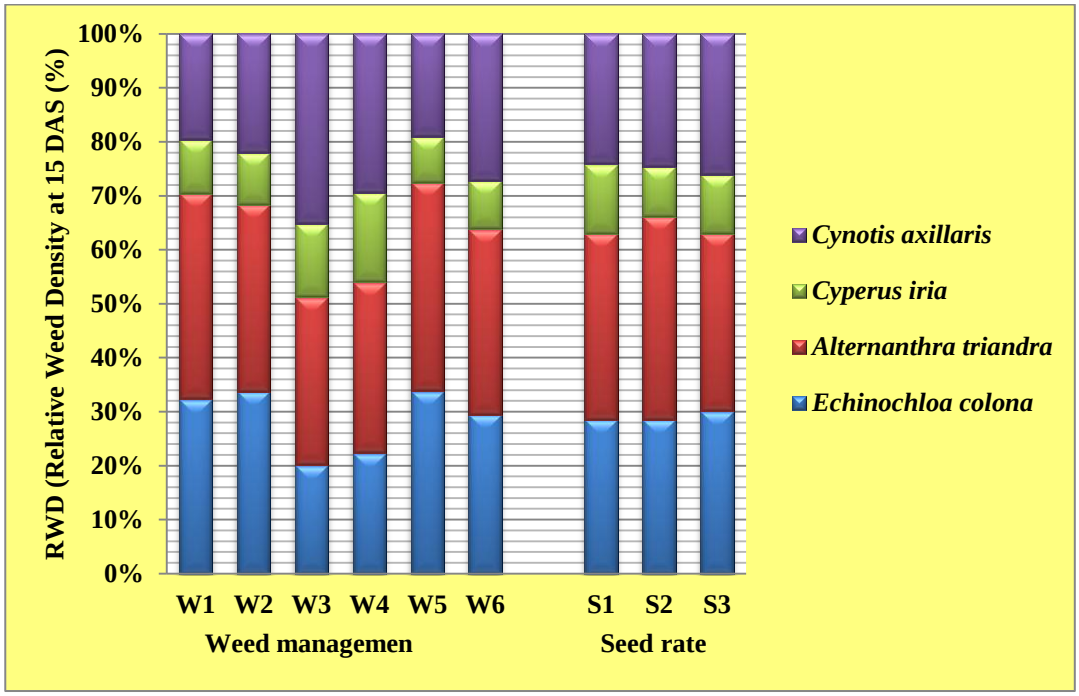
Due to various weed management options, maximum relative density of *Cyperus iria* was under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Whereas,maximum relative density of *Cyanotis axilliaris* was observed under (W_1) two hand weeding at 20 and 40 DAS.

At harvest, relative density of other weeds was maximum in (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS ans minimum was found (W_6) weedy check. Application of (S_3) 40 kg ha^{-1} seed rate recorded maximum relative density of other weeds. Whereas, it was minimum in (S_1) 80 kg ha^{-1} seed rate.

4.7.9 Weed growth rate (g $day^{-1}m^{-1}$)

Weed growth rate (WGR) during various crop growth intervals are presented in Fig. 4.14. Weed growth rate showed different response due to different weed management and seed rate options at various time intervals. Weed growth was maximum in (W_6) weedy check in all the observational stages in weed management practices.

At 15 to 30 DAS similar and lowest weed growth rate (WGR) was observed under (W_1) two hand weeding at 20 and 40 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. However, it was maximum in (W_6) weedy check. Among seed rate weed growth was minimum in high seed rate (S_1) 80 kg ha^{-1} which was found non significant among other seed rates.



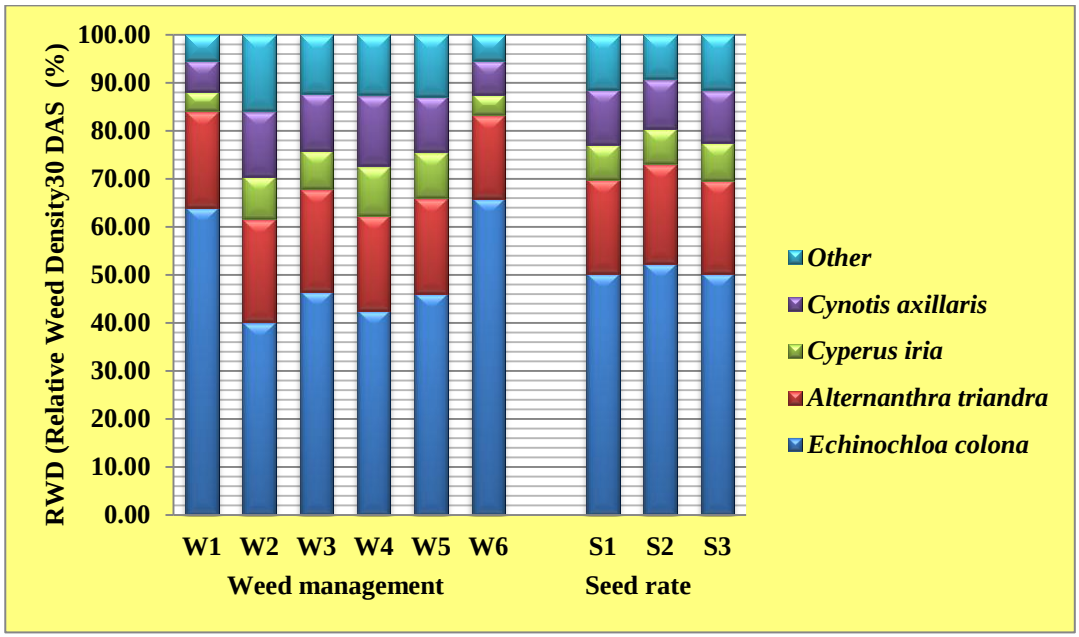
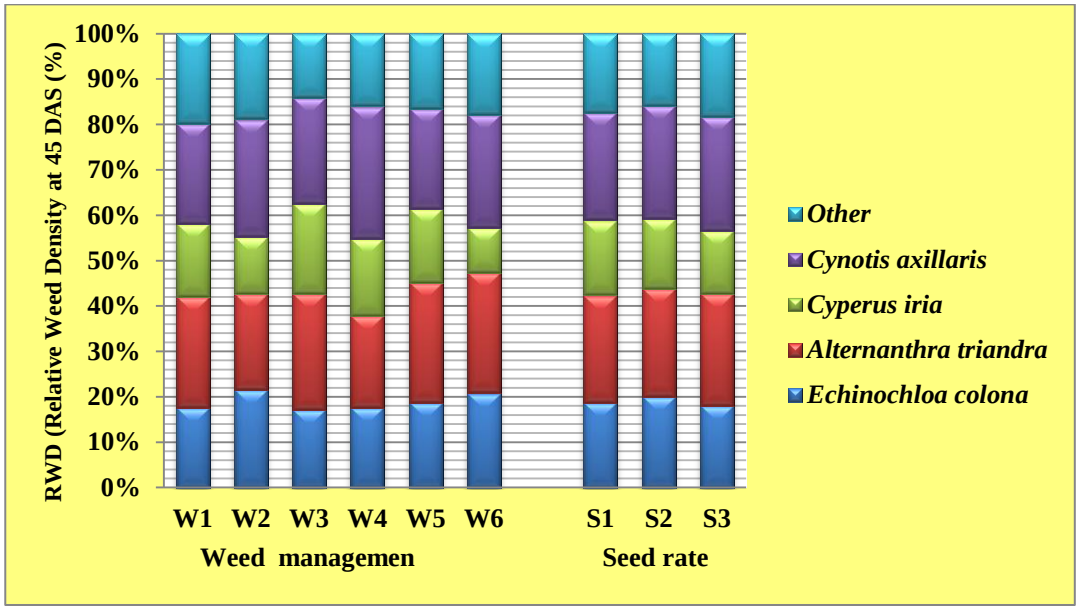


Fig 4.11: Species wise relative weed density (%) at 15 & 30 DAS as influenced by weed management and seed rate in direct line seeded rice



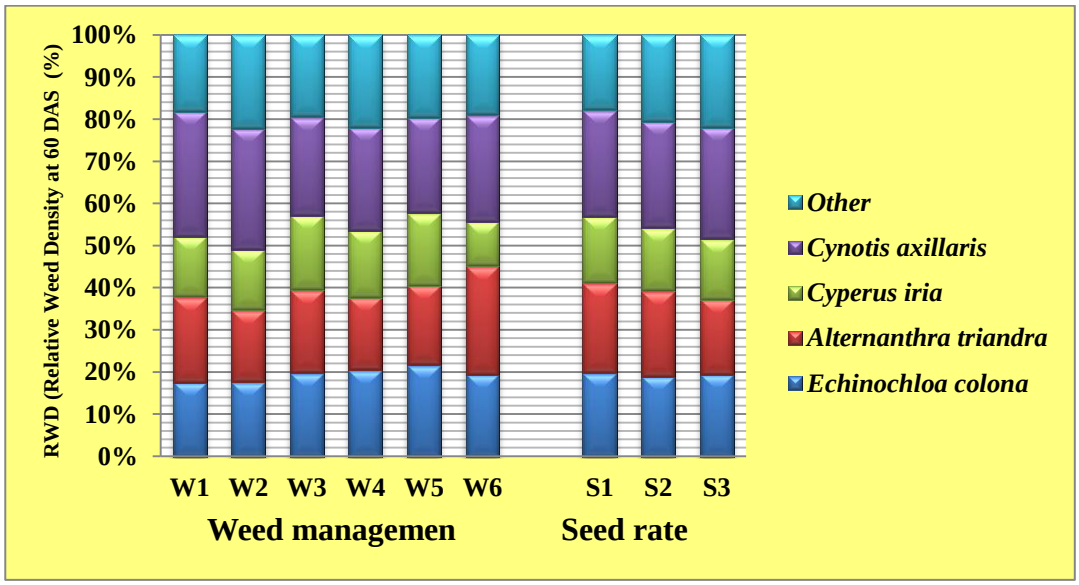


Fig 4.12 : Species wise relative weed density (%) at 45 & 60 DAS as influenced by weed management and seed rate in direct line seeded rice

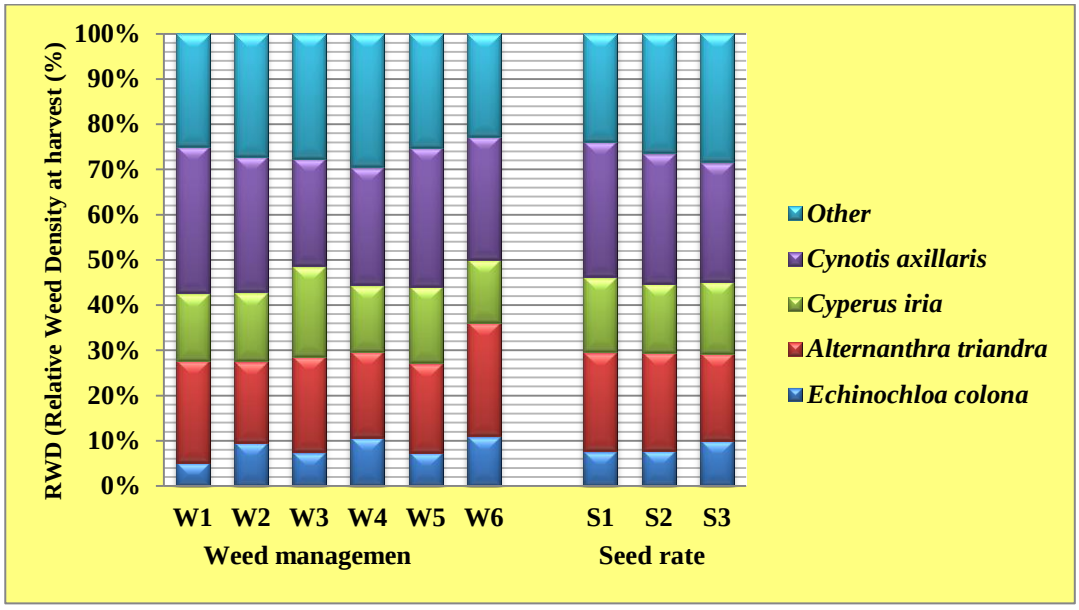


Fig4.13 : Species wise relative weed density (%) at harvest as influenced by weed management and seed rate in direct line seeded rice

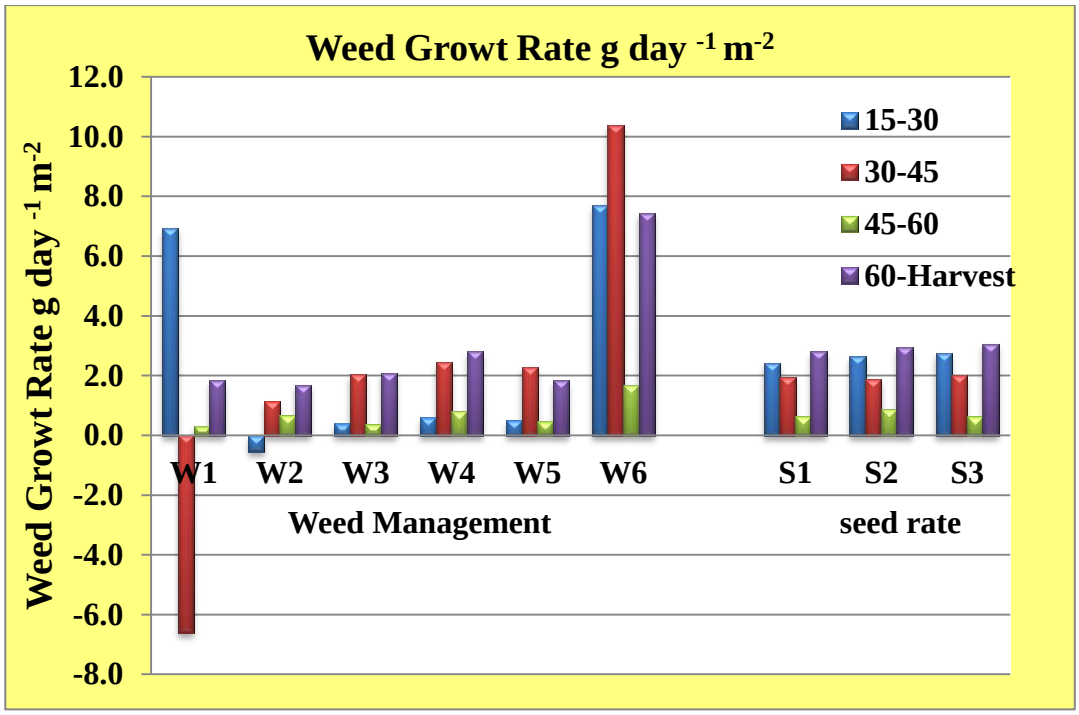


Fig 4.14: Weed growth rate at different time interval as influenced by weed management and seed rate in broadcasted direct seeded rice (mean of 2013-2014)

During 30 to 45 DAS growth rate of weeds was observed maximum during this period and it was low in (W_1) two hand weeding and (W3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Whereas, it was found maximum in (W6) weedy check. Difference in weed growth rate in regards to high to low seed rate was found equal during this period.

Declined weed growth was observed during 45 to 60 DAS and it was minimum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS whereas it was maximun in weedy check method. Among seed rate weed growth rate was maximum in (S_2) 60 kg ha^{-1} seed rate and found minimum in (S_3) 40 kg ha^{-1}.During 60 to harvest weed growth rate was observed minimum in all the weed management practices.

4.7.10 Discussion on weed

The weed density was significantly highest in untreated control which was due to absence of weed management practices throughout the rice growth period. Saha *et al*. (2005 a) observed that the maximum yield reduction due to weeds were 41 per cent in direct dry seeded rice. Among weed management practices, weed dry matter production was significantly highest in untreated control which was due to absence of suitable weed management practices. Weeds grow naturally and contributed the maximum weed density and their dry matter. Ramamurthy (1991), revealed that excessive weed growth and severe crop- weed competition drastically reduce the crop yield in the un weeded control and it was 88 % of the treatments where herbicides were applied in direct seeded rice. Mamun (1990) suggested that weed growth reduced the grain yield by 68-100% for direct seeded rice, 16-48% for transplant rice.

