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Optimization of Irrigation Scheduling in Direct Seeded Basmati Rice in North-Western Indo-Gangetic Plains and its Effect on Water Saving, Crop Productivity and Economics

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Abstract Based on five years study *kharif* seasons of 2010 and 2011 and at multiple locations at farmers' fields during 2011, 2012 and 2013, direct seeded rice (DSR (basmati) with first irrigation at 7 or 15 days and follow up irrigations at 5 days interval resulted into similar productivity, higher profitability and water productivity than PTR across five years, and it saved irrigation water to the extent of 18.4 to 20.4% in 2010 and 6.3 to 9.9% in 2011. However, first irrigation at 7-15 DAS and follow up irrigations at weekly interval (keeping rainfall into consideration) was realized to be the best irrigation schedule for optimum crop growth, productivity (similar to PTR); and higher economic returns, water productivity and water use efficiency along with irrigation water saving (41.8-45.0% in 2010 and 18.2-21.8% in 2011). Average grain yield of DSR (basmati) at farmers fields ranged from 36.0-40.7 q ha^{-1}, which was comparable to PTR (36.2-41.7 q ha^{-1}) with 22.5-30.3% average saving of irrigation water across three years.

Keywords Direct seeded rice, Irrigation scheduling, Productivity, Water saving, Economics.

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Introduction

On an average, 2500 liters of water is applied, ranging from 800 to more than 5000 liters, to produce 1 kg of rough rice [1], mostly due to high water requirements for puddling and losses associated with continuous flooding such as see page and deep percolation losses to ground water [2, 3]. Nearly 30% of the total water used (1400-1800 mm) in rice culture is consumed mainly in puddling and transplanting operations in Haryana, and it can be saved through DSR [4] with similar productivity as in PTR [5]. In regions, where wages are high, the labor cost savings in DSR can reach US$50 ha^{-1} [6]. Therefore, the present study was conducted to optimize the irrigation scheduling in direct seeded basmati rice.

Materials and Methods

Research experiment

A field experiment to optimize irrigation scheduling in DSR was conducted at CCS Haryana Agricultural University, Regional Research Station, Karnal during the *kharif* seasons of 2010 and 2011. The irrigation treatments (Table 1) were laid out in randomized complete block design replicated thrice with plot size of 14 m × 8 m. Irrigation was delayed by one day for each 10 mm rain fall/day with maximum counting of 50 mm rain per day. The soil of the experimental field was clay loam in texture, slightly alkaline in reaction (pH=8.5), low in organic carbon (0.33%), nitrogen (107 kg N/ha) and phosphorus (7 kg P_2O_5/ha) and medium in available potassium (185 kg K_2O/ha). Direct seeding of basmati rice cultivar CSR 30 was done in *vattar* condition (optimum soil moisture at field capacity) by using 20 kg seed/ha (after soaking treating with carbendazim @ 1 g/l water solution per kg seed for 24 h draining and drying for 2 h in shade before sowing) with seed drill on the evening of 20th June during both the years keeping row spacing of 20 cm and depth of 3-5 cm followed by light plan king. In puddled transplanted rice (PTR), 30 days old seedlings were transplanted manually (one seedling per hill) on 20 July during both the years in puddled plots at row spacing of 20 cm and plant spacing of 15 cm. The recommended doses of fertilizers for PTR were applied equally to PTR as well as DSR plots. In PTR plots, frequent irrigations were given to maintain the 5 ± 2 cm level of standing water up to 15 days after transplanting. After that irrigation was given as and when required to maintain the saturated conditions of soil. In DSR plots, irrigations were given as per treatments requirement (Table 1). Pre-emergence herbicide pretilachlor 1.0 kg ha^{-1} was applied by splash method in standing water at 3 DAT for control of weeds in PTR. In DSR, pendimethalin 1.0 kg ha^{-1} was applied just after sowing (JAS) and bispyribac-sodium 25 g ha^{-1} at 25 DAS as spray in a volume of 300 litre water ha$^{-1.}$ Manual weeding was also done at 50 DAS/DAT to combat any infestation of weeds in the crop. Irrigation was stopped one week before harvesting of the crop. Data on irrigation depth were computed based on the effective discharge of the tube-well (38.4 litres per second) and time taken for each irrigation. Data yield parameters and yield were recorded to draw valuable inference, and economics was also computed.

