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Crop establishment methods and weed management on growth and yield of dry direct-seeded rice

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ABSTRACT

A field study was undertaken to evaluate the crop establishment and weed management options for direct-seeded rice (DSR) in the Institute for Agricultural Sciences, BHU, Varanasi, India during rainy season in 2008 and 2009. The weed flora were grasses as *Echinochloa colona*, *Echinochloa crusgalli*, *Cynodon dactylon*, *Paspalum* spp., sedges as *Cyperus rotundus*, *Cyperus iria* and broad-leaved weeds like *Caesulia axillaris*. Data were recorded on weed dynamics, crop growth and yield of the direct-seeded rice crop. Rice established by zero-till DSR with 40 cm anchored residue had minimum density of grasses, sedges and broad-leaved weeds and dry weight at 60 DAS. Among weed management methods, use of pendimethalin 1000 g/ha (pre-em) *fb* azimsulfuron 35 g/ha at 15-20 DAS + one HW at 40 DAS proved to be most effective in minimizing the weed density, dry weight and weed persistence index (0.08 and 0.04) and in enhancing the weed control efficiency (72.04% and 76.77%). The maximum grain yield, straw yield and biological yield was found with application of pendimethalin 1000 g/ha (pre-em) *fb* azimsulfuron 35 g/ha at 15-20 DAS + one HW at 40 DAS, which was significantly superior to rest of the treatments during both the years of experimentation.

Key words: Crop establishment, Direct-seeded rice, Weed management, Weed persistence index, Zero-tillage

Dry direct-seeding is probably the oldest method of crop establishment. Historical accounts of rice cultivation in Asia indicate that, during its early period of domestication, rice used to be dry sown in a mixture with other crops that were established under the shifting cultivation system (Grigg 1974). In the 21st century, rising scarcity of agricultural land and water and continuing shortage of labour would maintain pressure for a shift towards direct seeding method in rice production system (Mortimer *et al.* 2005). The main driving forces of these changes are the rising wage rate, non-availability of labour and scarcity of water. Direct seeding offers certain advantage *i.e.* save labour, faster and easier planting helps in timely sowing, less drudgery, less water requirements, high tolerance to water deficit, often higher yield, low production cost and more profit, energy saving, better soil physical conditions for following crop (Balasubramanian and Hill 2002). Despite several advantages, various production obstacles are also encountered in direct-seeded rice in which heavy weed infestation is the major one.

Weeds cause heavy damage to direct-seeded rice (DSR) crop which can be to the tune of 5-100% (Kohle 1989). Manual removal of weeds is labour intensive, tedious, back breaking and does not ensure weed removal at critical stage of crop-weed competition due to non-availability of labours and sometimes bad weather condition which does not allow labours to move in the field. Thus, herbicides are considered to be an alternative/supplement to hand weeding (Singh *et al.* 2007). Herbicides are more effective in controlling the weeds besides reducing the total energy requirement for rice cultivation. Besides chemicals and manual weeding agronomic practices like, crop establishment by zero tillage or reduced tillage with residue retention play an important role in weed suppression and improving the yield. Hence, considering the importance the present investigation was undertaken to study the effect of different crop establishment and weed management methods on weed flora, crop growth and yield in direct dry seeded rice.

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MATERIALS AND METHODS

The study was undertaken during 2008 and 2009 at Institute of Agricultural Sciences, BHU, Varanasi, U.P., India. The soil of the experimental site was Gangetic alluvial having sandy loam in texture with pH 7.2. It was moderately fertile, being low in organic carbon (0.43%), available N (198 kg/ha) and medium in available P (24.6 kg/ha) and K (210 kg/ha). The experiment was laid out in split plot design with three crop establishment methods and nine weed management treatments in three replication. The treatments were, zero-till DSR, zero-till DSR with anchored resi-

