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Productivity, economics and resource conservation perspectives of direct seeded rice method of establishment: Evidence from Chhattisgarh

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Abstract
Over the past few decades, several parts of rice-growing regions in India have shifted from the transplanted rice establishment method and broadcasting method to the direct-seeded rice (DSR) establishment method. Unlike the transplanting method of establishment, the DSR establishment method can reduce soil erosion, slow the loss of organic matter, and lessen the degradation of soil's physical properties. For this reason a field experiment was conducted at research cum instruction farm of IGKV Raipur during 2016 and 2017 *kharif* season to evaluate the effects of different crop-establishment methods of rice on machine parameter, yield and yield parameters of rice; cost economics under different methods of rice establishment; and analyse the energy requirement of different crop-establishment methods of rice. The combined effect of tillage and seeding treatment under different tillage and sowing methods of rice has been evaluated. In the experiment of dry sowing of rice there were five tillage treatments with two sowing methods as combination was evaluated. In case of wet sowing of rice there were five tillage treatments with only one sowing method as combination was evaluated with randomized block design. The Labour saving of 15.4 and 8 per cent in DSR was observed as compared to mechanized transplanting and broadcasting method of rice establishment during both the years respectively. Tillage and crop establishment methods had a significant effect on rice yields. Yield of DSR was significantly higher (8-10%) than transplanting and broadcasting during both the years. The maximum cost of cultivation was noted under transplanted rice followed by broadcasting rice. The optimum desired seed bed for seeding rice was found under tillage treatment DT_3 and the optimum planting bed for transplanting rice was found under treatment WT_2 in terms of machine parameter, yield attributes, cost economics and energy uses. When compared to transplanted rice, a labour saving of 15-16 per cent (overall) was observed in DSR during both the years. The B: C ratio was highest in direct seeded rice (DSR) in DT_3 treatment (2.65) as compared to DT_1 broadcasting sowing (2.05) and WT_2 transplanted rice (1.60).

Keywords: Rice establishment method, transplant rice (TR), direct seeded rice (DSR), energy input-output, machine performance, field capacity, cost economics

Introduction

Rice (*Oryza sativa* L.) is cultivated on about 153 mha area in the world (9% of total cultivated area) and provides the stapple food of about half of the world population. In our country, rice is cultivated under area of 43.95 million hectare with a production level of 104.80 million tonnes and a yield of approximately 2390 kg/ha (Agricultural Statistics at a glance- 2015). The output of Indian rice grew from 53.6 million tonnes in 1980 to 110-115 million tonnes in 2015-16. Rice plays an essential role in the food security of the country and is the backbone of Indian agriculture. It is very popular in Chhattisgarh due to its versatile characteristics of suitability and adaptability with good market price. Rice crop is grown in Chhattisgarh through different methods (biasi, direct seeding in line, transplanting and lehi). All these methods adopted according to availability of resources (water, labour and machines for sowing) with the farmers. Biasi or bushenening, after usual field preparing, is essentially a process of transmitting seeds onto dry or wet soils. Rice plants and weeds develop up to 30-40 days concurrently and then ploughing (Single or cross) is performed in the presence of 10 cm of water in the standing rice crop. This activity is called Biasi and is carried out by wooden plough or biasi plough drawn from cattle. The conventional Biasi approach gives poor performance, resulting in high-cost delayed activity. The rice plants are placed erect after ploughing or service of biasi plough and gap filling is conducted within 3-4 days of biasi operation by local manual transplanting method. During the process, the majority of weeds are buried in soil.

The chalai process is regarded as the system of standing rice plants and eliminating weeds in the soil. The rice crop is sown in the shortest possible time under the biasi method of rice cultivation. Weeding is carried out at a low cost. The soil becomes soft and partly puddled, which enhances the capacity of retain water.

Puddling is carried out as it prevents water loss by percolation (churning the soil under saturated conditions), encourages the weed control (Killing weeds, burying weed seeds and retaining anaerobic conditions that discourage weed germination), and makes the soil soft for rice transplantation. There is however a need to switch to modern establishment method with far lower labour requirements than manual transplantation with growing labour shortages and expense. This can be accomplished by converting to mechanical transplantation or direct seeding, which also allows for quicker planting/seeding and improved standing of crops. The production of methods involving puddling as a prerequisite procedure has several disadvantages including higher tillage prices, adverse effects on soil structure for upland crops grown in rotation with rice and high water requirements for crop establishment. The analysis reveals that the irrigation water required for puddling differs from 100 mm to 544 mm. The culture of wetland rice thereby kills the structure of the soil and produces a poor physical condition for the next *rabi* season crop.