Manual weeding was found best among all the weed management during both the year. Due to manual weeding at 20 and 40 DAS significantly reduced the density and dry matter production of weeds. Manual weeding at 20 DAS control the first flush of weeds whereas weeding at 40 DAS removes the late coming weeds in the field. Two hand weeding completely removes weed during the critical period of rice weed competition. Due to this reason density and dry matter of

weeds was found minimum under this treatment. Nagappa and Biradar (2002) reported that among the weed management practices, two hand weeding at 20 and 40 days produced significantly higher yield over the un weeded check and density and dry matter of weed was minimum under manual weeding. Chandra *et al*. (1998) found that the lowest weed density of some species, total weed dry weight, greatest weed control efficiency (93.9%) were achieved by manual weeding at 25 and 40 DAS. Patra *et al*. (2006) reported that two hand-weeding at 20 and 40 DAS recorded the minimum weed population and dry weight and the highest weed control efficiency at 60 DAT and at harvest. El-Desoki (2003) found that two hand weeding at 20 and 40 DAT was very effective in controlling rice weed growth and increasing the yield. Lower weed growth rate in treatment was due to lower dry matter production of weeds.

Among the herbicide treatment, pre and post emergence application oxadiargyl 70 g ha^{-1} fallowed by bispyribac Na prove the minimum weed dry matter of weeds, weed index, maximum weed control efficiency. It was due to the fact that in the experimental field *Echinochloa colona*, *Alternanthra triandra*, *Cyperus iria* and *Cyanotis axillaris* were the major weeds and was controlled by sequential application of pre and post emergence application of oxadiargyl and bispyribac Na. as a result there was significant minimization of dry matter of weeds. This ultimately minimizes the dry matter of weeds, weed growth rate, weed index and weed control efficiency. Jadhav *et al*. (2008) stated that pre-emergence application of oxadiargyl 75 g ha^{-1} effectively control the weeds at early stage of crop growth followed by post-emergence application of bispyribac-Na 30 g ha^{-1} control the late coming weeds. . Kiran *et al*. (2010) observed that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} gave lowest density and dry weight of weeds with maximum weed control efficiency. Yadav *et al*. (2009) stated that bispyribac @ 25 g ha^{-1} applied at 15-25 DAT resulted 37-41 per cent increase in the grain yield of rice over weedy check .

Weed density and dry weight was found non significant in both the year in all the observational stage in direct line seeded rice. However, slightly low density and dry matter was recorded in 40 kg ha^{-1} seed rates as compared to high seed rate

due to the region rice plant in low seed rate was more competitive with weeds and does not allow the luxurious growth of weeds. Rice plant growth and development in low seed rate was superior as compared to high seed rate in all the stage right from initial to harvest with proper weed management practices, it does not allow the comfortable and vigorous growth of weeds in low seed rate plot.

The maximum weed control efficiency in hand weeding twice might be due to owing to less weed density and production of dry matter by weed in the treated plot. Nevse *et al*. (2010) reported that under the various weed management practices hand weeding twice (20 and 40 DAS) exhibited 95% weed control efficiency in direct seeded rice. Singh and Namdeo (2004) found that hand weeding (20 and 40 days after sowing) showed 72 per cent weed control efficiency. Hussain *et al*. (2008) conducted an experiment to manage the weeds in direct seed rice and concluded that the herbicides nominee gold 100SC (bispyribac sodium) proved as the best herbicides with 90.5 weed control efficiency. Walia *et al.* (2012) reported that integration of post emergence application (30 DAS) of bispyribac (25 and 30 g ha^{-1}) or azimsulfuron (20 g ha^{-1}) with pre-emergence application provided effective control of weeds and produced significantly higher grain yield than unweeded treatment. Sequential application of pre emergence herbicide oxadiargyl, early post emergence as azimsulfuron followed by bispyribac Na was showed maximum weed control efficiency and nearly equal to the two hand weeding due to the region chemical control method was also as effective as manual weeding and produced minimum dry matter of weeds. Weed control efficiency was high in low seed rate as compared to high seed rate difference between high and low seed rate was only 4 per cent in WCE and was found non significant. This may be the region due to less dry matter of weeds in low seed rate.

Weed index indicated that reduction in yield due to weed competition as compare to the maximum attained seed yield. The maximum weed index under untreated control was due to the fact, there was minimum seed yield. Application of pre and post emergence herbicide showed minimum weed index due to region there was maximum grain yield and minimum dry weight due to less density of

weed. Due to the region pre emergence control the initial weeds and post emergence controls the late coming weeds contributes good source and sink relation ultimately converted in high grain as well as straw yield as compared to untreated plot. Weed growth rate and weed index are directly related to the dry matter of weeds. Since, there was minimum dry matter of weeds under sequential application of pre and post emergence of oxadiargyl and bispyribac Na, all the parameters were the minimum and weed control efficiency was the maximum. High weed growth rate was in unweeded conteol plot due to natural growth of weeds in un treated plot. Weed growth rate was low in chemical control plot due to effictivness of herbicides and capicity to control the weed and restrict the growth of weeds in treated plot.

4.7.10 Dehydrogenase activity (µg TPF h^{-1} g^{-1})

Dehydrogenase is thought to be an indicator of overall microbial activity, because it occurs intercellularly in all living microbial cells and is linked with microbial oxydoreduction process Quilchano and Maranon. (2002)**.** Stepniewska and Wolinska (2005) state that specific kind of enzyme which play significant role in the biological oxidation of soil organic matter by transforming protons and electrons from substrates to acceptors. Soil dehydrogenase activity is considered to be a valuable parameter for assessing the side effects of herbicides treatments on the soil microbial biomass.

The dehydrogenase activity (DHA) was measured at 0, 30, 60, and at harvest stages during both the years (Table 4.52). The DHA was influenced significantly due to different weed management practices at 30, 60 DAS and at harvest during both the years. However dehydrogenase activity does not significantly influenced by the seed rate during both the year.

There, was no significant variation in dehydrogenase activity among treatments prior to herbicide application. Whereas it was observed that all the herbicides significantly inhibited the DHA after their application. The result is in agreement with the finding of Sebiomo *et al*. (2011) who observed that the application of herbicides to the soils led to a significant drop in dehydrogenase

activity with respect to untreated control soil samples. It can also be observed that, compared to weedy check and hand weeding twice all the herbicide treatments recorded significantly higher dehydrogenase activity. This might be due to the greater availability of carbon source for the growth and activity of micro-organisms. The result is in close agreement with the findings of Rao *et al*. (2012).

At 30 DAS all the herbicides treatment significantly reduced dehydrogenase activity over hand weeding method and weedy check. The effect of pre and post emergence herbicide on soil microbial activity was observed in this stage. The lowest dehydrogenase activity was observed in (W_4) pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS during both the year. However, dehydrogenase activity was increased in weedy check and hand weeding. Weedy check was found superior over two hand weeding in dehydrogenase activity. In soil at 30 DAS, it might be due to soil manipulation at 20 DAS by hand weeding which will increase the aeration support microbes for better growth.

At 60 DAS the harmful effect of different herbicide treatment narrowed down. In this stage maximum DHA was found in weedy check followed hand weeding. Among herbicide treatment significantly minimum dehydrogenase activity was found in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year. Brzeziñska (2006) observed a significant correlation between the dehydrogenase activity of soil and biomass of soil bacteria. Jezierska-Tys and Frac (2008) reported that dehydrogenase activity was also linked with the total fungal population.

At harvest all the treatment were at par which showed that by reaching to this stage all the herbicides degraded and there residues become non toxic to the microbial activities. This indicated that the different combination of pre emergence and post emergence are safe to ues.

Table 4.52: Dehydrogenase activity (µg TPF h^{-1} g^{-1}) of rhizosphere soil at different growth stages as influenced by weed management and seed rate in direct line seeded rice

Treatment	Dehydrogenase activity (µg TPF h^{-1} g^{-1} soil)											
	0DAS			30 DAS			60 DAS			Harvest		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management												
W_1:- Two hand weeding	31.81	38.07	34.94	51.58	51.93	51.75	77.34	76.78	77.06	34.27	34.46	34.50
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	32.01	38.10	35.06	22.70	24.98	23.84	27.07	29.18	28.12	33.60	33.72	33.66
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	32.39	37.91	35.15	18.18	19.76	18.97	15.04	15.78	15.41	32.92	32.31	32.61
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	31.88	36.45	34.17	15.35	16.86	16.11	20.15	20.69	20.42	33.35	34.72	34.03
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	31.96	38.48	35.22	19.15	21.85	20.50	24.62	26.47	25.54	34.14	34.03	34.08
W_6:- Weedy check	31.65	39.10	35.39	52.49	53.50	53.00	79.69	81.86	80.78	35.30	35.44	35.37
SEm±	0.35	0.69	.37	0.30	0.74	0.34	0.58	0.32	0.29	0.65	0.67	0.68
CD (P = 0.05)	NS	NS	NS	0.94	2.03	1.06	1.82	1.01	0.93	1.95	1.85	2.01
Seed rate (kg ha^{-1})												
S_1 :- 80	31.35	35.70	33.52	29.50	30.74	30.12	41.60	42.83	42.21	33.80	35.15	44.15
S_2 :- 60	31.96	36.13	34.05	29.89	31.41	30.65	41.97	43.32	42.64	34.04	35.37	44.33
S_3 :- 40	32.54	36.23	34.38	30.34	32.29	31.32	42.39	43.23	42.81	34.14	35.51	44.26
SEm±	0.28	0.24	0.25	0.17	0.43	0.18	0.18	0.12	0.09	0.10	0.08	0.02
CD (P = 0.05)	NS	NS	NS	NS	NS	0.72	NS	NS	0.35	NS	NS	0.10
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

44.8 Economics

The data with respect to cost of cultivation, gross return, net return and benefit cost are presented in Table 4.53 and 4.54 .The details about cost of cultivation of rice and treatment cost are presented in appendix X to XVI for 2013 and 2014, respectively.

During the investigation harvesting was done manually. But due to the different government scheme, rapid industrialization, migration of work force from village to urban area and lake of interest in farming, labour has become a major limiting factor in rice production system. Labourers are unavailable at peak time period for weeding and harvesting and it is costly also. So that harvester is the appropriate alternative to harvest the crop in Chhattisgarh. Now a days in every village harvesters are available on rant basis which is less time consuming as well as high monetary value. Therefore, to understand the difference between manual harvesting system and mechanical harvesting hypothetically, additional information is also presented here on economics. By calculating the data on economics involving low seed rate, sowing with machine, chemical method of weed control and harvesting through harvester *"the machine to machine production system"* will give the information about alternative rice production system for the Chhattisgarh. To calculate the cost of cultivation labour rate of MNREGA during 2013 and 2014 and C.G. Government procurement rate of produce are considered to calculate the economics.

The data on economics of direct seeded line sown rice reveals that the maximum cost of cultivation (₹ 30047) was found in hand weeding twice. Among the chemical weed management, it was ranging from ₹ 27653 to 29643 on mean basis. Whereas, difference between costs of cultivation in hand weeding and chemical control method (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS was ₹ 1776. Minimum cost of cultivation was recorded under weedy check. Difference between the manual harvesting and harvesting through combine harvester was ₹ 2233 ha^{-1} on the basis of two year mean. Harvesting through combine harvester offer timely operation for next crop by reducing time of harvesting and other operation.

Data on gross income reveals that the higher gross income (₹86690) was recorded under hand weeding and was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (₹ 85151) and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (₹ 83238) in both the year. However, minimum gross return was recorded under weedy check due to low grain yield as well as high weed infestation. Difference in gross return as compared to manual weeding with (W2) bispyribac-Na @25 g ha^{-1} at 20DAS and (W5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS was ₹ 1539 and ₹ 3452 which was very marginal difference and equivalent to one or two quintal grain yield ha^{-1}, respectively. Gross income was found non significant due to different seed rates.

Net income through manual harvesting was ₹ 62381 in year 2013 and it was ₹ 50906 in 2014 and difference between 2013 and 2014 was ₹11475 which is very significant difference in respect to net return. However, seed yield was high in 2014 as compared to the 2013 but due to price support by government of Chhattisgarh was ₹ 1650 in year 2013 and it was only ₹ 1400 in 2014 affected the net monitoring income in year 2014 in spite of high yield. Difference between net income through hand weeding and chemical control method (W_2 and W_5) was very marginal. On the basis of two year mean maximum net return was observed in (W_3) pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (₹ 56880) and it was at par with two hand weeding (₹ 56643) and (W5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (₹ 53595) . However, in weedy cheek method net income was only ₹ 3170. During the year 2014, net income was found negative which shows that the weed infestation was highly influenced the yield of the plot.

Net income from crop harvested through harvester was found maximum under(W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (₹ 67785) which was nearly equal to two hand weeding (₹ 67992). Difference between manual harvesting and harvesting through harvester was nearly ₹ 10000 higher in mechanical harvesting system. So that we can say that higher net income can be achieved by adopting the *"machine to machine rice production system".*

Among the seed rates cost of cultivation, gross income and net income does not show any critical difference in both the year in both the harvesting system.

Data on B: C. ratio revealed that in 2013 equal B: C ratio (2.2) was found in two hand weeding and (W_3) pre -emergence oxadiargyl 70 g ha-1 *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS.Whearas, in 2014 it was maximum in (1.8) (W_3) pre -emergence oxadiargyl 70 g ha-1 *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and it was negative in weedy check. On the basis of mean maximum B:C ratio was found in W_3 which was nearly equal to the two hand weeding. Higher B : C ratio through chemical control itself explains that combination of low seed rate and weed management through chemical method is the best replacement of hand weeding in direct seeded rice. B : C ratio of harvesting through harvester was higher as compared to the manual harvesting it was maximum (2.6) in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and nearlye equal to the two hand weeding. High monitary income per rupee invested can be achived through harvesting with harvester. The lowest B: C ratio (0.15) was found in un-weeded control treatment, it was negative in year 2014 in both the harvesting situation.Among the seed rate, highest B : C ratio was found in 40 Kg seed rate ha^{-1} followed by the 60 Kg and 120 Kg ha^{-1} seed rate. Difference between the B: C ratio in regards to the manual and harvester harvesting was 0.6 which is big difference in respect to the rice production system.

Hussain *et al*. (2008) revealed that the highest net benefits (₹18725 ha^{-1}) were observed in the plots treated with bispyribac sodium followed by ethoxysulfuron 60 WG (₹13900 ha^{-1}) and hand weeding, respectively. Kiran *et al*. (2010) recorded that the sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 75 g ha^{-1} gave highest net return (₹58,407 ha^{-1}) and benefit: cost ratio (3.06) due to increased grain yield and lesser cost of herbicide.

