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Comparative Performance of Direct Seeded Rice (DSR) and Puddled Transplanted Rice (PTR) in Rice-Wheat Sequence under Irrigated Agro-Ecosystem

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Abstract This Study was carried out at farmers' field during the period from 2010-11 to 2015-16 in district Panipat of Haryana, India to explore the scope of direct seeded rice (DSR) as an alternative of puddled transplanted rice (PTR) in rice-wheat cropping system. DSR is a resource conserving technology for this system being practiced in Haryana and other states falling within the Indo-Gangetic Plains (IGP) for the last many years. This study established that the DSR is water saving and labor saving technology and the cost of production is comparatively less than PTR. This technology was found to address the adverse effect of puddling as evident from 4–7% increase in the yield of wheat crop sequenced with DSR than the one sequenced with PTR. However, the rice grain yield remained the larger issue and yield penalty in DSR was observed in all the years of study except 2010-11 and 2015-16. DSR gave 7.7% higher grain yield than PTR in 2010-11 whereas yields were at par with PTR in 2015-16. DSR crop was found to do well in good monsoon years and with short duration cultivars. The DSR technology put to test in 2010-11 has been refined by addressing the yield limiting factors encountered during the study and success rate among DSR adopters has gone up who otherwise encountered very high yield penalty and even crop failures in the initial years. This study established that farmer participatory approach is the best for refining technologies involving paradigm shift wherein the farmer's opinion, concerns and issues find concurrent incorporation.

Keywords Direct seeded rice (DSR), Puddled transplanted rice (PTR), Water saving, Labor saving.

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Introduction

Rice is the principal food crop of the country and is grown in different agro-ecological situations. In the state of Haryana and other states falling within the Indo-Gengetic Plains (IGP), this crop is largely grown sequentially with wheat in an annual rotation, thus constituting a rice-wheat cropping system. This system though served the cause of food security and livelihood to millions of people but the sustainability of this system is now being questioned it becomes imperative to intervene through a cafeteria of all feasible resource conserving technologies (RCT). Direct Seeded Rice is among the latest RCTs evolved and recommended for this system.

In case of puddled transplanted rice 25–30 days old seedlings uprooted from small nursery bed are transplanted into puddled soils. Puddling benefits rice by reducing water percolation losses, controlling weeds, facilitating early seedling establishment and creating anaerobic conditions for better crop nutrition. But puddling operation coupled with manual transplanting requires lot of water and labor. Nearly 30% of the total water used (1400–1800 mm) in rice culture is consumed mainly in puddling and transplanting operation. The puddled transplanted rice is accused as being a major source of greenhouse gas (GHG) emission, particularly methane causing global warming and climate change. Repeated puddling destroys soil aggregates, reduces permeability in subsurface layers, and forms hard-pans at shallow depth, all of which operates negatively for succeeding wheat crop [1]. The work on crop diversification has shown that continued practice of puddled transplanted rice for decades together has altered the soil structure to the extent that such fields are rendered unfit for cultivation of pulses in sequence with rice crop. Direct seeded rice by avoiding puddling and water stagnation is likely to address all these concerns a shift from puddled transplanted rice (PTR) to Direct Seeded Rice (DSR) in irrigated areas is highly desirable. Under the circumstances, it was considered worthwhile to conduct trials on DSR at farmers' field to test agronomic and economic feasibility of this technology involving paradigm shift from anaerobic to aerobic growing condition. In the light of above facts, this investigation was carried out [2].

Materials and Methods

This Study was carried out at farmers field during the period from 2010-11 to 2015-16 in district Panipat of Haryana, India to evaluate the performance of direct seeded rice (DSR) in comparison to puddled transplanted rice (PTR). This district is situated in the high potential rice-wheat belt of the state. Rice occupies about 75% of total cropped area in *kharif* season and all of it is puddle transplanted rice. The technology package followed for PTR was time tested and perfected one but the technology package evolved for DSR was first put to test at farmer's field in the district. This technology package included the drilling of rice seeds directly in the main field after preparatory tillage instead of transplanting rice seedlings uprooted from a nursery bed, and then managing the complex weed flora through a battery of herbicides instead of relying upon the puddling and water stagnation. The water management and crop nutrition was suitably modified to adjust with the intermittent aerobic condition in DSR, and need based plant protection measures were taken. The study was confined to Basmati rice because high yield penalty in coarse rice has been reported by many workers. At the experimental sites, DSR and PTR were grown in adjacent fields of 0.4 ha (1 acre) each and both PTR and DSR were succeeded by when in *rabi* season. The soils of the experimental fields were loamy in texture having pH from 7.9 to 8.2, low in nitrogen, low in available phosphorus and high in available potash. Each plot was separately harvested for rice as well wheat for recording yield and yield gap was quantified in terms of percent of grain yield obtained in PTR. Economic analysis was done in terms of variable cost involved, gross returns, net returns and benefit-cost ratio. The rainfall data was also recorded during all the years of study to analyze the role of monsoonal rains in the success of DSR. The data so recorded from the PTR and DSR fields was compared to assess the performance of DSR in comparison to PTR and attempt was also to define most feasible approach to promote DSR along with the necessary policy initiatives.

