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RESEARCH ARTICLE

Effect of crop establishment and weed management methods on weed dynamics and productivity of direct-seeded rice in middle Indo-Gangetic Plains

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ABSTRACT

A field experiment was conducted during rainy seasons of 2018 and 2019 at the ICAR-Research Complex for Eastern Region Patna, Bihar to evaluate the effect of crop establishment methods and weed management treatments on weeds and productivity of direct-seeded rice (DSR). The treatments consisted of three upland DSR establishment methods, *viz.* zero-till direct-seeded rice:(ZT-DSR); conventional-till (CT)-dry DSR (CTDSR) and CTDSR-dust mulching, and three weed pressure maintenance treatments including: low weed pressure: maintained with pre-emergence (PE) application of pendimethalin (1.0 kg/ha) at 2 days after seeding (DAS) followed by *(fb)* post-emergence (PoE) application of bispyribac–Na (30 g/ha) PoE at 20 DAS *fb* hand weeding (HW) twice at 30 and 50 DAS; medium weed pressure: maintained with pendimethalin (1.0 kg/ha) PE at 2 DAS *fb* bispyribac–Na (30 g/ha) PoE at 20 DAS, and high weed pressure: maintained with pendimethalin (1.0 kg/ha) PE alone, in upland DSR under the middle Indo-Gangetic Plains (MIGPs). The major weeds recorded with upland DSR were *Cyperus rotundus*, *Cynodon dactylon*, *Echinochloa colona*, *Brachiaria ramosa*, *Caesulia axillaris* and *Physalis minima*. Significantly the lowest relative weed abundance, weed density and biomass were recorded in CT-DSR-dust mulching compared to ZT-DSR and CTDSR. Among the weed management treatment, maximum weed suppression was recorded in low weed pressure in comparison to medium and high-weed pressure management practices. Significantly higher grain yield (2.14 t/ha) and net returns (₹ 20869/ha) were obtained with CT-DSR-dust mulching. Hence, it may be concluded that for better rice productivity and weed management in upland DSR, CT-DSR-dust mulching with low weed pressure maintenance is the most potential and viable practices under the MIGPs.

Keywords: Direct-seeded rice, Dust mulching, Establishment method, Rice productivity, Weed management, Weed pressure

INTRODUCTION

Direct-seeded rice (DSR), in place of conventional puddled transplanting (PTR), provides an opportunity for labour and water savings, and has gained momentum in certain states of India. Globally, nearly 23% of rice area is under DSR (Rao *et al*. 2007). Weed control is challenging in DSR due to severity and diversity of the weed infestation, absence of standing water layer to suppress weed at rice emergence, and no seedling size advantage of rice over weed seedlings as both emerge simultaneously (Hassan and Upasani 2015). Many a times, it is very difficult to differentiate between grassy weeds like *Echinochloa* spp. and rice plants during early stages of growth (Rao 2021). Hand weeding is the most common method to suppress the weeds in rice. Scarcity of labor for timely weeding and high labor cost are major limitations of hand weeding. Herbicides are an alternative/supplement to hand weeding (Kumar *et al*. 2016). Although several pre-emergence herbicides provide good control of weeds but due to continuous use of such herbicides, a shift in weed flora and evolution of herbicide resistant weeds has been reported (Nazir *et al*. 2020). The sequential application of pre- and post-emergence herbicides is essential for broad-spectrum weed control. The present study was conducted to evaluate the effect of DSR establishment methods and weed management practices on weed management and rice productivity.

MATERIALS AND METHODS

This study was carried out for two consecutive years from 2018 and 2019 at the ICAR-Research Complex for Eastern Region, Patna, Bihar (25°30'N,

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85^{o}15'E, 52 m above mean sea levels). Total rainfall received during cropping season (June–October) was 715.7 and 911.5 mm in 2018 and 2019, respectively. Soil was clay loam (42% sand, 35% silt and 23% clay), low in organic carbon (0.46%), and N (212 kg/ha), and medium in available P (26 kg P/ha) and K (215 kg K/ha). Soil test was based on samples taken from upper 30 cm depth just prior to start of experimentation.

