INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2005/07–3–445–447
http://www.ijab.org

Transplanted Fine Rice (*Oryza sativa* L.) Productivity as Affected by Plant Density and Irrigation Regimes

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ABSTRACT

Crop husbandry practices such as plant density and irrigation regimes significantly affect the rice (*Oryza sativa* L.) crop at initial growth and development and ultimately grain yield. The objective of this study was to characterize the effects of increasing plant density and irrigation regimes on yield attributes, associated with optimum grain yield. Three plant densities (1, 2 and 3 seedlings hill^{-1}) and five irrigation regimes (8, 10, 12, 14 and 16 irrigations) were used in this experiment during 2000 and 2001. Plant density and increasing application of irrigation significantly increased both grain yield and its components. Plant density (two seedling hill^{-1}) with 14 irrigations (I_4) produced the maximum grain yield.

Key Words: Irrigation; Plant density; Productivity; Rice; Seedlings

INTRODUCTION

Rice is the second major grain crop of Pakistan It is grown on an area of 2226 thousand hectares, with an annual production of 4478 thousand tones and having an average yield of 2012 kg ha^{-1} (Anonymous, 2004). To keep pace with demand and supply of rice yield with the rapidly increasing population of the country, it is desired to have higher production of rice per unit area. There are many factors responsible for low yields of rice such as plant density, fertilization and application of irrigation levels etc.

Plant density exerts a strong influence on rice grain yield, because of its competitive effect initially in crop growth and development and finally on rice yield. Hu *et al.* (2000) studied that photosynthetic characters of rice were affected by plant population and grain yield increases linearly with plant density until some competitive effects become apparent. Feng *et al*. (2000) observed that number of effective panicles was greater with highest plant population.

Adequate water supply is one of the most important factors in crop production. The amount of irrigation water needed for crop depends on climate, crop and soil characteristics. Irrigation has been shown to increase the crop yield in arid climate but yield varies greatly (Sharma & Prasad, 1984; Wajid, 2004). Rao *et al.* (2000) found that grain and straw yields were significantly improved due to continuous submergence as compared to soil saturated to field capacity. Previous studies have found that grain yield increase proportionally with water supply and it is particularly high under flooded irrigation (Sharma, 1989). Heenan and Thompson (1984) found that delaying flooding until two weeks before panicle initiation reduced water use by 30% without increasing any significant loss in yield.

This study was designed to determine some suitable combinations of plant density and irrigation regime for optimum rice yield under the agro-climatic conditions of Faisalabad.

MATERIALS AND METHODS

The experiment was conducted on the Agronomic Research Area, University of Agriculture, Faisalabad, during 2000 and 2001. A randomized complete block design (RCBD) with factorial arrangement was employed with three replications per block. The study comprised of three plant densities (1, 2 & 3 seedling hill $^{-1}$) and five irrigation regimes (8 irrigations, 10 irrigations, 12 irrigations, 14 irrigations and 16 irrigations). The nursery was sown by dry method in the first week of June during both the seasons and wetland preparation (puddling) method was used for preparing the puddock for transplanting. Thirty days old seedlings were transplanted manually in the pudded field in standing water at 22.5 cm × 22.5 cm plant-to-plant and row-to-row distance. Recommended dose of fertilizer at the rate of 150-67-67 kg ha^{-1} was applied in the form of Urea, Single Super Phosphate (SSP) and Potassium Sulphate. All other crop husbandry practices were the same for all the treatments.

Data were recorded on yield and yield components, such as plant height, total number of tillers hill^{-1}, panicle bearing tillers hill^{-1}, 1000 grains weight, grain yield, straw yield and harvest index. Data collected were analysed statistically using "MSTAT" statistical computer package and differences among treatment means were compared employing least significant difference (LSD) test at probability level of 5% (Steel & Torrie, 1984).

