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Effect of nitrogen fertilization and seedling density on fine rice yield in Faisalabad, Pakistan

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Abstract

Rice seedlings density per hill and optimal nitrogen fertilization exercises a strong influence on rice growth and grain yield due to competitive effects both on the vegetative and reproductive development. Present study was conducted to explore the possible role of nitrogen fertilizer and seedlings density on rice kernel yield and yield contributing factors. Three nitrogen (N) rates viz. 75, 100 and 125 kg ha^{-1} and four seedling densities (1, 2, 3 and 4 seedlings $hill^{-1}$) were tested in the study. Panicle length, number of branches per panicle and kernels per panicle remained unaffected at varying levels of N and rice seedlings per hill. Two, 3 and 4 seedlings per hill along with 100 and 125 kg N ha^{-1} resulted in maximum rice kernel yield and harvest index due to enhanced number of panicle bearing tillers and 1000-kernel weight. While application of N at 75 kg ha^{-1} along with one seedling per hill revealed the poorest results with respect to 1000-kernel weight, panicle bearing tillers per hill and the kernel yield of rice. In crux, two seedlings $hill^{-1}$ at 100 kg N ha^{-1} proved to be the best combination for maximizing the rice yield in the Faisalabad area of Pakistan.

Keywords: rice, nitrogen levels, seedlings density, yield

Introduction

Rice is an important crop of Pakistan for its significance as country's second staple food after wheat and as a source of foreign exchange earnings. During 2010-11, Pakistan earned 823.16 million US$ by exporting 0.98 million tons of basmati rice (P.F.J., 2011).Despite the excellent yield potential (6.0 t ha^{-1}) of existing fine grain rice varieties, the harvested yield (3.5 t ha^{-1}) is less than optimal from rice crop due to poor management at farmer's level (Khan *et al*., 2006; Ahmad *et al*., 2006; Govt. of Pakistan, 2010). Timely plantation, suitable transplanting densities for optimum tillering, weed control, balanced fertilization and water management are critical for good vegetative growth and harvesting higher yields (Ehsanullah *et al*., 2007; Akbar *et al.,* 2011). Synchronization of nutrient supplementation to the crop plants with the demand is the important basis of getting higher yields (Islam *et al.*, 2007; Lin *et al*., 2009; Jabran *et al.*, 2011).

Nitrogen is involved in enzymatic reactions, protein synthesis and is a major component of amino acids and nucleic acids but at the same time 94% Pakistani soils are deficient in it (FAO, 2004). On one hand the nitrogen can be used at higher rates to increase the tillering in order to compensate the insect injured plant while on the other hand, this excess nitrogen can build huge insect population through enhanced vegetative growth (Rubia *et al*., 1996; Glen, 2000). Use of nitrogen fertilizer is inevitable to harvest higher yields but the information regarding the optimum dosage of nitrogen reported in the previous literature is contradictory. Many of the studies indicate that already used nitrogen rates are lower as the increasing applications of nitrogen increased the yield and yield contributing parameters of the rice crop (Ebaid and Ghanem, 2000; Hari *et al*., 2000; El-Batal *et al.*, 2004). Even under optimal N supply, the importance of increasing its use efficiency cannot be underestimated. Therefore N application either in excess or less than optimum rate affects both yield and quality of rice to remarkable extent, hence proper management of crop nutrition is of immense importance (Manzoor *et al*., 2006).

Plant density exerts a strong influence on rice growth and grain yield because of its competitive effects both on the vegetative and reproductive development (Ahmad *et al.*, 2005). Hu *et al.* (2000) observed that grain yield increases linearly with plant density until some competitive effects become apparent.

Lower plant population than optimal is the most yield limiting factor under the farmer's field conditions of Pakistan (Ahmad *et al*., 2005). The view of our farming community is that plant population is not the yield limiting

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factor because less number of plants per unit area produces more tillers. Distances between the hills and number of seedlings per hill determine the plant population in rice while the seedling number per hill affects the tillering time, tiller number, heading time and panicle size on each tiller.