Experiment was laid out in a split-plot design with three replications. Three DSR establishment methods, *viz*. zero-till direct-seeded rice (ZTDSR); conventional-till direct-seeded rice (CTDSR) and CTDSR-dust mulching were assigned to main-plots and three weed control treatments in sub-plots include: low weed pressure [maintained by pre-emergence application (PE) of pendimethalin (1.0 kg/ha) at 2 DAS followed by *(fb)* post-emergence application *(*PoE*) of* bispyribac-Na (30 g/ha) at 20 DAS) *fb* HW twice at 30 and 50 DAS], medium weed pressure [maintained by pendimethalin (1.0 kg/ha) PE at 2 DAS *fb* bispyribac-Na (30 g/ha) PoE at 20 DAS] and high weed pressure [maintained by pendimethalin (1.0 kg/ha) alone at 2 DAS]. In ZTDSR, rice was directly drilled with Happy seeder without any field preparation. In CTDSR, field was prepared by ploughing twice with cultivator followed by rotavator to get a fine tilth for ensuring easy movement of seed drill on dry soil. Dry seeding was done in both ZTDSR and CTDSR, where as in CTDSR-dust mulching, field was first irrigated and prepared at proper tilth, followed by sowing of seed with available soil moisture. In this case rice seeds were primed with water for overnight before sowing. We hypothesize that the dry upper soil surface reduces weed seed germination, but available soil moisture at lower depth allows rice seeds to germinate. Rice variety '*Naveen*' (115 days duration) was sown using seed rate of 25 kg/ha on 6th June in 2018 and 11th June in 2019, respectively in rows, 20 cm apart. To ensure the proper seed germination, seed priming (over-night soaking of seed followed by drying in shades before sowing) was done before crop sowing. Seeds were treated with carbendazim 2 g/kg seed before sowing.

Recommended dose of fertilizer (120, 60, 40 and 5 kg/ha N, P, K and Zn) was applied. Total quantity of P, K and Zn was applied basal, whereas nitrogen was applied in 3-equal split-each at basal, maximum tillering and panicle initiation. Weed density and biomass were recorded at 60 DAS with help of a quadrat (0.5 × 0.5 m) placed randomly at 4 places in each plot. Weeds within each quadrat were uprooted, separated species wise and counted. Weed samples were oven dried before weighing at 70^{0}C till constant weight (biomass) was achieved. Weed species abundance is the number of individuals per species. Relative species abundance was calculated by dividing the number of species from one group by total number of species from all groups. Observation on crop growth parameters, *viz*. plant height (cm), total leaves/hill (nos.) total green leaves/hill (no.), tillers/m^2, effective tillers/m^2, days to 50% flowering (nos.), days to physiological maturity (nos.) and yield attributes like panicle length (cm), grains/panicle (nos.), filled grains/panicle (nos.), 1000-grain weight (g), grain yield (t/ha) and crop productivity (kg/ha/day) were recorded at harvest. Sampling was done from an area of 25 m^2 in each plot to determine the above ground total dry weight (total biomass). Biomass (sum of straw dry weight and grain dry weight) was calculated using grain and total dry weight of each treatment. Crop was threshed manually; grains were cleaned and weighed for yield and expressed in t/ha. Data on weed density were subjected to square root transformation ($\sqrt{x+0.5}$) before statistical analysis to normalize their distribution. Data were analyzed statistically as per standard method (Panse and Sukhatme 1978). Test of significance of treatment differences was done on the basis of t-test. Significant difference between treatments mean was compared with the critical differences at 5% levels of probability.

RESULTS AND DISCUSSION

Effect of weather

There were large variations in rainfall intensity and distribution patterns during the experimentation. Average of mean rainfall during rice season (June–October) was 715.7 mm and 911.5 mm in 2018 and 2019, respectively. Rainfall was distributed quite uniformly during 2018, but during 2019, crop faced early and late-season drought during cropping periods resulted in decline crop yields. Mean monthly maximum and minimum temperature ranged between 28.7-37.4 and 16.1-28.2 ^{0}C during 2018 and 2019, respectively **(Figure 1)**.

Relative density (%) of weeds

Major weed associated with DSR were *Cyperus rotundus*, *Cynodon dactylon*, *Echinochloa colona*, *Brachiaria ramosa*, *Caesulia axillaris* and *Physalis minima* **(Table 1)**. Relative density varied according to crop establishment methods and weed management practices. Maximum relative abundance of *C. dactylon*, *E. colona*, *B. ramosa*, *C. axillaris* and *P. minima* was recorded in ZTDSR followed by CTDSR. While the maximum relative abundance of