Transplanting of rice is either performed by manually or mechanically. Transplanting rice seedlings by manually is most common practice among Indian farmers. (Singh and Vatsa, 2006) [6] stated that the transplanting is done with mechanical transplanter seedlings are transplanted at uniform depth and spacing thereby get establishment faster producing more number of tillers (16.8 tillers hill^{-1}) when compared to manual transplanting. Gangwar *et al*. (2008) [1] opined that effect of different rice establishment methods on yield of rice crop and stated that yield of rice under mechanical transplanting and manual transplanting was statistically at par however, the grain yield was differ significantly better in mechanical transplanting under puddled condition higher being recorded in mechanical transplanting under nonpuddled condition. Vasudevan *et al.* (2014) [11] stated that transplanting of paddy seedling with suitable mechanical transplanter seems to be most appropriate avenue as it save much of the labour requirement minimizes drudgery and attains optimum plant density that contributes to high productivity.

Conventional tillage and crop establishment *i.e*. broadcasting and transplanting is the most input intensive process in an agro-system and, therefore, more efficient alternatives are urgently needed. Potential solutions includes a shift from intensive tillage to no or reduced tillage and/or from manual transplanting to direct seeded rice (DSR). Direct-seeding is cost-effective, can save water through earlier rice crop establishment, and allows early sowing of wheat, chickpea (Ladha *et al*., 2003a; Singh *et al*., 2003) [5, 7]. Keeping in view, present study was conducted at research cum instruction farm of IGKV Raipur during 2016 and 2017 *kharif* season to evaluate the effects of different crop-establishment methods of rice on machine parameter, yield and yield parameters of rice; cost economics and analyse the energy requirement of different crop-establishment methods of rice.

Materials and Methods

Experimental site: The experimental site was situated at the Research Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh). It is located at Longitude 81.36^0 E and Latitude 21.16^0 N in the in the central part of Chhattisgarh, respectively, at an altitude of 298.86 meters above the mean sea level.

Agro-climate condition: Raipur comes under the seventh agro-climatic zone of India in terms of environment and it is classified as sub-humid with hot summer and cold winter (eastern plateau and hills). 1400 mm an average annual rain fall it receives, precipitated primarily (85%) during the period of June to September. The south west monsoon is the source of rains. During the winter and sometimes during the summer months, a few showers even arrive. May is the warm, and the coolest month of the year is December. During the summer, the weekly maximum temperature increases to 46°C and the minimum temperature during the winter season reaches as low as 6°C. During the months of June to October, the atmospheric humidity is relatively high from mid-June to March; air moisture changed between 70 to 90 per cent and June to July wind speed is from 6 – 10 km h^{-1}.

Treatments: The rice experiment was planned under direct seeded and transplanted system by choosing different combination of tillage implements and their passes. The sowing/planting was also planned in such a way that the both traditional and improved practices responses may be assessed. The selections of implements were done on the basis of review and prevailing farmer's practices. During *Kharif* two experiments were conducted *viz*. Study on tillage and sowing methods for direct seeded rice cultivation by using five tillage treatments with combination of two sowing methods; Study on wet tillage with one method of rice transplanting. In this experiment, five different tillage treatments and sowing/transplanting methods were studied for direct seeded and transplanted rice cultivation as the case may be. The treatments and details of tillage and crop establishment methods are summarized in Table 1.

