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Research Article

PHYSICOCHEMICAL, COOKING QUALITY AND PRODUCTIVITY OF RICE AS INFLUENCED BY PLANTING METHODS, PLANTING DENSITY AND NITROGEN MANAGEMENT

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ABSTRACT
Water resources in Indian Punjab, a major producer of rice, are under threat and there is a need to produce more rice with less water. Therefore, an experiment was conducted at Ludhiana, Punjab, India during summers of 2009 and 2010 to evaluate water saving technique in rice cultivation and their effect on rice quality and productivity. The experiment (split-plot) having three replications, involved 6 combinations of methods of planting (fresh bed and puddled flat) and three planting densities (21, 27 and 33 hills m^{-2}) in the main plots and nitrogen management [75% of recommended N, recommended N 120 kg ha^{-1}, 125% of recommended N and leaf color chart (LCC) guided N application] in the sub plots. The results indicated that transplanting rice on slopes of fresh beds did not adversely affect the quality and productivity of rice, but it resulted in a saving (19.50%) of irrigation water as compared to rice transplanted in puddled plots. The quality of rice was not affected by planting density but crop productivity increased with increasing planting density. Majority of the quality parameters responded significantly to N application. LCC based N management and recommended N level produced statistically equal grain yields.

Keywords: *Bed, Density, Irrigation, Nitrogen, Rice Grain Quality*

INTRODUCTION
Rice (*Oryza sativa* L.) is one of the most important cereals cultivated in the world as well as in India. It is a staple food of more than 50% of the world's population and it supplied 20% of calories required by world and 31% required by the Indian population, in the year 2005 (Anonymous, 2011).
There is an urgent need to produce more rice of acceptable quality per unit area with less water because rice is crucial for food and nutritional security for many Asian countries including India. Due to growing demand for fresh water in the domestic and industrial sectors it is becoming increasingly scarce and there is an urgent need to develop 'irrigation water saving techniques' that require less irrigation input than the traditional methods of rice cultivation. 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 latter one i.e. transplanting on beds, involves growing rice on raised beds where water is applied in furrows between the beds, thus providing a saturated soil conditions beneath the beds similar to that in alternate wetting and drying irrigations. Secondly, it does not need puddling and hence avoids the problems associated with it. Although, some work in rice planted on beds has been done and suggests irrigation water saving, but no concrete information is available on affects of beds on quality of rice. Planting density is a very important factor to achieve higher crop yields. Crop planted at optimum planting density gets favorable microclimate to efficiently utilize nutrients, solar radiation and space for growth, development and yield. The timely transplanted rice in puddled field, should be transplanted @ 33 hills m^{-2} but bed planted wheat requires 25% less seed rate. No such information is available on optimum planting density for rice transplanted on bed.
Nitrogen is a major plant nutrient and an important component of many vital organic compounds. Nitrogen improves the root system, which has special significance in absorption of water and nutrients

from the soil. Nitrogen deficiency is the most predominant nutritional disorder limiting crop yields worldwide. Hence, efficient use of N in crop production is crucial for increasing crop yield, quality, and environmental safety and has economic considerations. The N 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 N supplying capacity and crop growth due to difference in climatic factors. Kaur *et al*., (2006) reported a higher amount of available soil N in beds than conventionally transplanted rice. Thus, response of rice to N 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 fertilizers. One approach for increasing N fertilizer efficiency is to apply correct amount of the fertilizer based on prevailing agronomic practices and the second is to achieve synchrony between plant need and N supply. Since, plant growth reflects total N supply from different sources; therefore, plant N is the best indicator of N availability to the crops. Leaf colour chart (LCC) can be a useful tool to help decision making on time of application of N. The performance of bed transplanted rice along with LCC guided N management has not been studied. Thus in this context, the aim of the present study was to determine how the planting density and resource conservation technologies like bed planting and LCC influence the quality and productivity of rice. Secondly, to determine the optimum planting density and N management for rice transplanted on fresh beds.

