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Farmer's Field Evaluation of Direct Seeded Rice *vis-à-vis* Puddled Transplanted Rice in Kapurthala, Punjab

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ABSTRACT

The direct seeded rice (DSR) has emerged as an economically viable and sustainable option for timely rice establishment due to labor shortage amid Covid-19 pandemics. The crop production practices differ greatly among puddled transplanted rice (PTR) and DSR. Therefore, we compared the performance of different rice varieties viz. PR-121, PR-126 and Pusa-44 under two contrasting establishment methods (PTR vs. DSR). The study highlights that of the total area under rice, the highest area under DSR was in Sultanpur Lodhi block (about 68.2%), while the lowest area in Dhilwan block (about 41.9%). Results revealed higher benefit-cost ratio of rice establishment under DSR technology, compared with the PTR technology, regardless of the rice variety due to reduced (about 23.9%) cost of cultivation associated with rice establishment under DSR technology. About 68.9 per cent of the respondents perceived PTR as low cost effective, while about 4.7 per cent perceived PTR as highly cost effective. Conversely, about 16.0 per cent of respondents perceived DSR as low cost effective, while a large proportion (about 55.7%) perceived DSR as highly cost effective. About 14.1, 76.4 and 10.4 per cent of PTR farmers, while about 10.4, 69.8 and 14.1 per cent of DSR farmers perceived it as low, medium and highly profitable.

INTRODUCTION

Rice (*Oryza Sativa*) is an important cereal crop cultivated on about 13.5 million ha (Mha) in South Asia (Bhatt et al., 2021). It has been highly resources-, labor- and energy-intensive crop established after wheat (*Triticum aestivum* L.) in rice-wheat cropping system (Singh et al., 2019; Dhillon & Vatta, 2020). During the last few decades, rice productivity has either diminished or stagnant in the region (Bhatt and Kukal, 2015; Singh et al., 2021) with rapid decline in underground water in north-western India (Bhatt et al., 2021), large production of rice residue and its open field burning (Gupta et al., 2020), besides large emission of greenhouse gases (GHGs) (Singh et al., 2020; Singh et al., 2021) and deterioration of soil health (Bhatt et al., 2021). Recently, amid Covid-19 pandemics, rice growers have faced another problem of severe human labor shortage (Chaba & Damodara, 2020; Singh et al., 2020), due to imposed restrictions for the migratory labor from the adjoining states (Mukhra et al., 2020; Bhatt & Singh, 2021). The pandemics have changed the rice establishment method from traditionally puddled transplanted rice (PTR) to direct seeded rice (DSR) in entire north-western India (Singh et al., 2005; Bhatt & Singh, 2021). Under these water and labor shortage situations, farmers searched for some suitable alternative, of which un-puddled DSR emerged as economically viable option (Pandey & Velasco 2005; Kumar & Ladha, 2011; Bhardwaj & Sidana, 2019). The DSR has advantage of timely rice establishment and efficient weed management in a single tractor operation. Additionally, the DSR has co-benefits of avoiding puddling (a wet tillage), transplanting and maintaining standing water for initial two weeks after seedling transplanting (Gill & Bhullar, 2021). During *kharif*-2020, the majority of the farmers

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adopted DSR for the first time, and therefore, adopted diverse crop production and management practices which are entirely different from those adopted under PTR fields. The yield performance of DSR depends largely on effective weed management, efficient nutrient management, and ensured poor germination and optimum plant population besides several and other factors (Gautam et al., 2021; Reddy et al., 2018; Dhillon & Mangat, 2018). The present study was therefore, conducted to compare the performance of different crop production and management practice adopted by the rice growers in two different rice establishment methods viz. DSR vs. PTR in different administrative blocks of Kapurthala district of Punjab (north-western India).

METHODOLOGY

The present study was conducted in the Kapurthala district of Punjab during March-2021. Kapurthala district has 5 administrative blocks viz. Sultanpur Lodhi, Kapurthala, Phagwara, Dhilwan and Nadala. The data on total rice area under DSR, varieties established, weed management, crop grain yield were recorded from the respondent farmers in semi-structured questionnaire through face-to-face interviews. In the present study initially there were 106 respondents, of which about 13.2 per cent study sites were ploughed by the farmers due to partial to complete crop failure. Therefore, the present study analyzed data on only 92 respondents, who by the adoption of diverse management practices harvested their crops at maturity. The list of the DSR farmers was obtained from the state Department of Agriculture and Farmers’ Welfare, Punjab are the respondents were randomized selected from different villages representative of each administrative block. The data on total area under DSR and PTR method of rice establishment were recorded from each selected respondent. The information on rice variety established and weed management measures followed for pre-and post-emergence control measures was recorded. All data were compared among DSR and PTR and the yield difference from crop yield potential, district average, state average and national average were estimated. The economic analysis of DSR and PTR technology was done based on average cost of cultivation, average gross returns, average net returns, benefit-cost ratio etc. The average gross returns were calculated as a product of rice grain yield and the minimum support price decided by the Government of India (GOI) for 2021. The average net returns were calculated by subtracting the average cost of cultivation from average gross returns. The benefit-cost ratio was calculated as a ratio of average gross returns and average cost of cultivation.