Table 1. Effect of different irrigation schedules on yield attributes, grain yield and economics of direct seeded basmati rice during *kharif* seasons of 2010 and 2011. DAS : days after sowing; m.r.l : mere row length; PTR; puddled transplanted rice; DSR: direct seeded rice; LSD : least significant difference, NS : non-significant.

Treatments	Number of effective tillers/ m.r.l.		Panicle length (cm)		Number of grains/ panicle		1000-grain weight (g)		Grain yield (kg/ha)		Net returns over variable cost (Rs/ha)		B-C ratio (Over variable cost)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Conventional PTR (saturated field conditions)	65.3	81.5	23.5	22.0	64.1	56.8	23.2	22.8	3212	2620	67139	16342	3.19	1.44
DSR (1st irrigation at 7 DAS *fb* at 5 days interval)	76.7	106.8	23.5	21.9	57.0	45.7	23.2	22.5	3262	2670	75231	24211	4.18	1.85
DSR (1st irrigation at 7 DAS *fb* at 7 days interval)	75.7	101.0	23.0	21.8	56.0	45.5	22.8	22.0	3135	2540	72690	23010	4.25	1.85
DSR (1st irrigation at 7 DAS *fb* at 10 days interval)	70.8	89.7	23.3	21.5	53.1	43.9	22.5	21.8	3085	2196	71613	17743	4.27	1.68
DAS (1st irrigation at 15 DAS *fb* at 5 days interval)	72.5	101.3	23.7	21.7	56.6	46.3	22.8	22.4	3205	2607	73521	23437	4.11	1.83
DSR (1st irrigation at 15 DAS *fb* at 7 days interval)	73.3	98.5	23.0	21.5	55.8	44.9	22.7	22.2	3023	2490	69753	22483	4.19	1.84
DSR (1st irrigation at 15 DAS *fb* at 10 days interval)	70.7	84.7	23.0	21.4	51.9	42.3	22.5	21.9	2981	2004	68917	14518	4.21	1.56
LSD 5%	6.6	8.5	NS	NS	5.9	6.1	NS	NS	NS	249				

Table 2. Effect of different irrigation schedules on number of irrigations, irrigation depth, total water use, water productivity, irrigation water saving and water productivity in direct seeded basmati rice during *kharif* seasons of 2010 and 2011. DAS : days after sowing ; PTR : puddled transplanted rice; DSR: direct seeded rice.

Treatments	Number of irrigations		Irrigation depth (mm)		Total water use (mm)		Irrigation water saving (%)		Irrigation water productivity (kg grain /m^2)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Conventional PTR (saturated field conditions)	15	19	1255	1457	2254	1961	-	-	0.26	0.18
DSR (1st irrigation at 7 DAS *fb* at 5 days interval)	11	16	999	1365	1998	1869	20.4	6.3	0.33	0.20
DSR (1st irrigation at 7 DAS *fb* at 7 days interval)	8	13	730	1192	1729	1696	41.8	18.2	0.43	0.21
DSR (1st irrigation at 7 DAS *fb* at 10 days interval)	7	10	681	996	1680	1500	45.7	31.6	0.45	0.22
DSR (1st irrigation at 15 DAS *fb* at 5 days inferval)	11	15	1024	1313	2023	1817	18.4	9.9	0.31	0.20
DSR (1th irrigation at 15 DAS *fb* at 7 days interval)	7	12	690	1139	1689	1643	45.0	21.8	0.44	0.22
DSR (1th irrigation at 15 DAS *fb* at 10 days interval)	6	9	632	944	1631	1448	49.6	35.2	0.47	0.21

Farmer-participatory trials

To evaluate the performance of DSR compared to PTR, these acre size trials were conducted at 28 locations in 2011, four in 2012 and 2013 in Karnal and Kaithal districts of Haryana. Sowing was done using seed rate of 20 kg/ha with varieties CSR30 and PB1121 sown on 1-15 June in 2011 and 6-10 June in 2012 and 7-12 June in 2013 during respective years. The irrigation schedules of weekly interval were followed. Data on grain yield of whole plot was recorded and saving in irrigation water was worked out based on total number of irrigation hours required in DSR as compared to PTR.

