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Grain Yield of Transplanted Rice (*Oryza sativa* L.) as Influenced by Plant Density and Nitrogen Fertilization

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ABSTRACT

Rice (*Oryza sativa* L.) crop yield as the product of numbers of panicles per unit area, percentage of filled spikelets and the mean kernel weight, behave differently under variable crop husbandry practices. The objective of this two year study was to characterize the contribution of planting density and nitrogen fertilization to yield components and grain yield. Three plant densities (D_1, D_2 and D_3 seedlings hill^{-1}) and five fertilizer levels (0-0-0, 50-67-67, 100-67-67, 150-67-67 and 200-67-67 kg NPK ha^{-1}) were selected for this study. Grain yield increased from D_1 to D_2 density and then decreased. Average grain yield 3.6, 4.02 and 3.81 Mg ha^{-1} was obtained with D_1, D_2 and D_3, respectively. Increasing rates of nitrogen significantly increased grain yield up to 200 kg N ha^{-1}. Two years mean grain yield was 3.06, 3.36, 3.71, 4.34 and 4.59 Mg ha^{-1} in the respective fertilizer treatments.

Key Words: Nitrogen; Plant density; Rice; Yield

INTRODUCTION

Rice (*Oryza sativa* L.), second major food grain crop of Pakistan after wheat, is grown on an area of 2226 thousand hectares, with an annual production of 4478 thousand tones having an average yield of 2012 kg ha^{-1} (Anonymous, 2004). To meet the increased demand of food grain of rapidly increasing population, it is desirable to have higher per unit production of rice. There are many factors responsible for low yield of rice such as plant density, sowing time, judicious use of nitrogenous fertilizer (Ali *et al*., 2005), irrigation regimes and intercepted radiation etc. Among various nutrients, nitrogen is integral part of structural and functional protein, chlorophyll and nucleic acid. It plays a vital role in crop development (Tisdale *et al*., 1990), but is the most deficient element in our soils.

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

Rajarathinam and Balasabramaniyan (1999) concluded that yield parameters (panicles m^{-2}, panicle weight and length, grains panicle^{-1}, filled grains panicle^{-1}, 1000-grain weight), grain yield and harvest index were highest with the 200 kg N ha^{-1}. Keeping in view the immense importance of plant stand and nitrogen fertilization, the present study was undertaken to optimize yield of transplanted lowland rice under variable plant density and nitrogen fertilization at constant levels of P and K.

MATERIALS AND METHODS

The field experiments were conducted for two consective years on the Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan. Before transplanting, soil pH was 7.8-7.9, organic matter 0.73-0.76%, total nitrogen 0.046-0.048%, available P 6.15-6.19 ppm and available K 193-195 ppm in both the seasons. Treatments were three plant densities, viz. D_1= one seedling hill^{-1}, D_2 = two seedlings hill^{-1}, and D_3 = three seedlings hill^{-1} and five fertilizer levels viz., F_0= 0-0-0, F_1= 50-67-67, F_2 = 100-67-67, F_3 = 150-67-67, F_4 = 200-67-67 Kg ha^{-1} NPK. A randomized complete block design (RCBD) with factorial arrangements was applied along with three replications. Net plot size was 2m × 3m. There were 8 rows per plot and 12 plants per row. Thirty days old seedlings were transplanted manually in puddled field in standing water at 22.5cm × 22.5 cm plant to plant and row to row distance. All P, K and half of the N fertilizer in the form of single super phosphate (SSP), potassium pulphate and urea respectively were applied to each plot except control plots at the time of puddling before transplanting. The remaining dose of nitrogen as per treatment was applied at tillering. Total of 16 irrigations were applied to each treatment. All other agronomic practices such as weeding, plant protection measures etc were kept normal and uniform.

To assess the significance of treatments, all sets of data were subjected to analysis of variance by using "MSTAT" statistical computer package. Differences among treatments means were compared employing least significant difference (LSD) test at $P \leq 0.5$ (Steel & Torrie, 1984).

RESULTS AND DISCUSSION

Table I presents the data regarding plant height at maturity as affected by plant density and fertilizer levels. In both years increasing the plant density from one to three seedling hill^{-1} significantly decreased plant height. Plant height ranged from 135.88 to 140.93 cm among three densities. Increasing levels of N fertilizer at constant levels of P and K significantly increased the plant height in both the seasons (Table II). Averaged over two years, the mean plant height was 137.80 cm in 2000 and 139.14 cm in 2001. Plant density and fertilizer levels interaction was found to be non-significant in both the years. Increased plant height in rice with the increasing levels of N fertilizer may be attributed to greater supply of nitrogen resulting in increased nitrogen metabolism (Singh & Sharma, 1987). This appeared to increase the length of internodes resulting in higher plant height in the F_3 or F_4 fertilizer levels as compared to F_0 or lower levels of N fertilizer (Reddy *et al*., 1987; Milam & Sheppard, 1988).