Average gross returns (Rs. ha^{-1}) = Rice grain yield (Mg ha^{-1}) x MSP (Rs. Mg^{-1})

Average net returns (Rs. ha^{-1}) = Average gross returns (Rs. ha^{-1}) - Average cost of cultivation (Rs. ha^{-1})

$$\text{Benefit - cost ratio} = \frac{\text{Average gross returns (Rs. ha}^{-1}\text{)}}{\text{Average cost of cultivation (Rs. ha}^{-1}\text{)}}$$

Farmer’s perception on DSR and PTR method of rice establishment was evaluated based on problem solving, understandability, practicability, cost effectiveness, profitability, sustainability, compatibility, accessibility, acceptability and on preference scale.

RESULTS AND DISCUSSION

Area, varieties and weed management under DSR *vis-à-vis* PTR

These results revealed that of the total area under rice, about 54.2 per cent area was under DSR, while about 45.8 per cent area was under PTR (Table 1). Among different blocks, the highest area under DSR was in Sultanpur Lodhi (about 68.2%), and the lowest in Dhilwan (about 41.9%). In other blocks, the per cent area under DSR technology was about 56.5 per cent in Kapurthala, about 43.5 per cent in Phagwara and about 60.9 per cent in Nadala. About 82.3 per cent of total area was laser leveled by the farmers before rice establishment under DSR technology. The laser leveled area was lowest in Phagwara (about 64.9%) and the highest (about 94.8%) in Sultanpur Lodhi block. These results revealed that PR-121 was the most preferred variety in the study region, covering about 80 per cent of total rice area. The highest DSR area under PR-121 was in Sultanpur Lodhi (about 91%), and the lowest (about 70%) in Phagwara block, while about 85 per cent in Kapurthala and Nadala, about 86 per cent in Nadal blocks. Average across the blocks, PR-126 covers about 9 per cent, while Pusa-44 covers about 11 per cent of total rice area in Kapurthala district. The dominance of PR-121variety over PR-126 and Pusa-44 has been ascribed to its better performance in the region (Bharaj et al., 2014). The study highlights that of the total area under rice, the highest area under DSR was in Sultanpur Lodhi block (about 68.2% of total rice area), which could be ascribed to heavy textured soils, higher water table and the highest area under laser leveled technology (Table 1). On the other hand, the lowest area under DSR technology was in Dhilwan block (about 41.9% of total rice area) which was ascribed to light textured soils particularly near *Beas* river (Rafie & Kumar,

Table 1. Area and rice varieties under direct seeded rice (DSR) in Kapurthala district of Punjab, India

Particular	Administrative blocks					
	Sultanpur Lodhi (n=22)	Kapurthala (n=23)	Phagwara (n=20)	Nadala (n=21)	Dhilwan (n=20)	Mean
% of total rice area under DSR	68.2	56.5	43.5	60.9	41.9	54.2
% of total land area laser leveled before DSR	94.8	74.1	64.9	89.7	84.8	82.3
Number of DSR farmers and sown cultivars						
PR-121	20 (91)†	17 (85)	13 (70)	18 (85)	17 (86)	85 (80)
PR-126	–	03 (10)	04 (17)	02 (10)	02 (10)	09 (09)
Pusa-44	02 (09)	03 (5)	03 (13)	01 (5)	01 (4)	12 (11)

†Figures in parenthesis represent values in percent of farmers in a particular block

2021). Averaged across the administrative block, about 54.2 per cent of the total rice area was under DSR. The PR-121 was the most preferred variety under DSR and PTR in all blocks of Kapurthala districts covering about 70-91 per cent of total rice area (mean = 80% of total rice area). However, there was no much difference in the area under short duration PR-126 and long duration Pusa-44 variety in different administrative blocks of Kapurthala district.

These results revealed that 100 per cent farmers adopted post-emergence weed management measures in PTR method of rice establishment. However, under DSR fields, farmers prefer weed management through pre-emergence application of recommended herbicides. In DSR, about 4.4 per cent of the respondent farmers practice manual weed control measures, while about 78.6 and about 85.1 per cent prefer pre- and post-emergence weed control measures, respectively. Table 2 showed the majority (27.2-95.0%) of DSR was established under *tarr wattar* (field moist) conditions, while about 5.0-63.6 per cent was established under dry seeded conditions due to inherent farmer's practice of applying irrigation water before seed sowing as true during wheat. The highest area was *tarr wattar* DSR establishment was in Phagwara, while the lowest in Sultanpur Lodhi blocks. However, coming to weeds diversity, DSR fields, commonly observed with weeds such as Khora Kah (*Leptochloa chinensis*), Madana (*Datyloctenium aegyptium*), Motha (*Cyprus rotundus*) and Swank (*Echinochlo acolona*) which needs to controlled through either pre or post weed control (Dhillon & Mangat, 2018; Kumar & Ladha, 2011).