Table 4.53: Effect of different weed management practices and seed rate on Total Cost (₹ ha^{-1}) Gross Income and Net Income (₹ ha^{-1}) in direct line seeded rice

Treatment	Total Cost (₹ ha^{-1}) Manual Harvesting			Total Cost (₹ ha^{-1}) Through Harvester			Gross Income (₹ ha^{-1})			Net Income through Manual (₹ ha^{-1})			Net Income through Harvester (₹ ha^{-1})		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management															
W_1:- Two hand weeding	29006	31087	30047	27388	28228	27808	91387	81993	86690	62381	50906	56643	82218	53765	67992
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	27125	28182	27653	25507	25323	25415	80668	75931	78299	53543	47749	50646	72130	50608	61369
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	27673	28869	28271	26055	26010	26033	89216	81087	85151	61542	52218	56880	80494	55077	67785
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	28564	29804	29184	26946	26945	26946	85098	77743	81420	56534	47938	52236	76080	50797	63439
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	29248	30038	29643	27630	27179	27405	87479	78998	83238	58231	48959	53595	78233	51818	65026
W_6:- Weedy check	21840	22403	22122	23368	23218	23293	28618	21964	25291	6778	-439	3170	20814	-1254	9780
SEm±							1682	1737		1682	1737		1890	1737	
CD (P = 0.05)							5298	5472		5298	5472		5954	5472	
Seed rate (kg ha^{-1})															
S_1 :- 80	27543	28697	28120	26449	26451	26450	75794	68438	72116	48251	39741	43996	66944	41987	54466
S_2 :- 60	27243	28397	27820	26149	26151	26150	75005	69280	72143	47762	40883	44323	66256	43130	54693
S_3 :- 40	26943	28097	27520	25849	25851	25850	80434	71140	75787	53491	43042	48267	71784	45289	58536
SEm±							2378	1105	877	2378	1105	878	2412	1105	852
CD (P = 0.05)							NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)							NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.54: Effect of different weed management practices and seed rate on B: C ratio in direct line seeded rice

Treatment	B : C (Through Manual)			B : C (Through Harvester)		
	2013	2014	Mean	2013	2014	Mean
Weed management						
W_1:- Two hand weeding	2.2	1.6	1.9	3.0	1.9	2.5
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	2.0	1.7	1.8	2.8	2.0	2.4
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	2.2	1.8	2.0	3.1	2.1	2.6
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	2.0	1.6	1.8	2.8	1.9	2.4
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	2.0	1.6	1.8	2.8	1.9	2.4
W_6:- Weedy check	0.31	-0.02	0.15	0.89	-0.05	0.42
SEm±	0.06	0.06	0.04	0.06	0.07	0.04
CD (P = 0.05)	0.18	0.19	0.12	0.19	0.21	0.13
Seed rate (kg ha^{-1})						
S_1 :- 80	1.7	1.3	1.5	2.5	1.6	2.0
S_2 :- 60	1.7	1.4	1.5	2.5	1.6	2.1
S_3 :- 40	1.9	1.5	1.7	2.7	1.7	2.2
SEm±	0.1	0.1	0.03	0.1	0.1	0.03
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS

4.9 Energetics

Nowadays, energy usage in agricultural activities has been intensified in response to continued growth of human population, tendency for an overall improved standard of living and limited supply of arable land. Consequently, additional use of energy causes problems threatening public health and environment (Rafiee *et al*., 2010). However, increased energy use in order to obtain maximum yields may not bring maximum profits due to increasing production costs. In addition, both the natural resources are rapidly decreasing and the amount of contaminants on the environment is considerably increasing (Esengun *et al.*, 2007). The relation between agriculture and energy is very close. Agricultural sector itself is an energy user and energy supplier in the form of bio-energy (Alam *et al*., 2005). Agriculture is both a producer and consumer of energy. It uses large quantities of locally available noncommercial energy, such as seed, manure and animate energy, as well as commercial energies, directly and indirectly, in the form of diesel, electricity, fertilizer, plant protection, chemical, irrigation water, machinery etc. Efficient use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living (Singh *et al*., 2002).

The energy requirements for direct line seeded rice cultivation under different treatments method using labour, seed, fertilizer, herbicides *etc*. was estimated on the basis of standard energy coefficients (Mittal and Dhawan, 1988). Output energy was estimated with seed and straw yields with standard energy coefficients. Fixed energy inputs and variable energy inputs of seed and weed management are presented in appendix XXII to XXV. The standard energy coefficient for seed and straw of rice was multiplied with their respective yields and summed to obtain energy use efficiency, energy productivity. During the investigation crop was harvested manually but for the presentation and to understand the energy status of combine harvester on rice production system hypothetically calculation was also done if harvester is used to harvest the crop. Data with respect to total input energy MJ, total output energy MJ and output-input energy is presented in Table 4.55 and 4.56

Energy inputs required to the different treatments of weed management and seed rates were estimated. Input energy was highest (12.1 MJ X 10^3) in two hand weeding method followed by chemical treatments (ranging from 11.5 to 11.6 MJ X 10^3). However, the minimum energy required in weedy check method due to less labour required for harvesting and processing the produce(11.1 MJ X 10^3). Weed management through herbicides shows low input energy as compared to hand weeding. The input energy was high in combine harvester due to the use of heavy machine, high consumption of diesel as compared to manual harvesting system (ranging from 12.8 to 12.2 MJ X 10^3).

Maximum output energy was recorded under two hand weeding during both the year. However, it was at par with (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS during both the year whereas, it was also at par with (W_4) pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during 3013. Significantly lowest output energy was recorded under the weedy check. Due to weedy condition yield was very low in weedy check which reflects on output energy. As compared to the two hand weeding output energy was 64 per cent less under un-weeded control condition. This situation clearly indicates that the weeds are the major factor in production system. Energy was consumed by the weed for their growth and development in place of rice plant. During the investigation seed rate does not influence the output energy and almost similar output energy was produced by the 80, 60 and 40 kg ha^{-1} seed rate. However, the maximum output was produced by the 40 kg ha^{-1} seed rate followed by the 60 and 120 kg ha^{-1} seed rate.

The energy input output analysis is usually made to measure the energy efficiency. This analysis will determine how efficient the energy is used. Establishing the functional forms between energy inputs and output for agricultural crops are very useful in terms of determining elasticity of different energy inputs on yield (Turhan *et al*., 2008).To evaluate the performance of production system, output energy to input energy ratio and energy productivity (i.e. yield to input

energy ratio) in crop production systems have been used (Mohammadi *et al*., 2010; Unakitan *et al*., 2010).

Maximum and equal energy output input ratio was observed under two hand weeding and at par with (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS during 2013.Whereas, it was maximum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and was at par with two hand weeding and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS in 2014. However, the minimum output-input energy was produced by weedy check. Output-input ratio was almost 62 per cent less in weedy check as compared to the best treatment (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and 61 per cent less with two hand weeding. Output input energy was almost equal in chemical control and hand weeding, high output-input ratio in chemical control method supports the combination of herbicides and low seed rate may be the alternative of hand weeding method in direct line seeded rice. Energy output-input ratio was less in combine harvester method of harvesting as compared to the manual weeding, difference was only 5.5 to 6.5 per cent between the manual and combine harvester. Difference was not very much in manual and harvester harvesting system, but in harvester timely harvesting of crop provides chance for timely sowing of next crop. Harvester may be the solution of labour crisis during the peak time of harvesting at village. Harvester saves the time of threshing and winnowing and other operation which required more energy in rice production system this energy may be used for the next crop and other activity related to agriculture for high efficiency.

Efficient use of energy resources in agriculture is one of the principal requirements for sustainable agricultural productions. Therefore, energy saving has been a crucial issue for sustainable development in agricultural systems. Development of energy efficient agricultural systems with low input energy is the demand for current agriculture production system. Efficiency is defined as the ability to produce the outputs with a minimum resource level required (Sherman, 1988). In production, efficiency is a normative measure and is defined as the ratio of weighted sum of outputs to inputs or as the actual output to the optimal output

ratio. Efficient use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living (Singh *et al*., 2002).

Significantly , maximum energy use efficiency 9.8 and 107 was recorded under (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during 2013 and 2014 respectivly .However, it was at par with two hand weeding and (W_5) azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS during both the year. However, it was found minimum under weedy check. Difference between hand weeding and chemical control in respect to energy use efficincy was not very vast in respect to produce biological yield (q MJ ha^{-1}) by the per unit input energy which supports chemical control may be the alternative of hand weeding in direct line seeded rice production system.

Efficiency of harvesting through harvester was less as compared to the manual harvesting but the difference was very marginal in both the year. However, harvester reduces the human energy in rice production system and promotes the timely operation. Difference was only 4 to 5 percent between harvester and manual harvesting system which was not very big difference. But combine harvester reduced the human energy and promote timely sowing of next crop by saving the time. Seed rate did not influence the energy use efficiency in both the harvesting system.

Energy productivity is an important indicator for more efficient use of energy although higher energy productivity does not mean in general, more economic feasibility (Mohammadi *et al*., 2010). Energy productivity (kg MJ ha^{-1}) was recorded maximum in (W_3) pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS treatment which was at par with hand weeding and other chemical control method in both the year during the investigation. However, the energy productivity was higher in manual harvesting as compared to the combine harvester. But difference was very marginal ranging from 6 to 8 percent only. Energy productivity was non significant with respect to seed rate. This result supports the “machine to machine rice production system” in direct line seeded rice by adopting low seed rate with chemical control method.

Table 4.55: Effect of different weed management practices and seed rate on total in put energy, total output energy and energy output-input ratio in direct line seeded rice

Treatment	Total input energy ha^{-1} (MJ X10^3) 2013 & 2014	Total input energy ha^{-1} (MJ X10^3) 2013 & 2014	Total output energy ha^{-1} (MJ X10^3)			Energy Output - input ratio Manual			Energy Output - input ratio Harvester		
	Manual	Harvester	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management											
W_1:- Two hand weeding	12.1	12.8	154.4	164.9	159.6	12.8	13.7	13.2	12.1	12.9	12.5
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	11.5	12.2	138.5	150.9	144.7	12.1	13.1	12.6	11.4	12.4	11.9
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	11.5	12.2	151.5	165.1	158.3	13.2	14.3	13.8	12.4	13.5	12.9
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	11.6	12.3	147.2	155.8	151.5	12.7	13.4	13.1	12.0	12.7	12.3
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	11.5	12.2	147.2	159.7	153.5	12.8	13.9	13.3	12.1	13.1	12.6
W_6:- Weedy check	11.1	12.2	59.0	53.7	56.4	5.3	4.8	5.1	4.8	4.4	4.6
SEm±			3.6	2.5		0.3	0.2		0.3	0.2	
CD (P = 0.05)			11.2	7.9		1.0	0.7		0.9	0.6	
Seed rate (kg ha^{-1})											
S_1 :- 80	11.8	12.6	131.0	139.4	131.0	11.0	11.7	11.4	10.4	11.0	10.7
S_2 :- 60	11.5	12.3	132.2	140.7	132.2	11.4	12.1	11.8	10.7	11.4	11.1
S_3 :- 40	11.3	12.0	135.8	144.9	135.8	12.0	12.8	12.4	11.3	12.0	11.7
SEm±			3.8	2.8	1.4	0.3	0.2	0.1	0.3	0.2	0.1
CD (P = 0.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)			NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.56: Effect of different weed management practices and seed rate on energy use efficiency and energy productivity in direct line seeded rice

Treatment	Energy Use Efficiency (q MJ X10^{3})						Energy Productivity (kg MJ ha^{-1})					
	Manual			Harvester			Manual			Harvester		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Weed management												
W_1:- Two hand weeding	9.5	10.2	9.8	9.0	9.6	9.5	0.43	0.45	0.44	0.40	0.42	.41
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	9.0	9.8	9.4	8.4	9.2	9.0	0.40	0.43	0.41	0.37	0.41	.39
W_3:-PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	9.8	10.7	10.2	9.2	10.0	9.8	0.44	0.46	0.45	0.41	0.43	.42
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	9.4	10.0	9.7	8.9	9.4	9.4	0.41	0.44	0.43	0.39	0.41	.40
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20 g ha^{-1} at 15 and 35 DAS	9.5	10.3	9.9	8.9	9.7	9.5	0.43	0.45	0.44	0.40	0.42	.41
W_6:- Weedy check	4.0	3.7	3.8	3.7	3.3	4.0	0.14	0.12	0.13	0.13	0.11	.12
SEm±	0.24	0.2	0.17	0.2	0.2	0.16	0.01	0.01	0.01	0.01	0.01	0.01
CD (P = 0.05)	0.75	0.5	0.53	0.7	0.5	0.50	0.03	0.03	0.02	0.02	0.03	0.02
Seed rate (kg ha^{-1})												
S_1 :- 80	8.2	8.7	8.4	7.7	8.2	8.2	0.36	0.38	0.37	0.34	0.35	.35
S_2 :- 60	8.5	9.0	8.7	8.0	8.5	8.5	0.36	0.39	0.38	0.34	0.37	.36
S_3 :- 40	8.9	9.5	9.2	8.4	8.9	8.9	0.40	0.41	0.41	0.38	0.39	.39
SEm±	0.24	0.2	0.09	0.2	0.2	0.09	0.01	0.01	0.1	0.01	0.01	0.01
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (WM X SR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Chapter – V
SUMMARY AND CONCLUSIONS

Rice is the most important staple food crop of millions of mankind from dawn of civilization. Among the cereal crops, it serves as the principal source of nourishment for over half of the global population. In Indian agriculture, rice is the main source of livelihood for more than 150 million rural households. In world, rice is the second most widely consumed cereal next to wheat. Chhattisgarh state is popularly known as "Rice bowl" because of maximum area covered during *kharif* under rice contributing major share in national rice production. However, the production and productivity of rice per unit area is very low.

Rice growing ecologies are divided into rainfed uplands, rainfed low land and irrigated land. In Chhattisgarh, rice is grown by different sowing methods broadcast *biasi*, line sowing, *Lehi* and transplanting depending upon the type of soil, topography of the land, availability of water and labour. The predominant method of rice cultivation in Chhattisgarh is broadcast *beushening* (*biasi*). However, these methods have their own limitations. In direct seeded rice, the optimum seed rate is an important factor that affects crop micro-environment by influencing the degree of inter-plant competition. Therefore, while fixing seed rates for direct-seeded crop, the plants should be planted neither too thick nor too thin, so that the input-use efficiency may be enhanced to the maximum possible extent. Secondly, weeds play the vital role in reducing the crop yield and thereby resulting in high economic losses to farmers. It is therefore imperative to manage weeds from early crop growth period, so that the crop can make efficient utilization of applied and native inputs. *Beushening* is a traditional cultural practice of cross-ploughing the dry-seeded broadcast standing crop after 25-35 days, followed by seedling redistribution done during *Chalai* operation. Hand weeding is a common practice in most of the areas. Now a day, due to the scarcity of the labourers and higher rate of wages, use of herbicide is becoming more popular. On the other hand, use of single herbicide alone does not serve the purpose and one

hand weeding or mechanical weeding is essential for better weed management. To avoid hand weeding, sequential application of pre-emergence followed by post emergence herbicides will help in reducing the infestation of weeds throughout the growth period of direct seeded rice. Keeping, this view in mind the present experiment entitled **"Studies on broadcast and direct line seeded rice (*Oryza sativa* L.) under different seed rate and weed management practices for alternatives of beushening (*biasi)* operation"** was conducted during *kharif* 2013 and 2014 at instructional cum research farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The soil of the experimental field was *inceptisols* known as matasi. The soil was neutral in reaction, low in organic carbon, low in nitrogen, medium in phosphorus and high in potash contents. The climate of Raipur region is sub humid with hot and dry summer and mild winter. It comes under the Chhattisgarh plains agroclimatic sub zone of seventh agro-climatic region of India *i.e.*easteren plateau and hills.The average annual rainfall is about 1326 mm of which about 85 % is received during a span of four months, *i.e.* between June to September. The rainfall is largely contributed by south-west monsoon. The rainfall received during the cropping season of *Kharif* 2013 and 2014 was 1574 mm and 1029 mm, respectively which was sufficient for the growth and development of rice plant. The mean maximum temperature ranged from 25.7 ^{0}C to 21.4 ^{0}C and 27 ^{0}C to 17.6 ^{0}C and sun shine hours ranged from 8.6 to 0.7 and 8.3 to 0.5 per day during 2013 and 2014, respectively. Relative humidity throughout the crop season varied between 80 to 95 per cent at morning and 44 to 80 per cent in evening hours in both the years. This indicated clearly, that all the weather parameters i.e. relative humidity, sunshine hours, maximum and minimum temperatures and rainfall were normal and favorable for healthy growth of rice throughout the growing season during 2013 and 2014.

Two different experiments, on broadcast direct seeded rice, and direct line seeded rice were undertaken during two consecutive *kharif* season of 2013 and 2014. In both the experiments field was divided into six vertical strips and three horizontal strips. In vertical strips weed management and in horizontal strips seed rate were allocated. First experiment was, on broadcast direct seeded rice, the treatment comprised of six weed managements *i.e. Biasi* method (Farmer's

practice) (W_1) , two hand weeding at 20 & 40 DAS (W_2), pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3), pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS(W_4), pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS(W_5), weedy check (W_6) in vertical strips; and three seed rates ranging from *viz.*, 120 (S_1), 80 (S_2), and 40 (S_3), kg ha^{-1} in horizontal strips. Second experiment was on direct line seeded rice the treatment comprised of six weed managements *i.e.* two hand weeding at 20 and 40 DAS (W_1), bispyribac-Na @ 25 g ha^{-1} at 20DAS (W_2) , pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3) , pre-emergence (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS(W_4) and azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (W_5) in vertical strips; and three seed rates *viz.,* 80 (S_1), 60 (S_2), and 40 (S_3), kg ha^{-1} in horizontal strips.

