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Research Paper

Performance of rice (*Oryza sativa*) under different planting methods, nitrogen levels and irrigation schedules

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ABSTRACT

A field experiment was conducted during rainy season of 2009 and 2010 at Ludhiana, to develop water–saving techniques for production of rice (*Oryza sativa* L.). The experiment (split-plot) involved methods of planting (fresh bed and puddled flat) and nitrogen levels (75% of recommended N, recommended N–120 kg/ha and 125% of recommended N) in the main plots, and irrigation schedules (irrigation at day 1, day 2 and day 3 after water disappearance and at soil suction of 150±20 cm) in the subplots, with 3 replications. The transplanting of rice on sides of fresh beds resulted in 12.4% saving in total water expense, 11.5% higher water productivity, comparable benefit: cost ratio and a non-significant reduction (4.3%) in grain yield as compared to puddled flat. Nitrogen @120 kg/ha resulted in a significant increase in growth and yield attributes, grain yield (10.5%), water productivity (12.0%) and benefit: cost ratio (14.1%) as compared to 90 kg/ha. The highest grain yield (6.99 t/ha) was obtained with application of irrigation at 1 day after water disappearance and it was statistically at par with irrigation at 2 days after water disappearance (6.87 t/ha) and with irrigation based on soil suction (6.85 t/ha). The interaction between methods of planting and irrigation schedules was significant. The maximum grain yield (7.04 t/ha) was obtained in puddled flat plots irrigated at 1 day after water disappearance, being statistically at par with all other treatment combinations except with beds irrigated at 3 days after water disappearance (6.14 t/ha). Thus, higher crop, water productivity and benefit: cost ratio can be obtained by transplanting rice on the slopes of fresh beds along with application of 120 kg N/ha and irrigation at soil suction of 150±20 cm.

Key words : Fresh bed, Irrigation schedules, Nitrogen levels, Planting methods, Soil suction, Tensiometer

Rice is one of the most important cereals cultivated in the world as well as in India and Punjab. Punjab is a major contributor to the central pool of rice in India, its contribution ranged from 59.7% in 1979–80 to 21.5% in 2011–12. Sustainability of rice production in Punjab is threatened by increasing scarcity of irrigation water. Rice is often expressed as one of the most important reasons for fall in water table in central Punjab of India. In central Punjab, where rice is a major crop, the areas with watertable below 10 m depth increased from 3% in 1973 to 76% in 2002 (Hira *et al.,* 2004). Water is becoming increasingly scarce due to growing demand in the domestic and industrial sectors, there is an urgent need to develop 'irrigation water saving techniques' that require less irrigation input than the traditional method.

Currently, puddling for rice induces high bulk density, high soil strength and low permeability in subsurface layers, which can restrict root development, water and nutrient use from the soil profile by wheat after rice. Technologies for irrigation water saving in rice like direct seeding, ground cover system, alternate wetting and drying, direct seeding and transplanting on beds (soil saturation culture) etc. are being tried. The transplanting on beds does not need puddling and hence avoids the problems mentioned above. Many advantages of growing wheat on beds in the Indo-Gangetic plains have been reported, like reduced lodging, opportunities for mechanical weeding and relay intercropping, irrigation water savings of about 30%, reduced waterlogging, reduced seed rate by about 25–30%, higher availability of N, P and K. However, no concrete information is available on favourable effects of beds on rice, as reported above in wheat. Apart from agronomic practice like proper land leveling, proper transplanting time and selection of variety irrigation water can also be saved in rice by increasing the interval between 2 successive irrigations to a limit that does not have any negative impact on crop productivity. Recommended irrigation practices for transplanted rice in puddled field are to either

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apply irrigation 2 days after disappearance of ponded water from the field or to irrigate when soil water tension reaches 150±20 cm. Both of these practices need to be studied under the condition of rice transplanted on slopes of raised beds along with varying levels of nitrogen. Nitrogen requirement of rice can vary greatly from field to field, season to season and year to year because of high variability among fields, seasons and years in soil-nitrogen supplying capacity and crop growth due to difference in climatic factors. Kaur *et al.* (2006) reported a higher amount of available soil nitrogen in beds than conventionally transplanted rice. Thus, response of rice to nitrogen varies greatly according to soil conditions and agronomic practices. Nitrogen fertilizer management should be responsive to these large variables to achieve high efficiency from the applied fertilizer. Therefore, there is a need to study nitrogen requirement of rice transplanted on beds. In view of these, the present study was conducted to study the effect of planting methods, nitrogen levels and irrigation scheduling on performance of rice.