MATERIALS AND METHODS

The experiment was conducted at Punjab Agricultural University, Ludhiana, Punjab, India, during summer seasons of 2009 and 2010. The experimental site is situated in Trans-Gangetic agro-climatic zone, representing the Indo-Gangetic alluvial plain at 30^{o}56' N latitude, 75^{o}52' longitude and at an altitude of 247 m above mean sea level. The soil of the experimental field was loamy sand in texture. The organic carbon, available N, P and K content of 0-15 cm layer of soil were 0.42% 285, 20 and 265 kg ha^{-1}, respectively. Electrical conductivity and pH were 0.25dSm^{-1} and 7.93, respectively.

The experiment was laid out in split-plot design with 3 replications. The treatments comprised methods of planting [Bed (B) and flat (F)], planting density [21 (D_1), 27 (D_2) and 33 hills m^{-2} (D_3)] and N levels [75% of recommended N (N_1), recommended N 120 kg ha^{-1} (N_2), 125% of recommended N (N_3) and LCC guided N application (N_4)]. The main-plots consisted of 6 combinations of methods of planting and planting densities and sub-plot consisted of 4 N levels. The gross plot size of the main plot and the sub-plot were 108.68 and 23.63 m^{-2}, respectively. The net plot size of sub plots under the treatment combination FD_1, FD_2, FD_3, BD_1, BD_2 and BD_3, were 12.03, 12.21, 12.54, 11.56, 11.24 and 11.48 m^2, respectively. The nursery of rice variety PAU 201 was shown on 22nd and 24th May during 2009 and 2010, respectively, and the seedlings were transplanted on 28th and 26th June 2009 and 2010, respectively. In puddled plots, the field was puddled 4 times with a tractor mounted cultivator. After puddling the main plots were divided into four sub plots and buffers. Tractor drawn wheat bed planter was used to prepare fresh beds during both years of study. 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 puddled plots rice seedlings were transplanted at 20x23.8, 20x18.5 and 20x15 cm row to row and plant to plant spacing for D_1, D_2 and D_3, respectively. Each slope of bed was planted with one row of seedlings (two rows per bed) and plant to plant spacing of 14.28, 11.11 and 9.00 cm was maintained for D_1, D_2 and D_3, respectively. Rice seedlings were transplanted in the middle of the slopes of the beds. 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 broadcasted as per the treatments; the details of dose and date of application are given in Table 1. LCC was used for N_4 treatment. The first LCC reading was recorded at 15 days of transplanting (DAT) and thereafter, weekly readings were recorded between 0900-1000 hours. The colour of fully opened leaf (second from the top) from 10 different plants were matched with the LCC and in case the colour of six leaves were below critical level of four on LCC, then N was applied @ 28.75 kg ha^{-1}. This procedure was followed till the panicle initiation stage of rice.

Table 1: Details of N application

Treatments	Dose per application (kg ha^{-1})	Dates of application			
	2009				
N_1	30.00	28June	18July	8 August	-
N_2	40.00	28June	18July	8 August	-
N_3	50.00	28June	18July	8 August	-
N_4	28.75	28 June	16 July	11 August	26 August
	2010				
N_1	30.00	26June	17July	8 August	-
N_2	40.00	26June	17July	8 August	-
N_3	50.00	26June	17July	8 August	-
N_4	28.75	26 June	13 July	5 August	25 August

Water was kept ponded for first 15 DAT in puddled plots and beds were irrigated daily. After 15 DAT both puddled plots and beds were irrigated after two days of drainage of applied irrigation/ rain water. The depth of each irrigation was 7.5 cm for flat plots and 5 cm for bed plots. Irrigation application was stopped 15 days before harvest. The total depth of irrigation water applied to beds and flat plots were 165.00 and 210.00 cm during 2009, while during 2010 it was 155.00 and 187.50 cm, respectively. Analysis of variance was performed to determine the effect of treatments. The means were compared using Fisher's least significant difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Physical quality of paddy and rice

Hectoliter weight of paddy, length: width ratios of paddy and of raw milled rice were statistically not affected by methods of planting, planting densities and N management levels (Table 2).