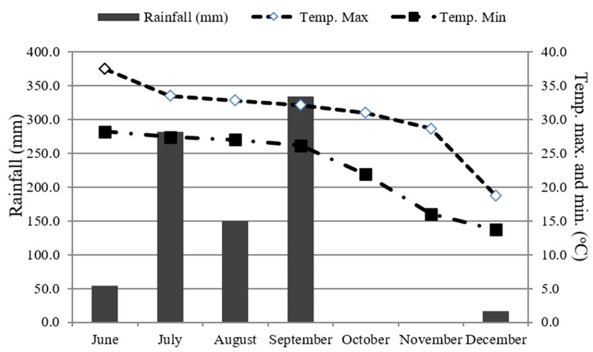

Figure 1. Mean monthly rainfall and temperature during rice growing period

Trianthema portulacastrum was noted with CTDSR-dust mulching followed by CTDSR. Higher weed density in ZTDSR during first year might be due to presence of more weed seeds on soil surface, which could have promoted greater and quick emergence of weed species that require light to germinate or smaller seeds that cannot emerge after burial by tillage. The highest relative density of *C. rotundus, C. dactylon, E. colona*, *T. portulacastrum*, *C. axillaris* and *P. minima* was recorded in low weed pressure followed by medium weed pressure. The highest relative density of *B. ramosa*, *C. axillaris* and other weeds was recorded with high weed pressure.

Weed density and biomass

Among the crop establishment method, CTDSR-dust mulching was the most effective in reducing density of *C. rotundus*, *C. dactylon*, *E. colona*, *B. ramosa*, *C. axillaris* and *P. minima* in comparison to other methods (**Table 2**). Significantly the lowest density of *T. portulacastrum* was found in ZTDSR followed by CTDSR. The lowest total weed biomass (14.5 g/m^2) was also recorded with CTDSR-dust mulching, and it was significantly superior to other crop establishment methods. Most of the weed seeds remain on top soil layer. Dust-mulching creates dry zone in top-soils resulting in lower germination of weed seeds due to moisture stress (Nazir *et al*. 2020).

Table 1. Effect of direct-seeded rice (DSR) establishment methods and weed management treatments onrelative density of weeds (%) (pooled data of 2 years)

Treatment	*Cyperus rotundus*	*Cynodon dactylon*	*Trianthema portulacastrum*	*Echinochloa colona*	*Brachiaria ramosa*	*Caesulia axillaris*	*Physalis minima*	Other weeds
Rice establishment method								
ZTDSR	29.6	5.66	15.8	4.02	13.3	24.3	4.75	2.54
CTDSR	32.6	2.48	27.6	2.49	11.4	17.7	3.89	1.93
CTDSR- dust mulching	23.7	1.38	53.0	1.13	5.0	12.8	1.99	1.12
Weed management treatment								
Low weed pressure	31.9	3.83	29.6	3.35	7.6	18.5	4.03	1.39
Medium weed pressure	31.6	3.65	29.7	2.68	9.2	18.2	3.74	1.37
High weed pressure	26.2	3.40	29.0	2.63	12.4	20.3	3.67	2.61

Table 2. Effect of direct-seeded rice (DSR) establishment methods and weed management treatments on weed density and biomass (pooled data of 2 years)

Treatment	Weed density (no./m^2)									Total weed biomass (g/m^2)
	Cyperus rotundus	*Cynodon Dactylon*	*Trianthema portulacastrum*	*Echinochloa colona*	*Brachiaria ramosa*	*Caesulia axillaris*	*Physalis minima*	Other weeds	Total	
Rice establishment method										
ZTDSR	8.49	3.74	6.19	3.16	5.24	7.42	3.46	2.28	15.4	18.1
	(73.4)	(14.0)	(39.3)	(9.92)	(32.9)	(60.3)	(11.75)	(6.28)	(248)	(338)
CTDSR	7.59	2.16	7.01	2.22	4.48	5.50	2.71	1.91	13.3	16.2
	(59.0)	(4.52)	(50.0)	(4.50)	(20.6)	(32.1)	(7.08)	(3.50)	(181)	(273)
CTDSR-dust mulching	5.99	1.58	8.67	1.45	2.75	4.28	1.86	1.46	12.1	14.5
	(36.3)	(2.10)	(81.3)	(1.73)	(7.60)	(19.7)	(3.06)	(1.73)	(153)	(216)
LSD (p=0.05)	0.34	0.39	0.74	0.42	0.61	1.59	0.47	0.37	1.0	1.4
Weed management treatment										
Low weed pressure	5.84	2.00	5.67	1.94	2.85	4.24	2.09	1.35	10.3	13.3
	(34.4)	(4.11)	(31.9)	(3.62)	(8.25)	(19.9)	(4.34)	(1.50)	(108)	(179)
Medium weed pressure	7.78	2.48	7.29	2.28	4.14	5.80	2.66	1.71	13.8	15.7
	(60.3)	(6.95)	(56.7)	(5.11)	(17.65)	(34.7)	(7.12)	(2.61)	(191)	(253)
High weed pressure	8.45	3.00	8.93	2.62	5.58	7.16	3.20	2.59	16.6	19.8
	(73.9)	(9.56)	(81.9)	(7.45)	(35.2)	(57.4)	(10.38)	(7.39)	(283)	(395)
LSD (p=0.05)	0.25	0.30	0.51	0.32	0.46	1.31	0.30	0.29	0.71	1.0