MATERIALS AND METHODS

The field experiment was conducted during the rainy (*Kharif*) season of 2009 and 2010 at Department of Agronomy, Punjab Agricultural University, Ludhiana (30°56' N, 75°52' E, 247 m above mean sea-level), in Punjab, India. The soil of the experimental field was loamy sand in texture, with pH 7.9, organic carbon 0.42%, electrical conductivity (EC) 0.25 dS/m and available N 285.3 kg/ha, P 19.7 kg/ha, K 265.3 kg/ha and bulk density was 1.62 g/cm^3. The field capacity (–0.3 bar) and permanent wilting point (–15 bar) of 0–180 cm soil profile were 38.92 and 13.86 cm respectively. The available water in the 0–180 cm soil profile was 25.06 cm. The experiment was laid out in split-plot design with 3 replications. Six combinations of 2 methods of planting (puddled flat and fresh beds) and 3 levels of nitrogen [75% of recommended N, i.e. 90 kg/ha, recommended N, i.e. 120 kg/ha and 125% of recommended N, i.e. 150 kg/ha] were assigned to main plots and 4 irrigation schedules [irrigation after 1 day (I_1), 2 days (I_2), 3 days (I_3) after disappearance of water and at soil suction of 150±20 cm measured by tensiometer (I_4)] in sub-plots. The recommended dose of phosphorus (30 kg P_2O_5/ha) as single superphosphate, potassium (30 kg K_2O/ha) as muriate of potash and zinc sulphate heptahydrate (62.5 kg/ha) were applied before puddling or formation of beds. Nitrogen through urea was applied in 3 splits (before transplanting, 3 and 6 weeks after transplanting) and the dose was as per the experimental treatments. In puddled flat plots, the field was puddled 4 times with the help of tractor-mounted cultivator. After puddling, the main plots were divided into 4 subplots and buffers. Tractor-drawn wheat bed planter was used to prepare beds. Fresh beds were prepared during both the years of study without puddling the soil. The width at top of each bed and furrow was 37.5 and 30 cm, respectively, and the depth of the furrow was 15 cm. In order to have recommended planting density (33 plants/m^2), in conventionally transplanted flat plots seedling were transplanted at 20 cm × 15 cm spacing. Each slope of beds was planted with 1 row of seedlings (2 rows per bed) and plant-to-plant distance of 9 cm was maintained. The 30-day-old seedlings of rice variety 'PAU 201' were transplanted on 28 and 26 June during 2009 and 2010 respectively. During the first 15 days water was kept standing in puddled plots and beds were irrigated daily. The irrigation was skipped if sufficient rain was received. The depth of each irrigation measured with Parshall flume was 7.5 cm for puddled plots and 5 cm for bed plots. Irrigation application was stopped 15 days before harvest. The weeds were controlled by applying Nominee Gold (Bispyribac 10 SC) on 20 days after transplanting (DAT) @ 250 ml/ha in puddled plots and @ 300 ml/ha in beds by using 380 liters/ha of water. During both years, the left-over weeds were removed by giving 2 hand-weedings at around 35 and 50 DAT. Total water expense was calculated by adding total rainfall, irrigation water applied to nursery and the main field. The rain during crop seasons of 2009 and 2010 was 81.80 and 65.18 cm and irrigation water applied to nursery were 1.68 and 1.49 cm respectively. Water productivity (kg/m^3) was calculated by dividing the grain yield (kg) with the total water expense (m^3).

RESULTS AND DISCUSSION

Growth

The methods of planting did not show significant effect on growth parameters of rice (Table 1). Nitrogen levels significantly affected the growth parameters. Maximum values of growth parameters were observed at 150 kg N/ha which was statistically at par with 120 kg N/ha and both these levels differed significantly from 90 kg N/ha.

