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Quality and productivity of rice as influenced by planting methods, nitrogen levels and irrigation scheduling in Northwest India

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ABSTRACT

Field experiments were conducted at Ludhiana, India, during 2009 and 2010 to study the effects of water saving techniques on quality and productivity of rice. The experiment was laid out in split-plot design with three replications. The main plots involved 6 combinations of planting methods (fresh bed and puddled flat) and nitrogen levels (90, 120 and 150 kg N ha^{-1}). Sub plots consisted of irrigation schedules [irrigation after 1 (I_1), 2 (I_2), 3 days (I_3) after disappearance of water and at soil suction of 150$\pm$20 cm (I_4)]. The results revealed that transplanting rice seedlings on freshly constructed beds saved 15.36 per cent irrigation water without any significant effect on quality and productivity of rice. Some of the quality parameters and rice productivity increased significantly only up to 120 kg N ha^{-1}. Higher values of milling parameters, protein and amylose content were obtained in I_3 which in most cases was statistically at par with I_2 and I_4. The maximum grain yield was obtained in puddled flat having I_1 irrigation schedule, which was statistically at par with all other treatment combinations except with beds irrigated after 3 days of water disappearance. Thus, in order to save water and produce rice of acceptable quality and productivity it should be transplanted on slopes of fresh beds, supplied with 120 kg N ha^{-1} and irrigated at soil matric suction of 150$\pm$20 cm.

Key words: *rice, fresh beds, cooking, milling, quality, protein, yield*

Rice is one of the most important cereals cultivated in the world. Five major rice producing countries viz. China, India, Indonesia, Bangladesh and Vietnam are producing 28.72, 19.52, 9.40, 6.97 and 5.69 per cent of the total rice produced in the world (calculated from data available at Anonymous, 2012a). It is a staple food of more than 50 per cent of the world's population as it supplied 20 per cent of calories required by world and 26, 31, 46, 71 and 65 per cent required by the people in China, India, Indonesia, Bangladesh and Vietnam respectively, in the year 2005 (Anonymous, 2012b).

Rice is generally grown under flooded or submerged conditions, therefore it is one of the biggest users of world's fresh water resources. Among these countries, India has been classified in water stress category (fresh water availability 1000-1700 m^3/person/year) and China under vulnerability category (fresh water availability 1700-2500 m^3/person/year) by FAO (Anonymous, 2012c).

Therefore, sustainability of rice production and food security in India is threatened due to water scarcity. Punjab state is a major contributor to the central pool of rice and its contribution ranged from 45.3 per cent in 1980-81 to 22.1 per cent in 2011-12. In central Punjab, where rice is a major crop, the areas with water table below 10 m depth increased from 3 per cent in 1973 to 76 per cent in 2002 (Hira *et al.*, 2004). Projections are that the water table in central Punjab will fall below 21 m in 55 per cent of the area in the year 2013 and in 2023 the water table will range between 21-49 m in 100 per cent area of Moga and Sangrur, 80 per cent in Patiala, 70 per cent in Ludhiana and 60 per cent in Jalandhar and Kapurthala districts (Sidhu and Chhibba, 2008).

Therefore, there is an urgent need to develop technologies to save irrigation water used in rice production. Many technologies for irrigation water saving in rice are being developed, but the promising one is transplanting rice seedlings on fresh raised beds. Raised beds were introduced to the rice-wheat system of the Indo-Gangetic plains in the mid 1990s, initially for wheat. Since then, many advantages of growing wheat on beds in the Indo-Gangetic plains have been reported such as reduced lodging, opportunities for mechanical weeding and relay intercropping, irrigation water savings of about 30 per cent, reduced water logging, reduced seed rate by about 25-30 per cent, higher availability of N, P and K and opportunities for improved fertilizer placement. Concrete information regarding the effect of beds on performance of rice particularly on its quality is lacking in literature. This is an important consideration and needs to be studied as rice quality is a matter of concern to many sections of the society like producers, millers, consumers, rice scientists etc.