Table 1 Treatment combination for rice establishment methods

Tillage and sowing practices			
Treatment	**Dry tillage (DT)**	**Treatment**	**Wet tillage (WT)**
DT_1	Cultivator x 2 +Broadcasting +Biasi by traditional animal drawn plough	WT_1	Cultivator x 1 + Rotavator x 1 + Transplanter
DT_2	Cultivator x 2 + Rotavator x 1 + broadcasting +Biasi by traditional animal drawn plough	WT_2	Cultivator x 2 + Rotavator x 1 + Transplanter
DT_3	Cultivator x 2 + Leveling x 1 + DSR DRILL	WT_3	Cultivator x 1 + Rotavator x 2 + Transplanter
DT_4	Cultivator x 2 + Rotavator x 1+ DSR DRILL	WT_4	Cultivator x 2 + Levelling+ Transplanter
DT_5	Rotavator x 2 + DSR DRILL	WT_5	Rotavator x 2 + Transplanter

Seeding and seed rate: Rice variety IGKV-R1, was sown in nurseries at seed rate of 40 kg ha^{-1} for mechanized puddled transplanting on 5th July during both years. Mechanized transplanting was done after 15 days of nursery sowing. Seed rate of 60 kg ha^{-1} was used for direct seeding and seeding was done at a spacing of 20 cm × 5 cm using a paddy DSR sowing machine on 20th June in both the years. Seed rate of 80 kg ha^{-1} was used for broadcasting sowing of rice on 20^{th} June in both the years.

Fertilizer application: A fertilizer dose of 100 kg N, 60 kg Pa and 20 kg K ha^{-1} was applied in all the treatments. In transplanted rice treatments 1/3 N and full dose of P and K fertilizers were applied at the time of puddling, whereas, in treatments DSR sowing 1/3 N and full dose of P and K were placed at a depth of 5 cm using DSR drill at the time of seeding. Remaining 2/3 N was applied in two equal splits at 21 and 50 days after sowing (DAS).

Weed management: To control weeds in experimental plot, combination of hand/mechanical and chemical weeding was carried as per standard practices and duration in all treatments of rice crop. The weeding operation done in line with manually operated Ambika paddy weeder in DSR and TR.

Yield and yield attributes:
Yield attributing parameters i.e. total number of panicles m^{-2}, number of grains $panicle^{-1}$ and 1000-grain weight and grain yield $plot^{-1}$ were recorded using $1m^2$ quadrate from three places in each plot at different stages of observation. At maturity, rice was harvested manually 10 cm above ground level and threshing was also done manually. DSR plots were harvested on October 27 during 2016 and October 28 during 2017, whereas, mechanized transplanting TR was harvested on November 25, during both the years.

Machine performance: The field evaluation of DSR machine was done by taking consideration of field capacity, efficiency, row spacing, hill distance, no. of hills/m^2, no. of missing hills/m^2, fuel consumption, cost of operation, labour requirement and payback period of the machine. Similarly field evaluation of mechanized transplanter was done by taking consideration of field capacity, efficiency, row spacing, fuel consumption, cost of operation, labour requirement.

Labour use: Human labour uses were recorded in rice crop for each treatment in each field operation, *viz*. tillage, seeding, irrigation, fertilizer and pesticide application, weeding, harvesting and threshing. For human labour, 8 hours were considered equivalent to one-man day.

Economic analysis: Cost of cultivation of various treatments was estimated on the basis of approved market rates for inputs by taking into account cost of seed, fertilizer, herbicides, pesticides, hiring charges of human labour and machines for different field operations. Gross returns were calculated on the basis of market rates (Rs. 1470 q^{-1} for 2016 and Rs. 1550 q^{-1} for 2017).

Energy analysis: Input energy requirement was calculated by considering energy from all source as human, diesel, seed, fertilizer, pesticide, tractor, machinery, irrigation, seed etc during all the operations of paddy cultivation whereas, output energy was calculated by taking into account energy from grain and straw under different treatments as prescribed by Panesar (2002) [4].

Data analysis: All the data on yield and yield parameters of rice, economics and energy were analyzed for one way analysis of variance (ANOVA) under randomized block design. For each character analysed, normal mean error (SEm+) and critical differences (C.D.) were worked out at the 5 percent stage to determine the difference between means. Unless indicated otherwise, differences were considered significant only when $P<0.05$.