Rice variety MTU 1010 was taken as test crop. Sowing was done after the monsoon under wet condition with the fertilizer application of 100, 60 and 40 kg N, P_2O_5 and K_2O ha^{-1}. The recommended package and practices except treatment was followed and treatments were imposed as per the plan. The observation on growth, yield attributes, weed, soil microflora, economics and energetic was recorded and computed and analyzed statistically. It is apparent, that rice crop responded with the weed management practices and seed rates. The salient findings of the present investigation are summarized below

Experiment No I: Studies on **broadcast rice** (*Oryza sativa* L.*)* under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation

- Significantly highest plant population was recorded under 120 kg ha^{-1}, while minimum number of plants (132 plants m^{-2}) was recorded in the 40 kg ha^{-1} seed rate.The population under 120 kg ha^{-1} was 137 % higher than 32 kg ha^{-1} and 25 % higher than 80 kg ha^{-1} seed rate.
- Different seed rate did not exhibit significant impact on the plant height. At early stage, plant height was found non significant. Whereas, significantly taller plants were recorded under *biasi* method at harvest. Among the hand

weeding and herbicide treatments, no significant difference in plant height was recorded.

- Dry matter plant^{-1} was significantly influenced by the different weed management practices except at early growth stage. At 15 DAS, dry matter was non significant. After that, significantly higher dry matter was produced under *biasi* method as compared to weedy check, but it was at par with two hand weeding and sequential application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the years. Among different seed rates dry matter accumulation was found non significant. Combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with *biasi* method produced maximum dry matter at harvest. Crop growth rate under *biasi* method was maximum in 45 to 60 days period. The lowest CGR was recorded under the unweeded control throughout the crop growth period. Among the different seeding rate, higher CGR was observed in (S_3) 40 kg ha^{-1}seed rate. Relative growth rate progressed up to the 30 days and after that declined slightly up to the 45 days but 45 after DAS onward, the decline in growth was very fast. Among the weed management practices, higher relative growth rate was observed with hand weeding during the 15-30 days period in both the year. Among the seeding rate, higher relative growth rate was observed with seed rate of 40 kg ha^{-1}.

- Different seed rates do not influence the total tillers, effective tillers, filled grains panicle^{-1} length of panicle and panicle weight and was found non significant during both years during all the observational period. However all above yield attributing parameters are maximum under 40 kg ha^{-1} seed rate and diference was non significant with other seed rates. Maximum number of total tillers, effective tillers, filled grains panicle^{-1} length of panicle and panicle weight was produced by the *biasi* method during both the year whereas, it was at par with two hand weeding at 20 and 40 DAS and sequential application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Whereas, the lowest numbers of yield attributes were recorded in weedy check. The combination of 40 kg seed rate with *biasi* method produced higher numbers of filled grain $^{-1}$ and effective tillers. Among the weed management

practices, test weight was highest in *biasi* method in both the year but it was similar and statistically at par with the hand weeding twice and chemical control of weeds.

- Significantly higher number of un-filled grains panicle^{-1} and sterility per cent was recorded in weedy check. Whereas, it was minimum under *biasi* operation during both the years. Among the seed rate highest number of un-filled grains and sterility was recorded under high seed rate 120 kg ha^{-1} as compared to the low seed rate.
- Among different weed management practices, *biasi* method proved significantly superior with respect to seed yield, straw yield and harvest index over other weed management practices but at par with the two hand weeding twice and application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS during both the years. Seed yield was slightly higher in the year 2014 might be due to favorable climatic conditions as compared to the year 2013. The minimum seed yield straw yield and harvest index was recorded under weedy check. There is no remarkable yield difference between the high seed rate and low seed rate. However, seed yield was highest in 40 kg ha^{-1} seed rate followed by the 80 kg ha^{-1} and 120 kg ha^{-1} seed rate respectively.
- Root volume and root dry weight was significantly affected by the weed management practices and seed rate at 50 and 70 DAS in direct seeded broadcast rice during both the years. At 50 DAS, root volume and root dry weight was higher under *biasi* method due to manipulated soil environment followed by hand weeding and chemical control method. After that at 70 DAS, it was higher under *biasi* method and was at par with hand weeding twice and application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3) during both the years. Whereas, among different seed rates 40 kg seed rate ha^{-1} produced significantly super root volume and root dry weighr due to the reason that optimum population provide better environment for the root growth over higher seed rate of 120 and 80 kg ha^{-1}
- The predominant weed species observed in the experimental field were *Echinochloa colona, Alternanthera triandra, Cyperus iria* and *Cynotis*

axillaris. At harvest, the major weed species, which infested in untreated control, were *Alternanthera triandra* (34 %), other weeds (23 %), *Cyanotis axillaris* (17 %), *Cyperus iria* (14 %) and minimum was *Echinochloa colona* (12 %) .

- Minimum density of total weeds at 15 and 30 DAS was recorded under sequential application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. At 45 DAS, significantly lowest weed density of total weeds was observed under the treatment of two hand weeding at 20 and 40 DAS. At 60 DAS, the minimum weed density was found under the *biasi* treatment which was at par with the hand weeding twice and sequential application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Among different seed rates non significant effect was found in total weed population but, slightly lower weed density recorded under 120 kg ha^{-1} seed rate.

- Minimum density of *Echinochloa colona, Alternanthra triandra, Cyperus iria* and *Cyanotis axillaris* was recorded under the sequential application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and was at par and produdced nearly equal density with pre-emergence application of (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS during 15 and 30 DAS. At 45 DAS, the lowest weed density of *Echinochloa colona* was observed under the *biasi* treatment which was at par with hand weeding twice. Result like 45 DAS was found at 60 DAS and at harvest. In *biasi* method minimum weed density was recorded followed by hand weeding and chemical control methods. Maximum density of *Echinochloa colona, Alternenthera triandra, Cyperus iria* and *Cyanotis axillaris* was recorded under the weedy check during all the observational stage and both the years. However, minimum weed density was recorded under 120 kg ha^{-1} seed rate at harvest and was non significant among other seed rates. Minimum number of *Echinochloa colona* was recorded in combination of (S_2 x W_2) 80 kg seed rate ha^{-1} with hand twice. Whereas, significantly minimum density of *Alternenthra triandra* was recorded in the combination of (S_1 x W_1) 120 kg seed rate ha^{-1}

with *bias*i operation. Density of *Cyperus iria* at 30 DAS was minimum under the combination of (S_1 x W_2) 120 kg seed rate ha^{-1} with two hand weeding during both the years.

- At 15 and 30 DAS, higher weed density of other weeds was observed under the *biasi* method, hand twice weeding and weedy check due to no weed management during this period. However, significantly lower number of other weed species was found under the sequential application of pre -emergence oxadiargyl 70 g ha^{-1}*fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS treatment which was at par with pre-emergence application of (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS at early stage. After that, at 60 DAS, and at harvest significantly lower number of other weed *spp*. was recorded in *biasi* method which was at par with two hand weeding and other chemical weed control treatments. Seed rate was found non significant at all the observational stage during both the years. However, the minimum weeds were recorded under 120 kg ha^{-1} seed rate which were nearly equal to 80 kg ha^{-1} and 40 kg ha^{-1} seed rates. At harvest, minimum densities of other weeds were recorded under the combination of 120 kg seed rate ha^{-1} with *biasi* operation (S_1x W_1) during both the year.

- Dry weight of total weeds at 15 DAS was found lowest under sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in year 2013.Whereas, it was lowest under sequential application of pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS during 2014. At 30 DAS, minimum dry weight of total weed was recorded under application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with the hand weeding twice. At 45 DAS, significantly lower weed dry weight was recorded under *biasi* method which was at par with hand weeding twice. Similar result like 45 DAS was recorded during 60 DAS and harvest. Among different seed rates there was non significant effect on dry weight at all the crop growth stage in both the years.

- Maximum dry weight of *Echinochloa colona, Alternanthera triandra, Cyperus iria* and *Cyanotis axillaris* was recorded under weedy check method in all the

observational stage during both the years. However, application of pre-emergence herbicides oxadiargyl and pyrazosulfuron controls the *Echinochloa colona Alternanthera triandra, Cyperus iria* and *Cyanotis axillaris* effectively at early crop growth stage at 15 and 30 DAS. During 45, 60 DAS and at harvest, minimum dry weight production of *Echinochloa colona* was recorded under *biasi* method, but it was at par with hand weeding twice. During 45 DAS, two hand weeding at 20 and 40 DAS produced lowest weed dry weight of *Alternanthera triandra*, but it was found at par with *biasi* method. During 30 and 45 DAS, significantly low dry matter of *Cyanotis axillaris* was recorded under two hand weeding at 20 and 40 DAS in year 2013. However, it was minimum in sequential application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in year 2014. At 60 DAS and at harvest, the lowest weed dry weight of *Alternanthera triandra Cyperus iria* and *Cyanotis axillaris* was observed under the *biasi* method but, it was at par with two hand weeding in both the years and nearly eual to application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Among different seeding rates at both the year and different growth stages there was no remarkable difference between the high seed rate and low seed rate in respect to dry weight of *Echinochloa colona Alternanthera triandra, Cyperus iria* and *Cyanotis axillaris.* However, minimum weed dry matter was produced under 120 kg ha^{-1} which was significantly at par with rest of seed rates. At harvest, significantly minimum dry weight o*f Alternenthra triandra* was recorded in the combination of (S_1 x W_1) 120 kg seed rate ha^{-1} with *biasi* method. Whereas, minimum dry weight of *Cyperus iria* was recorded under the combination of (S_2 x W_3) 80 kg seed rate ha^{-1} with application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS dring both the years.

- At 15 and 30 DAS, significantly lower dry weight of other weeds was obtained under the sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was at par with pre-emergence application of (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and pre-emergence application of (pretilachlor + bensulfuron) 660 g

ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year. At 60 DAS and at harvest minimum dry weights of other weeds were recorded in *biasi* method followed by hand weeding and chemical control method. Among different seed rates, the dry matter production of other weed species was equal and found non significant. At harvest minimum dry weight of other weeds were recorded under the combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with *biasi* method.

- Weed control efficiency at 15 and 30 DAS, was recorded maximum under sequential application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS. Whereas, it was maximum in *biasi* method during 45, 60 DAS. The WCE was 91.06 per cent in *biasi* method and 90.20 per cent in hand weeding and 85.95 per cent in the sequential application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Sequential application of oxadiargyl and bispyribac Na gave same WCE as *biasi* method and hand weeding. Among different seeding rates weed control efficiency was at par throughout the crop growth period in both the year. Whereas, the maximum weed control efficiency was recorded under 120 kg ha^{-1} seed rate at 60 DAS and at harvesting.

- Maximum weed index was recorded under un-weeded control plot ((loss of yield as compared to *biasi* method) and minimum weed index was recorded under hand weeding twice in both the year. Among the hand weeding and sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1}at 25 DAS weed index was 2.67 and 4.36 on the mean basis of two years. This shows that the application of pre emergence along with post emergence may be the alternative of hand weeding twice and biasi method. Among different seeding rates, minimum weed index was recorded under 40 kg ha^{-1} followed by 80 kg ha^{-1} and maximum index was in 120 kg ha^{-1} seed rate.

- At 15, 30 and 45 DAS, maximum relative weeds density was noticed by *Echinochloa colona* among all the species. Later on during 60 DAS relative weed density of other weeds were highest among the different weed species. At

harvest maximum relative weed density was recorded by other weeds followed by *Alternanthra triandra, Cyperus iria, Cyanotis axilliaris* and *Echinochloa colona* in descending order.

- At 15 and 30 DAS, RWD of *Alternanthra triandra* and *Cynotis axilliaris* was found minimum under sequential application of pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. The maximum relative weed density of *Echinochloa colona* was recorded under the two hand weeding during harvest. RWD at 30 DAS of *Cyperus iria* and *Cynotis axillaris* was found maximum under sequential application of pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. RWD of other weed species was found minimum under *biasi* method. The maximum relative weed density of other weed species was recorded under the 40 kg ha^{-1} seed rate.

- At 45 DAS, RWD of *Echinochloa colona Alternandra triandra* and *Cyperus iria* was maximum in weedy check. Whereas, RWD of *Cyanotis axillaris* was maximum in sequential application of pre-emergence (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS. *Cyanotis axilliaris* was recorded maximum under sequential application of pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during this stage.

- During 60 DAS, relative density of *Echinochloa colona* was maximum in weedy check. Wheras, RWD of *Alternanthera triandra* was found minimum in two hand weeding. Relative density of *Cyperus iria* was recorded maximum under *biasi* method and it was minimum in weedy check. Relative weed density of *Cyanotis axilliaris* was recorded maximum under weedy check and it was minimum in sequential application of pre-emergence (sand mix) pyrazosulfuron 20 g h^{a-1} *fb* bispyribac Na 20g h^{a-1} at 25 DAS**.**

- At harvest the maximum relative density of *Echinochloa colona* was recorded under weedy checks and it was minimum in *biasi* method. RWD of *Alternanthera triandra* was recorded maximum in sequential application of pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20

g ha^{-1} at 25 DAS. RWD was maximum under *biasi* method. Relative density of *Cyanotis axillaris* at harvest was recorded maximum under weedy check whereas, it was minimum in application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. However, among the seed rates relative density was maximum in (S_3) 40 kg ha^{-1} and minimum in (S_2) 80 kg ha^{-1} seed rate at harvest.

- Weed growth was maximum in weedy check in all the observational stages in weed management practices. At 15 to 30 DAS the lowest weed growth rate (WGR) was observed under hand weeding. During 30 to 45 DAS growth rate of weeds were maximum and it was low in *biasi* method due to *biasi* operation during this period and next was two hand weeding. Declined weed growth was observed during 45 to 60 DAS and it was minimum in *biasi* method followed by sequential application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Among seed rate, weed growth shows similar trends in seed rate ranging from 120 to 40 kg ha^{-1} .

- Soil dehydrogenase activity was influenced significantly due to different weed management practices. However, dehydrogenase activity was not significantly influenced by the seed rate during both the years. There was no significant variation in dehydrogenase activity among treatments prior to herbicide application. At 30 DAS, all the herbicides treatments significantly reduced dehydrogenase activity over *biasi* method, hand weeding and weedy check. The effect of pre and post emergence herbicide on soil microbial activity was observed in this stage. The lowest dehydrogenase activity was observed in pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. At 60 DAS the harmful effect of different herbicide treatment narrowed down. At harvest all the treatment were at par which showed that after reaching to this stage all the herbicides were degraded and there residues become non toxic to the microbial activities.

- Maximum cost of cultivation (₹ 32412) was found in hand weeding twice followed by *biasi* method (₹ 30912). Among the chemical weed management, it was ranging from ₹ 27070 to 27196 on mean basis. However, comparison

between costs of cultivation in chemical control method with *biasi* method, the difference was approximately ₹ 3600 ha^{-1} higher in *biasi* system.

- Higher gross income (₹ 92252) and net income (₹ 61341) was found in *biasi* method which was at par with hand weeding and chemical control method sequential application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS respectively. The minimum gross income and net income was found under the weedy checks. Difference between chemical control and *biasi* method was ₹ 306 only in respect to net income. Comparison between the manual harvesting and harvesting through harvester, difference in respect to net income was ₹ 2238 ha higher in harvesting through harvester.

- Data on B: C. ratio revealed that the maximum B:C ratio, income from per rupee invested was in the treatment sequential application of oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS followed by pre-emergence application of (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS and *biasi* method in both the year as well as in both the harvesting system. Among the seed rate, highest B : C ratio was found in 40 Kg seed rate ha^{-1} followed by the 80 Kg and 120 Kg ha^{-1} seed rate.

