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Planting methods and weed management to improve yield in dry-seeded rice

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ABSTRACT

A field experiment was conducted to evaluate the effect of planting methods and weed management in direct dry-seeded rice during summer season of 2012 and 2013 at Agricultural Research Farm, Institute of Agricultural Sciences Banaras Hindu University, Varanasi (Uttar Pradesh). The treatment comprised of five rice planting treatments, *viz*. conventional tillage normal spacing [row to row (R × R) -18 cm], conventional tillage square planting (R×R-20 cm, plant to plant (P × P)-20 cm), conventional tillage paired row (9-27-9 cm), reduced tillage paired row (9-27-9 cm), reduced tillage square planting (R × R -20 cm, P×P-20 cm) in main plot and sub-plot consisted of four weed management treatments, *viz*. weedy, two hand weeding, pendimethalin 1.0 kg/ha *fb* azimsulfuron 17.5 g/ha + bispyribac 25 g/ha (tank mixed) at 15 DAS *fb* one hand weeding (HW), oxadiargyl 50 g/ha *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha (ready mix) at 20 DAS *fb* 1 HW. Significant reduction in weed density and biomass was recorded in two hand weeding fb pendimethalin 1.0 kg/ha fb azimsulfuron 17.5 g/ha + bispyribac 25 g/ha (tank mixed) at 15 DAS *fb* 1 HW which resulted in improved growth and yield attributes and yield of rice. Amongst rice planting methods, conventional tillage normal spacing (R × R -18 cm) and conventional tillage paired row (9-27-9 cm) were able to compete with weeds more as compared to other rice planting methods resulting in lower weed density and weed biomass, enhanced rice growth and yield attributing characters and yield.

INTRODUCTION

In recent years, dry-seeded rice (DSR) has been introduced as an alternative to puddled-manually transplanted rice in India. At present, 23% of rice is direct-seeded globally (Rao *et al*. 2007). DSR needs only 34% of the total labour requirement and saves 29% of the total cost of transplanted crop (Ho and Romli 2000). However, heavy weed infestation is one of the major constraints in DSR causing severe yield losses especially in dry field conditions (Rao *et al*. 2007). Yield losses due to weeds varied from 40-100% in direct-seeded rice (Choubey *et al*. 2001). In dry-seeded rice, weed flora tends to be more diverse and weeds emerge in several flushes during the crop growth cycle.

Rice planting methods play an important role in influencing weed and crop growth and productivity. Mahajan and Chauhan (2011) observed that paired row planting pattern (15-30-15-cm row spacing) in DSR had a greater influence on weeds as compared to normal row planting system (23-cm row spacing). Paired row planting greatly facilitates weed suppression by maintaining rice plant's dominant position over weeds through modification in canopy structure. Roy *et al*. (2009) also reported that the yield of DSR can be enhanced with square planting (20 × 20 cm).

Chemical method of weed control is the most practical and cost-efficient (Bastiaans *et al*. 2008) and is an essential tools to control weeds in DSR. Most of the herbicides recommended for DSR are applied as pre-emergence to control weeds during initial period; however, a combination of herbicides may be more effective to control various flushes of weed. In general, herbicides used in DSR have a narrow weed control spectrum and do not provide season-long weed control. Azimsulfuron and ethoxysulfuron were found to effectively control a wide range of broad-leaf weeds and sedges (Walia *et al*. 2008), while pendimethalin was effective on grasses, and oxadiargyl on broad-leaf weeds (Ahmed and Chauhan 2014). The sequential application of pendimethalin and bispyribac sodium effectively controlled *Echinochloa* sp. and *Digitaria sanguinalis* while the control of *Eragrostis* spp. and *Leptochloa chinensis* was poor (Brar and Bhullar 2012). Singh *et*

al. (2015) reported 14-27% less rice grain yield with pendimethalin followed by bispyribac-sodium compared with the weed-free check due to biomass of weeds that escaped the herbicide applications. Mehta *et al*. (2010) reported good control of *E. crus-galli* with application of bispyribac-Na 30 g/ha, while azimsulfuron17.5 g/ha was effective on broad-leaf weeds and sedges including *Cyperus rotundus*. Therefore, for managing mixed type of weed flora, herbicides mixtures may be needed for broad-spectrum weed control. Hence, an experiment was conducted to study the effect of planting methods and weed management practices on weeds and the crop growth in dry-seeded rice.