due and reduced tillage DSR with zero till-drill. The weed management treatment included weedy check, weed free, hand weeding (20 and 40 DAS), glyphosate 1000 g/ha (pre-seeding) *fb* pendimethalin 1000 g/ha (pre-em), *fb* 2,4-D EE 500 g/ha at 25 DAS, pendimethalin 1000 g/ha (pre-em) *fb* 2,4-D EE 500 g/ha at 25 DAS + one hand weeding (HW) at 40 DAS, pendimethalin 1000 g/ha (pre-em) *fb* metsulfuron + cholorimuron 4 g/ha at 20 DAS + one HW at 40 DAS, pendimethalin 1000 g/ha (pre-em) *fb* azimsulfuron 35 g/ha at 15-20 DAS + one HW at 40 DAS, fenoxaprop with safener 56 g/ha + ethoxysulfuron 18 g/ha at 20-25 DAS + one HW at 40 DAS and bispyribac 25 g/ha at 20-25 one HW at 40 DAS in sub-plots. The crop establishment methods were kept in main plot whereas; weed management treatments adjust in sub-plots. Seeding was done with pre-sowing irrigation by zero-till drill machines in all the crop establishment methods. An uniform dose of 120 kg N + 60 kg P + 60 kg K + 5 kg Zn/ha was applied in all the treatments in the form of urea, DAP, MOP and $ZnSO_4$, respectively. Half of total N and full dose of P_2O_5, K_2O and Zn was applied as basal and remaining half dose of N was top dressed in two equal splits at active tillering and panicle initiation stage. Rice cv '*Sarjoo-52*' of 120-130 days duration was used as test variety. Dry seed of rice at 30 kg/ha was used for seeding by zero-till drill fitted with flatted roller. The total rainfall received during crop season was 1042.8 and 528.4 mm during 2008 and 2009, respectively. Distribution of rainfall was more uniform during first year as compared to second year in crop period. The crop received 2 and 4 irrigations during 2008 and 2009, respectively. Pre-emergence (just after sowing) and post-emergence (as per treatments) herbicides were applied with the help of a hand-operated knapsack sprayer fitted with flat-fan nozzle and water as a carrier at 600 litres/ha. Data on weed density were subjected to square root transformation ($\sqrt{x+0.5}$) before statistical analysis to normalize their distribution. The data were analyzed statistically as per standard method (Panse and Sukhatme 1978). Data on dry weight of weeds were recorded by cutting weeds at ground level, washed with tap water, sun dried first followed oven drying at 70 °C ± 2 for 48 hours and then weighed. To determine the effect of crop growth, data on initial plant population (m/row at 20 DAS), plant height (cm), tillers (m/row), plant dry matter (g/m row) recorded at harvest and leaf area index was recorded at 60 days after sowing. Weed control efficiency and weed persistence index was calculated using following formula.

$$\text{Weed control efficiency (WCE)} = \frac{(WD_C - WD_T)}{WD_C} \times 100$$

Where, WD_C is the weed density (number/m^2) in control plot; WD_T is the weed density (number/m^2) in treated plot; in both $WD_C$and WD_T; the unit should be same or uniform.

$$\text{Weed Persistence Index (WPI)} = \frac{\text{Weed population in treated plot}}{\text{Weed population in control plot}} \times \frac{\text{Weed dry weight in treated plot}}{\text{Weed dry weight in control plot}}$$

RESULTS AND DISCUSSION

Effects on weeds

Experimental field was infested with grassy (*Echinochloa colona*, *E. crusgalli*, *Paspalum* spp., *Cynodon dactylon*), sedges (*Cyperus rotundus* and C*yperus iria*), and broad-leaved weed (*Caexulia auxillaries*). Among the weed flora, averaged over two years, the maximum relative percentage was of *Echinochloa colona* (23.8, 24.5 and 23.4%), *Echinochloa crusgalli* (23.4, 24.0 and 22.9%), *Cyperus rotundus* (16.1, 15.7 and 16.2%) and *Caesulia axillaries* (7.8, 6.8 and 8.2%) in zero-till DSR, zero-till DSR with anchored residue and reduced till, respectively.