- Maximum output energy was recorded under the *biasi* method. Although, minimum output energy was recorded under the weedy check. During the investigation seed rate does not influence the output energy and almost similar output energy was produced by the 120, 80 and 40 kg ha^{-1} seed rate. Maximum energy output input ratio was observed in *biasi* method in 2013 and during 2014 it was maximum in pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g h^{a-1}at 25 DAS (13.5). Energy output-input ratio was less in combine harvester method of harvesting as compared to the manual weeding, difference was only 5.5 to 6.5 per cent between the manual and combine harvester**.**

- The maximum energy use efficiency was recorded in *biasi* system in 2013, however, it was maximum in pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS during the 2014. All other weed management practices produced almost equal efficiency except the weedy check method which produced the minimum efficiency in both the year. Efficiency of

harvesting through harvester was less as compared to the manual harvesting but the difference was very marginal in both the years. Energy productivity was recorded maximum in application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS treatment which was at par with *biasi* method and hand weeding and other chemical control method in both the year during the investigation. However, the energy productivity was higher in combine harvester as compared to the manual harvesting.

Experiment II: Studies on **direct line seeded rice** (*Oryza sativa* L.) under different seed rate and weed management practices for alternatives of beushening (*biasi*) operation

- Significantly higher plant population was recorded under 80 Kg ha^{-1} , while minimum number of plants was recorded in the 40 kg ha^{-1} seed rate.The population under 80 kg ha^{-1} was 90 % higher than 40 Kg ha^{-1} and 44 % higher than 60 Kg ha^{-1} seed rate. Different seed rate did not exhibit significant impact on the plant height. At early stage, plant height was found non significant. Whereas, At 30 DAS significantly taller plant recorded under the application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. After that tallest plant was recorded under the two hand weeding which was at par with sequential application of pre and post emergence herbicides.

- Dry matter $plant^{-1}$ was significantly influenced by the different weed management practices except at early growth stage. At 15 DAS, dry matter was found non significant. After that, significantly higher dry matter was produced under two hand weeding at 20 and 40 DAS. Among different seed rates dry matter accumulation was found non significant. maximum dry matter was produced under the combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with two hand twice during both the years. The lowest CGR was recorded under the unweeded control throughout the crop growth period. Crop growth rate was influenced significantly due to different weed management practices during 15-30, 30-45 and 45-60 DAS in both the years of investigation but after that from 60-harvest the crop growth did not differ significantly with weed management practices. Among the different seeding rate, higher CGR was observed in 40 kg

ha^{-1}seed rate. Relative growth rate progressed up to 30 days and after that declined slightly up to 45 days after, 45 DAS onward the decline in growth was very fast. Among the weed management practices, higher relative growth rate was observed with hand weeding during the 15-30 days period during both the years. After that, it was maximum in application of pre and post emergence herbicides. Whereas, during 60-harvest it was non significant. Among the seed rates, higher relative growth rate was observed with of 40 kg ha^{-1} seed rate.

- Seed rates does not influence the total tillers, effective tillers, filled grains $panicle^{-1}$ length of panicle and panicle weight and was found non significant during both years during all the observational period. However above yield attributing parameters was maximum under 40 kg ha^{-1} seed rate and diference was found non significant with other seed rates. Maximum number of total tillers, effective tillers, filled grains $panicle^{-1}$ length of panicle and panicle weight was produced by the hand weeding twice at 20 and 40 DAS and was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25. Whereas, the lowest number of yield attributes was recorded under weedy check. Maximum number of total tillers and effective tillers was found in the combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with two hand weeding at 20 and 40 DAS during both the years. Among the weed management practices, test weight was highest in hand weeding in both the year but it was similar and statistically at par with chemical control method.

- Significantly higher number of un-filled grains $panicle^{-1}$ and sterility per cent was recorded in weedy check. Whereas, it was minimum under hand weeding twice. Among the seed rate highest number of un-filled grains and sterility was recorded under high seed rate 80 kg ha^{-1}.
- Among different weed management practices, hand weeding twice proved significantly superior seed yield, straw yield and harvest index over other weed management practices but at par with sequeantial apliication of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and apllication of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Seed yield

was slightly higher in 2014 might be due to favorable climatic conditions as compared to 2013. The minimum seed yield, straw yield and harvest index was recorded under weedy check. There is no remarkable yield difference between the high seed rate and low seed rate. However, seed yield was highest under 40 kg ha^{-1} seed rate followed by the 60 kg ha^{-1} and 80 kg ha^{-1} seed rate respectively.

- Root volume and root dry weight was significantly affected by the weed management practices and seed rate at 50 and 70 DAS in direct line seded rice during both the years. At 50 DAS, root volume and root dry weight was higher under hand weeding twice. After that at 70 DAS, it was higher under hand two hand weeding at 20 and 40 DAS and was at parwith application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (W_3) and appilication of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (W_5) during both the years. Whereas, among different seed rates 40 kg seed rate ha^{-1} produced significantly super root volume and root dry weighr due to reason optimum plant population and weed management provide better environment for the root growth over higher seed rate 80 and 60 kg ha^{-1}.
- The predominant weed species observed in the experimental field were *Echinochloa colona, Alternanthra triandra, Cyperus iria* and *Cyanotis axillaris* At harvest, the major weed species, which infested in untreated control, were *Cyanotis axillaris* (31%), *Alternanthra triandra* (27%), other weeds (24%), *Cyperus iria* (11%) and minimum was *Echinochloa colona* (7%), respectively.
- Application of pre-emergence herbicides oxadiargyl 70 g ha^{-1} and pretilachlor + bensulfuron 660 g ha^{-1} controls the total weed density at early stage. At 30 and 60 DAS, significantly lowest weed density was recorded under two hand weeding was at par and nearly equal with other chemical control methods. At 60 DAS and harvest, significantly minimum total weed density was recorded under hand weeding twice and was at par with squential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Whereas, maximum weed density was observed under un-weeded control plot throughout crop growth period. Among different seed rates at early stage, minimum density of total weeds was recorded under 80 kg seed rate ha^{-1} which

was found non significant different with other seed rates. Aftre that, at 60 DAS and harvest, total weed density was recorded under 40 kg ha^{-1} seed rate and it was non significant with other seed rates.

- Density of *Echinochloa colona, Alternenthra triandra, Cyperus iria* and *Cyanotis axillari* significantly influenced by weed management practices. At 15DAS, significantly minimum weed density of was recorded under the sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and at par with pre-emergence application of pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Whereas, at 30 DAS lowest weed density of above weed*s* was found under manual weeding twice and it was equal to other chemical weed control method. After that at 45,60 DAS and harvest, minimum density of weeds was recorded under hand weeding twice and was at par and comparable with sequantial application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Among different seeding rates at 15, 30 and 45 DAS slightly lower density of weeds under 80 kg^{-1}. But after that, it was minimum under 40 kg ha^{-1} seed and was non significant among different seed rates. Significantly minimum number of *Echinochloa colona* was recorded under the combination of (S_3 x W_1) 40 kg seed rate ha^{-1} with hand weeding twice at harvest. Density of *Alternenthra triandra* was minimum under the combination of (S_3 x W_3) 40 kg seed rate ha^{-1} with the application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year. Whereas, minimum density of *Cynotis axillaris* was recorded under the combination of (S_3 x W_3) 40 kg seed rate ha^{-1} with the application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS during both the year.
- At 30 and 45 DAS, significantly minimum weed density of other weeds was recorded under hand weeding twice and was at par with application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Difference between, manual and chemical control was very marginal showed that herbicides are as effective as hand weeding twice. Among the seed

rates minimum weeds were found in the 40 kg ha^{-1} seed rat which was non significant at all the stages during both the years.

- Weed management practices provided significant effect on total dry matter accumulation of weeds. At 15 DAS, significantly lowest weed dry weight was recorded under the application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. At 30 DAS it was lowest in two hand weeding. Whereas, At 45, 60 DAS and harvest, minimum total dry weight of weeds was recorded under two hand weeding and was at par with sequantial application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. However, maximum dry weight of weed was recorded in weedy check.
- Dry weight of *Echinochloa colona, Alternenthra triandra, Cyperus iria* and *Cyanotis axillari* significantly influenced by weed management practices. Application of pre-emergence herbicides oxadiargyl and combination of pretilachlor + bensulfuron controled the above weeds effectively at early stage. At 30 DAS, significantly lower weed dry weight was observed in hand weeding twice which was nearly equal to all other chemical weed management practices. At 45 DAS minimum weed dry weight was recorded under manual weeding and was at par with application of pre-emergence oxadiargyl followed by bispyribac Na and application of early post as azimsulfuron followed by bispyribac Na.Whereas, at 60 DAS and at harvest, similar trend was recorded. Among different seed rate, at 15,30 and 45 DAS, minimum weed dry matter was recorded under 80 kg ha^{-1} after that during 60 and harvest it was minimum in 40 kg ha^{-1} seed rate and was found non significant among at all the seed rates during both the years.
- Significantly lowest dry matter of other weed was recorded under sequential application of oxadiargyl and combination of pretilachlor + bensulfuron during early crop growth period. After that, at 45 DAS, lowest dry weight of other weeds was recorded under application of pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. At 60 DAS and at harvest, significantly lower dry matter of other weed was recorded under

hand weeding twice and was at par with application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Among different seed rates, in respect to dry matter production of other weed, it was found non significant among high seed rates and low seed rates.

- Weed control efficiency at 15 DAS was recorded maximum under apllication of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS in 2013 which was at par with apllication of pre-emergence (pretilachlor + bensulfuron) 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Result prove that the, applications of pre-emergence herbicides oxadiargyl 70 g ha^{-1} and pretilachlor + bensulfuron @ 660 g ha^{-1} effectively control the weeds and provide better growth condition to the rice crop. Whereas, among different seeding rates, maximum weed controled efficiency was recorded under the 80 kg ha^{-1} seed rate which was statistically equal to 60 kg ha^{-1} and 40 kg ha^{-1}.
- At harvest Weed control efficiency was recorded maximum under two hand weeding at 20 and 40 DAS which was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Sequential application of oxadiargyl, azimsulfuron and bispyribac Na presented same WCE as two hand weeding, difference between hand weeding and chemical control was less than 2 per cent. Among different seeding rates, weed control efficiency was at par throughout the crop growth period.
- Maximum weed index was recorded under un-weeded control plot (73.34). However, minimum weed index was recorded under application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (1.90 %) followed by application of azimsulfuron 35 g ha-1 *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (3.99 %). Loss of yield as compared to hand weeding was very marginal so that chemical control might be the better option for the farmers.
- Maximum relative weed densit**y** at early stage was noticed by *Echinochloa colona* among all the weed species. Whereas, during 30 DAS it was maximum in *Cyanotis axilliaris* and *Alternanthra triandra*. Later on during 60 DAS

relative weed density was found maximum under other weeds species. At harvest minimum relative weed density was recorded under *Echinochloa colona* among all the weed *spp***.**

- Relative weed density at 15 DAS, minimum relative weed density of *Echinochloa colona* was recorded under application of pre -emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, whereas, RWD of *Alternanthra triandra* was found minimum under application of pre-emergence pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} .RWD of *Cynotis axilliaris* was minimum in hand weeding. Whereas, seed rate did not show any critical difference in RWD of *Cynotis axilliaris.* Relative weed density of *Cyperus iria* was recorded minimum under weedy check at 15 DAS.
- Relative weed density at 30 DAS, maximum relative weed density of *Echinochloa colona* was recorded under weedy check. Among different weed management practices, RWD of *Alternanthra triandra* was recorded nearly equal relative density among all the weed management practices. At 30 DAS RWD of *Cyperus iria* and *Cynotis axilliaris* was found minimum in weedy check. RWD of other weed species was found minimum under aplication of pre-emergence apllication of pretilachlor + bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1}.
- At 45 DAS, relative weed density at *Echinochloa colona* and *Cynotis axilliaris* was found maximum under weedy check whereas, it was minimum in application of pre-emergence oxadiargyl *fb* bispyribac Na. RWD of *Alternandra triandra* was recorded minimum under apllication of pre-emergence pretilachlor+bensulfuron *fb* bispyribac Na. RWD of *Cyperus iria* was found minimum under weedy check method.
- Later on during 60 DAS relative density of *Echinochloa colona* was maximum in application of pre-emergence pretilachlor + bensulfuron *fb* bispyribac Na .RWD of *Alternanthra triandra* was found minimum under application of bispyribac-Na. Relative density of *Cyperus iria* was recorded maximum under *biasi* method.Whereas, maximum relative weed density of *Cynotis axilliaris* was recorded under weedy check. RWD of other weed was minimum under

two hand weeding whereas it was maximum in bispyribac-Na @25 g ha^{-1} at 20DAS..

- Maximum relative density of *Echinochloa colona* at harvest was recorded under apllication of azimsulfuron *fb* bispyribac Na 15 and 35 DAS. RWD, of *Alternanthra triandra* was recorded maximum in weedy check. Whereas, maximum relative density of *Cyperus iria* was under aplication of pre-emergence oxadiargyl *fb* bispyribac Na at 25 DAS and maximum relative density of *Cynotis axilliaris* was observed under hand weeding twice.
- Weed growth rate showed differential response due to different weed management and seed rate options at various time intervals. Weed growth was maximum in weedy check in all the observational stages. Whereas, At 15 to 30 DAS similar and lowest weed growth rate (WGR) was observed under two hand weeding at 20 and 40 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. However, it was maximum in weedy check during all the observational stages. Declined weed growth was observed during 45 to 60 DAS and it was minimum in sequeantial application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Among seed rate weed growth rate was minimum under 40 kg ha^{-1}.
- The dehydrogenase activity was influenced significantly due to different weed management practices. However, dehydrogenase activity does not significantly influenced by the seed rate during both the year. The effect of pre and post emergence herbicide on soil microbial activity was observed after 30 DAS. The lowest dehydrogenase activity was observed under apllication of pre-emergence application of pretilachlor+bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS followed by application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS. After 60 DAS, the harmful effect of different herbicide treatment narrowed down. At harvest all the herbicides degraded and there residues become non toxic to the microbial activities.
- Economics of direct seeded line sown rice reveals that the maximum cost of cultivation (₹ 30047) was found in hand weeding twice. Among the chemical weed management, it was ranges from ₹ 27653 to 29643. Difference between

the manual harvesting and harvesting through combine harvester was ₹ 2233 ha^{-1}. Data on gross income reveals that the higher gross income (₹86690) was recorded under hand weeding and was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (₹ 85151) and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (₹ 83238).

- Net income through manual harvesting was ₹ 62381 in year 2013 and it was ₹ 50906 in 2014. Difference between net income through hand weeding and chemical control method was very marginal. Difference between manual harvesting and harvesting through harvester was nearly ₹ 10000 higher in mechanical harvesting system.
- On the basis of two year mean maximum B:C ratio was found in sequeantial application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS which was nearly equal to the two hand weeding. High monitary income per rupee invested was high under harvesting with harvester as compared to manual harvesting. Difference between the B: C ratio in regards to the manual and harvester harvesting was 0.6 which is big difference in respect to the rice production system.
- Maximum output energy was recorded under two hand weeding during both the year. However, it was at par with application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. During the investigation, seed rate did not influence the output energy and almost similar output energy was produced by the 80, 60 and 40 kg ha^{-1} seed rate. Energy output-input ratio was less in combine harvester as compared to the manual weeding, difference was only 5.5 to 6.5 per cent between the manual and combine harvester. Difference was not very much in manual and harvester harvesting system, but in harvester timely harvesting of crop provides chance for timely sowing of next crop.
- Significantly, maximum energy use efficiency was recorded under the application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and it was found minimum under weedy check. Efficiency of

harvesting through harvester was less as compared to the manual harvesting but the difference was very marginal in both the year.

- Energy productivity was recorded maximum under the application of pre-emergence oxadiargyl followed by bispyribac Na @20 g ha^{-1} at 25 DAS. However, the energy productivity was higher in manual harvesting as compared to the combine harvester. But difference was very marginal ranging from 6 to 8 percent only.