MATERIALS AND METHODS

A field trial was conducted at Institute of Agricultural Sciences, Banaras Hindu University, Varanasi ($25^0$18'N latitude and $88^0$36'E latitude at an altitude of 129 metres above the mean sea level), Uttar Pradesh (India) during summer seasons of 2012 and 2013. Climatologically, the region has a subtropical climate and is subjected to extremes of weather conditions *i.e*., extremely hot summer and cold winter. The area also receives some winter showers due to western disturbances during December to February. The maximum temperature usually fluctuates between 22 °C and 40.7 °C while minimum temperature varied from 8.6-29.9 °C. Total rainfall of 715.8 mm and 1137.7 mm was received during rice crop seasons of 2012 and 2013, respectively.The soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction (pH 7.56) with low organic carbon content (0.43%) and available nitrogen (183.6 kg/ha), and medium in phosphorus (18.6 kg/ha) and potassium (218.9 kg/ha). Rice cultivar '*MTU 7029*' was direct-seeded and the experiments were laid out in a split plot design on 28th June 2012 and 26th June 2013 with 20 treatment combinations replicated thrice.

Main plot consisted of five planting methods treatments, *viz*. i) Conventional tillage normal spacing [row to row (R × R) -18 cm)]; ii) Conventional tillage square planting [(R × R-20 cm, plant to plant (P × P)-20 cm)]; iii) Conventional tillage paired row (9-27-9 cm); iv) Reduced tillage paired row (9-27-9 cm); v) Reduced tillage square planting (R × R -20 cm, P×P-20 cm) and sub-plot consisted of four weed management treatments, *viz*. weedy, two hand weeding (HW) at 20 and 40 DAS , pendimethalin 1 kg/ha pre emergence(1- 3 DAS) followed by (*fb*) azimsulfuron 17.5 g/ha +bispyribac 25 g/ha (tank mixed) at 15 DAS *fb* 1 HW at 40 DAS, oxadiagryl 50 g/ha pre-emergence(1- 3 DAS) *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha at 20 DAS *fb* 1 HW at 40 DAS.

The seed was sown manually in paired and square planting at appropriate planting geometry with the help of *Kudal* (local iron made tool fixed with wooden handle for furrow maker) whereas in conventional tillage plots, seeds were sown with zero till seed drill implement. In conventional tillage plots the seeds bed was prepared by deep ploughing followed by two harrowing. In reduced tillage plots the field was harrowed once followed by sowing of rice seeds. A uniform fertilizer dose of 120, 60 and 60 kg N, P_2O_5 and K_2O/ha in the form of urea, single super phosphate and muriate of potash was applied to each experimental unit. Half dose of nitrogen and full dose of phosphorus and potassium were applied as basal to rice crop at the time of sowing. The required quantity of herbicides were applied with manually operated knapsack sprayer fitted with flat-fan nozzle using spray volume 300 L water/ha. Weed density and bio-mass were recorded at 60 DAS and at harvest stages, with the help of a quadrate (0.5 x 0.5 m) placed randomly at two spots in each plot. All the biometrical observations on crop and weeds were observed as per the standard practices. The crop was harvested at full physiological maturity, sun-dried for a week and threshed manually. All the data were subjected to analysis of variance and treatment means were compared using LSD (p=0.05) (Gomez and Gomez 1984). The data on weed density and weed biomass were subjected to square-root ($\sqrt{X+1}$) transformation before statistical analysis to normalize their distribution.

RESULTS AND DISCUSSION

Effect on weed

Major weed species present in experimental field were *Cynodon dactylon* (4%), *Echinochloa colona* (21%), *E. crus-galli* (11%) among grasses; *Cyperus iria* (10%),*Cyperus difformis* (9%), *Fmbristylis miliacea* (2%) among sedges and *Ammania baccifera* (7%), *Caesulia axillaris*(12%), *Commelina benghalensis* (5%), *Eclipta alba* (3%) and *Ludwigia parviflora* (13%) among broad-leaved weeds and other minor weeds were approximately 3%.