Table 2: Effect of methods of planting, planting densities and N management on physical properties of paddy and rice

Treatments	Hectoliter weight of paddy (kg hectoliter^{-1})		L:W (paddy)		L:W (raw milled rice)		Weight of 1000 milled rice grains (g)	
	2009	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
Methods of planting								
Bed	50.00	49.67	3.77	3.72	3.11	3.08	18.10	17.98
Flat	50.89	50.56	3.82	3.79	3.12	3.12	18.33	18.23
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS
Planting densities								
D_1	50.86	50.56	3.82	3.79	3.13	3.11	18.29	18.18
D_2	50.39	50.18	3.80	3.75	3.12	3.11	18.23	18.11
D_3	50.10	49.60	3.77	3.73	3.10	3.07	18.13	18.02
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS
N management								
N_1	50.25	49.55	3.73	3.72	3.08	3.07	17.88	17.77
N_2	50.47	50.16	3.78	3.75	3.12	3.10	18.27	18.15
N_3	50.67	50.36	3.82	3.79	3.12	3.10	18.41	18.30
N_4	50.41	50.38	3.84	3.77	3.13	3.12	18.30	18.20
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	0.21	0.21

The weight of 1000 milled rice grains (Table 2) also varied non-significantly with methods of planting and planting densities. However, N management significantly influenced weight of 1000 milled rice grains. Maximum weight of 1000 milled rice grains was recorded in N_3 level of N management and it was statistically at par with N_2 and N_3 levels. However, weight of 1000 milled rice grains produced by N_2, N_3 and N_4 levels remained significantly higher than N_1 during both years of study. The increase in weight of 1000 milled rice grains with increase in N dose might be attributed to better growth of plants. This could have led to an increased rate of photosynthesis leading to more accumulation and transfer of photosynthates from source to sink, causing an increase in weight of grains.

Milling Quality

The milling quality parameters namely brown, milled and head rice recovery (Table 3) were statistically not affected by various methods of planting and planting densities. The results regarding planting density are in accordance with the results of Xu *et al.*, (2008) as they also reported that planting density has no effect on milling quality of rice.

Table 3: Effect of methods of planting, planting densities and N management on milling quality of rice (expressed as percentage of paddy)

Treatments	**Brown rice recovery (%)**		**Head rice recovery (%)**		**Head rice recovery (%)**	
	2009	**2010**	**2009**	**2010**	**2009**	**2010**
Methods of planting						
Bed	84.12	84.15	70.89	70.26	59.60	58.45
Flat	83.81	83.73	70.07	69.83	59.03	57.78
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
Planting densities						
D_1	84.04	84.04	70.49	70.15	59.43	58.18
D_2	83.98	83.94	70.48	70.06	59.33	58.15
D_3	83.88	83.83	70.47	69.92	59.19	58.01
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
N management						
N_1	83.13	82.89	69.38	69.16	58.67	57.31
N_2	83.84	84.07	70.49	69.95	59.30	58.16
N_3	84.39	84.29	71.02	70.37	59.59	58.38
N_4	84.52	84.50	71.03	70.69	59.71	58.61
$LSD_{0.05}$	0.71	0.85	0.81	0.77	0.61	0.85

The highest brown, milled and head rice recoveries were was noticed in N_4 level of N management which were statistically at par with N_2 and N_3 levels. All these N management levels resulted in significantly higher brown, milled and head rice recoveries than N_1 level of N management. The findings of this study matches with those of Liu *et al.*, (2009) and Ma *et al.*, (2009). The higher brown rice recovery with higher dose of N may be due to better development of rice grains than hull. The reason for higher head rice recovery with higher dose of N application may be attributed to higher protein content (Table 4) of rice which increased with increasing dose of N. Leesawatwong *et al.*, (2005) reported that higher N application resulted in accumulation of storage protein in lateral regions of polished grains. This high density storage protein increases hardness of rice grains and thus could have made rice grains more resistant to breakage during milling.