CONCLUSIONS:

Broadcast direct seeded rice

- Seed yield of broadcast direct seeded rice was high under the *biasi* method (52.2 q ha^{-1}) and was statistically at par with the hand weeding twice (50.8 q ha^{-1}) and sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS (50.0 q ha^{-1}) during investigation. It was only 2.7 per cent higher as compared to hand weeding and 4.7 per cent as compared to sequential application of pre and post emergence herbicide.
- Non significant difference was observed between seed rates ranging from 120, 80 and 40 kg ha^{-1} during both the years. However, yield was slightly higher under 40 kg seed rate ha^{-1} in broadcast direct seeded rice.
- Combination of 40 kg ha^{-1} seed rate with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS gave similar yield as high seed rate with *biasi* method and hand weeding.
- Higher yield attributes *i.e.* total tillers, effective tillers, filled grains $panicle^{-1}$ length of panicle and panicle weight was produced by the *biasi* method during both the year whereas, it was at par with two hand weeding at 20 and 40 DAS and sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. Whereas, the lowest numbers of yield attributes were recorded under weedy check.
- Root volume and root dry weight was significantly influenced by the weed management practices and seed rates. It was higher under *biasi* method due to manipulated soil environment, followed by hand weeding and chemical control method. Whereas, 40 kg seed rate ha^{-1} produced higher root volume and root dry weight due to optimum plant population favouring better environment for root growth.
- Higher gross income (₹ 92252) and net income (₹ 61341) was found under *biasi* method which was at par with hand weeding twice and sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS, respectively. Chemical control method might be the

alternative for the *biasi* method as the difference between both the weed management practices was ₹ 306 only in respect to net income.

- Higher income from per rupee invested was found under the sequential application of oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (2.25) followed by application of pre-emergence application of (sand mix) pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 25 DAS (2.13) and *biasi* method (1.99). The B:C raio was higher under chemical control method, supporting that the combination of low seed rate with chemical control might be the better alternative of *biasi* method in Chhattisgarh

- Net income and B:C ratio was higher under harvesting through harvester as compared to manual harvesting and the difference was significant. So that we can conclude that, the higher monitary income can be achieved by adopting *"machine to machine rice production system"* with the combination of optimum seed rate and adopting appropriate weed management options.

- Similar output input ratio, energy used efficiency and energy productivity was produced by the *biasi* method and chemical control method during investigation. Whereas, the energy productivity was higher in combine harvester as compared to the manual harvesting. So that it can be concluded that justified use of resources can be achieved for rice production system under the combination of optimum plant population and appropriate weed management practices along with the use of machines.

- At harvest all the treatment were at par with regards to dehydrogenase activity which showed that herbicides oxadiargyl, bispyribac, pyrazosulfuron and combination of pretilachlor+bensulfuron degraded and there residues become non toxic to the microbial activities.

- Weed density and weed dry matter was less under *biasi* method as compared with hand weeding and sequeantial application of pre emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of sand mix pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20 g h^{-1} at 25 DAS.

- Sequential application of oxadiargyl and bispyribac Na showed same WCE as *biasi* method and hand weeding twice. Whereas, weed index and weed growth rate was minimum under *biasi* method and nearly equal to hand weeding and chemical control method. So that, application of pre emergence followed by post emergence may be the better alternative of hand weeding and *biasi* method.

- Among the herbicides the combination sequential application of pre emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of sand mix pyrazosulfuron 20 g ha^{-1} *fb* bispyribac Na 20 g h^{-1} at 25 DAS would be the better choice for farmers in broadcast direct seeded rice.

Direct line seeded rice

- Under direct line seeded rice, superior seed yield was recorded under hand weeding twice and was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS.
- Seed rates ranging from 80, 60 and 40 kg ha^{-1} did not influence seed yield of direct line seeded rice significantly. However, marginally high seed yield was recorded under 40 kg seed rates ha^{-1}.
- Combination of 40 kg seed rate ha^{-1} with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS gave similar yield as high seed yield with hand weeding in direct line seeded rice.

- Higher yield attributes *i.e.*total tillers, effective tillers, filled grains $panicle^{-1}$ length of panicle and panicle weight was produced by the hand weeding twice and was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 and apllication of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Yield attributes was non significant among 80, 60 and 40 kg seed rates ha^{-1}.

- Root volume and root dry weight was significantly influenced by the weed management practices and seed rate and was higher under hand weeding twice followed by chemical control method. Whereas, 40 kg seed rate ha^{-1} produced higher root volume and root dry weight.
- Weed density and weed dry matter was less under hand weeding twice and was comparable with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS.
- Among the herbicides, the sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS would be the better option for direct line seeded rice.
- Gross income was high in direct line seeded rice under hand weeding twice (₹86690) and was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (₹ 85151) and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS (₹ 83238). Similarly higher net income was recorded under hand weeding twice and difference between net income through hand weeding and chemical control method was very marginal. Net and gross income and B:C ratio was higher under harvesting through harvester support the *"machine to machine rice production system"* sowing through machine, weed management through chemical herbicides and harvesting by harvester in direct line seeded rice.
- B:C ratio was higher under sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS (2.0) and hand weeding twice (1.9). B:C ratio was higher under harvesting through harvester as compared to manual harvesting in direct line seeded rice.
- Output energy and output-input energy was higher under two hand weding and was at par with sequential application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS. Energy

use efficiency and energy productivity was recorded higher under application of pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS.

- Output-input energy, energy use efficiency and energy productivity was higher under manual harvesting as compared to harvesting through harvester but the difference was very marginal, but harvesting through harvester gave chance for timely sowing of next crop.
- Dehydrogenase activity was influenced significantly due to different weed management practices. The lowest dehydrogenase activity was observed under application of pre-emergence application of pretilachlor+bensulfuron 660 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS. After 60 DAS, the harmful effect of different herbicide treatment narrowed down. At harvest all the herbicides degraded and their residues become non toxic to the microbial activities.
- Sequential application pre-emergence oxadiargyl 70 g ha^{-1} *fb* bispyribac Na @ 20 g ha^{-1} at 25 DAS and application of azimsulfuron 35 g ha^{-1} *fb* bispyribac Na 20g ha^{-1} at 15 and 35 DAS showed same weed control efficiency as hand weeding twice. Whereas, weed index and weed growth rate was minimum under hand weeding method and nearly equal to chemical control method. So that, application of pre emergence followed by post emergence might be the better alternative of hand weeding in direct seeded rice.

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Appendix-I : Weekly meteorological data during crop growth period of first year (From 04.06.2013 to 28.0.2013)

Standard Meteorological Weeks	Month and Date	Max. Temp. (°C)	Min. Temp. (°C)	Rain-fall (mm)	Rainy days	Relative Humidity (%)		Wind Velocity (Km h^{-1})	Evapo-ration (mm)	Sun Shine (hours)
						I	II			
23	**Jun 04-10**	37.8	26.1	55.3	3	80	49	8.8	8.8	6.5
24	**11-17**	32.4	25.0	105.2	3	87	67	7.5	4.4	2.6
25	**18-24**	34.4	25.8	46.4	2	83	67	7.5	6.2	5.6
26	**25-01**	30.4	24.9	41.0	3	88	73	11.8	3.9	1.4
Average		**33.8**	**25.5**	**62.0**	**3**	**85**	**64**	**8.9**	**5.8**	**4.0**
27	**Jul 02-08**	31.3	24.5	73.5	3	90	70	6.7	4. 7	4.4
28	**09-15**	31.2	24.3	144.4	5	93	78	7.7	4.3	3.9
29	**16-22**	30.5	25.3	44.6	5	95	74	6.4	2.9	2.3
30	**23-29**	28.4	24.7	88.2	4	92	83	9.0	2.1	0.7
31	**30-05**	28.3	23.9	255.8	5	95	84	7.4	2.7	1.3
Average		**29.9**	**24.5**	**121.3**	**4**	**93**	**78**	**7.4**	**3.3**	**2.5**
32	**Aug 06-12**	31.1	24.7	87.4	4	93	76	5.2	3.6	3.3
33	**13-19**	31.3	24.3	177	5	95	80	3.2	3.2	3.3
34	**20-26**	27.9	23.8	60.5	4	92	84	9.3	2.1	1.5
35	**27-02**	29.3	24.5	120.8	3	95	80	5.8	2.8	3.1
Average		**29.9**	**24.3**	**111.4**	**4**	**94**	**80**	**5.9**	**2.93**	**2.8**
36	**Sep 03-09**	31.1	24.8	54.8	4	93	76	3	4	4.2
37	**10-16**	31.9	25.2	11.6	1	92	73	2	3.6	6.2
38	**17-23**	29.9	24.1	92.6	4	93	77	3.7	2.8	2.5
39	**24-30**	32.0	24.9	28.6	1	93	68	2.7	4.0	6.3
Average		**31.2**	**24.8**	**46.9**	**3**	**93**	**74**	**2.9**	**3.6**	**4.8**
40	**Oct 01-07**	30.1	24.1	45.2	5	95	75	3.6	3	4.2
41	**08-14**	30.2	23.3	8.6	1	89	71	4.6	3.4	3.5
42	**15-21**	30.7	21.4	0	0	91	56	2	3.5	8.6
43	**22-28**	28.8	22.6	32.6	2	96	73	3.9	2.7	2.1
Average		**30.0**	**22.9**	**21.6**	**2**	**93**	**69**	**3.5**	**3.2**	**4.6**
Cumulative Total				**363.2**						

Appendix-II: Weekly meteorological data during crop growth period of second year (From 02.07.2014 to 18.11.2014)

Standard Meteorological Weeks	Date	Max. Temp. (°C)	Min. Temp. (°C)	Rain-fall (mm)	Rainy days	Relative Humidity (%)		Wind Velocity (Km h^{-1})	Evapo-ration (mm)	Sun Shine (hours)
						I	II			
27	**Jul 02-08**	37.7	27	9	1	72	44	9	8.5	5.3
28	**09-15**	34.3	23.8	152.8	7	92	72	8.4	6.6	20
29	**16-22**	28.5	24.6	260.2	6	95	88	12.1	2.8	0.5
30	**23-29**	28.7	23.8	37.2	4	95	82	9.4	2.7	1.6
31	**30-05**	29.8	24.8	136.0	7	95	86	9.7	4.0	1.9
Average		**31.8**	**24.8**	**119.0**	**5**	**90**	**74**	**9.7**	**4.9**	**5.9**
32	**Aug 06-12**	30.2	24.8	42.1	3	91	71	9.1	3.6	2.8
33	**13-19**	31.8	25.3	45	3	91	70	7.0	4.7	5.5
34	**20-26**	32.3	25.1	25.8	2	92	73	4.0	3.7	3.4
35	**27-02**	31.8	25.0	84.8	4	91	76	5.8	4.1	3.6
Average		**31.5**	**25.1**	**49.4**	**3**	**91**	**73**	**6.48**	**4.0**	**3.8**
36	**Sep 03-09**	25.1	28.3	79.5	4	94	83	6.2	1.7	0.5
37	**10-16**	30.5	24.3	41	3	95	79	5.8	3.3	3.4
38	**17-23**	32.1	24.6	57.6	3	94	68	3.6	3.7	4.4
39	**24-30**	33.4	24.0	0	0	93	57	2.1	4.1	8.3
Average		**30.3**	**25.3**	**44.5**	**3**	**94**	**72**	**4.4**	**3.2**	**4.2**
40	**Oct 01-07**	33.2	24	0	0	91	57	2.5	3.9	8.3
41	**08-14**	30.4	23.6	52.2	2	89	66	6.9	3.6	4.9
42	**15-21**	31.5	22.5	1.2	0	91	56	2.6	3.4	8.4
43	**22-28**	29.1	19.4	5.4	1	92	52	2	2.8	5.9
44	**29-04**	30.1	16.9	0	0	94	37	1.9	3.0	8.0
Average		**30.9**	**21.3**	**11.8**	**1**	**91**	**54**	**3.2**	**3.3**	**7.1**
45	**Nov 05-11**	30.7	17.6	0	0	88	44	3	3.4	7.8
46	**12-18**	31.4	19.3	0	0	84	35	2.8	3.6	6.8
Average		**31.1**	**18.5**	**0**	**0**	**86**	**40**	**2.9**	**3.5**	**7.3**
Cumulative Total				**224.8**						

Appendix III: Fixed cost in broadcasted rice experiment during *Kharif* 2013 for (₹ ha^{-1})

S. No.	Particulars	Input	Rate (₹)	Total cost (₹ ha^{-1})
1	**Land preparation**			
	a. Ploughing twice	6	600	3600.00
	b. Harrowing twice	5	600	3000.00
2	**Sowing**			
	a. Cost of sowing labor	1	143	143.00
	b. Labor cost	0	143	0.00
3	**Fertilizer application (100:60:40)**			
	a. Requirement of urea	166.52	5.8	965.82
	b. Requirement of DAP	130.00	25.2	3276.00
	c. Requirement of MOP	66.66	17.64	1175.88
	c. Application cost	2	143	286.00
6	**Harvesting, threshing and winnowing**			
	a. Through Labour (W1,W2,W3W4,W5)	50	143	7150.00
	b. Through Labour(W6)	30	143	4290.00
	c. Harvester(2.5 hr Harvester+2.5 hr tractor +3 Labour)	2.5	(1500+600+ 143)	5679
7	**Land revenue**		Rs.500	500.00
	Sub total A : Through Labour (W1,W2,W3W4,W5)			20096.70
	Sub total B : Through Labour (W6)**			17236.70
	Sub total C : Harvester(2.5 hr Harvester+2.5 hr tractor +3 Labour)***			18625.70
8	**Miscellaneous**		10% of common cost	
Total A : (Sub total + 10% of Sub Total)				**22106.37**
Total B : (Sub total + 10% of Sub Total)				**18960.37**
Total C: (Sub total + 10% of Sub Total)				**20488.27**

***Labour Cost ₹ 143 day^{-1} in MANREGA during 2013, ** Less labour are required in control plot for harvesting due to less plant stand and yield, *** Assumed if harvesting through harvester as practiced in villages now a day**

Calculation of Gross Return: For calculation of gross return Chhattisgarh Government procurement rate are considered for grain yield it was @ ₹ 1350 + 300 incentive = ₹ 1650 q^{-1} in the year 2013 & @ ₹ 1400 q^{-1} in year 2014 . Straw @ ₹ 1 kg^{-1}

Appendix IV: Variable cost of seed in broadcasted rice experiment during *Kharif* 2013 & 2014 (₹ ha^{-1})

Treatment	Quantity (kg ha^{-1})	Rate (₹ kg^{-1})	Total cost (₹ ha^{-1})
S_1 - 120	120	15	**1800**
S_2 - 80	80	15	**1200**
S_3 - 40	40	15	**600**

Appendix V: Variable cost of weed management in broadcasted rice experiment *Kharif* 2013 (₹ ha^{-1})

Treatments	Quantity (g ha^{-1})	*a.i.* (%)	Rate (Commer-cial product) (₹. lit^{-1} kg^{-1})	Treatment Cost	Cost of Spraying (₹)	Total Cost (₹ ha^{-1})
W_1:- *Biasi* method				6250*	0	**6250**
W_2:- HW 20 & 40 DAS		50	143 /Labour	7150	0	**7150**
W_3:- Oxa 70 g ha^{-1} *fb* Bis Na @20 g ha^{-1} at 25 DAS	87.5+ 200	80+10	5900+7750	735+1550	249	**2534**
W_4:- Pretila+ Ben 660 g ha^{-1} *fb* Bis @ 20 g ha^{-1} at 25 DAS	11000+ 200	6+10	160+7750	1760+1550	358	**3668**
W_5:- Pyrazo20 g ha^{-1} *fb* Bisa 20g/h at 25 DAS	200+ 200	10+10	2500+7750	1550+500	358	**2408**
W_6:- Weedy check	0	0	0	0	0	**0**

*Biasi @ ₹ 2500/acre

Appendix VI : Treatment cost in broadcasted rice experiment during *Kharif* 2013 (₹ ha^{-1})