Plant density and nitrogen levels also significantly affected total number of tillers hill^{-1} in both the years. The number of tillers hill^{-1} was increased gradually in both the years. Overall mean number of tillers hill^{-1} was 24.9 in 2000 and 25.3 in 2001 (Table I). The response of increasing plant density to the number of tiller hill^{-1} was similar to that noted by Choudhry (1997) under similar environmental conditions. Reddy (1986) reported that each tiller appears at pre-defined development stage, but the increase in density decreased the number of tillers hill^{-1}due to less space available to the plant. Miller *et al*. (1991) observed that panicles per square meter were the most important component of yield and accounted for 89% of the varieties in yield. Data showed that plant density did not significantly affect the number of panicle bearing tillers (Table I). The number of panicle bearing tillers ranged from 16.31 to 17.08 during both the years. Lower nitrogen rates (up to 100 kg N ha^{-1}), did not significantly affect the number of panicles bearing tillers, however, the higher nitrogen rates (150 & 200 kg N ha^{-1}) significantly increased this attribute. The mean number of panicle bearing tillers hill^{-1} was 16.3 in 2000 and 17.0 in 2001 (Table II). A greater number of panicle bearing tillers produced by F_3 or F_4 fertilizer levels may be attributed to optimum supply of NPK in these treatments. Non-significant differences in the number of panicle among different densities were probably due to adequate available space, which did not create severe competition among these levels of densities (Singh *et al*., 1985; Singh & Sharma, 1987). Average numbers of panicles (15-17) obtained in this study are similar to reported data on rice (Aslam, 2000).

The 1000- grain weight was not significantly influenced by plant density in both the years (Table I). Grain weight varied from 15.79 to 16.14 g among various densities during both the years. In contrast significant differences were recorded for 1000-grain weight with

Table I. Effect of plant density on plant height, total number of tillers hill^{-1}, panicle bearing tillers hill^{-1}, 1000-grain weight, grain yield, straw yield and harvest index

Treatments	2000							2001						
Seedlings	Plant height (cm)	Total tillers	Panicle bearing tillers	1000-grain weight (g)	Grain yield Mg ha^{-1}	Straw yield Mg ha^{-1}	Harvest index (%)	Plant height (cm)	Total tillers	Panicle bearing tillers	1000-grain weight (g)	Grain yield Mg ha^{-1}	Straw yield Mg ha^{-1}	Harvest index (%)
One hill^{-1}	139.43a	23.38b	16.35	15.86	3.51c	8.14b	29.95b	140.93a	23.98b	17.02	16.10	3.70c	8.33b	30.63b
Two hill^{-1}	138.07a	26.15a	16.40	15.88	3.92a	8.31a	31.79a	139.17ab	26.67a	17.08	16.14	4.12a	8.51a	32.51a
Three hill^{-1}	135.88b	25.27a	16.31	15.79	3.71b	8.28b	30.89b	137.31b	25.33ab	16.98	16.03	3.92b	8.48ab	31.53ab
LSD (5%)	2.06	1.56	0.95	0.71	0.19	0.14	1.45	1.96	1.01	0.99	0.58	0.20	0.15	1.46
Significance	**	**	ns	ns	**	*	*	**	**	ns	ns	**	*	*
Linear	**	*	ns	ns	*	Ns	ns	**	*	ns	ns	*	ns	ns
Quadratic	ns	*	ns	ns	**	Ns	*	ns	**	ns	ns	**	ns	*
Mean	137.79	24.93	16.35	15.84	3.72	8.24	30.88	139.14	25.32	17.03	16.09	3.91	8.44	31.56

*, ** = Significant at 5% and 1%, respectively; ns = Non-significant and means sharing different letters differ significantly at ≤0.05

Table II. Effect of fertilizer levels on plant height, total number of tillers hill^{-1}, panicle bearing tillers hill^{-1}, 1000-grain weight, grain yield, straw yield and harvest index

Treatments	2000							2001						
Fertilizer levels	Plant height (cm)	Total tillers	Panicle bearing tillers	1000-grain weight (g)	Grain yield Mg ha^{-1}	Straw yield Mg ha^{-1}	Harvest index (%)	Plant height (cm)	Total tillers	Panicle bearing tillers	1000-grain weight (g)	Grain yield Mg ha^{-1}	Straw yield Mg ha^{-1}	Harvest index (%)
0-0-0	130.61d	16.64d	15.15c	14.34c	2.98d	7.13d	29.49b	131.79d	17.43e	15.78c	14.44c	3.14d	7.32d	30.06b
50-67-67	135.67c	23.23c	16.02bc	15.26bc	3.28c	7.75c	29.57b	136.33c	23.02d	16.68bc	15.79b	3.44c	7.94c	30.24b
100-67-67	138.81b	26.54b	16.22abc	16.18ab	3.62b	8.49b	29.87b	139.60b	26.97c	16.89abc	16.44ab	3.81b	8.68b	30.55b
150-67-67	140.80ab	28.40ab	16.94ab	16.71a	4.23a	8.84a	32.35a	143.31a	28.79b	17.63ab	16.89a	4.46a	9.03a	33.08a
200-67-67	143.08a	29.87a	17.43a	16.73a	4.47a	9.01a	33.10a	144.67a	30.41a	18.15a	16.93a	4.71a	9.21a	33.85a
LSD 5%	3.60	2.72	1.23	0.92	0.24	0.18	1.87	2.53	1.30	1.28	0.75	0.26	0.20	1.88
Significance	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Linear	**	**	ns	**	**	**	**	**	*	ns	**	**	**	**
Quadratic	ns	ns	ns	**	Ns	**	ns	ns	**	ns	**	ns	**	ns
Cubic	ns	ns	ns	ns	Ns	Ns	ns	ns	ns	ns	ns	ns	ns	ns
Mean	137.79	24.93	16.35	15.84	3.72	8.24	30.88	139.14	25.32	17.03	16.09	3.91	8.44	31.56