Weed density

The rice established with zero-till DSR with anchored residue had minimum density among crop establishment methods at 60 DAS. Maximum weed density was recorded under reduced till DSR followed by zero-till DSR (Table 1). All weed management treatments resulted in significant reduction in total weed density as compared to weedy check. The significant effect of establishment methods with anchored residue and herbicides in combination with hand weeding can be ascribed to the broad spectrum of weed control (Singh *et al.* 2006, Singh *et al*. 2007). Application of pendimethalin *fb* azimsulfuron + one HW 40 DAS showed maximum efficacy in minimizing all kinds of weed flora and proved significantly superior over all the weed management treatments. The next best treatment in this respect was pendimethalin 1000 g/ha (pre-em) *fb* 2,4-D EE 500 g/ha at 25 DAS + one HW at 40 DAS. The integration of post-emergence herbicide and hand weeding (HW) as fenoxaprop with safener 56 g/ha + ethoxysulfuron 18 g/ha at 20-25 DAS + one HW at 40 DAS and bispyribac 25 g/ha at 20-25 one HW at 40 DAS were less effective as compared to other weed control treatments in minimizing the density of weeds. This is due to the fact that field was infested with complex weed flora and these herbicides cannot control

Table 1. Effect of crop establishment methods and weed management on density of weeds (no./m^2), weed dry weight, WCE and WPI at 60 DAS

Treatment	Grasses		Sedges		Broad-leaved weeds		Weed dry weight (g)		Weed control efficiency (%)		Weed persistence index	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Establishment method												
Zero-till DSR	18.2 (380)	17.3 (344)	9.07 (99.0)	8.19 (82.3)	4.26 (20.6)	3.64 (15.6)	7.85 (70.2)	7.13 (57.5)	52.4	58.9	0.27	0.21
Zero-till DSR with residue	17.4 (347)	16.4 (310)	8.28 (83.4)	7.23 (66.6)	3.64 (15.0)	3.03 (10.6)	7.27 (59.8)	6.94 (54.4)	53.0	65.6	0.21	0.17
Reduced tillage DSR	18.6 (396)	17.7 (359)	9.51 (107)	8.70 (90.5)	4.53 (23.3)	4.05 (19.0)	7.92 (72.3)	7.33 (61.7)	50.8	57.9	0.30	0.24
LSD (P=0.05)	0.53	0.50	0.25	0.23	0.31	0.10	0.23	0.21	-	-	-	-
Weed management												
Glyphosate *fb* pendimethalin *fb* 2,4-D EE	18.4 (340)	17.2 (297)	8.58 (73.6)	7.24 (52.6)	4.17 (17.1)	3.45 (11.6)	7.51 (56.0)	7.03 (49.0)	57.8	68.2	0.19	0.14
Pendimethalin *fb* 2,4-D + one HW at 40 DAS	16.9 (286)	15.6 (243)	6.86 (47.2)	5.04 (26.1)	3.67 (13.1)	2.83 (7.71)	6.93 (47.5)	6.61 (43.3)	66.3	74.2	0.13	0.09
Pendimethalin *fb* metsulfuron + chlorimuron + one HW at 40 DAS	20.9 (435)	19.8 (393)	10.95 (119)	9.94 (98.6)	4.26 (17.7)	3.58 (12.3)	8.37 (69.5)	7.96 (62.9)	50.3	58.6	0.31	0.21
Pendimethalin *fb* azimsulfuron + one HW at 40 DAS	14.8 (218)	13.2 (176)	4.36 (18.7)	3.92 (15.4)	2.79 (7.73)	1.91 (3.69)	6.38 (40.3)	6.17 (37.5)	72.0	76.8	0.08	0.04
Fenoxaprop with safener + ethoxysulfuron + one HW	23.1 (534)	22.2 (491)	12.96 (168)	12.1 (147)	5.17 (26.8)	4.63 (21.4)	10.0 (100)	8.40 (70.1)	24.9	40.2	0.56	0.48
Bispyribac + one HW	22.3 (499)	21.4 (456)	12.28 (150)	11.4 (130)	4.71 (22.0)	4.10 (16.6)	9.49 (90.5)	8.16 (66.2)	34.7	46.1	0.47	0.39
Hand weeding (20 and 40 DAS)	19.9 (398)	18.9 (356)	10.20 (104)	9.11 (83.2)	5.04 (26.2)	4.52 (21.7)	7.83 (60.9)	7.48 (55.5)	62.6	63.9	0.25	0.16
Weedy check	25.7 (661)	25.0 (624)	13.68 (186)	12.9 (166)	6.80 (46.0)	6.40 (40.7)	11.9 (142)	11.7 (135)	0.00	0.00	1.00	1.00
Weed free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	100	100	0	0
LSD (P=0.05)	0.41	0.39	0.21	0.19	0.27	0.08	0.18	0.16	-	-	-	-