Results and Discussion

Grain yield and yield components: Different tillage and crop establishment method had a significant effect on yield attributes of rice crop. With respect to method of establishment statistically significant weight of panicles was recorded in dry tillage of direct sowing of rice (DSR) during both the years. Lower panicle weight was recorded in transplanted rice (TR) over other establishment methods during both the years (Table 2). The result reveal that dry tillage and wet tillage rice sowing treatment were having statistically similar number of sound grains $panicle^{-1}$ but direct seeded dry tillage rice (DSR) were superior over wet tillage transplanted rice (TR) during both the years (Table 2). There was no any significant difference in test weight of grain due to different dry tillage methods of sowing during both the years. As regards to various method of transplanted rice, significantly higher test weight was recorded in wet tillage WT_1 transplanted rice during both the years, however, it was at par with DT_4 and DT_3 during year 2016 and 2017. Minimum test weight was noticed in the dry tillage dry sowing of rice treatment DT_1 during both the years.
Tillage and crop establishment method had a significant effect on rice grain yields. Grain yield differed significantly due to different tillage and sowing methods of rice. Dry tillage direct seeded rice treatment (DT_3) produced maximum grain yield of 57.5 q ha^{-1} and 50.0 q ha^{-1} during 2016 and 2017, respectively which was statistically similar to transplanting WT_2 (52 and 48.75 q ha^{-1} during 2016 and 2017, respectively) (Table 2). Minimum grain yield (43.75 and 35.25 q ha^{-1} during 2016 and 2017, respectively) was harvested in broadcasting DT_2. The higher values of yield attributes were obtained with higher moisture regimes. Favourable moisture condition makes the soil nutrients in available form and it keeps alive photosynthesis. In general during second year yield of both dry sowing and transplanted rice showed numerically low as compared to first year because in second year crop was suffered from stress during its critical period due to low rainfall during grain filling stage. Gong *et al*. (2013) reported that the grain filling period of rice is critical to the formation of rice grain yield and its quality, whereas the air temperature in this period has significant effects on the rice grain filling.

Table 2: Yield attributes of rice under both dry and wet tillage crop establishment methods

Treatment	Panicle weight (g)			Sound grains panicle^{-1}			Test weight (g)			Yield (q ha^{-1})		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Dry tillage and sowing treatment												
DT_1	2.27	1.95	2.11	161.00	150.67	155.83	22.43	21.77	22.1	44.83	42.16	43.49
DT_2	2.1	1.90	2	158.67	124.33	141.5	22.73	22.23	22.48	43.75	35.25	39.5
DT_3	3.15	2.63	2.89	166.00	162.33	164.16	24.20	24.30	24.25	57.5	50	53.75
DT_4	2.68	2.47	2.57	162.00	147.33	154.66	24.00	24.53	24.26	48.66	38.5	43.58
DT_5	2.93	2.50	2.71	159.67	150.67	155.17	23.83	23.73	23.78	46	34.16	40.08
SEm±	0.06	0.10	0.08	5.46	12.22	8.84	0.39	0.46	0.425	1.9	2.8	2.35
CD (P=0.05)	0.21	0.33	0.27	17.79	39.87	28.83	1.28	1.53	1.405	6.5	9.1	7.8
Wet tillage and transplanting treatment												
WT_1	2.63	2.31	2.47	158.00	161.33	159.66	24.27	24.30	24.28	49.33	45.33	47.33
WT_2	2.86	2.27	2.565	159.00	151.00	155	24.20	23.37	23.78	52	48.75	50.37
WT_3	2.62	2.17	2.395	160.00	132.33	146.16	23.77	22.70	23.23	50.33	49.17	49.75
WT_4	2.54	2.26	2.4	152.67	154.67	153.67	23.10	23.90	23.5	45.66	45.25	45.45
WT_5	2.59	2.27	2.43	157.33	152.67	155	22.77	22.60	22.68	47.33	46.25	46.79
SEm±	0.37	0.11	0.24	6.19	5.64	5.915	0.30	0.37	0.335	4.65	3.2	5.24
CD (P=0.05)	1.21	0.38	0.795	20.1	18.38	19.24	1.00	1.21	1.105	12.18	10.7	11.44