Results and Discussion

Grain yield

Yield gain of 7.7% was observed in DSR over the PTR in 2010-11 but reverse trend was observed in subsequent years. Yield penalty to the extent of 14.7% was observed in DSR during the year 2012-13. The yield penalty in DSR showed diminishing trend after 1212-13 and yield gap in 2015-16 was merely 1% which may be rated as negligible or insignificant (Table 1). The lower yields in DSR than PTR in the northwestern Indo-Gangetic Plains were also reported earlier [3].

Table 1. Grain yield and economic returns in direct seeded rice (DSR) in comparison to puddled transplanted rice (PTR).

Year	Treat-ments	No. of Trials	Variety	Rice yield (q/ha)	Yield gap (%)	Market price (Rs/q)	Cost Rs/ha	Gross returns Rs/ha	Net returns Rs/ha	Net additional returns Rs/ha	Benefit-cost ratio	Wheat yield (q/ha)
2010-11	PTR	5	CSR 30	30.0	-	2650	28312	79500	51188	-	2.81	50.2
	DSR			32.3	7.7		25883	85595	59712	8524	3.31	52.2
2011-12	PTR	10	CSR 30	31.0	-	1800	34158	55800	21642	-	1.63	51.8
	DSR			29.0	-6.5		32895	52200	19305	-2337	1.59	54.0
2012-13	PTR	10	Pusa	44.9	-	2610	37822	117189	79367	-	3.10	48.4
	DSR		Basmati 1121	38.3	-14.7		37693	99963	62270	-17097	2.65	50.9
2013-14	PTR	20	Pusa	40.9	-	4230	40530	173007	132477	-	4.27	47.2
	DSR		Basmati 1121	38.3	-6.4		39088	162009	122921	-9556	4.15	48.4
2014-15	PTR	20	Pusa	43.7	-	2700	42916	117990	75074	-	2.75	42.4
	DSR		Basmati 1121	42.1	-3.7		42003	113670	71667	-3407	2.71	45.4
2015-16	PTR	20	Pusa	50.8		1600	42808	81280	38472	-	1.90	48.2
	DSR		Basmati 1509	50.3	-1.0		41975	80480	38505	33	1.92	50.3
Mean	PTR	85		40.2	-		37758	104128	66370	-	2.76	48.0
	DSR			38.4	-4.5		36590	98986	62397	-3973	2.71	50.2

The yield trend is explainable though number of correlated factors. Yield gap in DSR and PTR during the period of study showed correlation with the rainfall behavior as recorded in terms of total rains (mm) and no. of rainy days during the rice crop period (June-October). The yield gain in DSR in 2010-11 could be attributed to very good monsoonal rains facilitating submerged conditions even in DSR (Table 2) and thereby the DSR crop could escape from weed problem and nutrition issues as anticipated in the absence of puddling but could exploit the positives such as higher plant population. Hence, the yield gain in DSR over PTR in 2010-11 was exceptional one and could not be generalized to draw any conclusion on the relative performance of DSR.

The diminishing trend in yield penalty in DSR during the years of study could be attributed to critical management interventions done on the basis of the experience in previous years. Weed problem was successfully tackled through combination of pre-emergence and post-emergence herbicides. The experience of 2012-13 revealed that forced maturity and early senescence in DSR than PTR is the major cause of yield penalty in DSR. Similar phenomenon and consequent yield penalty was also reported earlier [3]. In order to address the phenomenon of forced maturity and early senescence in DSR, it was strategized to enhance crop vigor during reproductive phase by applying additional split of nitrogen 12–15 days before heading along with need based foliar sprays before and after heading, and also to increase the frequency of irrigation during the reproductive phase with possible water stagnation few days before and after heading. The strategy worked well by reducing the yield penalty and similar yield in DSR and PTR in 2015-16 (Table 1) has raised the optimism that DSR could succeed and become acceptable to the farmers. The beneficial effect of foliar sprays in DSR has also been reported earlier [4]. Comparatively better performance of DSR in 2015-16 may also be attributed to varietal shift to Pusa Basmati 1509. Pusa Basmati 1509 has shorter crop duration (115–120 days) in comparison to 145–155 in Pusa Basmati 1121 and 150–160 days in CSR 30. The short crop duration is desirable trait for cultivars meant for DSR [5].