Data are subjected to square root transformation ($\sqrt{x+0.5}$); Data given in parentheses are original values; DAS - Days after sowing

initial flush of weeds and all three types of weeds like, grasses, sedges and broad-leaved weeds. Singh *et al*. (1999) and Yaduraju and Mishra (2004) also reported that control of initial weed emergence facilitates better environment for direct seeded rice crop.

Weed dry weight

Significant variation in total weed dry weight under different weed management and crop establishment methods was observed. Zero-till DSR with anchored residue had minimum weed dry weight and the maximum weed dry weight was recorded by reduced till DSR (Table 1). This might be due to the fact that zero-till DSR with anchored residue of wheat crop facilitates in minimizing the weed infestation through soil. Singh *et al.* (2007) also mentioned that previous crop residue provide soil cover helps to minimize the weed dry weight. Among weed management treatments, pendimethalin *fb* azimsulfuron + one hand weeding recorded the minimum weed dry matter followed by pendimethalin *fb* 2,4-D EE + one HW. The reason behind this integration of pre- and post-emergence herbicides along with manual weeding minimized the weed dry weight. Wallia *et al*. (2008) reported that integration of pre-emergence application of pendimethalin followed by post-emergence of azimsulfuron resulted in effective weed control. The maximum weed dry weight recorded in weedy plots in respect to other treatment. Among herbicidal treatments, fenoxaprop + ethoxysulfuron + one hand recorded maximum weed dry weight.

Weed control efficiency and weed persistence index

Weed control efficiency (WCE) varied significantly at 60 days after sowing under different weed control treatments (Table 1). Weed control efficiency recorded minimum in reduced tillage DSR while maximum in zero-till DSR with anchored residue plots. The data clearly showed the effect of keeping anchored residue in weeds management. Maximum weed control efficiency (100%) was found with weed free at 60 days after sowing. Whereas, in weed management treatments weedy plots contain minimum WCE. The maximum WCE is found in pendimethalin + *fb* azimsulfuron + one hand weeding. The reason of good control of weeds was because of pre-emergence application of herbicide which controled first flush of

grassy weeds and post application controled the sedges and broad-leaved weeds and one hand weeding helped to minimize the problem of remaining weeds in experiment. The integrated weed control appeared essential for raising direct-seeded rice (Gill 2008). This may be attributed to least competition as a result of effective suppression of sedges and dicot weeds thereby enabling plant to exhibit full potential in a competition free environment as evident by higher WCE in the said treatments. Similar results have been reported by Bahar and Singh (2004). Fenoxaprop + ethoxysulfuron + one hand weeding was not as effective as combined application of pre- and post-emergence herbicides. Weed persistence index showed the relevance of weed management on comparative basis (Table 1). Minimum weed persistence index recorded under zero-till DSR with anchored residue treatment (0.21 and 0.17) among crop establishment methods while, maximum in reduced tillage DSR (0.30 and 0.24). In weed management methods, minimum weed persistence index recorded under pendimethalin *fb* azimsulfuron + one hand weeding (0.08 and 0.04). The next treatment in this respect was pendimethalin *fb* 2,4-D EE + one HW at 40 DAS (0.13 and 0.09).