Machine performance: The average field capacity of DSR machine in all treatments was found to be 0.56 ha h^{-1} with efficiency of 78.33% (Table 3). The number of plants per meter square was 45 in DSR machine as compared to 22 in mechanized transplanting. There was 4.6% missing hills in DSR machine. The minimum average time required per hectare for combined tillage and sowing operation under direct seeded rice cultivation was 5.08 h ha^{-1} under treatment DT_1 and the saving of time in treatment DT_1 (cultivator x 2 + broadcasting) than other treatments was about 35.73, 13.06, 46.17 and 16.27 per cent over DT_2, DT_3, DT_4 and DT_5, respectively. Thus, it is clear that broadcasting sowing system was most time saving which was due to minimum passes of tillage implements and also for less time consuming in sowing operation. The treatment DT_4 (cultivator x 2+ rotavator x 1 + DSR drill sowing) was most time consuming in respect to other treatments because of more number of tillage passes compared to other tested treatments. In case of time requirements, the treatments DT_4, DT_2 and DT_5 differ significantly with each other. However, the treatment DT_1 and DT_3 did not show any significant difference, whereas DT_3 and DT_5 were statistically at par. The average minimum time required per hectare for combined puddling and transplanting operation in wet transplanted rice field was 8.37 h ha^{-1} under treatment WT_1 and the saving of time in treatment WT_1 (cultivator x 1 + rotavator x 1 + transplanting) than other treatments was about 19.53, 10.75, 7.92 and 1.18 per cent over WT_2, WT_3, WT_4 and WT_5 respectively (Table 4). In case of time requirements, the treatments WT_1 and WT_2 differ significantly with each other. However, the treatment WT_1 and WT_5 did not show any significant difference, whereas WT_3 and WT_4 were statistically at par. Thus, it is clear that transplanting system was most time consuming which was due to additional time required for puddling operation compare to dry sowing of rice.

The average minimum fuel consumption of dry sowing rice was recorded 14.59 lit ha^{-1} in treatment DT_1 and maximum 30.91 lit ha^{-1} in treatment DT_4 respectively (Table 3). The treatment DT_4 was higher fuel consumption in respect to other treatments because the more number of tillage passes compared to other tested treatments. In case of fuel consumption the treatment DT_2 and DT_3 did not show any significant difference, whereas DT_3 and DT_5 were statistically at par. The fuel consumption was about 47.45, 35.77, 75.21 and 52.62 per cent higher in treatment DT_2, DT_3, DT_4 and DT_5 respectively compared to DT_1. The analysis shows that the different tillage systems have a marked effect on fuel consumption for performing tillage and sowing operations. The average minimum fuel consumption of transplanted rice treatments was recorded 15.70 lit ha^{-1} in treatment WT_1 and maximum fuel consumption was recorded 21.70 lit ha^{-1} in WT_3 respectively (Table 4). The treatment WT_3 was higher fuel consumption in respect to other treatments because of more number of tillage passes compared to other tested treatments. In case of fuel consumption the treatment WT_2, WT_3 and WT_4, WT_5 did not show any significant difference, whereas WT_4 and DT_5 were statistically at par. The fuel consumption was about 31.84, 32.33, 7.23, and 2.26 per cent higher in treatment WT_2, WT_3, WT_4 and WT_5 respectively compared to WT_1. Similar results also reported by other researchers Gill and Dhingra (2002) [2] and Pandey and Velasco (2002) [6].

Table 3: Effect of different tillage and sowing implement/machine performance on dry sowing of rice on mean basis of two years

S. N.	Particulars	Treatment (DT_1)			Treatment (DT_2)				Treatment (DT_3)			Treatment (DT_4)				Treatment (DT_5)		
		Cul x 1	Cul x 2	BD	Cul x 1	Cul x 2	Rot x 1	BD	Cul x 1	Cul x 2	DSR	Cul x 1	Cul x 2	Rot x 1	DSR	Rot x 1	Rot x 2	DSR
1	Av. Depth of cut, cm	9.1	9.7	-	9.5	9.0	8.6	-	10.2	9.5	4.6	10.4	9.7	9.3	4.2	9.8	9.2	4.0
2	Av. Width of operation, m	1.84	1.82	-	1.85	1.83	1.55	-	1.86	1.82	1.78	1.85	1.83	1.56	1.76	1.84	1.82	1.77
3	Av. Speed of operation, km / h	2.6	2.8	-	2.6	2.9	2.8	-	2.5	2.8	2.4	2.4	2.8	2.8	3.2	2.5	2.8	3.1
4	Draft, kN	6.3	6.0	-	6.8	6.2	5.6	-	6.2	5.8	2.46	6.4	5.7	5.5	2.58	6.2	5.6	2.63
5	Theoretical field capacity, ha /h	0.79	0.79	-	0.79	0.79	1.01	-	0.79	0.79	0.72	0.79	0.79	1.01	0.72	1.01	1.01	0.72
6	Field capacity,ha / h	0.48	0.50	-	0.48	0.53	0.43	-	0.46	0.51	0.60	0.44	0.51	0.47	0.56	0.46	0.51	0.54
7	Time required for 1 ha, (h/ha)	2.08	2	1	2.08	1.89	2.32	1	2.17	1.96	1.66	2..7	1.96	2.12	1.78	2.17	1.96	1.85
8	Field efficiency, %	60.6	63.9		60.75	67.08	43		58.2	64.5	83	55.7	64.5	46.5	77	45.4	50.5	75
9	Fuel consumption, lit/ ha	7.69	7.0	-	7.90	6.42	9.51	-	8.02	6.27	6.80	8.8	6.86	9.11	7.65	9.54	7.84	7.80