The maximum values of growth parameters were produced by irrigation schedule of irrigating at 1 day after water disappearance, which was statistically at par with irrigation at 2 days after water disappearance and irrigation based at soil suction of 150±20 cm and these 3 irrigation schedules resulted in significantly higher values of growth parameters than irrigation at 3 days after water disappearance. The lowest values of growth parameters in irrigation at 3 days after water disappearance may be attributed to the fact that plants under this treatment could not get sufficient water to fulfill their evapotranspirational needs.

Days taken to 50% flowering

Rice transplanted on beds required approximately 5 more days for 50% flowering, which was significantly more than that required by puddled plots (Table 1). These results confirm those of Beecher *et al.* (2006). Increase in levels of nitrogen application delayed the occurrence of 50% flowering. Maximum days for 50% flowering were taken by plants irrigated at 3 days after disappearance of water and it was statistically higher than rest of the irrigation schedules. These results support the findings of Huan *et al.* (2008). The delay in 50% flowering in beds may be due to the reason that in beds the apical meristem of rice is not covered with water. Collinson *et al.* (1995) reported that covering the apical meristem of plant with water promotes flowering in rice. Similar reason may also explain the delay in flowering with decreasing irrigation frequency, as the interval between the irrigation increased it resulted in an increase in duration for which the apical meristem remained out of water.

Yield attributes

The 2 methods of planting resulted in statistically similar values of yield attributes (Table 1). The values of yield attributes increased significantly up to 120 kg N/ha; however the further increase at 150 kg N/ha was found to be statistically non-significant. Among irrigation schedules, irrigation at 1 day after water disappearance showed the maximum values of yield attributes and it was statistically at par with irrigation at 2 days after water disappearance and with soil suction-based irrigation. These 3 irrigation schedules produced significantly higher values of yield attributes than irrigation at 3 days after water disappearance. The severe water stress in plots irrigated at 3 days after disappearance of water might have resulted in low seed setting rate and reduction in test weight as reported by Huang *et al.* (2008).

Nutrient uptake

The N, P and K uptake (kg/ha) by paddy grain and straw varied non-significantly among methods of planting (Table 1). The uptake of N and P uptake by rice increased significantly up to 120 kg N/ha and the further increase was found to be statistically non-significantly. Potassium uptake by rice did not differ significantly among different levels of nitrogen application. Different irrigation schedules failed to have any significant effect on nitrogen uptake by rice. Maximum phosphorus uptake was observed in plots irrigated at 1 day after disappearance of water and it was statistically at par with irrigation schedule in which irrigation was applied at 2 days after disappearance of water and it differed significantly from rest of the irrigation schedules. The reason for higher phosphorus uptake with increasing amount of irrigation water might be due to more solubilization of soil phosphorus by water resulting

Table 1. Effect of methods of planting, nitrogen levels and irrigation schedules on growth parameters, yield attributes and N, P and K uptake of rice (pooled data of 2009 and 2010)

Treatments	Tillers/m^2 at harvest	Dry-matter at harvest (g/m^2)	Days taken for 50% flowering*	Grains/ panicle	1,000-grains weight (g)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
Methods of planting								
Bed	268.0	1378.9	104.7	134.8	24.5	144.9	40.2	223.5
Flat	283.9	1433.6	99.8	139.5	24.8	147.3	42.9	238.0
SEm±	5.1	24.5	0.3	3.3	0.1	3.8	1.1	6.3
CD (P=0.05)	NS	0.98	1.0	NS	NS	NS	NS	NS
Nitrogen (kg/ha)								
90	257.1	1312.3	101.2	129.2	24.3	128.8	36.8	222.3
120	280.4	1431.3	101.8	139.7	24.8	149.9	43.4	237.7
150	290.4	1475.1	103.8	142.5	24.9	159.5	44.4	232.3
SEm±	6.3	30.0	0.4	4.0	0.2	4.7	1.4	7.7
CD (P=0.05)	19.8	94.6	1.2	12.6	0.5	14.8	4.3	NS
Irrigation schedules								
I_1	285.8	1435.4	101.0	139.6	24.8	144.3	44.6	246.0
I_2	281.3	1418.6	101.7	138.0	24.7	147.4	43.5	241.0
I_3	258.4	1360.6	104.3	133.3	24.4	142.9	36.1	202.6
I_4	278.3	1410.3	102.0	137.7	24.7	149.7	41.9	233.5
SEm±	5.0	12.9	0.5	2.3	0.1	2.9	0.9	5.5
CD (P=0.05)	14.4	37.1	1.5	6.6	0.2	NS	2.6	15.6