Effect on crop growth

Application of pre- and post-emergence herbicides did not show any phytotoxic symptoms on rice plant. Crop growth was variably recorded in the experiment on the basis of crop establishment and different weed management methods. Initial plant population recorded maximum in zero-till DSR with anchored residue (28.11 and 30.52 m/row) which is significantly superior over rest of the crop establishment methods. Zero-till DSR with anchored residue contains (6.7% and 7.6%) and (10.3 and 12.2%) more initial plant population over zero-till DSR and reduced tillage DSR during both the year (Table 2). This result occurred due to presence of residue (anchored or loose) conserve the moisture and inhibits the weed growth. Among the weed management methods pendimethalin *fb* azimsulfuron + one hand weeding recorded maximum initial plant population. Plant height was recorded at harvest is maximum under zero-till DSR with anchored residue but at par with zero-till DSR and reduced tillage DSR, respectively. Among the weed management methods, pendimethalin *fb* azimsulfuron + one hand weeding recorded maximum plant height. It is significantly superior over the rest of the treatment in first year (2008) while, at par with other treatments in second year (2009). Effective tillers recorded in per meter row length in the experiment varied with the stage to stage and treatment wise. During first year, effective tillers was maximum in zero-till DSR with anchored residue but at par with rest of the crop establishment methods while, in second year, zero-till DSR with anchored residue was significantly superior over rest of the treatments. Plant dry matter at harvest was observed significantly among the crop establishment methods. Zero-till DSR with anchored residue had recorded maximum plant dry matter production (g/m row) which is significantly superior over zero-till DSR and reduced tillage DSR treatments. Zero-till DSR with anchored residue produced (9.31% and 11.66%) and (9.32% and 11.28) more plant dry matter rather than zero-till DSR and reduced tillage DSR, respectively. These similar results are corroborated by Yadav and Singh (2006). In weed management methods, weed free showed the maximum crop height, tillers and crop dry matter production which is significantly superior over rest of the treatments.

Leaf area index of direct seeded rice increased with crop age and recorded at 60 days after sowing (Table 2). Among the crop establishment methods, zero-till DSR with anchored residue (3.87 and 3.97) attained maximum leaf area index rather than zero-till DSR and reduced till DSR during both the year. In weed management methods, maximum LAI were recorded under weed free (4.71 and 4.80) treatment and at par with the application of pendimethalin *fb* azimsulfuron + one hand weeding (4.53 and 4.70) during both the years and significantly superior over rest of the treatments. Similar results were also in agreement with Gill *et al*. (2006).

Effect on crop yield and harvest index

Rice established by zero-till DSR with anchored residue produced significantly higher grain yield than other two methods of establishment (Table 3). The maximum grain yield was recorded during both the years (4.56 and 4.78 t/ha) in zero-till DSR with anchored residue method which was 25.6% more than reduced till DSR and 16.2% more than zero-till DSR. Similar findings were also mentioned by Gill (2008) and Mishra *et al*. (2012). All the herbicidal treatments either applied in sequential combination with herbicides or with hand weeding significantly increased yield of rice as compared to weedy check during both the years of investigation. Among weed management methods, pendimethalin *fb* azimsulfuron + one hand weeding (5.45 and 5.54 t/ha) produced significantly maximum grain yield over rest of the treatments during the experimentation of both the years. Singh *et al*. (2010) reported that combination of azimsulfuron with pre-emergence herbicide produce significantly higher grain yield and straw yield. This is due to the fact that application of herbicides and manual weeding reduced the weed competition which enabled the direct seeded

Table 2. Effect of crop establishment methods and weed management on growth attributes in direct seeded rice