Chemical Constituents of Milled Rice

Methods of planting and planting densities (Table 4) failed to have significant effect on protein, amylose and amylopectin content of milled rice.

Table 4: Effect of methods of planting, planting densities and N management on chemical constituents of milled rice

Treatments	**Protein (%)**		**Amylose (%)**		**Amylopectin (%)**	
	2009	**2010**	**2009**	**2010**	**2009**	**2010**
Methods of planting						
Bed	8.78	8.69	17.16	15.86	59.04	60.41
Flat	8.50	8.36	16.48	15.71	60.00	60.90
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
Planting densities						
D_1	8.87	8.78	17.24	16.12	58.89	60.07
D_2	8.65	8.54	16.86	15.99	59.47	60.43
D_3	8.41	8.26	16.36	15.25	60.21	61.46
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
N management						
N_1	8.17	8.05	15.95	14.89	60.83	61.99
N_2	8.62	8.54	16.99	15.88	59.38	60.55
N_3	8.85	8.74	17.12	16.04	59.04	60.21
N_4	8.92	8.77	17.23	16.35	58.84	59.86
$LSD_{0.05}$	0.40	0.45	1.00	0.93	1.37	1.21

The highest protein and amylose content (Table 4) was obtained in N_4 level of N management. During both years N_4 level was statistically at par with N_2 and N_3 level of N management. All these levels (N_2, N_3 and N_4) differed significantly from N_1 level. Increase in protein content by N_2, N_3 and N_4 levels of N management over N_1 level during 2009 was 5.51, 8.32 and 9.18%, respectively, and the corresponding values for 2010 were 6.09, 8.57 and 8.94%. During 2009, N_2, N_3 and N_4 levels resulted in 6.52, 7.34 and 8.03% and during 2010 these three levels resulted in 6.65, 7.72 and 9.81% increase in amylose content over N_1 level, respectively. Findings of this study matches with those of Gautam *et al.*, (2008) and Zhang *et al.*, (2008).

he increase in protein content of milled rice with increasing dose of N might be due to the fact that N is an integral part of proteins and its increased application might have resulted in increased N content (%) in rice grains, which ultimately increased its protein content. The reason for highest protein content in case of N_4 might be due to the fact that N was applied late (at about 60 DAT) which might have resulted in higher N content (%) in rice grains and hence protein content, whereas in other treatments last dose of N was applied at around 40 DAT.

During both the years, highest amylopectin content was found in N_1 level of N management and it differed significantly from other N management levels. The decrease in amylopectin content with an increase in N application might be due to the fact that amylopectin content is inversely proportional to protein content in rice grains and the protein content increased with increasing levels of N application.

Cooking Quality

The length: width ratio of cooked milled rice (Table 5) varied non-significantly with different methods of planting, planting densities and N management levels. The elongation ratio, water uptake ratio and gruel solid loss also varied non-significantly among different methods of planting and planting densities.

Table 5: Effect of methods of planting, planting densities and N management on cooking quality rice and grain yield of paddy

Treatments	L:W (cooked milled rice)		Elongation ratio		Water uptake ratio		Gruel solid loss (%)		Grain yield (t ha^{-1})	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Methods of planting										
Bed	2.84	2.80	1.44	1.47	3.11	3.21	9.03	9.61	7.08	6.53
Flat	2.89	2.91	1.49	1.50	3.14	3.16	9.14	9.74	7.42	6.85
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting densities										
D_1	2.83	2.80	1.43	1.44	3.12	3.19	9.05	9.64	6.70	6.03
D_2	2.88	2.87	1.47	1.50	3.13	3.19	9.08	9.66	7.27	6.79
D_3	2.89	2.90	1.50	1.51	3.12	3.18	9.12	9.72	7.79	7.26
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	0.44	0.42
N management										
N_1	2.91	2.91	1.54	1.53	3.19	3.24	9.38	10.00	6.70	6.19
N_2	2.90	2.90	1.52	1.53	3.16	3.20	9.07	9.64	7.33	6.76
N_3	2.87	2.74	1.50	1.48	3.13	3.19	8.95	9.57	7.53	6.95
N_4	2.79	2.86	1.30	1.41	3.01	3.12	8.94	9.49	7.45	6.87
$LSD_{0.05}$	NS	NS	0.06	0.07	0.12	0.06	0.11	0.21	0.21	0.20