Cul.- Cultivator, Rot.- Rotavator BD- broadcasting sowing, DSR direct seeded rice sowing by seed drill.

Table 4: Effect of different tillage and transplanting machine performance on transplanted rice on mean basis of two years

S. N.	Particulars	Treatment (WT_1)			Treatment (WT_2)				Treatment (WT_3)				Treatment (WT_4)			Treatment (WT_5)		
		Cul x1	Rot. x1	TPR	Cul x 1	Cul x 2	Rot x 1	TPR	Cul x 1	Rot x 1	Rot x 2	TPR	Cul x 1	Cul x 2	TPR	Rot x 1	Rot x 2	TPR
1	Av. Depth of cut, cm	12.1	11.9	10.4	12.5	12.0	1.6	-	12.2	11.5	12.3	10.6	13.4	12.7	10.2	12.8	12.2	10.0
2	Av. Width of operation, m	1.91	2.01	1.2	1.92	1.95	2.01	1.21	1.93	1.96	2.03	1.78	1.92	1.96	1.76	2.01	2.05	1.77
3	Av. Speed of operation, km / h	3.5		2.3	3.4	3.8	4.1	2.2	3.1	3.7	4.0	2.4	3.3	3.5	2.3	3.9	4.2	2.22
4	Draft, kN	2.3	2.1	-	2.6	2.1	2.3	-	2.8	2.5	1.9	-	2.7	2.2	-	2.8	2.1	-
5	Theoretical field capacity, ha /h	0.79	1.01	0.30	0.79	0.79	1.01	0.30	0.79	0.79	1.01	0.30	0.79	0.79	0.30	1.01	1.01	0.30
6	Field capacity,ha / h	0.67	0.84	0.176	0.65	0.72	0.82	0.14	0.59	0.72	0.81	0.18	0.633	0.70	0.165	0.78	0.86	0.166
7	Time required for 1 ha, (h/ha)	1.49	1.19	5.68	1.53	1.35	1.21	6.09	1.69	1.39	1.23	5	1.57	1.42	6.06	1.28	1.16	6.02
8	Field efficiency, %	84	83.1	58.6	82.2	91.1	81	54.6	74	80	91	60	79	91	55	77	85	55.3
9	Fuel consumption, lit/ ha	5.51	4.40	5.80	5.81	4.59	4.96	5.80	6.25	5.28	4.44	5.80	6.12	4.97	5.80	5.63	4.64	5.80

Labour use: In rice cultivation, a labour saving of 15.4 and 8 per cent in DSR (DT_3) was observed as compared to mechanized transplanting and broadcasting method of rice establishment during both the years respectively. In rice cultivation, total labour use mainly depends on the weed management and biasi and chalai operation in broadcasting method. Sehrawat et al. (2010) [9, 10] also observed 13-16% labour saving in DSR as compared to manual puddled transplanted rice.

Yield economics and energy: Yield economics and energy analysis was done by taking mean data of both the years (Table 5). The cost of cultivation was found minimum in DT_1 (Rs. 23470.15 ha^{-1}) followed by DT_3 (Rs. 23770.35 ha^{-1}) and transplanting WT_1 (Rs. 29586.85 ha^{-1}). Net returns in DSR treatments in DT_3 was found maximum (Rs 58759.5 ha^{-1}) and followed by (Rs 46384.5 ha^{-1}) in mechanized transplanting (WT_2) and (Rs 44113.5 ha^{-1}) in broadcasting (DT_1). B: C ratio was highest in DT_3 (2.65) followed by DT_1 (2.05) and WT_2 (1.60). Kumar (2011) [3] also observed similar findings and found higher B:C ratio (1.19-1.27) in DSR as compared to (1.08) in manual puddled transplanted rice.