*Data subjected to square root transformation ($\sqrt{x+0.5}$), Values in parentheses are original; Low weed pressure: pre-emergence application (PE) of pendimethalin (1.0 kg/ha) at 2 DAS followed by *(fb)* post-emergence application (PoE) *of* bispyribac–Na. (30 g/ha) at 20 DAS fb HW twice (30 and 50 DAS); Medium weed pressure: application of pendimethalin (1.0 kg/ha) PE. at 2 DAS *fb* bispyribac-Na (30 g/ha) PoE at 20 DAS; High weed pressure: pendimethalin (1.0 kg/ha) PE at 2 DAS

Among the weed management practices, low weed pressure maintenance treatment recorded significantly lower infestation of all weeds compared to medium and high weed pressure. In previous studies, Nazir *et al.* (2020) reported lowest weed biomass with sequential application of pendimethalin PE *fb* azimsulfuron PoE. Bispyribac-Na + azimsulfuron PoE would be a potential herbicide combination if both grassy and broadleaved weeds are present in field. These results were in close conformity with the findings of Singh *et al.* (2017) and Saha *et al.* (2021).

Rice growth, yield attributes, grain yield and economics

Rice growth, yield attributes and grain yield were significantly influenced by the crop establishment methods and weed management treatments (**Table 3** and **4**). Maximum plant height (105.2 cm), days to 50% flowering (88.3), days to physiological maturity (119), total green leaves/hill (61.5), tillers/m^2 (127.7) and other yield attributes, *viz.* panicle length (26.0 cm), grains/panicle (205.4), 1000-grain weight (22.8 g), rice grain yield (2.14 t/ha) and crop productivity (18.6 kg/ha/day) were recorded in CTDSR-dust mulching due to lesser crop-weed competition, followed by CTDSR. The lowest values of these parameters were recorded in ZTDSR. Dust-mulching conditions enabled crop to make the maximum use of inputs for crop growth, and thereby for formation and development of yield attributes. Similar findings were also reported by Saha *et al.* (2021).

Among the weed management practices, growth attributes *i.e.,* plant height (104.2 cm), days to 50% flowering (87.5), days to physiological maturity (120.7), total green leaves/hill (63.5), tillers/m^2 (161.3) and other yield attributes, *viz.* panicle length (25.5 cm), grains/panicle (181.5) and 1000-grain weight (22.6 g), grain yield (2.88 t/ha) and crop productivity (25.1 kg/ha/day) were significantly higher in low weed pressure management practices compared to medium and high weed pressure due to lower infestation of weeds in low and medium weed pressure compared to high weed pressure which reduced the crop-weed competition for nutrients and moisture supply, resulting in proper pollination and seed setting in rice(Kumar *et al.* 2020).

Table 3. Effect of direct-seeded rice (DSR) establishment methods and weed management treatments on rice growth attributes (pooled data of 2 years)

Treatment	Plant height (cm)	Days to 50% flowering (no.)	Days to physiological maturity (no.)	Total leaves/hill (no.)	Tillers/ m^2 (no.)	Panicle length (cm)	Grains/ panicle (no.)	1000-grain weight (g)
Rice establishment method								
ZTDSR	95.0	79.8	110.3	35.2	66.2	17.9	130.6	19.2
CTDSR	99.6	83.7	114.8	47.7	121.1	21.6	134.7	21.1
CTDSR-dust mulching	105.2	88.3	119.0	61.5	127.7	26.0	205.4	22.8
LSD (p=0.05)	2.2	1.8	3.2	5.8	10.0	1.6	18.5	1.2
Weed management treatment								
Low weed pressure	104.2	87.5	120.7	63.5	161.3	25.5	181.5	22.6
Medium weed pressure	99.1	83.2	116.8	50.6	80.0	21.6	159.6	21.4
High weed pressure	96.5	81.1	106.6	30.3	73.7	18.5	129.8	19.2
LSD (p=0.05)	1.9	1.6	2.3	3.4	3.8	1.0	7.6	0.9