The rice planting methods had significant effect on total weed density at 60 DAS and at harvest during both the years (**Table 1**). The minimum weed density was recorded under CT paired row method which was found significantly superior to CT normal spacing at 60 DAS. However, both treatments were at

par with each other, at harvest stage during both the years. Paired row planting might have facilitated weed suppression by maintaining rice plant's dominant position over weeds through modification in canopy structure. Similar findings were also reported by Mahajan and Chauhan (2011) wherein paired row spacing stressed weeds more as compared to conventional method of sowing. The maximum weed density was recorded under RT square planting method followed by CT square planting and RT paired row method during 2012 and it was at par during 2013 at 60 DAS. Nevertheless, at harvest stage, the maximum weed density was found in RT square planting method which was at par with CT square planting and RT paired row rice planting method during both the years. Amongst weed management treatment, the minimum weed density and biomass was recorded under two hands weeding, which was significantly superior over other weed management treatments during both the years. However, all the weed management treatments were superior to weedy which recorded lower density of weeds during both the years. Similar finding was reported by Rana *et al.* (2016)

At 60 DAS, the minimum weed biomass was recorded in CT paired row planting which was at par with CT normal spacing rice planting methods during both the years. However, at harvest stage, the minimum weed biomass was recorded in CT square planting which was significantly superior over rest of the methods during 2012 and it was at par during 2013. Further, at 60 DAS, RT square planting recorded the maximum weed biomass which was at par with CT square planting during both the years. However, at harvest stage, weed biomass was significantly higher in RT square planting than other rice planting methods during 2012. During 2013, RT square planting and CT square planting had statistically comparable weed biomass with each other.

The highest weed control efficiency (WCE) was recorded in CT paired row method followed by CT normal spacing at 60 DAS and at harvest stages (**Table 1**). Amongst weed management practices, highest WCE was recorded in two hand weeding treatment followed by pre- emergence application of pendimethalin 1.0 kg/ha followed by post-emergence application of azimsulfuron 17.5 g/ha+ bispyribac 25 g/ha at 15 DAS *fb* one HW. These results corroborated with previous findings of Mahajan *et al.* (2014), who reported lowest weed biomass in paired row planting coupled with sequential application of pendimethalin followed by bispyribac-sodium.

Table 1. Effect of rice planting and weed management methodson weed density, weed biomass, weed control efficiency of weeds (no./m^2) at 60 DAS and at harvest of dry-seeded rice

Treatment	Weed density (no./m^2)		Weed biomass (g/m^2)		Weed control efficiency (%)	
	2012	2013	2012	2013	2012	2013
Rice planting method at 60 DAS						
CT Normal Spacing(R × R -18 cm)	6.74(62)	6.94(63)	13.4(249)	13.7(250)	67.6	63.3
CT Square planting(R × R-20 cm, P × P-20 cm)	6.84(63)	7.15(66)	15.7(327)	15.8(333)	63.7	61.4
CT Paired Row(9-27-9 cm)	5.86(45)	6.30(49)	13.4(226)	13.4(227)	68.9	68.4
RT Paired Row(9-27-9 cm)	6.78(61)	7.13(68)	14.5(280)	14.7(286)	66.1	62.3
RT Square Planting(R × R -20 cm, P×P-20 cm)	7.24(67)	7.58(70)	16.4(365)	16.6(371)	62.0	54.7
LSD (p=0.05)	0.38	0.45	0.98	1.11		
Weed management at 60 DAS						
Pendimethalin *fb* azimsulfuron + bispyribac *fb* 1 HW	6.28(40)	6.50(42)	16.1(266)	16.4(270)	53.9	51.0
Oxadiagryl *fb* metsulfuron + chlorimuron *fb* 1 HW	7.01(49)	7.43(55)	17.8(322)	18.0(328)	43.9	44.1
Two hand weeding	1.38(2)	1.82(3)	0.7(0)	0.7(0)	99.1	100
Weedy	12.1(146)	12.3(152)	23.7(571)	23.9(576)	0.0	0.0
LSD (p=0.05)	0.36	0.41	0.74	0.90		
Rice planting method at harvest						
CT Normal Spacing(R × R -18 cm)	4.78(30)	5.31(35)	11.8(192)	12.0(199)	75.5	74.9
CT Square planting(R × R-20 cm, P × P-20 cm)	5.33(38)	5.80(43)	12.7(224)	13.0(233)	75.1	74.3
CT Paired Row(9-27-9 cm)	4.57(29)	5.18(34)	11.4(178)	11.6(185)	75.7	75.5
RT Paired Row(9-27-9 cm)	5.15(36)	5.64(41)	12.4(211)	12.6(218)	75.5	74.7
RT Square Planting(R × R -20 cm, P×P-20 cm)	5.74(43)	6.12(48)	13.2(241)	13.4(248)	74.1	73.5
LSD (p=0.05)	0.47	0.71	0.32	0.69		
Weed management at harvest						
Pendimethalin *fb* azimsulfuron + bispyribac *fb* 1 HW	4.43(19)	5.06(25)	12.8(165)	13.2(173)	65.6	64.7
Oxadiagryl *fb* metsulfuron + chlorimuron *fb* 1 HW	5.31(28)	5.83(34)	13.8(192)	14.2(201)	60.0	59.1
Two hand weeding	1.10(1)	1.59(2)	0.7(0)	0.7(0)	100	100
Weedy	9.61(92)	9.95(99)	21.9(480)	22.1(492)	0.0	0.0
LSD (p=0.05)	0.25	0.38	0.25	0.52		