Grain yields and farmers perceptiveness

The mean grain yields of PR-121, PR-126 and Pusa-44 were 7.50, 7.33 and 7.68 Mg ha^{-1} under PTR, while 6.73, 6.54 and 6.75 Mg ha^{-1} under DSR in Kapurthala district (Table 3). The mean rice grain yield of three varieties under PTR was significantly higher (by about 11.4-13.8%), compared with DSR. However, within each rice establishment method, the mean rice grain yield of three varieties did not differ significantly. As compared with the yield potential of each rice variety, the mean grain yield of PR-121, PR-126 and Pusa-44 under PTR method was lower by 0.13, 0.17 and 0.13 Mg ha^{-1}, respectively. The corresponding yield gap under DSR method was of higher magnitude; about 0.90, 0.96 and 1.06 Mg ha^{-1}, respectively. As compared with the state average yield, the mean rice grain yields of PR-121, PR-126 and Pusa-44 were higher by about1.33, 1.16 and 1.51 Mg ha^{-1}, respectively under PTR, and about 0.56, 0.37 and 0.58 Mg ha^{-1}, respectively under DST technology. However, the mean rice grain yields of studied fields were higher by about 1.02, 0.85 and 1.20 Mg ha^{-1} under PTR and about 0.25, 0.06 and 0.27 Mg ha^{-1}, respectively under DSR technology (Table 3). The higher grain yield under PTR technology could be ascribed to lesser weed population, regular supply of moisture and nutrients while poor yields at DSR fields associated with poor germination, heavy weeds and nutrient deficiencies particularly at light textured sandy soils (Bhatt & Kukal, 2015; Gautam et al., 2021). Moreover, farmer's practiced DSR technology for the first time at their fields, therefore, may be because of less awareness regarding different soil management and crop production technologies the crop yield was decreased. The poor seed germination particularly in the fields with deep seed placement by untrained drivers, heavy weed pressure and frequent iron (Fe) deficiency in DSR fields has been ascribed to reduced grain yields (Kumar & Ladha, 2011; Dhillon & Mangat, 2018).

Farmer's perception towards different rice establishment methods was evaluated based on different scales (Table 4). In the study area, farmers adopted DSR technology under compulsion due to scarcity of migratory labor during *kharif*-2020 (Bhatt & Singh, 2021). These results revealed that only about 14.1 per cent of the respondents had low understandability for PTR technology, which was about 32.1 per cent for DSR technology. About 17.9 per cent of respondents had high understandability for PTR, while only about 3.8 per cent had such understandability for DSR technology. About 68.9 per cent of the respondents perceived PTR as low cost effective, while about 4.7 per cent perceived PTR as highly cost effective. Conversely, about 16.0 per cent of respondents perceived DSR as low cost effective, while a large proportion (about 55.7%) perceived DSR as highly cost effective. About 14.1, 76.4 and 10.4 per cent of PTR farmers perceived it as low, medium and highly profitable, while about 10.4, 69.8 and 14.1 per cent of DSR farmers perceived it as low, medium and highly profitable. These results revealed that about 17.9, 16.0 and 66.0 per cent of PTR and about 28.3, 57.5 and 14.2 per cent of DSR farmers perceived low, medium and high preference for future planning.

Economics of DSR in comparison to PTR

PTR option required more cost to cultivate as compared to DSR due to absence of puddling operations and required lower labor requirements. Under PTR, net return per hectare was reported to be 7.1, 7.9 and 10.4 per cent higher as compared to the DSR (Table 5). The mean cost of cultivation was Rs. 39.4 x 10^3 ha^{-1} for three

Table 2. Weed management practices and moisture regime for direct seeded rice (DSR) establishment in Kapurthala district

Blocks	Weed management method (% of total respondents)				Moisture regime for DSR establishment	
	PTR	DSR			*Tarrwattar* DSR	Dry DSR
	Post-emergence	Manual	Chemical			
			Pre-emergence	Post-emergence		
Sultanpur Lodhi	100	3.4	77.3	81.8	27.2	63.6
Kapurthala	100	4.3	65.0	78.3	56.5	30.4
Phagwara	100	4.7	80.0	100	95.0	5.0
Nadala	100	5.0	90.5	95.2	71.4	19.0
Dhilwan	100	4.5	80.0	70.0	50.0	50.0
Mean	100	4.4	78.6	85.1	60.0	33.6