Economic analysis

The data on cost of production reveals that cost in-

Table 2. Rainfall pattern during the *rabi* crop season for the period of study (2010 to 2015). Source: Deputy Director Agriculture office Panipat.

		Months					
Year	Rainfall	Jun	Jul	Aug	Sep	Oct	Total
2010	Rainfall (mm)	27.5	182.8	140.8	199.3	0	550.4
	No. of Rainy Days	2	17	17	18	0	54
2011	Rainfall (mm)	74.5	19.5	68.3	113.5	0	275.8
	No. of Rainy Days	11	9	12	8	0	40
2012	Rainfall (mm)	4.0	37.5	158.0	28.5	0	228
	No. of Rainy Days	1	5	11	4	0	21
2013	Rainfall (mm)	51.0	41	109.0	22	21	244
	No. of Rainy Days	6	7	11	3	1	28
2014	Rainfall (mm)	10.6	31.9	33.5	137.8	4.0	217.8
	No. of Rainy Days	4	4	5	7	1	21
2015	Rainfall (mm)	47.3	180.3	83.3	55.0	4.5	370.4
	No. of Rainy Days	9	13	18	3	2	45

curred in the PTR is comparatively higher than DSR and the trend was same during all the years of study (Table 1). The saving in DSR in comparison to PTR accrued from the avoidance of puddling and manual transplanting in DSR. At the same time weed management and fertilizer application proved more costly in DSR than PTR but the net balance was in favor of DSR. The available literature is unanimous on the issue that cost incurred in DSR is comparatively less than PTR.

The gross returns being the function of grain yield were higher in DSR than PTR in 2010 but reverse trend observed in subsequent years. The trend is the same as obtained with respect to the grain yield (Table 1). The net returns were higher in DSR than PTR in 2010 where DSR crop was double benefited from yield gain and lower cost. To the contrary, net returns were comparatively less in DSR during 2011-12 to 2014-15 because reduced cost could not offset the yield penalty. The net returns in DSR and PTR were almost at par in 2015-16. The benefit-cost ratio was more favorable in PTR than DSR except in 2010 and 2015. It is clear that parity in net returns in DSR and PTR is essential to make DSR technology acceptable to farmers and for that parity in grain yield in DSR and PTR has to targeted and achieved because reduction in the cost in DSR are not so attractive.

Water requirement

This study was conducted at farmer's field and it was not possible to exactly measure the water requirement of PTR and DSR. However, in such studies farmer's perception and reaction provides necessary input to draw any opinion on any relevant issue. The farmer's reaction about comparative water requirement in DSR and PTR was recorded from the farmers conducting trials and also from other farmers adopting DSR. All the farmers reported that there is substantial saving of water in DSR during vegetative phase but DSR crop requires more water than PTR during reproductive phase owing to increased frequency of irrigation. Overall, the farmer's opinion leaned in favor water saving in DSR than PTR. Relatively less water use in DSR than PTR despite the longer crop duration in main field largely occurs by avoiding large quantity of water otherwise used in puddling and transplanting operation in PTR [4].

Labor requirement

Compared to PTR, DSR is a labor saving technology and it provides cutting edge to DSR because the labor is scare and costly in the domain areas of study. The labor intensive operation of manual transplanting of seedlings in PTR is avoided in DSR. Infact most important driver prompting the farmers to try DSR is the saving of labor as they need not to pursue and appease the migratory labor for transplanting operation. There is unanimity in the available literature that DSR is a labor saving technology provided weeds are managed through herbicides.

Wheat yield

Wheat crop grown in succession with DSR recorded higher grain yield than the wheat crop grown in succession with PTR in all the years of study. The yield gain in wheat crop succeeding DSR ranged from 4.0 to 7.0% during the period of study. The adverse effect of puddling done in PTR on the yield of subsequent wheat crop has also been reported earlier [5] and number of other workers.

Conclusion

This study conducted from 2010-11 to 2015-16 generated valuable information on all the aspects of DSR. DSR has an edge over PTR in terms of reduced cost, labor and water saving and yield gain in succeeding wheat crop but such edges would be meaningful only when DSR yields at par or nearly equal to PTR under variable growing conditions. The technology package for DSR has been suitably refined through this study as to be acceptable among the farmers. Though horizontal expansion is still eluding and area is district is confined to few hundred hectares but a mental twist among the farmers is all apparent showing inclination towards DSR. Nevertheless, sustained research efforts are needed to further improve the DSR technology to make it more productive and profitable. The system warrants government support for some initial years to motivate the farmers to shift from PTR to DSR. This study established that farmer participatory approach is the best for refining technologies involving paradigm shift wherein the farmer's opinion, concerns and issuses find concurrent incorporation.

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