S. No	Treat-ment	Fixed Cost (₹ha^{-1}) Manual Harvesting	Harvesting through Harvester	Treatment Cost (₹. ha^{-1})		Total Cost (₹ha^{-1}) Manual Harvesting	Total Cost (₹ha^{-1}) Through Harvester
				Weed management	Seed rate		
1	S_1W_1	22106	20488	6250	1800	30156	28538
2	S_1W_2	22106	20488	7150	1800	31056	29438
3	S_1W_3	22106	20488	2534	1800	26440	24822
4	S_1W_4	22106	20488	3668	1800	27574	25956
5	S_1W_5	22106	20488	2408	1800	26314	24696
6	S_1W_6	18960	20488	0	1800	20760	22288
7	S_2W_1	22106	20488	6250	1200	29556	27938
8	S_2W_2	22106	20488	7150	1200	30456	28838
9	S_2W_3	22106	20488	2534	1200	25840	24222
10	S_2W_4	22106	20488	3668	1200	26974	25356
11	S_2W_5	22106	20488	2408	1200	25714	24096
12	S_2W_6	18960	20488	0	1200	20160	21688
13	S_3W_1	22106	20488	6250	600	28956	27338
14	S_3W_2	22106	20488	7150	600	29856	28238
15	S_3W_3	22106	20488	2534	600	25240	23622
16	S_3W_4	22106	20488	3668	600	26374	24756
17	S_3W_5	22106	20488	2408	600	25114	23496
18	S_3W_6	18960	20488	0	600	19560	21088

Appendix-VII : Fixed cost in broadcasted rice experiment during 2014 (₹ ha^{-1})

S. No.	Particulars	Input	Rate	Total cost (₹. ha^{-1})
1	**Land preparation**			
	c. Ploughing twice	6	600	3600
	d. Harrowing twice	5	600	3000
2	**sowing**			
	d. Cost of sowing labor	3	600	1800
	e. Labor cost	1	167	167
3	**Fertilizer application (100:60:40)**			
	a. Requirement of urea	166.52	5.69	947
	b. Requirement of DAP	130.00	23.62	3071
	c. Requirement of MOP	66.66	16.79	1119
	f. Application cost	2	167	334
6	**Harvesting, threshing and winnowing**			
	a. Through Labour (W_1,W_2,$W_3$$W_4$,$W_5$)	50	167	8350
	b. Through Labour(W_6)	30	167	5010
	c. Harvester(2.5 hr Harvester+2.5 hr tractor +3 Labour)	2.5	(1500+600 +143)	5751
7	**Land revenue**		₹.500	500
	Sub total A : Through Labour (W_1,W_2,W_3, W_4,W_5)			22888
	Sub total B : Through Labour (W6)**			19548
	Sub total C : Harvester(2.5 hr Harvester+2.5 hr tractor +3 Labour)***			20289
8	**Miscellaneous**		10% of common cost	
Total A : (Sub total + 10% of Sub Total)				**25177**
Total B : (Sub total + 10% of Sub Total)				**21503**
Total C: (Sub total + 10% of Sub Total)				**22318**

***Labour Cost ₹ 167 /day in MANREGA during 2013, ** Less labour are required in control plot for harvesting due to less plant stand and yield, *** Assumed if harvesting through harvester as practiced in villages now a day**

Appendix-VIII: Variable cost of weed management in broadcasted rice experiment during *Kharif* 2014 (₹ ha^{-1})

Treatment	Quantity (g ha^{-1})	*a.i.* (%)	Rate (Commercial product) (₹lit^{-1} kg^{-1})	Treatment Cost	Cost of Spraying (₹)	Total Cost (₹ ha^{-1})
W_1:- *Biasi* method				6250	0	**6250**
W_2:- HW 20 & 40 DAS		50 Labour	167	8350	0	**8350**
W_3:- Oxa 70 g ha^{-1} *fb* Bis Na @20 g ha^{-1} at 25 DAS	87.5+ 200	80+10	5900+7750	735+ 1550	215	**2534**
W_4:- Pretila+ Ben 660 g ha^{-1} *fb* Bis @ 20 g ha^{-1} at 25 DAS	11000+ 200	6+10	160+7750	1760+ 1550	418	**3668**
W_5:- Pyrazo20 g ha^{-1} *fb* Bisa 20g h^{-1} at 25 DAS	200+ 200	10+10	2500+7750	1550+ 500	418	**2408**
W_6:- Weedy check	0	0	0	0	0	**0**

*Biasi @ ₹ 2500/acre, Seed cost as in 2013

Appendix-IX : Treatment cost in broadcasted rice experiment during *Kharif* 2014 (₹ ha^{-1})

S. No	Treatment	Fixed Cost (₹ha^{-1}) Manual Harvesting	Harvesting through Harvester	Treatment Cost (₹ ha^{-1})		Total Cost (₹ha^{-1}) Manual Harvesting	Total Cost (₹ ha^{-1}) Through Harvester
				Weed management	Seed rate		
1	S_1W_1	25177	22318	6250	1800	33227	30368
2	S_1W_2	25177	22318	8350	1800	35327	32468
3	S_1W_3	25177	22318	2534	1800	29511	26652
4	S_1W_4	25177	22318	3668	1800	30645	27786
5	S_1W_5	25177	22318	2408	1800	29385	26526
6	S_1W_6	21503	22318	0	1800	23303	24118
7	S_2W_1	25177	22318	6250	120	31547	28688
8	S_2W_2	25177	22318	8350	120	33647	30788
9	S_2W_3	25177	22318	2534	120	27831	24972
10	S_2W_4	25177	22318	3668	120	28965	26106
11	S_2W_5	25177	22318	2408	120	27705	24846
12	S_2W_6	21503	22318	0	120	21623	22438
13	S_3W_1	25177	22318	6250	600	32027	29168
14	S_3W_2	25177	22318	8350	600	34127	31268
15	S_3W_3	25177	22318	2534	600	28311	25452
16	S_3W_4	25177	22318	3668	600	29445	26586
17	S_3W_5	25177	22318	2408	600	28185	25326
18	S_3W_6	21503	22318	0	600	22103	22918

Appendix-X: Fixed cost in direct line seeded rice experiment during Kharif 2013 for (₹ ha^{-1})

S. No.	Particulars	Input	Rate	Total cost (₹ha^{-1})
1	**Land preparation**			
	a. Ploughing twice	6 h	600	3600.00
	b. Harrowing twice	5 h	600	3000.00
2	**Sowing**			
	a. Cost of sowing (Tractor)	3 h	600	1800.00
	b. Labor cost	1	143	143.00
3	**Fertilizer application**			
	a. N 100 kg ha^{-1}	166.52	5.8	965.82
	b. P_2O_5 60 kg ha^{-1}	130.00	25.2	3276.00
	c. K_2O 40 kg ha^{-1}	66.66	17.64	1175.88
	d. Application cost	2	143	286.00
6	**Harvesting, threshing and winnowing**			
	a. Through Labour (W_1,W_2,W_3, W_4,W_5)	50	143	7150.00
	b. Through Labour (W_6)	30	143	4290.00
	c. Harvester(2.5 hr Harvester+2.5 hr tractor +3 Labour)	2.5	(1500+600 +143)	5679
7	**Land revenue**		₹500	500.00
	Sub total A : Through Labour (W_1, W_2, W_3, W_4, W_5)			21896.70
	Sub total B : Through Labour (W_6)			19036.70
	Sub total C : Harvester(2.5 hr Harvester+2.5 hr tractor +3 Labour)			20425.70
8	**Miscellaneous**		10% of common cost	
	Total A : (Sub total + 10% of Sub Total)			**24086.37**
	Total B : (Sub total + 10% of Sub Total)			**20940.37**
	Total C: (Sub total + 10% of Sub Total)			**22468.27**

***Labour Cost ₹ 143 day^{-1} in MANREGA during 2013, ** Less labour are required in control plot for harvesting due to less plant stand and yield, *** Assumed if harvesting through harvester as practiced in villages now a day**

Calculation of Gross Return : For calculation of gross return Chhattisgarh Government procurement rate are considered for grain yield it was @ ₹ 1350 + 300 incentive = ₹ 1650 q^{-1} in the year 2013 & @ ₹1400 q^{-1} in year 2014 . Straw @ ₹ 1 kg^{-1}

Appendix-XI : Variable cost of seed in direct line seeded rice experiment during *Kharif* 2013 & 2014 (₹ha^{-1})

Treatments	Quantity (kg ha^{-1})	Rate (₹ kg^{-1})	Total cost (₹)
S1 - 80	80	15	1200
S2 - 60	60	15	900
S3 - 40	40	15	600

Appendix-XII: Variable cost of weed management in direct line seeded rice experiment during *Kharif* 2013 (₹ ha^{-1})

Treatments	Quantity (g ha^{-1})	a.i. ha^{-1} (%)	Rate (Commercial product) (₹ lit^{-1} kg^{-1})	Treatment cost	Cost of spraying (₹)	Total cost (₹ha^{-1})	Total cost (₹ha^{-1})
W_1:- Two hand weeding		30	143	4290	0	4290	4290
W_2:- Bispyribac-Na @25 g ha^{-1} at 20DAS	250	10	7750	1937.5	201	2138.5	2138
W_3:- Pre -emergence Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	87.5+200	80+10	8400+7750	735+1550	402	2687	2687
W_4:- Pre-emergence (Pretilachlor + Bensulfuron) 660 g/ha *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	11000+200	6+10	160+7750	1760+1550	268	3578	3578
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20g ha^{-1} at 15 and 35 DAS	70+200	50+10	33036+7750	2310+1150	402	4262	4262
W_6:- Weedy check	0	0	0	0	0	0	0

Appendix-XIII : Treatment cost in direct line seeded rice experiment during *Kharif* 2013 (₹ha^{-1})

S. No	Treat-ment	Fixed Cost (₹ha^{-1}) Manual Harvesting	Harvesting through Harvester	Treatment Cost (₹ha^{-1})		Total Cost (₹ha^{-1}) Manual Harvesting	Total Cost (₹. ha^{-1}) Through Harvester
				Weed management	Seed rate		
1	S_1W_1	24086	22468	4020	1200	29306	27688
2	S_1W_2	24086	22468	2139	1200	27425	25807
3	S_1W_3	24086	22468	2687	1200	27973	26355
4	S_1W_4	24086	22468	3578	1200	28864	27246
5	S_1W_5	24086	22468	4262	1200	29548	27930
6	S_1W_6	20940	22468	0	1200	22140	23668
7	S_2W_1	24086	22468	4020	900	29006	27388
8	S_2W_2	24086	22468	2138.5	900	27125	25507
9	S_2W_3	24086	22468	2687	900	27673	26055
10	S_2W_4	24086	22468	3578	900	28564	26946
11	S_2W_5	24086	22468	4262	900	29248	27630
12	S_2W_6	20940	22468	0	900	21840	23368
13	S_3W_1	24086	22468	4020	600	28706	27088
14	S_3W_2	24086	22468	2138.5	600	26825	25207
15	S_3W_3	24086	22468	2687	600	27373	25755
16	S_3W_4	24086	22468	3578	600	28264	26646
17	S_3W_5	24086	22468	4262	600	28948	27330
18	S_3W_6	20940	22468	0	600	21540	23068

Appendix-XIV: Fixed cost in direct line seeded rice experiment during *Kharif* 2014 for (₹ ha^{-1})

S. No.	Particulars	Input	Rate	Total cost (₹ha^{-1})
1	**Land preparation**			
	a. Ploughing twice	6 h	600	3600
	b. Harrowing twice	5 h	600	3000
2	**Sowing**			
	a. Cost of sowing (Tractor)	3 h	600	1800
	c. Labor cost	1	167	167
3	**Fertilizer application**			
	a. N 100 kg ha^{-1} (Urea)	166.52	5.69	947
	b. P_2O_5 60 kg ha^{-1} (DAP)	130.00	23.62	3071
	c. K_2O 40 kg ha^{-1} (MOP)	66.66	16.79	1119
	d. Application cost	2	167	334
6	**Harvesting, threshing and winnowing**			
	a. Through Labour (W_1,W_2,W_3, W_4,W_5)	50	167	8350
	b. Through Labour (W_6)	30	167	5010
	c. Harvester(2.5 hr Harvester+2.5 hr tractor +3 Labour)	2.5	(1500+600+ 143)	5751
7	**Land revenue**		₹500	500
	Sub total A : Through Labour (W_1, W_2,W_3, W_4,W_5)			22888
	Sub total B : Through Labour (W_6)			19548
	Sub total C : Harvester(2.5 hr Harvester+2.5 hr tractor +3 Labour)			20289
8	**Miscellaneous**		10% of common cost	
	Total A : (Sub total + 10% of Sub Total)			**25177**
	Total B : (Sub total + 10% of Sub Total)			**21503**
	Total C: (Sub total + 10% of Sub Total)			**22318**

***Labour Cost ₹ 143 day^{-1} in MANREGA during 2013, ** Less labour are required in control plot for harvesting due to less plant stand and yield, *** Assumed if harvesting through harvester as practiced in villages now a day**

Calculation of Gross Return : For calculation of gross return Chhattisgarh Government procurement rate are considered for grain yield it was @ ₹ 1350 + 300 incentive = ₹1650 q^{-1} in the year 2013 & @ ₹1400 q^{-1} in year 2014 . Straw @ ₹ 1 kg^{-1}

Appendix-XV: Variable cost of weed management in direct line seeded rice experiment during *Kharif* 2014 (₹ ha^{-1})

Treatments	Quantity (g ha^{-1})	a.i. ha^{-1} (%)	Rate (Commercial product) (₹lit^{-1} kg^{-1})	Treat-ment cost	Cost of spraying (₹)	Total cost (₹ha^{-1})
W_1:- Two hand weeding		30	167	5010	0	5010
W_2:- Bispyribac-Na @25 g ha^{-1} at 20DAS	250	10	7750	1937.5	167	2104.5
W_3:- Pre -emergence Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	87.5+200	80+10	8400+7750	735+1550	501	2795
W_4:- Pre-emergence (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	11000+200	6+10	160+7750	1760+1550	417	3727
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20g ha^{-1} at 15 and 35 DAS	70+200	50+10	33036+7750	2310+1150	501	3961
W_6:- Weedy check	0	0	0	0	0	0

Appendix-XVI: Treatment cost in direct line seeded rice experiment during *Kharif* 2014 (₹ ha^{-1})

S. No	Treatment	Fixed Cost (₹ha^{-1}) Manual Harvesting	Harvesting through Harvester	Treatment Cost (₹ha^{-1})		Total Cost (₹ha^{-1}) Manual Harvesting	Total Cost (₹ha^{-1}) Through Harvester
				Weed management	Seed rate		
1	S_1W_1	25177	22318	5010	1200	31387	28528
2	S_1W_2	25177	22318	2104.5	1200	28482	25623
3	S_1W_3	25177	22318	2792	1200	29169	26310
4	S_1W_4	25177	22318	3727	1200	30104	27245
5	S_1W_5	25177	22318	3961	1200	30338	27479
6	S_1W_6	21503	22318	0	1200	22703	23518
7	S_2W_1	25177	22318	5010	900	31087	28228
8	S_2W_2	25177	22318	2104.5	900	28182	25323
9	S_2W_3	25177	22318	2792	900	28869	26010
10	S_2W_4	25177	22318	3727	900	29804	26945
11	S_2W_5	25177	22318	3961	900	30038	27179
12	S_2W_6	21503	22318	0	900	22403	23218
13	S_3W_1	25177	22318	5010	600	30787	27928
14	S_3W_2	25177	22318	2104.5	600	27882	25023
15	S_3W_3	25177	22318	2792	600	28569	25710
16	S_3W_4	25177	22318	3727	600	29504	26645
17	S_3W_5	25177	22318	3961	600	29738	26879
18	S_3W_6	21503	22318	0	600	22103	22918

Appendix-XVII: Standard values for calculation of energy relationship during the course of investigation