The maximum elongation ratio, water uptake ratio and gruel solid loss was observed in N_1 level of N management which was statistically at par with N_2 and N_3 levels while they all differed significantly from N_4 level of N management. The reason for higher elongation ratio, water uptake ratio and gruel solid loss at lower levels of N management might be attributed to the higher carbohydrate content (amylose + amylopectin) of rice grains at lower levels of N application. Carbohydrates are responsible for elongation of rice grains after cooking as they absorb water during cooking and results in an increase in length of grains. The higher gruel solid loss at lower level of N management might be due to the fact that during cooking, carbohydrates get dissolved in water and leads to an enhanced gruel solid loss while cooking.

Grain Yield

Puddled plots (flat) produced 74.22 and 68.54 q ha^{-1} of grains during 2009 and 2010, respectively, which were statistically at par with 70.82 and 65.31 q ha^{-1} produced by rice transplanted on beds in the respective years (Table 5). Statistically similar grain yield among the two methods of planting has also been reported by Singh *et al.*, (2009). This might be due to favorable physical, chemical and biological and moisture conditions in the soil.

During both the years of study, the highest grain yield was obtained in D_3 level of planting density. During first year D_3 resulted in 16.32 and 7.25% higher grain yield than D_1 and D_2 levels, respectively, whereas in 2010 the corresponding increase was 20.41 and 7.02%. The grain yield increased significantly with increase in planting density and similar results were also reported by Brar and Walia (2001). The higher grain yield in D_3 level of planting density might be due to higher number of plants and panicle m^{-2} in it as compared to other planting densities. Nitrogen management significantly influenced the rice grain yield during both the years of study. The highest grain yield was obtained with application of N equal to 125% of recommended dose (N_3), which was statistically at par with N_2 (100% of recommended) and N_4 (LCC guided). Whereas, significantly lowest grain yield was recorded in N_1 level of N management. These results are in line with Yadav *et al.*, (2009) and Vishwakarma *et al.*, (2008) as these studies also found significant response of rice grain yield to N up to 120 kg N ha^{-1}. Among N_2, N_3 and N_4 levels of N management, the latter one i.e. N management through LCC is a better option than other two treatments levels because it required 5 and 35 kg less N ha^{-1} as compared to N_2 and N_3 levels, respectively. The reason may be that in LCC based N management, N is applied based on the need of the crop and the last dose was applied around 60 DAT during both years, where as in other treatments the last dose was applied around at 40 DAT. Statistically similar grain yield along with saving in N by following LCC guided N application as compared to blanket applications was also reported by Nachimuthu *et al.,* (2007) and Singh *et al.,* (2007).

Conclusion

Based on the results of the present field study it can be concluded that transplanting rice on slopes of fresh beds did not adversely affect the physicochemical, cooking qualities and productivity of rice, but it resulted in a saving (19.50%) of irrigation water as compared to rice transplanted in puddled plots.

The physicochemical and cooking qualities of rice were not affected by planting density but crop productivity increased with increasing planting density and was highest in rice transplanted @ 33 hills m^{-2}.

Majority of physical quality parameters of rice were not affected by N management levels but rest of the physicochemical and cooking quality parameters responded significantly to N management levels. The crop productivity was statistically similar among the N management levels of N_2, N_3 and N_4. LCC guided N management saved 5 and 35 kg N ha^{-1} as compared to N_2 and N_3 levels, respectively.

Thus, in rice acceptable physicochemical and cooking qualities along with higher crop productivity can be obtained by transplanting it @ 33 hills m^{-2} on the slopes of freshly constructed beds and by following LCC based N management.

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