Net tillers per unit area are similar, when seedlings are planted at recommended distance i.e. 23 cm. The farming community ignores the fact that late tertiary tillers have short panicle length, less spikelets per panicle, least grain weight and eventually tertiary tillers contribute less towards grain yield. Main shoot has larger panicle, more spikelets and a higher percentage of high density grains as compared with primary, secondary and tertiary tillers. The main shoot and primary tillers have higher harvest index and yield (Rao, 1994). The study was therefore aimed at determining the effect of nitrogen and number of seedlings per hill on the productivity of transplanted fine grain rice.

Materials and Methods

The present study to explore the role of varying levels of N and rice seedlings density on growth and yield of rice was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad (73.09^o E, 31.25^o N and 183 meters a.s.l.), Pakistan during Kharif 2007. The experimental area was quite uniform and soil analysis was done to assess the soil fertility status. Total nitrogen and available phosphorus were determined by the methods of Jackson (1962) and Watanabe and Olsen (1965), respectively. Soil texture was determined by the method of Moodie *et al.,* (1959). Soil EC, pH, organic matter and available potassium were determined according to the procedures given in the Hand Book No. 60 of the U.S. Salinity Lab. Staff (1954). The physico-chemical analysis of the soil is given in Table 1.

Table 1: Physico-chemical analysis of soil

Determination	Unit	Value	Status
Textural class	Sandy clay loam		
pH		7.80	-
EC	dS m^{-1}	1.72	-
Organic matter	%	0.75	deficient
Total nitrogen	%	0.028	deficient
Available phosphorus	mg kg^{-1}	6.85	deficient
Available potassium	mg kg^{-1}	119.0	Medium
Saturation	%	33.60	-

The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement having net plot size of 2.25 m x 6.0 m and replicated three times. Three nitrogen levels (75, 100 and 125 kg ha^{-1}) were randomized in main plots and four seedling densities (1, 2, 3 and 4 seedlings per hill) were kept in sub plots. The crop was planted at row spacing of 22.5 cm. Nitrogen was applied in three splits i.e. 1/3rd of the nitrogen at transplanting and remaining 2/3 rd in two equal splits; each at tillering and at panicle initiation. The source of nitrogen was urea (46% N). Weather data during the course of the study are given in Table 2.

Table 2: Weather data during the course of the study

Month	Mean Monthly Temperature (°C)	Mean Monthly Relative Humidity (%)	Total Monthly Rainfall (mm)
June	34.0	37.0	29.9
July	31.9	54.9	149.7
August	32.6	51.3	19.5
September	30.2	51.4	12.2
October	24.8	32.6	0
November	20.3	47.0	0

Nursery of the fine rice variety Super Basmati was raised using dry bed method. Experimental site was puddled by providing the field with flood irrigation and ploughing and planking it three times. The crop was fertilized with phosphorus and potassium fertilizers each at 67 kg ha^{-1} using single super phosphate (18% P_2O_5) and sulphate of potash (50% K_2O), respectively. A total of twenty irrigations each having depth of 3 acre inches were applied to the crop.

Plant height was measured using twenty primary tillers selected randomly from each plot at maturity from base of the tiller to tip of panicle with a meter stick and then averaged. Twenty hills were selected at random from each plot to count the number of tillers per hill. Fertile and unfertile numbers of tillers were counted individually and then total number of tillers were obtained by adding the number of fertile and unfertile tillers per hill. Twenty panicles were selected randomly from each plot at maturity while panicle length was measured from base of the panicle to its tip with the help of a meter stick and then average was calculated. Number of branches per panicle was counted manually by taking twenty panicles selected randomly at maturity from each plot and then average was calculated. Twenty panicles, selected at random from each plot were threshed manually, number of kernels of each panicle was counted individually and their average was calculated to determine the number of kernels per panicle. Thousand kernels were counted manually from a random sample of kernels taken from each plot and weighed on digital balance to determine 1000-kernel weight in grams. The crop was harvested at maturity, tied into bundles in respective plots. Biological yield of each treatment was recorded with the help of a spring balance after three days drying in the field.