Apart from planting technique irrigation water can also be saved in rice by increasing the interval between two successive irrigations to a limit that does not have any negative impact on crop's quality and productivity. Recommended irrigation schedule for transplanted rice in puddled flat field is either to apply irrigation two days after disappearance of ponded water from the field or to irrigate when soil water tension reaches 150$\pm$20 cm. Irrigation schedules need to be studied for this water saving planting method in context to the quality and productivity of rice.

Nitrogen is an important constituent of proteins and they have a role in deciding the various aspects related to quality and productivity of rice. Moreover, nitrogen deficiency is the most predominant nutritional disorder in the soils. The rising prices of nitrogen fertilizers necessitate for its optimum utilization. The new method of planting (beds) may have different moisture conditions in the soils, which may alter the nitrogen availability to rice. Thus, its optimum dose should be studied to have maximum benefit from the applied nitrogen.

These changes in planting methods, irrigation schedules and nitrogen application can lead to change in nutrient availability. The changed nutrient availability can influence the quality and productivity of rice. Therefore, the present study was conducted to study the effect of water saving planting method along with varying levels of nitrogen and irrigation schedules on quality and productivity of rice.

MATERIALS AND METHODS

The field experiments were conducted at Punjab Agricultural University, Ludhiana, Punjab, India, during wet seasons of 2009 and 2010. The soil of experimental field was loamy sand in texture. The soil pH, electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium content of 0-15 cm layer was 7.93, 0.25 dSm^{-1}, 0.42 per cent, 285.27, 19.65 and 265.29 kg ha^{-1}, respectively. The experiment was laid out in split plot design with 3 replications. Six combinations of 2 methods of planting [Puddled flat (F) and Fresh raised bed (B)] and 3 levels of nitrogen [75 per cent of recommended N (N_1), recommended N 120 kg ha^{-1} (N_2) and 125 per cent of recommended N (N_3)] 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 ponded water from soil surface and at soil suction of 150$\pm$20 cm measured by tensiometer (I_4)] in sub plots. Analysis of variance was performed to determine the effect of various treatments and the means were compared using critical difference (CD) at 5 per cent probability level.

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. In bed plots each slope of bed was planted with one row of seedlings (two rows per bed) and plant to plant distance was 9 cm. The recommended dose of phosphorus (30 kg P_2O_5 ha^{-1}) as single super phosphate, potassium (30 kg K_2O ha^{-1}) as muriate of potash and zinc sulphate heptahydrate (62.5 kg ha^{-1}) were applied before puddling or formation of beds. Nitrogen in the form of urea was applied in 3 equal splits (before transplanting, 3 and 6 weeks after transplanting) and the dose was as per the experimental treatments. The seedlings of rice variety 'PAU 201' were transplanted on 28th and 26th 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 was 7.5 cm for flat plots and 5 cm for beds. Irrigation application was stopped before 15 days of harvest. During 2009, the total irrigation water applied to beds and puddled flat was 171.25 and 202.50 cm, respectively, while different nitrogen levels were applied with 186.88 cm of irrigation water, whereas, the irrigation treatments of I_1, I_2, I_3 and I_4 received 238.75, 187.50, 157.50 and 163.75 cm of irrigation water, respectively. The corresponding values for the year 2010 were 152.50, 180.00, 166.25, 222.50, 171.25, 128.75 and 142.50 cm. The paddy obtained from the different treatments was cleaned and dried in sun and was used for determination of quality parameters by the methods described in the following sections.

Grains were allowed to fall from an overhead storage hoper into a container of one liter capacity, container was filled and the grains were leveled with the help of a scale. The weight of grains (kg) was recorded in triplicate; average was multiplied with 100 to convert it into hectoliter weight (kg hectoliter^{-1}).

