



Productivity and profitability of direct-seeded rice under varying establishment methods and weed management practices

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ABSTRACT

A field experiment was conducted at Banaras Hindu University, Varanasi (2016–17) to evaluate the effect of crop establishment and weed management practices on productivity, economics and resource-use efficiency of direct-seeded rice (DSR). The treatments included three crop establishment methods, viz. Zero-tillage-DSR+*Sesbania* co-culture (ZT-DSR+SCC), ZT-DSR+residue+*Sesbania* co-culture (ZT-DSR+R+SCC) and Conventional till-DSR+*Sesbania* co-culture (CT-DSR+SCC) assigned to main-plots and five weed management practices, viz. WMP₁- pendimethalin (1000 g/ha) *fb* bispyribac-sodium (25 g/ha) 20 days after sowing (DAS), WMP₂-pendimethalin (1000 g/ha) *fb* pyrazosulfuron (30 g/ha) 20 DAS+1 hand weeding (HW) 45 DAS, WMP₃- pendimethalin (1000 g/ha) *fb* chlorimuron+metsulfuron (4+4 g/ha) 20 DAS+1 HW 45 DAS, WMP₄- Weed-free and WMP₅- Weedy check assigned to sub-plots. The experiment was laid-out in a three-time replicated split-plot design. Results showed that, ZT-DSR+R+SCC recorded higher growth parameters, such as dry matter accumulation (DMA), leaf area index (LAI), yield attributes and enhanced grain yield, net return and water productivity by 16.9, 61.9 and 20% and 11.0, 69.7 and 10.3% during 2016 and 2017, respectively over CT-DSR+SCC. Among weed management practices, pendimethalin (1000 g/ha) *fb* chlorimuron+metsulfuron (4+4 g/ha) 20 DAS+1 HW 45 DAS recorded higher DMA, LAI, yield attributes and finally enhanced grain yield, net returns and water productivity by 31.9, 39.2 and 33.3% and 35.7, 36.6 and 37.5% during 2016 and 2017, respectively over weedy check. Hence, ZT-DSR+R+SCC along with pendimethalin (1000 g/ha) *fb* chlorimuron+metsulfuron (4+4 g/ha) 20 DAS+1 HW 45 DAS could be adopted for higher yield, net returns and resource-use efficiency of DSR.

Keywords: Direct-seeded rice, Herbicide, *Sesbania*, Zero-tillage

Direct seeded rice (DSR) cultivation offers multiple benefits over conventional transplanted rice (TPR) including less requirement for labour, water, etc., returns higher or similar economic productivity, facilitates soil health buildup and also emits lesser amount green-house gases (GHGs), particularly methane (Farooq *et al.* 2011). Moreover, rice – wheat cropping system practised on more than 10 m ha area in India, timely sowing of wheat crop after DSR could be possible as DSR matures 7–10 days earlier than the conventional TPR. Generally, conventional tillage (CT) is practised to raise DSR crop throughout the diverse rice production ecologies, which requires higher cost of repeated tillage operations and renders the soil susceptible to erosion and other forms of degradation. In contrast, zero-tillage (ZT) envisages sowing in a single pass resulting in

a considerable saving of fuel, energy and manual power and reduces GHGs emission. Moreover, residue retention and *Sesbania* brown manuring could be exploited to further reduce weed population, minimizing crop-weed competition, finally leading to higher yield and economic return (Verma *et al.* 2016). Yet, the success of DSR is often constrained by severe infestation of diverse weeds, posing longer crop-weed competition for growth factors, consequently causing greater loss of crop yield (Dass *et al.* 2017). The yield losses in DSR would be as high as 80% under un-checked weed condition (Mahajan *et al.* 2009). As weeds have variable growth habits and life cycles so no single method can effectively control weeds in all situations (Dass *et al.* 2015). Although, the use of herbicides is considered as the most practical and feasible way of coping up with weed problem, but the use of a single herbicide molecule may not be able to effectively check the growth of diverse weed flora possessing varying growth patterns and competitive ability, encountered in DSR (Singh *et al.* 2007). However, a suitable combination of herbicides of different mode of action and time of application can be chosen in addition to manual HW for greater control of weeds leading to higher yield and monetary return in DSR (Rao *et al.* 2007). Hence,

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the current investigation was undertaken to find out the most productive and remunerative crop establishment methods and weed management practices for DSR.