The crop was threshed manually to determine kernel yield per plot and converted into ha^{-1} by unitary method. The grain yield was adjusted to 10% moisture content and presented in t ha^{-1}. Straw yield (t ha^{-1}**)** was obtained by subtracting the kernel yield from the biological yield. Harvest index (HI) was calculated as ratio between kernel yield and biological yield expressed in percentage.

The collected data were statistically analyzed by using Fisher's analysis of variance technique and LSD test at 5% probability was used to compare the differences among treatments' means (Steel *et al*., 1997). The interaction between N levels and seedlings density was significant, so only interactive effects have been presented.

Results

Analyzed data indicate that interaction between nitrogen levels and seedling density had significant effect on plant height, 1000-kernel weight, fertile tillers per hill, kernel yield and harvest index, and non-significant effect on panicle length, number of branches per panicle and number of kernels per panicle of rice (Table 3). One and four seedlings per hill under 100 kg ha^{-1} N application, and one, three and four seedlings per hill under 125 kg ha^{-1} N application resulted in maximum plant height. Two seedlings per hill under 100 and 125 kg ha^{-1} N application and one, two, three and four seedlings per hill under 75 kg ha^{-1} N application resulted in minimum plant height (Table 3). Likewise, one, two, three and four seedlings per hill under 100 and 125 kg ha^{-1} N and four seedlings per hill under 75 kg ha^{-1} N application produced heavier kernels than one or two seedlings per hill under 75 kg ha^{-1} N application (Table 3).

Four seedlings per hill under 100 kg ha^{-1} N application and two or three seedlings per hill with 125 kg N ha^{-1} produced maximum panicle bearing tillers per hill while one seedling per hill in all N levels produced least panicle bearing tillers per hill in rice (Table 3). Two, three and four seedlings per hill with 100 kg N ha^{-1}, and all four seedling densities with 125 kg ha^{-1} N application resulted in ceiling rice kernel yield while one or two seedlings per hill with 75 kg ha^{-1} N application resulted in least kernel yield of rice (Table 3). Four seedlings per hill under 75 kg ha^{-1}, one, two and three seedlings per hill under 100 kg ha^{-1}, and one, three and four seedlings per hill under 125 kg ha^{-1} N application produced higher straw yield while one, two and three seedlings per hill with 75 kg ha^{-1} N application resulted in lower straw yield of rice (Table 3). Two, three and four seedlings per hill with 100 kg ha^{-1} N application, and two and four seedlings per hill with 125 kg ha^{-1} N application resulted higher in harvest index of rice. One, two and four seedlings per hill with 75 kg ha^{-1} N application,

Table 3: Effect of different nitrogen levels and seedling density per hill on yield and yield contributing parameters of rice