Table 3. Grain yield differences under puddled transplanted rice (PTR) and direct seeded rice (DSR) in Kapurthala, Punjab, India

Rice variety	Grain yield potential (Mg ha^{-1})†	Farmers field rice grain yield (Mg ha^{-1}) under different methods$^{\Delta}$		Difference in rice grain yield (Mg ha^{-1}) at farmers' fields over yield potential	
		PTR	DSR	PTR	DSR
PR-121 (*n*=85)	7.63	7.50bA	6.73aA	0.13 (1.7)$^{\#}$	0.90 (11.8)
PR-126 (*n*=9)	7.50	7.33bA	6.54aA	0.17 (2.3)	0.96 (12.8)
Pusa-44 (*n*=12)	7.81	7.68bA	6.75aA	0.13 (1.7)	1.06 (13.6)

Yield gaps (t ha^{-1}) for different varieties

Particular	PTR			DSR		
	PR-121	PR-126	Pusa-44	PR-121	PR-126	Pusa-44
P.A.U.'s recommended yield†	7.63	7.50	7.81	7.63	7.50	7.81
State average yield¶	6.17					
District average yield**	6.48					
Actual yield at farmers' fields	7.50	7.33	7.68	6.73	6.54	6.75
Yield difference from demo average	0.13	0.17	0.13	0.90	0.96	1.06
Yield difference from state average	-1.33	-1.16	-1.51	-0.56	-0.37	-0.58
Yield difference from district average	-1.02	-0.85	-1.20	-0.25	-0.06	-0.27

$^{\Delta}$Mean values followed by different letters was significantly (p<0.05) different by least significant difference (LSD) test.
$^{\#}$Values in the parentheses represent percent variation in rice grain yield over potential yield.

Table 4. Farmer's perceptiveness towards different rice establishment methods.

Perception indices	Perception point scale (Number of respondents)					
	Puddled transplanted rice (PTR)			Direct seeded rice (DSR)		
	Low	Medium	High	Low	Medium	High
Problem solving	21	74	11	6	70	30
Understandability	15	72	19	34	68	4
Practicability	34	59	13	40	61	4
Cost effectiveness	73	28	5	17	30	59
Profitability	15	81	11	17	74	15
Sustainability	19	81	6	28	70	8
Compatibility	25	66	15	30	74	2
Accessibility	8	47	51	57	23	25
Acceptability	19	19	68	15	85	6
Preference	19	17	70	30	61	15

Table 5. Economic analysis of puddled transplanted rice (PTR) *vis-à-vis* direct seeded rice (DSR)

Economic indices	Puddled transplanted rice (PTR)			Direct seeded rice (DSR)		
	PR-121	PR-126	Pusa-44	PR-121	PR-126	Pusa-44
Cost of cultivation (Rs. 000' ha^{-1})	39.4	39.4	39.4	31.8	31.8	31.8
Average gross returns (Rs. 000' ha^{-1})	140.1	136.9	143.4	125.7	122.2	126.1
Net returns (Rs. 000' ha^{-1})	100.7	97.5	104.1	94.0	90.4	94.3
Benefit-cost ratio	3.56	3.48	3.64	3.95	3.84	3.97

rice varieties under PTR, while Rs. 31.8 x 10^3 ha^{-1} under DSR depicting saving of Rs. 7,600 ha^{-1}. The higher cost of cultivation for PTR technology was ascribed to expenditure on nursery establishment, diesel cost for wet-tillage (*puddling*) and seedling transplanting cost (Chauhan et al., 2012; Bhatt et al., 2021). The average gross returns were Rs. 140.1, 136.9 and 143.4 x 10^3 ha^{1} for PR-121, PR-126 and Pusa-44, respectively under PTR technology. However, under DSR technology, average gross returns were Rs. 125.7, 122.2 and 126.1 x 10^3 ha^{1}, respectively. These results revealed higher benefit-cost ratio of rice establishment under DSR technology, compared with the PTR technology, regardless of the rice variety. It could be ascribed to reduced (about 23.9%) cost of cultivation associated with rice establishment under DSR technology than the PTR technology. Lower required labor and un-puddled conditions were main factors for better economic profitability of DSR (Singh et al., 2005; Dhakal et al., 2015).

CONCLUSION

As compared to the PTR that suffered from higher labor, water and energy issues, DSR proved to be more profitable and environment friendly rice establishing option in the region. In spite of reported lower yields in all the studied blocks of the district due to higher weed pressure DSR reported with higher profits in all preferred rice cultivars due to required lower labor requirements and cost of field preparation than PTR. Hence, the present study concludes that DSR must be preferred in the water and labor scarce region over the PTR due to its lesser costs of cultivation and drudgery.

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