MATERIALS AND METHODS

The field experiment was conducted during rainy seasons of 2016 and 2017 at Banaras Hindu University, Varanasi, U.P. (25° 18'N latitude, 83° 03'E longitude and at an elevation of 128.93 m). Experimental site falls under semi-arid to sub-humid climate and received a total of 1094.8 and 641.4 mm rainfall during 2016 and 2017, respectively. Experimental field was sandy clay loam in texture having a pH of 7.9 and 0.43% organic carbon. The experiment was set in a split-plot design and replicated thrice. The treatments consisted of 15-combinations of 3 crop establishment methods: zero-tillage-DSR+*Sesbania* co-culture (ZT-DSR+SCC), ZT-DSR+residue+*Sesbania* co-culture (ZT-DSR+R+SCC) and conventional tillage-DSR+*Sesbania* co-culture (CT-DSR+SCC) allocated to main-plots and 5-weed management practices (WMP): WMP₁- pre-emergence application of pendimethalin (1000 g/ha) *fb* bispyribac-sodium (25 g/ha) 20 DAS, WMP₂- pre-emergence application of pendimethalin (1000 g/ha) *fb* pyrazosulfuron (30 g/ha) 20 DAS+one hand weeding (1 HW) 45 DAS, WMP₃- pre-emergence application of pendimethalin (1000 g/ha) *fb* chlorimuron+metsulfuron (4+4 g/ha) 20 DAS+1 HW 45 DAS, WMP₄- Weed free and WMP₅- Weedy check allotted in sub-plots. Thus, there were 45-experimental plots each of 12 m² (4 m × 3 m size). ZT and CT plots were prepared separately. Rice variety Rajendra Kasturi was manually sown at 20 cm row spacing at 40 kg/ha during the last week of July and harvested in the first week of November. The crop was fertilized with 120 kg N, 60 kg P₂O₅ and 40 kg K₂O/ha through urea, single super phosphate and muriate of potash. Full dose of P₂O₅ and K₂O and half of the N was applied basally at the time of sowing and remaining half of the N was top-dressed in two equal splits of 30 kg each at active tillering and panicle initiation stages. Rice residue (4 t/ha) was applied in the respective treatments 3 DAS. *Sesbania* seeds were sown at 25 kg/ha in between the rice rows; *Sesbania* was knocked-down by spraying 2, 4-D at 0.5 kg/ha 40 DAS. Herbicides like-pendimethalin, bispyribac-sodium, pyrazosulfuron and chlorimuron+metsulfuron were sprayed using a spray volume of 500 L/ha and HW was also done as per treatment. For weed-free treatment, HW was done as and when required. As rainfall was sufficient in the 1st year of investigation, no irrigation was applied. During 2nd year of study, the crop was irrigated twice.

For determining dry matter accumulation (DMA), samples from 50 cm row length were taken by cutting the plant from ground level and sun-dried for 2–3 hours and later oven-dried at 65⁰ C till the constant weight was achieved. The dry-weights were recorded using an electrical balance. The samples cut for measuring DMA were also used for determining leaf area index (LAI) using a digital leaf area meter. Effective tillers were counted by placing a quadrat

of 50 × 50 cm² area at two random spots in each plot and expressed as number/m². Randomly five panicles from each plot were taken and from them panicle-weight, panicle-length and grains/panicle were determined. For determining grain yield, crop was harvested from net-plot after leaving aside border area of 50 cm on each side of the plot, carefully bundled, tagged and brought to the threshing floor, left there for sun-drying separately. The individual bundle was weighed after complete drying and then threshed; produce from each plot was then converted into kg/ha. Treatment-wise cost of cultivation was computed considering market price of each input and other operational costs while, gross returns were computed based on market price of rice grain and straw prevailing during study years. Net return was obtained by subtracting cost of cultivation from the gross return. B: C ratio was calculated dividing gross returns by cost of cultivation. Production efficiency (PE) and monetary efficiency (ME) were calculated by dividing grain yield with crop duration and net returns, respectively. Water productivity (WP) was calculated dividing grain yield with total water-use (Dass and Chandra 2013a). All data were analyzed as per the standard procedure for “Analysis of Variance” (ANOVA) as described by Rana *et al.* (2014). The significance of treatments was tested by ‘F’ test at 5% level of probability. Treatment means were compared using critical difference (CD).