Nitrogen level	Seedling density	Plant height (cm)	Panicle length (cm)	Number of branches per panicle	Number of kernels panicle	1000-kernel weight (g)	Panicle bearing tillers per hill	Straw yield (t ha^{-1})	Kernel yield (t ha^{-1})	Harvest index (%)
75 kg ha^{-1}	One	102.8 bc	27.2	11.13	138.67	18.52 c	11.67 d	6.46 c	3.46 d	34.43 bc
	Two	100.6 c	27.83	11.27	140.67	18.80 c	14.00 b	6.73 bc	3.53 cd	34.41 bc
	three	101.5 bc	27.87	12.73	137.67	19.83 b	14.33 c	6.60 bc	3.73 bc	36.11 b
	four	101.4 bc	28.43	12.07	136.67	20.85 a	15.67 bc	7.30 a	3.80 b	34.23 bc
100 kg ha^{-1}	one	107.3 a	27.47	12.27	140	21.00 a	12.33 d	7.23 ab	3.73 bc	34.03 c
	two	103.4 bc	29.17	12.53	138	21.00 a	15.00 bc	7.13 ab	4.20 a	37.05 ab
	three	103.8 b	28.37	12.47	137.33	20.90 a	15.67 bc	7.13 ab	4.20 a	37.06 ab
	four	105.1 ab	27.9	12.6	142	20.66 a	17.00 ab	6.86 b	4.26 a	38.32 a
125 kg ha^{-1}	one	107.6 a	27.83	12.67	141.67	21.06 a	12.33 d	7.20 ab	4.03 ab	35.91 bc
	two	103.1 bc	28.33	12.6	146.67	21.08 a	18.00 a	6.93 b	4.26 a	38.10 a
	three	105.9 ab	27.87	12.93	145.67	21.05 a	17.00 ab	7.26 ab	4.03 ab	35.69 bc
	four	105.5 ab	28.13	12.67	134	20.56 a	16.00 b	7.06 ab	4.10 a	36.71 ab
LSD for interaction at $p \leq 0.05$		3.16	NS	NS	NS	0.73	1.47	0.36	0.24	1.97

NS = Non-significant; Means not sharing the same letter with in a column differ significantly from each other at 5% level of probability one seedling per hill with 100 kg ha^{-1} N application, and one and three seedlings per hill with 125 kg ha^{-1} N application resulted in least harvest index of rice (Table 3).

Discussion

Panicle bearing (fertile) tillers and heavier grains directly contributes to the final kernel yield of rice (Hu *et al*., 2000). In this study, higher seedling densities (2, 3 and 4 seedlings per hill) compared with one seedling per hill resulted in higher kernel yield at higher N levels (100 and 125 kg ha^{-1}) compared with lower rate of N (75 kg ha^{-1}). Aforementioned higher kernel yield in this study might be the direct result of significant improvement in panicle bearing tillers and kernel weight as panicle length and number of grains per panicle remained unaffected (Table 3). Earlier, Ahmad *et al.* (2005) also concluded that higher N rates with higher seedling density enhanced the number of tillers that directly contribute to the rice grain yield. N being the major component of chlorophyll and hence possessing the important role in photosynthesis plays its role in yield maximization due to more accumulation of assimilates that resulted in heavier grains (Tisdale *et al*., 1990). There are many reports available that highlight the role of N in enhancing the rice kernel yield due to its involvement in enhancing fertile tillers, kernel weight, number of kernels per panicle and harvest index (Ahmad *et al*., 2005; Manzoor *et al*., 2006; Rajarathinam and Balasabramaniyan, 1999; Lin *et al*., 2009).

Distances between the hills determine the plant population in rice while the seedling number per hill affects the tillering time, tiller number, heading time and panicle size on each tiller. Plants generated from primary and secondary tillers are equally productive to mother plants while plants generated from tertiary tillers are the least productive due to their least consumption of nitrogen as they came into existing in later stages of crop establishment (Counce *et al*., 1996).

Nitrogen in combination with proper seeding densities may play its role for optimizing rice yields per unit area (Lin *et al*., 2009). It is evident from the data that genetically controlled yield contributing parameters like panicle length, branches per panicle and kernels per panicle were not affected more than 15% by the management practices or managed environment like the application of nitrogen (Table 3). Several reports highlight the positive correlation between higher levels of N application along with higher seedlings density to harvest maximum potential of different rice cultivars including hybrids as well (Ahmad *et al*., 2005; Salahuddin *et al*., 2009; Lin *et al*., 2009). Higher harvest index at higher N levels along with two seedlings per hill might be due to their higher kernel and lower straw yield that indicate efficient assimilate portioning (Table 3; Rajarathinam and Balasabramaniyan, 1999; Ahmad *et al*., 2005).

In conclusion, rice transplanting using two seedlings per hill along with 100 kg N ha^{-1} was the most suitable treatment to fetch maximum kernel yield.

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