Table 4. Effect of direct-seeded rice (DSR) establishment methods and weed management on rice yields and economics (pooled data of 2 years)

Treatment	Grain yield (t/ha)			Cost of cultivation (x10^3 ₹/ha)	Gross returns (x10^3 ₹/ha)	Net returns (x10^3 ₹/ha)	Crop productivity (kg/ha/day)	Economic efficiency (₹/ha/day)
	2018	2019	Pooled					
Rice establishment methods								
ZTDSR	1.82	1.17	1.50	31.01	42.57	11.44	13.0	100
CTDSR	2.03	1.56	1.80	36.71	50.04	13.33	15.6	116
CTDSR-dust mulching	2.34	1.93	2.14	38.70	59.57	20.87	18.6	182
LSD (p=0.05)	0.20	0.34	0.27	2.44	6.40	7.89	2.3	69
Weed management practices								
Low weed pressure	3.18	2.57	2.88	34.76	75.71	40.95	25.1	40949
Medium weed pressure	2.65	1.48	2.07	34.94	52.83	17.78	18.0	17778
High weed pressure	0.36	0.61	0.49	36.74	23.65	-13.09	4.2	-13086
LSD (p=0.05)	0.17	0.27	0.22	1.81	4.59	5.59	1.9	5589

Low weed pressure: pre-emergence application (PE) of pendimethalin (1.0 kg/ha) at 2 DAS followed by (*fb*) post-emergence application (PoE) of bispyribac–Na. (30 g/ha) at 20 DAS *fb* HW twice (30 and 50 DAS)], Medium weed pressure: application of pendimethalin (1.0 kg/ha) PE. at 2 DAS *fb* bispyribac-Na (30 g/ha) PoE at 20 DAS); High weed pressure: pendimethalin (1.0 kg/ha) PE at 2 DAS

Table 5. Interaction effect of direct-seeded rice (DSR) establishment methods and weed management treatments on rice grain yield (pooled data of 2 years)

Weed pressure/Rice establishment method	ZTDSR	CTDSR	CTDSR-dust mulching	Mean
Low weed pressure	2.21	2.93	3.49	2.88
Medium weed pressure	1.83	1.96	2.43	2.07
High weed pressure	0.46	0.50	0.50	0.48
Mean	1.50	1.80	2.14	
			SEm±	LSD (p=0.05)
Direct-seeded rice (DSR) establishment method (E) at same weed pressure			0.13	0.38
Weed pressure (W) at same/different crop establishment method (E)			0.12	0.34
Rice establishment method (E)			0.07	0.27
Weed pressure (W)			0.08	0.22
ExW			0.13	0.38

Low weed pressure: pre-emergence application (PE) of pendimethalin (1.0 kg/ha) at 2 DAS followed by (*fb*) post-emergence application (PoE) of bispyribac–Na. (30 g/ha) at 20 DAS fb HW twice (30 and 50 DAS)], Medium weed pressure: application of pendimethalin (1.0 kg/ha) PE. at 2 DAS fb bispyribac-Na (30 g/ha) PoE at 20 DAS); High weed pressure: pendimethalin (1.0 kg/ha) PE at 2 DAS

The interaction effect between crop establishment method and weed management for grain yield clearly indicated that crop establishment methods have their effects on yield when weeds are controlled effectively (low and medium weed pressures). CTDSR with dust mulching under low weed pressure provided the maximum grain yield (3.49 t/ha). There was no response of crop establishment methods under high weed pressure due to very poor grain yield obtained during both the years (**Table 5**). Results of current research are in congruity with previous reports of superior weed control in DSR with pendimethalin PE *fb* bispyribac-Na PoE (Mahajan *et al*. 2009). In spite of higher cost of cultivation, net returns (₹ 20869/ha) were significantly higher with CTDSR-Dust mulching compared to ZTDSR (**Table 4**), due to higher grain yield. Among the weed management treatments, low weed pressure resulted in maximum net returns. High weed pressure resulted in to net loss of ₹ 40949/ha.

Thus, it may be concluded that growing of rice in CTDSR-dust mulching along with pendimethalin (1.0 kg/ha) PE at 2 DAS *fb* bispyribac-Na (30 g/ha) PoE at 20 DAS *fb* HW twice at 30 and 50 DAS is better options to manage weeds and improve rice productivity under rainfed ecosystem of middle Indo-Gangetic plains.

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