The length and breadth of paddy, raw and cooked milled rice were measured. For measurement of length ten kernels were arranged in straight line on a table and the cumulative length was measured in mm. Similarly, for breadth ten kernels were arranged breadth wise on a table and the cumulative breadth were measured in mm. The average of length and breadth was calculated and grain length: breadth ratio was determined.

Two lots of one thousand grains of milled rice were counted from each treatment. Their average weight was recorded and was expressed in grams at 14 per cent moisture content. The clean paddy samples (200 g) were shelled in laboratory using Satake sheller equipped with rubber rolls. The distance between the rubber rolls were adjusted according to the thickness of grains to get the minimum breakage. Shelled (brown) rice was weighed and expressed as percentage of paddy (hulled/brown rice recovery).

Brown rice samples were milled (polished) in Rice Polisher of Mc Gill (USA) to remove the polish (bran). The time of polishing was adjusted to achieve 6-8 per cent of milling. Milled rice was weighed and expressed as percentage of paddy.

The kernels with more than two-third length were considered as head rice. Rice sizing device was used to separate broken kernels from the milled rice. Head rice was weighed and expressed as percentage of paddy.

Protein and amylose content of milled rice were determined with Zx 800 Near Infrared Grain Analyzer of Zeltex Inc. Amylopectin content in milled rice was determined by using the following formula given by Low (1994).

Amylopectin (%) = 100-{Moisture (%)+Protein (%)+Amylose (%)+Ash (%)}

All the chemical constituents were expressed as percentage at 14 per cent moisture content in milled rice.

Elongation ratio was determined by dividing average length of cooked whole kernels by average length of uncooked whole kernels.

Two grams of milled rice was cooked in 20 ml of distilled water for minimum cooking time (determined separately for all samples) in boiling water bath. The contents were drained to remove the gruel. The superficial water on cooked rice grains was removed by pressing them between the folds of filter paper sheets. Then the grains were weighed. Water absorption ratio was calculated by dividing the weight of cooked grains by the weight of uncooked grains (2 g).

The grain yield (paddy) was expressed in kg ha^{-1} at 14 per cent moisture content.

RESULTS AND DISCUSSION

During both the years, different methods of planting, nitrogen levels and irrigation schedules (Table 1) failed to have any significant effect on physical parameters of rice viz. hectoliter weight of paddy, length: width ratio of paddy and milled rice. Weight of 1000 milled rice grains was also statistically similar between the both methods of planting.

However, weight of 1000 milled rice grains increased significantly up to N_2. The increase in weight of 1000 milled rice grains with increase in levels of nitrogen application might be attributed to better growth of plants receiving higher levels of nitrogen.

Maximum weight of 1000 milled rice grains

Table 1. Effect of methods of planting, nitrogen levels and irrigation schedules on physical parameters of paddy and rice

Treatments	Hectoliter weight of paddy (kg Hectoliter^{-1})		Length : width ratio of paddy		Length : width ratio of raw milled rice		Weight of 1000 milled rice grains (g)	
	2009	2010	2009	2010	2009	2010	2009	2010
Methods of planting								
Bed	50.16	50.13	3.79	3.75	3.11	3.09	18.20	18.17
Flat	50.25	50.21	3.80	3.78	3.13	3.10	18.44	18.40
CD (P<0.05	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen levels								
N_1	49.91	49.90	3.77	3.73	3.09	3.10	18.02	18.03
N_2	50.29	50.29	3.80	3.78	3.13	3.07	18.44	18.41
N_3	50.41	50.31	3.82	3.78	3.13	3.12	18.50	18.42
CD (P<0.05	NS	NS	NS	NS	NS	NS	0.33	0.30
Irrigation schedules								
I_1	50.10	50.05	3.80	3.82	3.12	3.09	18.43	18.41
I_2	49.95	50.17	3.79	3.75	3.13	3.11	18.41	18.37
I_3	50.31	50.28	3.76	3.69	3.10	3.06	18.09	18.03
I_4	50.46	50.15	3.84	3.80	3.13	3.12	18.35	18.32
CD (P<0.05)	NS	NS	NS	NS	NS	NS	0.20	0.26

was obtained in plots irrigated at one day after disappearance of water (I_1), however, I_1 was statistically at par with I_2 and I_4. All these three irrigation schedules (I_1, I_2 and I_4) had significantly higher weight of 1000 milled rice grains than I_3.