Details of irrigation schedules are given under Materials and Methods; *From sowing of nursery in its higher availability to plants and hence an increase in phosphorus uptake. Among different irrigation schedules, maximum K uptake was found in plots irrigated at 1 day after disappearance of water and it was statistically at par with plots irrigated at 2 days after disappearance of water and at soil suction-based irrigation. The increase in potassium uptake by rice with increasing amount of irrigation water might have happened due to addition of K through underground water used for irrigation, which contained 4 ppm of K. This might have led to an addition of 3 kg K/ha with every irrigation of 7.5 cm depth applied in puddled plots, while each irrigation of 5 cm depth to beds might have added 2 kg K/ha. Our findings support by the results of Singh and Bishnoi (1998). They found on an average addition of 8.85 kg K/ha to soil with each irrigation of 7.5 cm using underground water.

Grain and straw yield

The grain and straw yield of rice varied non-significantly among the 2 methods of planting (Table 2). These findings match with the results of Singh *et al.* (2009). The grain and straw yield increased significantly up to 120 kg N/ha and the further increase was statistically non-significant. These results support the findings of Yadav *et al.* (2009). The increase in grain and straw yield with the increase in nitrogen levels might be attributed to increase in growth parameters and yield attributes. Among the irrigation schedules, maximum grain and straw yields were obtained in plots irrigated at 1 day after disappearance of water, being statistically at par with irrigation application at 2 days after disappearance of water and with soil suction (150±20 cm) based irrigation. These 3 irrigation schedules resulted in statistically higher grain yield than irrigation application at 3 days after disappearance of water. The results confirm the findings of Jalota *et al.* (2009). The reduction in grain yield with reduction in amount of irrigation water applied might be due to the fact that due to less availability of water the physical and chemical conditions of soil might not have been favourable for proper growth and formation of yield attributes, as is evident from the data on these parameters.

In case of grain yield interaction between methods of planting and irrigation schedules was found to be significant (Table 3). The maximum grain yield was obtained in rice transplanted in puddled plots and irrigated at 1 day after disappearance of water and it was statistically at par with all irrigation schedules in puddled and bed plots, except with beds irrigated at 3 days after disappearance of water. The grain yield obtained in beds irrigated at 3 days after disappearance of water was lowest and it differed significantly from rest of the treatment combinations.

Irrigation applied

Averaged over 2 years the beds required 7 more irriga-

Table 2. Effect of methods of planting, nitrogen levels and irrigation schedules on yield, total water expense (TWE), water productivity and economics of rice (pooled data of 2009 and 2010)

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Number of irrigations	TWE (cm)	Water productivity (kg/m^3)	Total cost (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
Methods of planting									
Bed	6.65	9.14	33	237.0	0.29	19,426	65,163	45,737	2.35
Flat	6.95	9.45	26	266.3	0.26	20,296	68,137	47,841	2.36
SEm±	0.12	0.18	-	-	0.01	-	-	-	-
CD (P=0.05)	NS	NS	-	-	0.01	-	-	-	-
Nitrogen (kg/ha)									
90	6.30	8.58	29	251.6	0.25	19,709	61,726	42,017	2.13
120	6.96	9.50	29	251.6	0.28	19,861	68,184	48,322	2.43
150	7.15	9.80	29	251.6	0.29	20,013	70,042	50,029	2.50
SEm±	0.14	0.22	-	-	0.01	-	-	-	-
CD(P=0.05)	0.45	0.69	-	-	0.02	-	-	-	-
Irrigation schedules									
I_1	6.99	9.50	37	305.7	0.23	20,694	68,493	47,799	2.31
I_2	6.87	9.42	28	254.5	0.27	19,906	67,289	47,383	2.38
I_3	6.50	8.90	21	218.2	0.30	19,343	63,655	44,312	2.29
I_4	6.85	9.36	24	228.2	0.30	19,500	67,164	47,664	2.44
SEm±	0.07	0.12	-	-	0.003	-	-	-	-
CD (P=0.05)	0.19	0.34	-	-	0.01	-	-	-	-

Details of irrigation schedules are given under Materials and Methods tions than puddled plots. However, the quantity of water applied to beds was lower than the puddled plots. The reason for higher number of irrigations to beds might be early disappearance of water from beds, which was the criterion for scheduling the irrigations. The different nitrogen levels required similar number of irrigations because nitrogen levels did not have any effect of time required for water to disappearance from the plots. Among the irrigation schedules, the maximum number of irrigations was applied in plots irrigated at 1 day after disappearance of water and the minimum were in plots irrigated at 3 days after disappearance of water.