Energy input was lowest in DT_5 (9712 MJ ha^{-1}) in DSR sowing method followed by DT_1 (9891.5 MJ ha^{-1}) in broadcasting sowing method and WT_4 (9869 MJ ha^{-1}) in transplanted rice treatments. Energy output: input ratio was highest in DT_3 followed by WT_1 and DT_1 with 20.69, 18.63 and 16.82, respectively.

Table 5: Comparison of yield economics and energy use in various crop establishment methods of rice

Treatment	Cost of cultivation (Rs ha^{-1})		Net Income (Rs ha^{-1})		B:C ratio		Energy Input (MJ ha^{-1})		Energy output (MJx10^3 ha^{-1})		Energy Output-Input ratio	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Dry tillage and sowing treatment												
DT_1	22948.3	23992	45369	42858	2.20	1.90	9914	9869	163.85	169.27	16.51	17.13
DT_2	24354	25487	42422	31727	1.94	1.38	10293	10229	169.52	146.60	16.45	14.32
DT_3	23264.7	24276	63439	54080	3.00	2.30	9754	9683	206.40	196.41	21.1	20.28
DT_4	24758.7	25770	49179	35643	2.19	1.48	10121	10009	189.24	169.09	18.6	16.89
DT_5	23781.7	23992	53345	28573	2.46	1.17	9770	9654	160.82	148.03	16.45	15.31
SEm±	341.34	797.64	7762	8749	0.32	0.38	164.7	208.95	15.28	17.16	1.81	1.54
CD (P=0.05)	1113.1	2601.3	25316	28533	1.06	1.25	1280.4	681.41	49.82	55.96	5.90	5.01
Wet tillage and transplanting treatment												
WT_1	28470.7	30703	46016	39563	1.80	1.28	9963	9901	207.52	162.47	20.82	16.45
WT_2	29590	31823	49030	43739	1.85	1.36	10280	10216	200.60	178.95	19.51	17.52
WT_3	29830	32063	46485	44144	1.73	1.37	10414	10344	199.40	147.72	19.14	14.27
WT_4	28096.3	30329	40449	39808	1.60	1.31	9925	9813	194.21	173.81	19.51	17.40
WT_5	28613	30846	42849	41051	1.66	1.32	9969	9853	191.24	177.36	19.18	18.0
SEm±	342.11	562.23	7159	8882	0.28	0.28	143.64	60.67	13.14	16.64	1.298	1.76
CD (P=0.05)	1115.7	1833.5	23348	28965	0.94	0.92	468.44	197.84	42.85	54.267	4.24	5.73

Conclusion

In this study, direct seeding of rice practice was evaluated with conventional practices. It is clear that direct seeded rice practices may perform similarly in all agro ecological conditions and savings. Yield of DSR was significantly higher (8-10%) than transplanting and broadcasting during both the years. The findings of studies conducted on “Productivity, Economics and Resource Conservation Perspectives of Direct Seeded Rice method of Establishment” clearly visualized that among both methods of rice establishment combination of dry tillage (cultivator x 2) direct seeded rice by DSR sowing machine proved optimum and better followed by transplanting and broadcasting than rest of the other treatments combinations, which gave higher growth, yield attributes, cost effective yield and net profit and benefit: cost ratio of rice. The maximum cost of cultivation was noted under transplanted rice followed by broadcasting rice. The optimum desired seed bed for seeding rice was found under tillage treatment DT_3 and the optimum planting bed for transplanting rice was found under treatment WT_2 in terms of machine parameter, yield attributes, cost economics and energy uses. When compared to transplanted rice, a labour saving of 15-16 per cent (overall) was observed in DSR during both the years. The B: C ratio was highest in direct seeded rice (DSR) in DT_3 treatment (2.65) as compared to DT_1 broadcasting sowing (2.05) and WT_2 transplanted rice (1.60). The data presented in the study shows that DSR can also be a viable solution under scarcity of labour and water. but, there is need to develop proper weed management practices and requires further study to access the long term effects of herbicides on soil, water and development of weed flora.

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