RESULTS AND DISCUSSION

Growth parameters: Crop establishment method, ZT-DSR+R+SCC recorded higher DMA and LAI as compared to ZT-DSR+SCC and CT-DSR+SCC during both years. Higher growth parameters in ZT-DSR+R+SCC might be due to better initial establishment, lower weed infestation and favourable environment for crop growth. Similar, results were also found by Dahipahle and Singh (2018). On the contrary, CT-DSR+SCC recorded significantly lower DMA and LAI due to higher crop-weed competition owing to more infestation of weeds. However, among weed management practices, WMP₃ recorded higher DMA and LAI followed by with WMP₂ and WMP₁, respectively. Higher growth parameters in WMP₃ could be due to the fact that crop under this treatment had suffered comparatively less competition from weeds for nutrients, moisture, space and light owing to greater control of weeds. This result was in accordance with the findings of Singh *et al.* (2014).

Yield attributes: Significantly higher number of effective tillers/m², panicle-length, panicle-weight, grains/panicle and 1000-grain weight were recorded in ZT-DSR+R+SCC than ZT-DSR+SCC and CT-DSR+SCC during both study years (Table 1). Higher yield attributes in ZT-DSR+R+SCC could be due to higher crop growth, better partitioning of photosynthates from source to sink as a result of higher nutrient uptake (Dass and Chandra 2013a) owing to lower crop-weed competition (Sutalia and Singh 2017). Among weed management practices, WMP₃ recorded maximum number of effective tillers/m², grains/panicle, panicle-weight, panicle-length and 1000-grain weight followed

Table 1 Effect of crop establishment methods and weed management practices on dry matter accumulation, leaf area index and yield attributes of DSR

Treatment	Dry matter accumulation/ row at harvest (g/m row length)		Leaf area index at 90 DAS		Effective tillers/ m ²		Panicle length (cm)		Panicle weight (cm)		Grains/ panicle		1000-grain weight (g)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
<i>Crop establishment method</i>														
ZT-DSR+SCC	211	191	3.85	3.50	215	204	23.5	22.4	2.52	2.43	216	205	13.5	12.9
ZT-DSR + R + SCC	234	212	4.87	4.43	223	212	24.1	22.9	2.62	2.50	217	207	13.6	12.9
CT-DSR + SSC	200	183	4.35	3.96	206	196	23.4	22.2	2.47	2.30	202	192	12.9	12.2
SEm±	8.3	8.6	0.04	0.06	4.6	4.4	0.18	0.17	0.03	0.03	3.6	3.5	0.16	0.15
CD (P=0.05)	22.3	23.2	0.12	1.80	12.8	12.1	0.49	0.47	0.07	0.06	10.1	9.6	0.44	0.42
<i>Weed management practice</i>														
WMP ₁	212	192	4.10	3.72	197	187	23.4	22.1	2.53	2.39	201	194	13.2	12.6
WMP ₂	220	200	4.40	3.99	216	205	23.5	22.3	2.52	2.40	212	201	13.3	12.6
WMP ₃	221	201	4.90	4.45	220	209	24.0	22.8	2.62	2.41	219	208	13.4	12.7
WMP ₄	238	215	5.45	4.95	246	233	24.1	22.9	2.63	2.49	224	212	13.6	12.9
WMP ₅	200	189	2.96	2.68	195	185	23.2	22.1	2.36	2.26	205	191	13.1	12.5
SEm±	6.4	5.5	0.12	0.12	2.9	2.8	0.20	0.19	0.03	0.03	4.3	4.1	0.11	0.10
CD (P=0.05)	11.6	10.8	0.43	0.39	6.1	5.8	0.40	0.38	0.07	0.06	8.9	8.5	0.23	0.12

by WMP₂ and WMP₁. Higher yield attributes in WMP₃ could be because the pre-emergence and post-emergence applications of herbicides supplemented with manual HW considerably reduced crop-weed competition enabling crop to make maximum use of inputs like-nutrients, moisture, sunlight and space, etc. for crop growth finally leading to better formation and development of yield attributes.