DAS=Days after seeding; HW=hand weeding; CT=Conventional tillage; RT= Reduced tillage; Pendimethalin *fb* azimsulfuron + bispyribac *fb* 1 HW = Pendimethalin 1 kg/ha PE *fb* azimsulfuron 17.5 g/ha + bispyribac 25 g/ha 15 DAS *fb* 1 HW; Oxadiagryl *fb* metsulfuron + chlorimuron *fb* 1 HW = Oxadiagryl 50 g/ha (Pre.) *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha 20 DAS *fb* 1 HW

Effect on crop

Significantly, higher rice dry matter accumulation was recorded under CT normal spacing which was at par with CT paired row rice planting methods whereas RT paired row rice planting method resulted in lower dry matter accumulation (**Table 2**). This may be due to reduced competition by weeds in these treatments. CT paired row rice planting method registered the maximum number of tillers which was at par with RT paired row method. LAI was observed maximum under CT paired row rice planting method which was at par to CT square planting, CT normal spacing and RT paired row and significantly superior over RT square planting during both the years.

Amongst weed management treatments, two hand weeding had the maximum plant height, dry matter accumulation, number of tillers/m^2 and it was found significantly superior over rest of the treatments during both the years. Two hand weeding treatment had the maximum LAI which was at par to pendimethalin 1.0 kg/ha *fb* azimsulfuron 17.5 g/ha+ bispyribac 25 g/ha 15 DAS *fb* 1 HW and oxadiagryl 50 g/ha *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha 20 DAS *fb* 1 HW treatment. Tank mixture of herbicides had broadened the spectrum of weed control in such a way that each herbicide controls the weeds missed by other one as reported by Kumar and Ladha (2011). At the same time, pre-emergence application of herbicide followed by broad spectrum control of weeds by combination of herbicides and manual weeding might have controlled weeds appearing in several flushes, resulting in better performance of growth attributes in these treatments. Pendimethalin 1.0 kg/ha *fb* azimsulfuron 17.5 g/ha + bispyribac 25 g/ha 15 DAS *fb* 1 HW and oxadiagryl 50 g/ha *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha 20 DAS *fb* 1 HW treatment was significantly superior over the weedy for all the growth attributes during both the years. The lowest plant height was recorded in weedy check followed by oxadiagryl 50 g/ha *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha 20 DAS *fb* 1 HW.

Significantly higher number of panicles/m^2 was recorded under CT paired row followed by CT square planting rice planting methods. (**Table 3**) However, significantly higher number of grains per panicle was recorded under RT square planting which was at par with CT square planting and CT paired row planting. CT paired row rice planting method had the maximum test weight which was significantly superior to CT normal spacing.

Two hand weeding treatment resulted in longer panicle length which was at par to pendimethalin 1 kg/ha *fb* azimsulfuron 17.5 g/ha + bispyribac 25 g/ha 15 DAS *fb* 1 HW and oxadiargyl 50 g/ha *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ ha 20 DAS *fb* 1 HW and weedy during 2012. Two hand weeding treatment recorded the maximum number of panicles, number of grains per panicle and test weight followed by pendimethalin 1 kg/ha *fb* azimsulfuron 17.5 g/ha+ bispyribac 25 g/ha 15 DAS *fb* 1 HW treatment. All the weed management treatments showed significantly superior yield attributing characters as compared to weedy during both the years.