S. No	Input/output form	Units	Energy coefficient(MJ)	Remarks
1.	Labour Adult man			
	Adult man	Man hour^{-1}	1.96	
	Adult Woman	Women hour^{-1}	1.57	
2.	Animals			
	Bullocks			
	Large	Pair hour^{-1}	14.05	Body weight above 450 Kg
	Medium	Pair hour^{-1}	10.10	Body weight 350- 450 Kg
	Small	Pair hour^{-1}	8.07	Body weight less than 350 Kg
3.	Chemical fertilizer			
	N	Kg ha^{-1}	60.6	
	P_2O_5	Kg ha^{-1}	11.10	
	K_2O	Kg ha^{-1}	06.70	
4.	Chemicals			
	Superior chemical (Herbicides)	Kg^{-1}	120	Chemical requires dilution at the time of application
	Inferior chemical	Kg^{-1}	10.0	DDT , Gypsum or other chemical not requires dilution at the time of application
5.	Machinery			
	Tractor	hour^{-1}	14.23	
	Combine harvester	hour^{-1}	101.4	
	Cultivator	hour^{-1}	3.76	
	Seed drill	hour^{-1}	6.27	
	Disc harrow	hour^{-1}	7.31	
7.	Diesel	Litre^{-1}	56.31	
8.	Paddy seed	Kg^{-1}	14.70	
9.	Main product (grain)	Kg^{-1}	14.70	
10	By –product (straw)	Kg^{-1}	12.50	

Appendix-XVIII : Fixed energy input in broadcasted rice experiment, MJ ha^{-1} (2013 and 2014)

S. No.	Operation	Time	Rate of energy, MJ	Total energy MJ ha^{-1}
A.	**Land preparation**			
	a. Ploughing twice	Total 6 h		
	1.Tractor	6 h	14.23 $hour^{-1}$	85.38
	2.Diesel	6 h	56.31 litre -1 Diseal	1182.51
	3.Driver	6 h	1.96 man $hour^{-1}$	11.76
	4.Cultivator	6 h	4.32 MJ $hour^{-1}$	22.56
	b. Harrowing twice	Total 5 h		
	1.Tractor	5 h	14.23 $hour^{-1}$	71.15
	2.Diesel	5 h	56.31 litre $^{-1}$	844.65
	3.Driver	5 h	1.96 man $hour^{-1}$	9.80
	4.Cultivator	5 h	7.31 $hour^{-1}$	36.55
B.	**Sowing**			
	a. Cost of sowing Broadcasting	1 Labour (8 hr/day)		15.68
C.	**Fertilizer application**			
	a. N 100 kg ha^{-1}	100 kg ha^{-1}	60.6 kg^{-1}	6060.00
	b. P_2O_5 60 kg ha^{-1}	60 kg ha^{-1}	11.10 kg^{-1}	666.00
	c. K_2O 40 kg ha^{-1}	40 kg ha^{-1}	6.70 kg^{-1}	268.00
	d. Application cost	2 Labour (8 hr/day)	1.96 man $hour^{-1}$	31.36
D.	**Harvesting, threshing and winnowing**			
	a) Through Labour(W_1,W_2,W_3W_4,W_5)	50 (8 h day^{-1})	1.96 man $hour^{-1}$	784.00
	b) Through Labour(W_6)	30 (8 h day^{-1})	1.96 man $hour^{-1}$	470.40
	c)Combine harvester(2.5 h Harvester+2.5 h tractor +3 Labour)	Harvester 2.5 h +Tractor 2.5 hr+labour (3*2.5) h +Diesel 5 l h^{-1} Harvester + Diesel 3.5 l h^{-1} Tractor	1.1.4 $hour^{-1}$+14.23 $hour^{-1}$+1.96 man $hour^{-1}$ + 56.31 litre $^{-1}$	**254+36+14.7 +1196.58 =1501.28**
Grand Total A : Harvesting through Labour (W1,W2,W3W4,W5)				**10060**
Grand Total B : Harvesting through Labour (W6)				**9746.40**
Grand Total C : Harvesting through Harvester				**10777.28**

Appendix-XIX: Variable energy input of seed in broadcasted rice experiment (2013 and 2014), MJ ha^{-1}

Treatment	Requirement of seed	Rate of energy, MJ	Total energy MJ ha^{-1}
S_1 - 120	120	14.70 kg^{-1}	**1764**
S_2 - 80	80	14.70 kg^{-1}	**1176**
S_3 - 40	40	14.70 kg^{-1}	**588**

Appendix-XX: Variable energy input of weed management in broadcasted rice experiment (2013-2014), MJ ha^{-1}

Operation	Requirement (g) ha^{-1}	Requirment (kg) ha^{-1}	Rate of energy, MJ	Total energy MJ ha^{-1}	Labour energy for spraying ha^{-1}	Total energy
W_1:- *Biasi* method (Farmer's practice)	Field Capacity 0.018 ha hour^{-1}	-	Labour-1.96 man hour^{-1}, Bullocks -14.05 Pair hour^{-1}, Impliment-.398 hour^{-1}	896	-	**896**
W_2:- Two hand weedings at 20 & 40 DAS	50	50 Labour	1.57 Women hour^{-1}	628.00		**628.00**
W_3:- PE Oxadiargyl 70 g ha^{-1} *fb* Bispyribac Na @20 g ha^{-1} at 25 DAS	87.5+200	(.0875+.2) =0.2875	120 kg-1	34.5	47.04	**81.54**
W_4:- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	11000+200	(11+.2)= 11.2	(10 kg-1 + 120 kg-1)	134	39.2	**173.2**
W_5:- PE (sand mix) Pyrazosulfuron 20 g ha^{-1} *fb* Bispyribac Na 20g h^{-1} at 25 DAS	200+200	(.2+.2)=.4	120 kg-1	48	39.2	**87.2**
W_6:- Weedy check	0	0	0	0	0	**0**

Appendix-XXI : Total energy input in broadcasted rice experiment, MJ ha^{-1} (2013 and 2014)

S. No	Treatment	Fixed energy MJ ha^{-1}	Harvesting through Harvester MJ ha^{-1}	Variable energy		Total energy manual MJ ha^{-1}	Total energy Harvester MJ ha^{-1}
				Weed management MJ ha^{-1}	Seed rate MJ ha^{-1}		
1	S_1W_1	10089	10777.28	896	1764	12749	13437
2	S_1W_2	10089	10777.28	628	1764	12481	13169
3	S_1W_3	10089	10777.28	82	1764	11935	12623
4	S_1W_4	10089	10777.28	173	1764	12027	12714
5	S_1W_5	10089	10777.28	87	1764	11941	12628
6	S_1W_6	9776	10777.28	0	1764	11540	12541
7	S_2W_1	10089	10777.28	896	1176	12161	12849
8	S_2W_2	10089	10777.28	628	1176	11893	12581
9	S_2W_3	10089	10777.28	82	1176	11347	12035
10	S_2W_4	10089	10777.28	173	1176	11439	12126
11	S_2W_5	10089	10777.28	87	1176	11353	12040
12	S_2W_6	9776	10777.28	0	1176	10952	11953
13	S_3W_1	10089	10777.28	896	588	11573	12261
14	S_3W_2	10089	10777.28	628	588	11305	11993
15	S_3W_3	10089	10777.28	82	588	10759	11447
16	S_3W_4	10089	10777.28	173	588	10851	11538
17	S_3W_5	10089	10777.28	87	588	10765	11452
18	S_3W_6	9776	10777.28	0	588	10364	11365

Appendix-XXII : Fixed energy input in direct line seeded rice experiment, MJ ha^{-1} (2013 and 2014)

S. No.	Operation	Requirement	Rate of energy, MJ	Total energy MJ ha^{-1}
A.	**Land preparation**			
	a. Ploughing twice	Total 6 h		
	1.Tractor	6 h	14.23 hour^{-1}	85.38
	2.Diesel	**6h**	**56.31 litre -1 Diesel**	1182.51
	3.Driver	**6h**	1.96 man hour^{-1}	11.76
	4.Cultivator	**6h**	4.32 Mjhour^{-1}	25.92
	b. Harrowing twice	Total 5 h		
	1.Tractor	5 h	14.23 hour^{-1}	71.15
	2. Diesel	5h	**56.31 litre -1 Diesel**	844.65
	3.Driver	5h	1.96 man hour^{-1}	9.80
	4.Harrow	5h	7.31 hour^{-1}	36.55
B.	**Sowing**			
	a. Cost of sowing	Total3 h		
	1.Tractor	3 h	14.23 hour^{-1}	42.69
	2. Diesel	3h	**56.31 litre -1 Diesel**	422.33
	3.Driver	3h	1.96 man hour^{-1}	5.88
	4.Seed drill	3h	6.27 MJ hour^{-1}	18.81
	b. Labor	1 Labour (8 hr day^{-1})	1.96 man hour^{-1}	5.88
C.	**Fertilizer application**			
	a. N 100 kg ha^{-1}	100 kg ha^{-1}	60.6 kg^{-1}	6060.00
	b. P_2O_5 60 kg ha^{-1}	60 kg ha^{-1}	11.10 kg^{-1}	666.00
	c. K_2O 40 kg ha^{-1}	40 kg ha^{-1}	6.70 kg^{-1}	268.00
	d. Application cost	2 Labour (8 h day^{-1})	1.96 man hour^{-1}	9.80
D.	**Harvesting, threshing and winnowing**			
	a) Through Labour (W_1, W_2, W_3, W_4, W_5)	50 (8 h day^{-1})	1.96 man hour^{-1}	784.00
	b) Through Labour (W_6)	30 (8 h day^{-1})	1.96 man hour^{-1}	470.40
	c) Harvester(2.5 h Harvester+2.5 h tractor +3 Labour + desile)	Harvester 2.5 hr +Tractor 2.5 hr+labour (3*2.5) hr+ diesel 5 l/h harverter + 3.5 l h^{-1} tractor	101.4 hour-1+14.23 hour-1+1.96 man hour -1 + 56.31 l-1	254+36+14.7+1196.58 =1501.28
	Grand total A : Through Labour (W1,W2,W3W4,W5)			**10551**
	Grand total B : Through Labour (W6)			**10238**
	Grand total C : Harvester(2.5 hr Harvester+2.5 hr tractor +3 Labour)			**11268**

Appendix-XXIII : Variable energy input of seed in direct line seeded rice experiment (2013 and 2014), MJ ha^{-1}

Operation	Requirement	Rate of energy, MJ	Total energy MJ ha^{-1}
S1 - 80	80	14.70 kg^{-1}	1176
S2 - 60	60	14.70 kg^{-1}	882
S3 - 40	40	14.70 kg^{-1}	588

Appendix-XXIV: Variable energy input of weed management in direct line seeded rice experiment (2013 and 2014), MJ ha^{-1}

Operation	Requirement (g) ha^{-1}	Requirement (kg) ha^{-1}	Rate of energy, MJ	Total energy MJ ha^{-1}	Spray Labour energy ha^{-1}	Total energy
W_1:- Two hand weeding	50	50 Labour	1.57 Women hour^{-1}	628.00		**628.00**
W_2:- Bispyribac-Na @25 g ha^{-1} at 20DAS	250	0.25	120 kg^{-1}	30.00	23.52	**53.52**
W_3:- PE Oxadiargyl 70 g/ha *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	87.5+200	(.0875+.2) =0.2875	120 kg^{-1}	34.50	47.04	**81.54**
W_4:- PE (Pretilachlor + Bensulfuron) 660 g ha^{-1} *fb* Bispyribac Na @ 20 g ha^{-1} at 25 DAS	11000+ 200	(11+.2) =11.2	(10 kg^{-1} + 120 kg^{-1})	134	31.36	**165.36**
W_5:- Azimsulfuron 35 g ha^{-1} *fb* Bispyribac Na 20g ha^{-1} at 15 and 35 DAS	70+200	(.07+.2) =.27	120 kg^{-1}	32.40	47.04	**79.44**
W_6:- Weedy check	0	0	0	0.00		**0.00**

Appendix-XXV: Total energy input in direct line seeded rice experiment, MJ ha^{-1} (2013-2014)

S. No	Treatment	Fixed energy MJ ha^{-1}	Harvesting through harvester MJ ha^{-1}	Variable energy		Total energy manual MJ ha^{-1}	Total energy harvester MJ ha^{-1}
				Weed management MJ ha^{-1}	Seed rate MJ ha^{-1}		
1	S_1W_1	10551	11268	628	1176	12355	13072
2	S_1W_2	10551	11268	53.52	1176	11781	12498
3	S_1W_3	10551	11268	81.54	1176	11809	12526
4	S_1W_4	10551	11268	165.36	1176	11892	12610
5	S_1W_5	10551	11268	79.44	1176	11807	12524
6	S_1W_6	10238	11268	0	1176	11414	12444
7	S_2W_1	10551	11268	628	882	12061	12778
8	S_2W_2	10551	11268	53.52	882	11487	12204
9	S_2W_3	10551	11268	81.54	882	11515	12232
10	S_2W_4	10551	11268	165.36	882	11598	12316
11	S_2W_5	10551	11268	79.44	882	11513	12230
12	S_2W_6	10238	11268	0	882	11120	12150
13	S_3W_1	10551	11268	628	588	11767	12484
14	S_3W_2	10551	11268	53.52	588	11193	11910
15	S_3W_3	10551	11268	81.54	588	11221	11938
16	S_3W_4	10551	11268	165.36	588	11304	12022
17	S_3W_5	10551	11268	79.44	588	11219	11936
18	S_3W_6	10238	11268	0	588	10826	11856

RESUM

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M.Sc (Ag)	2000-2001	Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)
B.Sc.(Ag)	1998-99	Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)
H.S.S.C	1993	Board of Seco. Edu. M.P. Bhopal
H.S.C	1991	Board of Seco. Edu. M.P. Bhopal
NET (Agronomy)	2001	A.S.R.B. New Delhi

Record of service:

Name of employer	Name of post	Place	Date of joining	Date of leaving
IGKV, Raipur	Scientist	Department of Agronomy AICRP – Forage Crops	28/05/2015	Till Date
IGKV**, Raipur**	Scientist	DKS CARS, Bhatapara	25/8/2014	27/05/2015
IGKV**, Raipur**	Scientist	DKS Farm, Bhatapara	08/08/2014	23/8/2014
IGKV**, Raipur**	Scientist	Dr.R.H.Rich. Res.& Inst.Farm, Baronda	27/11/2009	07/08/2014
IGKV**, Raipur**	Scientist	AICRP Linseed	20/04/2005	26/11/2009
IGKV**, Raipur**	TA	Adhoc Project on Weed control	27/05/2002	21/11/202
IGKV**, Raipur**	SRF	NATP-RRPS-17	22/11/2002	31/12/204
IGKV	STA	IRRI-IGAU CURE WG-1	11/1/2005	19/04/2005

Publication:

Research papers published: 15

Papers presented in seminar/symposia: 1

Technical bulletins: 6

Manuals: 4

Popular articles: 35

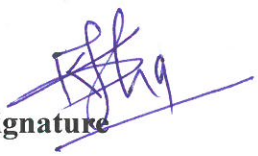
Leaflets: 10

Folders: 5

Project - Final Reports: 10

Extension CD (Compact Disc):3

ATLAS: 1



Signature

Vita

Santosh Kumar Jha, the author of this thesis was born on 27th January, 1975 at Jagdalpur (Bastar), Chhattisgarh. He accomplished primary education at his native place. He passed his H.S.S.C exam from Bal Vihar Vidalaya, Jagdalpur (Bastar) Chhattisgarh with first division in 1993.

In 1995, he joined Indira Gandhi Krishi Vishwavidlaya, Raipur, Chhattisgarh and fruitfully obtained Bachelors Degree of Agriculture, in the year 1999 with an OGPA of 7.1 out of 10 point scale. After that in the year 2000, he joined M.Sc. Ag. Course in the discipline Agronomy under Indira Gandhi Krishi Vishwavidlaya Raipur, Chhattisgarh and passed in 2001with an OGPA of 7.4 out of 10 point scale. During his Masters Degree he worked on "Nutritient Management on Scented Rice". In the year 2001 after completion of the Masters Degree he joined Department of Land & Water Management as SRF under NATP project. During this period he worked on watershed management at Village level. In the same year he qualified National Eligibility Test conducted by ASRB, New Delhi.

In the year 2005, he joined Department of Agronomy as Scientist in AICRP Linseed project. During this period he did his research on linseed crop and the team developed three linseed varieties. After that he gave his services to Baronda farm, He managed the farm brilliantly and generated the resources and revenue by producing quality breeder and foundation seed for the farming community of the state. He is having 10 years experience of teaching and research and also guided the students of Masters Degree. Presently, he is working on AICRP Forage Crops and Utilization as a Project Incharge.



Signature