Yield: Significantly higher grain yield was recorded in ZT-DSR+R+SCC compared to ZT-DSR+SCC and CT-DSR+SCC during both study years. Higher yield in ZT-DSR+R+SCC could be due to higher crop growth and development, improvement in yield attributes and better translocation of photosynthates from source to sink (Dass and Chandra 2013a) as a result of greater weed control. Lower grain yield was recorded under CT-DSR+SCC because of poor crop growth and yield attributes due to higher crop-weed competition. Among the weed management practices, WMP₃ recorded higher grain yield followed by with WMP₂ and WMP₁. Higher grain yield in WMP₃ resulted from higher crop growth, marked improvement in DMA and yield attributes due to greater weed control. The lower yield recorded under weedy check was attributed due to maximum crop-weed competition and poor yield attributing characters as a result of abundance of weeds.

Production efficiency and water productivity: Maximum PE and water

productivity (WP) were recorded in ZT-DSR+R+SCC due to higher yield under this treatment (Fig 1). The lower PE and WP recorded in CT-DSR+SCC owed to lower yield during both years of experimentation. Among the weed management practices, WMP₃ recorded maximum PE and WP (Fig 2) as a result of higher yield in this treatment followed by WMP₂ and WMP₁.

Economics and monetary efficiency: ZT-DSR+R+SCC recorded higher cost of cultivation, gross return (GR), net return (NR) and monetary efficiency (ME) than the ZT-DSR+SCC and CT-DSR+SCC (Table 2). Higher cost of cultivation in ZT-DSR+R+SCC was due to additional investment on residue and its application cost, whereas higher GR and NR in this treatment attributed to higher yield leading to higher ME over other treatments. The next best treatment was ZT-DSR+SCC, which recorded

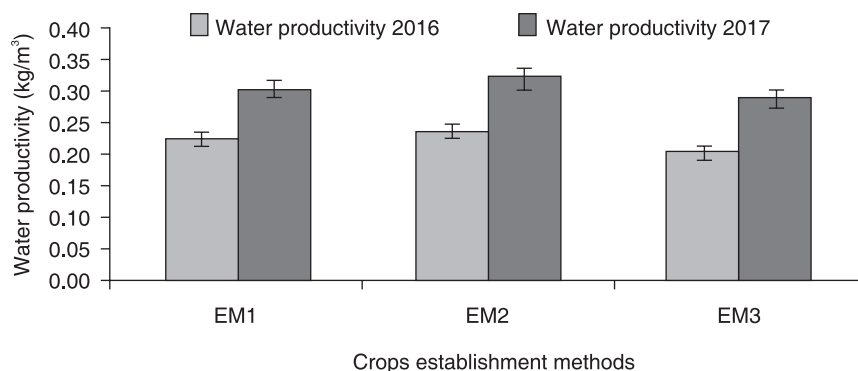


Fig 1 Effect of crop establishment methods on water productivity of DSR.