Effect on rice yield

Amongst rice planting methods, CT paired row method recorded the maximum rice grain and straw yields which was at par with CT normal spacing, CT square planting and RT paired row method and it was found significantly superior over RT square planting

Table 2. Effect of rice planting and weed management methods on dry-seeded rice plant height (cm), dry matter accumulation (g/running m), no. of tillers/m^2, leaf area index at 60 days after rice seeding

Treatment	Plant height (cm)		Dry matter accumulation (g/running m)		No. of tillers/m^2		Leaf area index	
	2012	2013	2012	2013	2012	2013	2012	2013
Rice planting method								
CT Normal Spacing(R × R -18 cm)	51.0	49.8	96.2	94.8	223.5	222.5	3.13	3.10
CT Square planting(R × R-20 cm, P × P-20 cm)	50.1	49.0	76.5	75.1	217.7	216.8	3.23	3.15
CT Paired Row(9-27-9 cm)	50.7	49.7	95.6	93.4	244.7	243.7	3.34	3.22
RT Paired Row(9-27-9 cm)	49.9	48.9	65.9	64.0	244.0	243.0	2.97	2.89
RT Square Planting (R × R -20 cm, P×P-20 cm)	49.6	48.7	69.8	68.2	207.2	206.3	2.48	2.41
LSD (p=0.05)	NS	NS	2.27	2.60	9.90	10.77	0.39	0.36
Weed management								
Pendimethalin 1.0 kg/ha (Pre.) *fb* azimsulfuron 17.5 g/ha + bispyribac 25 g/ha 15 DAS *fb* 1 HW	51.1	50.0	87.0	85.1	235.4	234.4	3.21	3.14
Oxadiagryl 50 g/ha (Pre.) *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha 20 DAS *fb* 1 HW	49.2	48.3	70.5	68.4	227.4	226.5	3.15	3.05
Two hand weeding	53.1	52.0	106.7	105.3	287.1	286.1	3.32	3.25
Weedy	47.7	46.6	59.0	53.7	159.8	158.8	2.43	2.37
LSD (p=0.05)	0.75	0.83	3.98	4.15	9.71	9.54	0.20	0.20

*DAS=Days after seeding; HW=Hand weeding; CT=Conventional tillage; RT= Reduced tillage

Table 3. Effect of rice planting and weed management methods on dry-seeded rice yield attributes and yield

Treatment	Panicle length (cm)		No. of panicles/m^2		No. of grains/panicle		Test weight (g)		Grain yield (t/ha)		Straw yield (t/ha)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Rice planting method												
CT Normal Spacing (R × R -18 cm)	24.1	24.6	413.7	410.6	115.0	113.7	23.5	23.2	5.8	5.6	8.4	8.2
CT Square planting(R × R-20 cm, P × P-20 cm)	25.2	25.0	427.7	420.8	116.9	115.6	23.3	23.0	5.7	5.5	7.7	7.5
CT Paired Row(9-27-9 cm)	24.7	24.4	481.0	473.7	115.8	114.5	24.2	23.8	5.9	5.7	9.0	8.8
RT Paired Row(9-27-9 cm)	24.9	24.6	382.3	376.3	109.7	108.4	22.2	21.9	5.7	5.5	8.4	8.2
RT Square Planting(R × R -20 cm, P×P-20 cm)	25.0	24.7	350.3	344.2	119.0	117.7	22.4	22.0	5.1	4.9	6.5	6.3
LSD (p=0.05)	NS	NS	17.8	18.2	3.90	4.84	0.6	0.6	.46	.37	1.59	1.6
Weed management												
Pendimethalin 1.0 kg/ha (Pre.) *fb* azimsulfuron 17.5 g/ha + bispyribac 25 g/ha 15 DAS *fb* 1 HW	25.1	24.8	446.7	441.9	125.2	123.7	23.2	22.9	6.5	6.4	8.1	7.9
Oxadiagryl 50 g/ha (Pre.) *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha 20 DAS *fb* 1 HW	24.5	24.2	407.7	401.1	114.7	113.4	22.0	21.7	6.0	5.8	8.3	8.1
Two hand weeding	25.2	24.9	474.4	467.7	131.9	130.6	25.0	24.7	7.2	7.0	8.7	8.5
Weedy	25.0	24.6	315.2	309.9	89.5	88.1	22.2	21.9	2.8	2.6	6.9	6.7
LSD (p=0.05)	0.44	NS	13.54	13.76	3.60	3.84	0.55	0.65	.37	.41	1.1	1.1