The brown, milled and head rice recoveries varied non-significantly among methods of planting during both the years of study (Table 2). Among nitrogen levels the brown, milled and head rice recoveries increased significantly up to N_2. The increase in brown, milled and head rice recoveries with an increase in nitrogen application rates was also reported by Liu *et al.* (2009). The increase in brown rice recovery with higher dose of nitrogen might have been due to better development of rice grain as compared to husk. The increase in milled and head rice recovery with an increase in nitrogen levels might be attributed to higher protein content of rice (Table 3), receiving higher dose of nitrogen. Lessawatwong *et al.* (2005) found that higher nitrogen application resulted in higher accumulation of storage protein in lateral regions of polished grains. This high density storage protein increased the hardness of rice grains and thus might have made rice grains more resistant to breakage during milling.

During first year of study, maximum brown rice recovery was recorded in I_3 which was statistically at par with I_4. Similarly, I_4 was statistically at par with I_2. While in the second year of study, brown rice recovery in I_2, I_3 and I_4 were statistically at par with each other and higher than I_1. During both years, maximum milled and head rice recoveries were obtained in I_3 which was statistically at par with I_2 and I_4 and they differed significantly from I_1. The increase in milled and head rice recoveries with decrease in the amount of irrigation water applied might be attributed to the increase in protein content of milled rice (Table 3).

Protein, amylose and amylopectin contents of head rice were not affected significantly by methods of planting (Table 3). During both the years of study, significant increase in protein and amylose content of milled rice were observed only upto a nitrogen level of N_2. The increase in protein content of milled rice grains with an increase in dose of nitrogen applied was also reported by Kavitha *et al.* (2008). Among nitrogen levels maximum amylopectin content was recorded in milled rice produced in plots receiving 75 per cent of recommended nitrogen (N-$_1$) and it was statistically at par with N_2. However, nitrogen levels of N_2 and N_3 were also at par with each other. The decrease in amylopectin content with an increase in nitrogen levels might be due to the fact that an increase in nitrogen application resulted in higher protein content of milled rice. As protein and

Table 2. Effect of methods of planting, nitrogen levels and irrigation schedules on milling quality of rice (expressed as percentage of paddy)

Treatments	Brown rice recovery		Milled rice recovery		Head rice recovery	
	2009	2010	2009	2010	2009	2010
Methods of planting						
Bed	84.42	83.25	70.38	69.43	59.65	58.53
Flat	84.00	82.84	70.18	69.15	59.56	58.44
CD (P<0.05)	NS	NS	NS	NS	NS	NS
Nitrogen levels						
N_1	83.53	82.34	69.75	68.70	59.05	57.93
N_2	84.45	83.32	70.40	69.48	59.74	58.67
N_3	84.66	83.48	70.68	69.67	60.02	58.86
CD (P<0.05	0.55	0.73	0.64	0.67	0.64	0.70
Irrigation schedules						
I_1	83.05	81.93	69.43	68.51	58.66	57.61
I_2	84.29	83.22	70.28	69.27	59.61	58.52
I_3	84.82	83.40	70.87	69.91	60.46	59.28
I_4	84.69	83.63	70.52	69.46	59.69	58.54
CD (P<0.05)	0.52	0.68	0.66	0.65	0.89	0.85

Table 3. Effect of methods of planting, nitrogen levels and irrigation schedules on chemical constituents of milled rice