Table 2 Effect of crop establishment methods and weed management practices on yield, economic and monetary efficiency of DSR

Treatment	Grain yield (kg/ha)		Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		B:C ratio		PE (%)	PE (%)	ME (%)	ME (%)
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
	<i>Crop establishment method</i>													
ZT-DSR +SCC	2472	2324	44799	47403	75110	71080	30311	23677	1.68	1.50	19.8	18.6	8.16	9.82
ZT-DSR +R+SCC	2610	2447	49883	52487	85496	80351	35613	27864	1.71	1.53	20.9	19.6	7.33	8.78
CT-DSR + SSC	2233	2205	48153	50757	70147	67177	21994	16420	1.46	1.32	17.9	17.6	10.15	13.43
SEm±	78	74	377	432	378	471	94	94	0.01	0.02	-	-	-	-
CD(P= 0.05)	234	220	1047	1199	1050	1309	262	262	0.03	0.05	-	-	-	-
<i>Weed management practice</i>														
WMP ₁	2395	2261	43948	46142	75628	69743	31680	23601	1.72	1.51	19.2	18.1	7.56	9.58
WMP ₂	2457	2348	46858	50502	76877	71972	30019	21470	1.64	1.43	19.7	18.8	8.18	10.94
WMP ₃	2606	2522	47508	51002	82900	77320	35392	26318	1.74	1.52	20.9	20.2	7.36	9.58
WMP ₄	2760	2638	63314	64158	87323	86772	24009	22614	1.38	1.35	22.1	21.1	11.50	11.67
WMP ₅	1976	1858	36434	39275	61865	58542	25431	19267	1.70	1.49	15.8	14.9	7.77	9.64
SEm±	41	39	377	432	378	471	94	94	0.01	0.02	-	-	-	-
CD (P= 0.05)	127	119	778	892	780	973	195	195	0.02	0.04	-	-	-	-

Cost of cultivation=common cost + treatment cost

Cost of paddy grain ₹ 1700/100 kg; Cost of paddy straw ₹ 500/100 kg

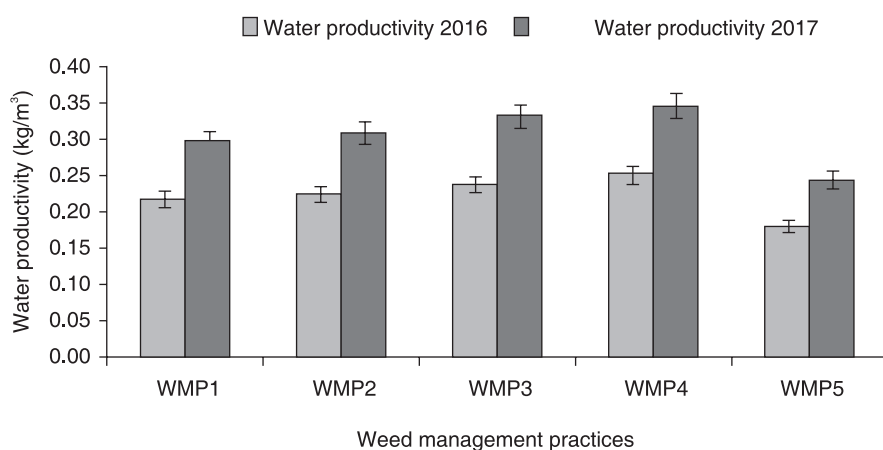


Fig 2 Effect of weed management practices on water productivity of DSR.

comparatively lower cost of cultivation and higher GR, NRs and ME. However, minimum cost of cultivation and GR and NR were recorded in CT-DSR+SCC. Similar results have also been reported by Paliwal *et al.* (2017). Among the weed management practices, WMP₃ recorded maximum cost of cultivation, GR and NR and ME followed by with WMP₁ and WMP₂. Higher GR and NR in WMP₃ was due to higher yield which, in turn, led to greater ME.

The results of the study showed that zero-till direct-seeded rice+*Sesbania* co-culture (ZT-DSR+R+SCC) recorded higher growth parameters, yield attributes, yield, net returns and water productivity than other crop establishment methods. Among weed management practices, application of pendimethalin (1000 g/ha) *fb* chlorimuron+metsulfuron (4+4 g/ha) 20 DAS+1 HW 45 DAS was best in terms of rice growth, productivity and resource-use efficiency.

Hence, establishment method ZT-DSR+R+SCC and weed management practice, pendimethalin (1000 g/ha) *fb* chlorimuron+metsulfuron (4+4 g/ha) 20 DAS+1 HW 45 DAS could be adopted for obtaining higher yield, net returns and resource-use efficiency in DSR.

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