Treatment	Initial plant population (m/row at 20 DAS)		Plant height (cm)		Tillers (m/row)		Plant dry matter production (g/m row)		Leaf area index (at 60 DAS)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Establishment method										
Zero-till DSR	26.2	28.2	96.3	99.8	44.3	45.5	961	987	3.72	3.73
Zero-till DSR with residue	28.1	30.5	98.0	102	46.2	48.9	1050	1080	3.78	3.97
Reduced tillage DSR	25.2	26.8	95.8	98.9	43.9	44.6	941	970	3.87	3.72
LSD (P=0.05)	1.82	2.02	NS	NS	NS	3.23	67	69	0.27	0.26
Weed management										
Glyphosate *fb* pendimethalin *fb* 2,4-D EE	28.0	28.4	92.0	100	46.4	48.3	1013	1043	4.13	3.99
Pendimethalin *fb* 2,4-D + one HW at 40 DAS	29.1	28.7	98.2	103	48.7	50.2	1054	1089	4.36	4.43
Pendimethalin *fb* metsulfuron + chlorimuron + one HW at 40 DAS	25.0	27.2	98.1	98.2	42.2	44.9	964	980	3.72	3.62
Pendimethalin *fb* azimsulfuron + one HW at 40 DAS	30.1	34.1	103	106	55.2	55.3	1111	1163	4.53	4.70
Fenoxaprop with safener + ethoxysulfuron + one HW	23.7	26.1	91.7	94.4	38.4	37.6	913	921	3.04	3.24
Bispyribac + one HW	25.1	26.9	95.3	98.0	39.0	41.2	944	957	3.54	3.42
Hand weeding (20 and 40 DAS)	26.6	28.9	96.0	99.7	44.2	44.8	978	1001	3.88	3.79
Weedy check	19.7	19.8	91.8	91.2	29.3	35.0	739	772	2.19	2.28
Weed free	31.3	36.4	104	110	59.9	59.5	1140	1186	4.71	4.80
LSD (P=0.05)	1.10	1.16	3.90	4.11	1.88	1.93	40.36	41.47	0.16	0.16

DAS, Days after sowing

Table 3. Effect of crop establishment methods and weed management on grain yield straw yield, biological yield and harvest index

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Biological yield (t/ha)		Harvest Index (%)	
	2008	2009	2008	2009	2008	2009	2008	2009
Establishment methods								
Zero-till DSR	3.90	4.10	5.49	5.68	9.42	9.78	41.1	41.4
Zero-till DSR with residue	4.60	4.78	6.33	6.55	10.89	11.34	41.4	42.0
Reduced tillage DSR	3.60	3.76	5.11	5.23	8.75	8.99	41.0	41.2
LSD (P=0.05)	0.29	0.30	0.40	0.41	0.69	0.71	2.80	2.81
Weed management								
Glyphosate *fb* pendimethalin *fb* 2,4-D EE	4.40	4.58	5.96	6.18	10.36	10.76	42.5	42.5
Pendimethalin *fb* 2,4-D + one HW at 40 DAS	4.72	4.93	6.32	6.50	11.05	11.43	42.8	42.8
Pendimethalin *fb* metsulfuron + chlorimuron + one HW at 40 DAS	3.74	3.92	5.35	5.52	9.09	9.44	41.1	41.5
Pendimethalin *fb* azimsulfuron + one HW at 40 DAS	5.45	5.54	7.16	7.22	12.61	12.76	43.2	43.3
Fenoxaprop with safener + ethoxysulfuron + one HW	3.03	3.23	4.58	4.75	7.61	7.98	39.9	40.4
Bispyribac + one HW	3.29	3.52	4.89	5.07	8.18	8.59	40.2	40.9
Hand weeding (20 and 40 DAS)	4.00	4.17	5.59	5.88	9.59	10.06	41.7	42.0
Weedy check	2.03	2.19	3.65	3.76	5.68	5.95	35.7	36.8
Weed free	5.68	5.85	7.32	7.54	13.01	13.39	43.7	43.7
LSD (P=0.05)	0.17	0.18	0.24	0.24	0.41	0.42	1.69	1.70

rice plant for better utilization of nutrient and growth factors which ultimately resulted in higher grain yield. Same pattern was observed in respect of straw yield and biological yield. Maximum harvest index was noticed in zero-till DSR with anchored residue (41.38 and 42.05) among crop establishment methods while in weed management methods pendimethalin *fb* azimsulfuron + one hand weeding had the maximum harvest index.

It can be concluded that zero-till DSR with anchored residue with pendimethalin 1000 g/ha (pre-emergence) *fb* azimsulfuron 35 g/ha at 15 - 20 DAS + one HW at 40 DAS was found to be most effective for minimizing weed growth and maximizing crop growth and yield of direct-seeded rice.

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