Treatments	Protein (%)		Amylose (%)		Amylopectin (%)	
	2009	2010	2009	2010	2009	2010
Methods of planting						
Bed	8.94	8.73	17.00	16.76	58.96	59.39
Flat	8.59	8.40	16.47	16.13	59.83	60.34
CD (P<0.05	NS	NS	NS	NS	NS	NS
Nitrogen levels						
N_1	8.28	8.08	15.81	15.60	60.71	61.11
N_2	8.94	8.73	17.01	16.73	59.14	59.60
N_3	9.08	8.88	17.39	17.00	58.33	58.89
CD(P=0.05)	0.46	0.45	1.16	0.99	1.74	1.60
Irrigation schedules						
I_1	8.25	8.07	15.77	15.41	60.83	61.35
I_2	8.69	8.49	16.73	16.39	59.44	59.97
I_3	9.16	8.93	17.43	17.30	58.37	58.72
I_4	8.96	8.77	17.00	16.67	58.93	59.43
CD (P<0.05)	0.40	0.40	0.90	0.96	1.27	1.33

amylopectin content are inversely proportional to each other, therefore, an increase in protein content led to a corresponding decrease in amylopectin content.

Maximum protein content in milled rice was found in rice produced by I_3 level of irrigation and it was statistically at par with I_4. It was also found that I_2 and I_4 were statistically at par with each other. As in present study, the decrease in protein content with higher amounts of irrigation was also reported by Pirmoradian *et al.* (2004). The reduction in protein content at higher amounts of irrigation application may be attributed to synthesis of more amounts of carbohydrates as compared to proteins. Maximum amylose content was observed in I_3 which was statistically at par with I_2 and I_4. These three irrigation schedules (I_2, I_3 and I_4) resulted in significantly higher amylose content in milled rice than in rice grains produced by irrigation schedule of I_1. Among irrigation schedules, maximum amylopectin content was recorded in I_1 and it was significantly higher than other irrigation schedules.

During the two years of study rice produced by both methods of planting had statistically similar cooking qualities like length: width ratio of cooked milled rice, elongation ratio and water uptake ratio (Table 4). Length: width ratio of cooked milled rice was statistically similar among different nitrogen levels. The application of nitrogen at the rate of 90 kg ha^{-1} (N_1) resulted in maximum elongation ratio. However N_1 remained statistically at par with N_2 but differed significantly from N_3. Nitrogen application significantly influenced water uptake ratio during first year only and the effects were statistically non-significant during the second year. During the first year maximum water uptake ratio was noticed in N_1, which was statistically at par with N_2. However, N_2 and N_3 were also statistically at par with each other. The higher elongation and water uptake ratio in grains obtained from lower levels of nitrogen application might be attributed to higher carbohydrate (amylose + amylopectin) content in them as compared to the grains obtained from plots receiving higher levels of nitrogen.

Length: width ratio of cooked milled rice was statistically similar among different irrigation schedules (Table 4). Maximum elongation and water uptake ratio was observed in rice produced by I_1. However, I_1 remained statistically at par with I_2 and I_4 and these irrigation schedules differed significantly from I_3. The reason for higher elongation ratio and water uptake ratio in the plots receiving more amount of irrigation water might also be attributed to higher carbohydrate content among the rice grain produced in these plots.

During two years of study, grain yield varied non-significantly among the two methods of planting (Table 4). Statistically similar grain yield among the bed and flat transplanted rice was also reported by Singh *et al.* (2009). The grain yield increased significantly up to N_2 level of nitrogen application and the further increase was found to be statistically non-significant during both the years. During the first year N_2 and N_3 resulted in 7.69 and 10.1 per cent higher grain yield than N_1, respectively. However, during the second year the respective increase was 13.6 and 17.3 per cent.