*, ** = Significant at 5% and 1%, respectively; ns = Non-significant and means sharing different letters differ significantly at ≤0.05

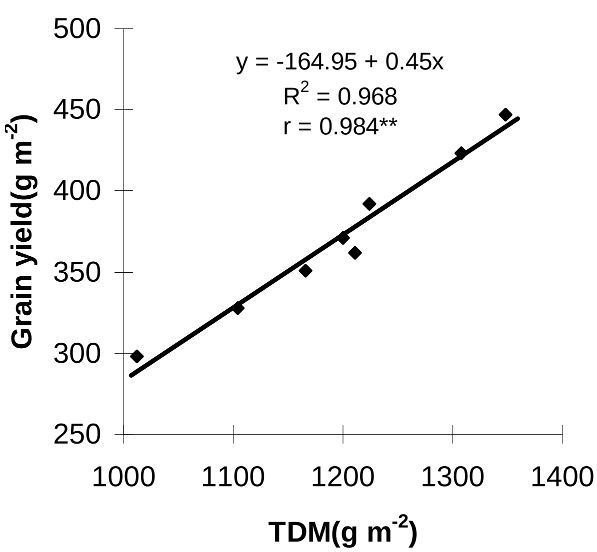
different N rates in both the years. In 2000, the mean grain weight achieved was 14.34 g in F_0, 15.26 g in F_1 16.18 g in F_2, 16.71 g in F_3 and 16.73 g in F_4 fertilizer levels. Equivalent figures ranged from 14.44 g to 16.93 g 1000^{-1} grain among various N fertilizer levels in 2001 (Table II). Similar results were noted by others with nitrogen fertilizer management on cereals under similar agro-ecological conditions (Choudhry, 1997; Rasheed *et al*., 2004).

In both years, increased plant density from D_1 to D_2 significantly affected the grain yield, and the response was quadratic in nature (Table I). The grain yield ranged from 3.51 to 4.12 Mg ha^{-1} among the various plant densities during both the years. With each increment of N fertilizer up to 200 kg ha^{-1}, grain yield increased significantly. Overall mean grain yield was 3.7 and 3.91 Mg ha^{-1} in 2000 and 2001, respectively.

Further, yield was significantly and linearly related to TDM in both the years and the common regression line accounted for 97% variance in the pooled data (Fig. 1). Here, the greater grain yield for F_4 compared with lower level of N application could be due to enhanced N use efficiency that caused corresponding increases in the respective components. Earlier studies indicate an increase in grain yield of rice and other cereals in response to increased N level up to 120 kg ha^{-1} (Agarwal *et al*., 1985; Zia, 1987; Chaudhry 1997; Ali *et al*., 2005). These results also corroborate the findings of Park (1988) and Mohapatra *et al*. (1989) who reported the yield components and grain yield were increased by increasing N level in rice and the sink size contributed more to yield and harvest index than source activity.

Data regarding straw yield showed significant effects of treatments during both the seasons. Plant density increased the straw yield with increasing density but the response was quadratic in nature. However, increasing N fertilizer levels increased straw yield significantly and linearly in both the seasons. Generally increasing level of N fertilizer and higher plant density increased straw yield. The results are supported by the work of Hussain *et al*. (1989) and Choudhry (1997) who found that increasing N application (120-160 kg ha^{-1}) increased straw yield in rice. The effect of plant density on harvest index was significant and this response was quadratic in nature. The harvest index increased with increasing density from one to two and declined at three seedling $hill^{-1}$. The harvest index ranged from 29.95 to 32.51% among various plant densities during both the years. Increasing rates of N application significantly increased harvest index up to F_3 (150 kg N ha^{-1}). Thereafter, difference in harvest index between F_3 and F_4 N levels were non-significant (Table II). Overall harvest index was 30.88% in 2000 and 31.56% in 2001. Generally high density increase grain yield and decrease harvest index (Park, 1988).

Fig. 1. Relationship between grain yield and total dry matter during 2000



CONCLUSIONS

It is concluded that growth and grain yield of fine rice (Basmati-385) significantly influenced by plant density and nitrogen. The maximum yield was achieved with plant stand of two seedlings $hill^{-1}$ and nitrogen application at the rate of 200 kg ha^{-1} and these responses are quadratic in nature. From the above discussion it emerges that application of N @ 200 kg ha^{-1} with planting density of two seedlings $hill^{-1}$ is the most appropriate combination to obtain optimum rice yield under agroclimatic conditions of Faisalabad.

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