Total water expense

The total water expense (cm) in rice transplanted in puddled plots was 12.4% higher than rice transplanted on beds (Table 2). This might be due to the difference of 2.5 cm in each irrigation applied to puddled and bed plots. The total water expense was same among different nitrogen levels. This might be due to the reason that no differential irrigation was planned for different nitrogen levels. Minimum total water expense was observed in rice transplanted in beds and irrigated at 3 days after disappearance of water (Table 3). On the other hand, the maximum total water expense was found in rice transplanted in puddled plots and irrigated at 1 day after disappearance of water.

Water productivity

The water productivity of rice transplanted on beds was 11.5% higher than rice transplanted in puddled plots (Table 2). This might be attributed to 12.4% lower water expense in beds than puddled plots. Among nitrogen levels, the water productivity increased significantly up to 120 kg N/ha and the further increase was statistically non-significant. The reason for increase in water productivity with increasing levels of nitrogen was the increase in grain yield with increasing nitrogen levels and on the other hand, all nitrogen levels were having same water expense. Among the different irrigation schedules, the maximum water productivity was noticed in plots irrigated at 3 days after disappearance of water and at soil suction of 150±20 cm and they differed significantly from rest of the irrigation schedules. The interaction between methods of planting and irrigation schedules was found to be statistically significant. The beds irrigated at 3 days after disappearance of water and at soil suction of 150±20 cm showed significantly higher water productivity than rest of the treatment combinations. This might be attributed to the reduced irrigation water used in these treatment combinations.

Economics

The total cost, gross and net returns was about 4.4% lower in bed planted rice than rice transplanted in puddled plots, however, the benefit: cost ratio was almost similar in case of both the methods of plantings. The benefit: cost ratio of beds will become higher than puddled plots if we include the cost of diesel which farmers use for irrigating the rice during power failure. As the cost of diesel used for 1 irrigation to puddled field will be 1.5 times of that used for beds and the reason is the difference (1.5 time) in amount of water required for each irrigation for puddled (7.5 cm) and bed (5 cm) plots. The total cost, gross, net return and benefit: cost ratio were highest with 150 kg N/ha, however, the grain yield obtained with 150 kg N/ha was statistically at par with that obtained by using 120 kg N/ha. Among irrigation schedules, the total cost, gross and net returns were maximum with irrigation at 1 day after disappearance of water, but the benefit: cost ratio was highest in soil suction-based irrigation schedule. Among the combination of methods of planting and irrigation schedules the benefit: cost ratio was highest in beds irrigated according to soil suction-based irrigation schedule.

It may be concluded that for obtaining higher crop, water productivity and benefit: cost ratio, while using less irrigation water, rice should be transplanted on the slopes

Table 3. Interaction effect between methods of planting and irrigation schedules on yield, total water expense (TWE), water productivity and benefit: cost ratio of rice (pooled data of 2009 and 2010)

Treatment	Grain yield (t/ha)		TWE (cm)		Water productivity (kg/m^3)		Benefit: cost ratio	
Irrigation	Bed	Flat	Bed	Flat	Bed	Flat	Bed	Flat
I_1	6.94	7.04	265.6	318.8	0.25	0.22	2.35	2.27
I_2	6.78	6.95	235.1	273.8	0.29	0.25	2.42	2.34
I_3	6.14	6.85	200.1	236.3	0.31	0.29	2.19	2.39
I_4	6.74	6.96	220.1	236.3	0.31	0.29	2.45	2.44
Mean	6.65	6.95	237.0	266.3	0.29	0.26	2.35	2.36
SEm±	0.10	-			0.004	-		
CD (P=0.05)	0.32	-			0.01	-		

Details of irrigation schedules are given under Materials and Methods of freshly constructed beds along with application of 120 kg N/ha and irrigated at soil suction of 150±20 cm.

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