Among the irrigation schedules, the maximum grain yield was obtained with application of irrigation one day after disappearance of ponded water (I_1), which was statistically at par with that obtained with irrigation after two days after disappearance of water

Table 4. Effect of methods of planting, nitrogen levels and irrigation schedules on cooking quality of milled rice and grain yield of paddy

Treatments	Length : width ratio of cooked milled rice		Elongation ratio		Water uptake ratio		Grain yield (kg ha^{-1})	
	2009	2010	2009	2010	2009	2010	2009	2010
Methods of planting								
Bed	2.90	2.87	1.48	1.46	3.28	3.49	6946	6353
Flat	2.95	2.91	1.43	1.52	3.24	3.50	7207	6699
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen levels								
N_1	2.90	2.90	1.51	1.55	3.29	3.53	6680	5917
N_2	2.93	2.90	1.47	1.49	3.27	3.51	7194	6721
N_3	2.95	2.86	1.39	1.42	3.22	3.44	7355	6939
CD (P<0.05)	NS	NS	0.08	0.07	0.06	NS	473	504
Irrigation schedules								
I_1	2.94	2.93	1.52	1.53	3.32	3.60	7221	6758
I_2	2.91	2.90	1.45	1.51	3.26	3.50	7135	6598
I_3	2.95	2.86	1.37	1.38	3.19	3.36	6823	6168
I_4	2.90	2.88	1.48	1.52	3.27	3.51	7127	6580
CD (P<0.05)	NS	NS	0.08	0.12	0.07	0.11	173	257

(I_2) and tensiometer guided irrigation (I_4). These irrigation schedules (I_1, I_2 and I_4) produced statistically higher grain yield than I_3. Statistically similar grain yield obtained between different irrigation schedules and in tensiometer based irrigation was supported by the findings of Jalota *et al.* (2009).

In case of grain yield the interaction between methods of planting and irrigation schedules was found to be statistically significant during both the years of study (Table 5). The maximum grain yield was obtained in rice transplanted in puddled plots and irrigated after one day of disappearance of water (FI_1). However, it (FI_1) remained statistically at par with all other treatment combinations (FI_2, FI_3, FI_4, BI_1, BI_2 and BI_4) except BI_3. The application of irrigation three days after disappearance of water to beds (BI_3) produced the lowest grain yield and it differed significantly from rest of the treatment combinations. The reason for statistically similar grain yield in all treatment combination (methods of planting and irrigation schedules) except BI_3 might be attributed to severe drying of soil because BI_3 was applied with only 135 and 115 cm of irrigation water during 2009 and 2010, respectively, which could have reduced the rate of photosynthesis due to which grain yield might have reduced. Nguyen *et al.* (2009) found that photosynthetic rate of flat transplanted rice is statistically similar to rice under saturated soil culture (bed) in which water table was maintained at a depth of 15 cm but it was statistically higher than saturated soil culture having water table at 20 cm depth, this might have happened during our study. The best treatment combination was BI_4 as it produced statistically similar grain yield as compare to FI_2 (general recommendation) but it resulted in saving of 27.14 per cent (average of two years) of irrigation water

Table 5. Interaction effect between methods of planting and irrigation schedules on grain yield (kg ha^{-1}) of paddy

Treatments	Grain yield (kg ha^{-1})			
	2009		2010	
	Bed	Flat	Bed	Flat
I_1	7164	7277	6713	6802
I_2	7050	7219	6506	6689
I_3	6529	7116	5747	6590
I_4	7041	7214	6444	6715
CD (P<0.05)	245	364		

In light of the results of the present investigation, it can be concluded that transplanting rice seedlings on slopes of freshly constructed beds resulted in 15.36 per cent saving of irrigation water as compared to puddled plots (conventional method used by farmers) without any significant reduction in grain quality and yield of rice. Keeping in view the weight of 1000 milled rice grains, milling parameters, protein content, cooking quality and the grain yield, transplanted rice should be applied with nitrogen at the rate of 120 kg ha^{-1} and it should be irrigated at soil matric suction reaches 150$\pm$20 cm. Thus, in order to save water and produce rice of acceptable quality and productivity it should be transplanted on slopes of fresh beds, supplied with 120 kg N ha^{-1} and irrigated at soil matric suction of 150$\pm$20 cm.

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