*DAS=Days after seeding; HW=hand weeding; CT=Conventional tillage; RT= Reduced tillage

method during both the years. (**Table 3**). Improved performance of growth and yield attributes in paired row planting might have resulted in realization of enhanced rice grain yield. Similar findings were also reported by Mahajan *et al*. (2014). The maximum rice grain yield (7.2 and 7.0 t/ha) was recorded under two hand weeding treatments during 2012 and 2013, respectively. Rice grain yield recorded in this treatment was followed by pendimethalin 1.0 kg/ha *fb* azimsulfuron 17.5 g/ha + bispyribac 25 g/ha 15 DAS *fb* 1 HW treatment (6.5 and 6.4 t/ha). Integration of herbicidal and manual weeding night have weed control and improved resulted in better performance of growth an yield attributes. The minimum rice grain yield (2.8 and 2.6 t/ha) was recorded under weedy treatment during first and second year, respectively. Two hand weeding treatment recorded the maximum straw yield which was at par with oxadiagryl 50 g/ha *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha 20 DAS *fb* 1 HW and pendimethalin 1 kg/ha *fb* azimsulfuron 17.5 g/ha+ bispyribac 25 g/ha 15 DAS *fb* 1 HW treatment.

REFERENCES

Ahmed Sand and Chauhan BS. 2014. Performance of different herbicides in dry-seeded rice in Bangladesh. *The Scientific World Journal*. 2014: Article ID 729418, 14 pages:http://dx.doi.org/10.1155/2014/729418.

Bastiaans L, Paolini R and Baumann DT. 2008. Focus on ecological weed management what is hindering adoption? *Weed Research* **48**: 481-491.

Brar HS and Bhullar MS. 2012. Dry-seeded rice productivity in relation to sowing time, variety and weed control. *Indian Journal of Weed Science* **44**: 193-195.

Choubey NK, Kohle SS and Tripathi RS. 2001. Relative performance of cyhalofop-butyl for weed control in direct seeded rice. *Indian Journal of Weed Science* **33**(3&4): 132-135.

Gomez KA and Gomez AA. 1984. *Statistical Procedures for Agricultural Research.* An International Rice Research Institute book, A Wiley-Inter science publication.

Ho and Romli. 2000. Impact of direct seeding on rice cultivation: Lessons from the Mudaarea of Malaysia In: *Proceedings Workshop on direct seeding*: *Research Strategies and Opportunities* held 25-28 January, 2000, Bangkok, Thailand.

Kumar, V and Ladha JK. 2011. Direct seeding of rice: Recent developments and future research needs, *Advances in Agronomy* **111**: 297-413.

Mahajan G and Chauhan BS. 2011. Effects of planting pattern and cultivar on weed and cropgrowth in aerobic rice system. *Weed Technology* **25**(4): 521-525.

Mahajan G, Poonia V and Chauhan BS. 2014. Integrated weed management using planting pattern, cultivar, and herbicide in dry-seeded rice in Northwest India. *Weed Science* **62**(2): 350- 359

Mehta R, Yadav DB, Yadav A, Punia SS, Malik RK and Mehta A. 2010. Weed control efficiency of bispyribac- sodium in transplanted and direct-seeded rice and its residues in soil, rice grain and straw. *Environment and Ecology* **28**(1A): 275-279.

Rana SS, Badiyala D, Sharma N, Kumar R, Thakur R, Kumar S and Pathania P. 2016. Herbicide combinations for weed management under direct-seeded rice in Himachal Pradesh. *Indian Journal of Weed Science* **48**(3): 266-271.

Rao AN, Johnson DE, Sivaprasad B, Ladha JK and Mortimer AM. 2007. Weed management in direct-seeded rice. *Advances in Agronomy* **93**: 153-255.

Roy HP, Salam MA, Islam MR, Ahammed KU, Akhter B and Khalequzzaman KM. 2009. Weed infestation and yield performance of *boro* rice in direct seeding method as influenced by green growth regulator and herbicides. *International Journal of Sustainable Crop Production* **4**(1): 83-90.

Singh M**,** Bhullar MS and Chauhan BS. 2015. Influence of tillage, cover cropping, and herbicides on weeds and productivity of dry direct-seeded rice**.** *Soil and Tillage Research* **147**: 39-49.

Walia US, Bullar MS, Nayyar S and Walia SS. 2008. Control of complex weed flora of dry seeded rice (*Oryza sativa* L) with pre and post emergence herbicides. *Indian Journal of Weed Science* **40**: 161-164.