Results and Discussion

Research experiment

Yield and yield attributes

The highest number of effective tillers/m.r.l. was recorded in DSR with first irrigation at 7 DAS and follow up irrigations at 5 days interval (76.7/m.r.l. in 2010 and 106.8/m.r.l., in 2011 (Table 1). Similar results were also reported earlier also [7–10]. The panicle length 23.0-23.7 cm in 2010 and 21.4-22.0 cm in 2011 was statistically similar across all the treatments. Whereas, the number of grains per panicle was found statistically higher under PTR (64.1 in 2010 and 56.8 in 2011) as compared to DSR. Contrary to this, higher panicle length under PTR as compared to DSR has been was reported else where [10] and also higher number of grains per panicle [9–11]. 1000-grain weight found statistically similar in DSR and PTR during both years. Higher 1000-grain weight under PTR as compared to DSR at some locations [10] while reverse to this other locations [9]. The highest grain yield was recorded in DSR with first irrigation at 7 DAS and follow up irrigations at 5 days interval (3262 kg ha^{-1} in 2010 and 2670 kg ha^{-1} in 2011) which was statistically similar to the treatment of first irrigation at 7 or 15 DAS and follow up irrigations at 7 days interval (3023-3135 kg ha^{-1} in 2010 and 2490-2540 kg ha^{-1} in 2011). Higher grain yield in DSR than PTR was also reported earlier many researchers [9, 12, 13]. Similar grain yield under PTR and DSR has also been reported Ladha et al. [14], while higher grain yield in PTR than DSR was also reported else where [15].

Economics

Treatments of first irrigation at 7 or 15 DAS with follow up irrigations at 7 days interval gave lower net returns (Rs 69753-72690 ha^{-1} in 2010 and Rs 22483-23010 ha^{-1} in 2011) but higher or similar B-C ratio (4.19-4.25 in 2010 and 1.84-1.85 in 2011) than the treatments with follow up irrigation interval of 5 days (Net returns of Rs 73521-75231 ha^{-1} in 2010 and Rs 23437-24211 ha^{-1} in 2011; B-C ratio of 4.11-4.18 in 2010 and 1.83-1.85 in 2011) (Table 1).

Water saving

The highest irrigation water requirement was in PTR

Table 3. Irrigation water saving and productivity of direct seeded basmati rice at farmers' field in Karnal and Kaithal districts of Haryana during *kharif* seasons of 2011 to 2013. DSR : direct seeded rice; PTR : puddled transplanted rice.

District	No. of sites	Variety	Grain yield (q/ha) Direct seeded rice	Puddled transplanted rice	Irrigation water saving under DSR (%)
2011					
Karnal	5	PB1121	41.7	40.9	19
''	7	CSR30	32.2	32.3	34
Kaithal	7	PB1121	39.4	39.4	35
''	9	CSR30	32.8	32.8	33
Mean			36.5	36.4	30
2012					
Karnal	1	PB1121	43.0	45.0	20
''	2	CSR30	34.0	35.0	30
Kaithal	1	PB1121	45.0	45.0	35
Mean			40.7	41.7	28
2013					
Karnal	3	PB1121	40.0	40.4	25
Kaithal	1	CSR30	32.0	32.0	20
Mean			36.0	36.2	23

(1255 mm in 2010 and 1457 mm in 2011) (Table 2) as compared to all irrigation schedules in DSR. There was saving of 18.4-49.6% and 6.3-35.2% in irrigation water under DSR compared to PTR during 2010 and 2011, respectively. Total water saving of 18-30% in DSR with different irrigation schedules as compared to PTR has been reported earlier also [4]. Similarly, 10-50% savings in water have been claimed with Dry-DSR compared with PTR when irrigation application criteria after crop establishment were either the appearance of hairline cracks or tensiometer-based (-20 kPa at 20 cm depth) [16-18]. The lowest irrigation water productivity was recorded in PTR (0.26 kg m^{-3} in 2010 and 0.18 kg m^{-3} in 2011) (Table 2). Irrigation water productivity in DSR with first irrigation at 7 DAS or 15 DAS each with follow up irrigations at 5 days intervals ranged between 0.20-0.33 kg grain m^{-3}, while it was 0.22 to 0.43 kg grain m^{-3} in follow up irrigation at 7 days interval.

Farmer-participatory trials

Basmati cultivars under DSR gave an average grain yield of 36.0-40.7 q ha^{-1} which was similar to PTR (36.2-41.7 q ha^{-1}) over three years across multi-locations with irrigation water saving of 30.3, 28.3 and 22.5% during 2011, 2012 and 2013, respectively (Table 3).

Conclusion

Based on present five years study, first irrigation at 7-15 DAS and follow up irrigations at weekly interval (Kepping rainfall into consideration) in DSR (basmati) was realized as the best irrigation schedule for optimum crop growth, productivity (similar to PTR) ; and higher economic returns, water productivity and water use efficiency along with huge savings in irrigation water.

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