RESULTS AND DISCUSSION

In both seasons plant density did not significantly affect plant height and plant height ranged from 126.19 to 128.57 cm (Table I). Increasing amount of irrigation significantly increased plant height as compared to lower level of irrigation application. In both the seasons, difference in plant height between I_4 and I_5 were not significant. In 2000, plant height was 119.74, 122.66, 126.86, 131.02 and 133.12 cm in I_1 through I_5 respectively. Equivalent figures in 2001 were 121.07, 124.02, 128.27, 132.47 and 134.60 respectively (Table II). These results are in line with the findings of other scientists who also reported taller plant, with increase in water supply (Rao & Parasad, 1985; Choudhry, 1997).

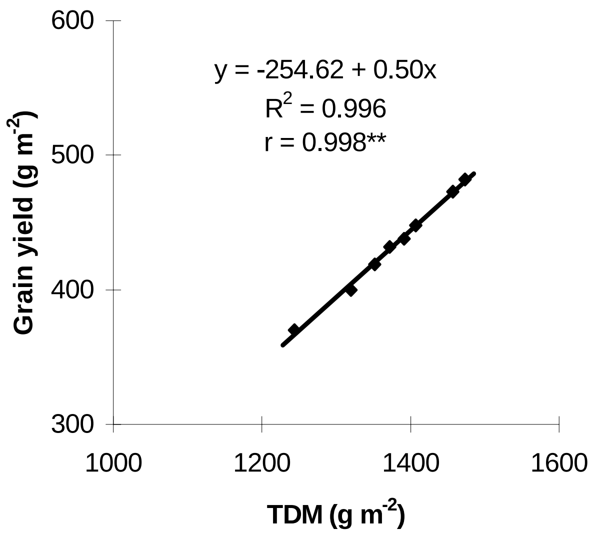
The data regarding total number of tillers hill^{-1} indicated that maximum number of tillers hill^{-1} was produced by D_2 in both the seasons. Differences in number of tillers hill^{-1} in D_2 and D_3 were, however, statistically similar in both the seasons and total number of tillers hill^{-1} ranged from 17.10 to 18.56 among different plant densities (Table I). In both, seasons increasing irrigation levels from I_1 to I_5 significantly and linearly increased total numbers of tillers hill^{-1}. Differences in the numbers of tillers hill^{-1} between I_4 to I_5 irrigation levels were, however, significant. In 2000 total number of tillers hill^{-1} were 14.77, 16.26, 17.63, 19.35 and 19.84 in I_1 through I_5 respectively. Equivalent figures in 2001 were 15.26, 16.79, 18.21, 19.99 and 20.49 (Table II). Rivero *et al*. (1986) reported that number of tillers per unit area was increased in rice at higher levels of irrigation.

In the both seasons, plant density did not significantly affect the number of panicle bearing tillers hill^{-1} and it ranged from 15.47 to 16.19 (Table I). Increasing amount of irrigation water from I_1 to I_5 significantly and linearly increase the number of panicle bearing tiller hill^{-1} in both seasons except in control when the differences in the number of panicle bearing tillers hill^{-1} between I_4 and I_5 were not evident. Mean panicle bearing tillers hill^{-1} were 16.09 and 16.52 during 2000 and 2001, respectively (Table II).

Results indicated that the plant density significantly affected the 1000-grain weight during 2001 but not in 2000. The D_2 significantly produced the greater 1000-grain weight as compared to D_1 or D_3 treatments. Increasing level of irrigation application significantly influenced the mean grain weight during 2000 and the response was linear, but not in 2001. However, 1000-grain weight varied from 16.86 to 17.89 among different irrigation treatments. Overall mean grain weight was 17.04 for the year 2000 and 17.4g during 2001 (Table II).

Plant density significantly affected the grain yield during both the seasons (Table I), and this response was quadratic in nature. Maximum grain yield was noted in case of D_2 followed by D_3 and D_1 and it ranged from 3.96 to 4.48

Fig. 1. Transplanted fine rice productivity as affected by plant density and irrigation regimes



Mg ha^{-1} in both the years. Increasing irrigation levels from I_1 to I_5 linearly increased the grain yield. However, difference in grain yield between I_4 and I_5 were statistically at par in both the years. The I_3 was also superior in grain yield than I_1 or I_2 irrigation levels. Grain yield was positively and linearly related with total dry matter in both the seasons and common regression line showed 99.6% variance in the data (Fig. I). During 2000, grain yield was 3.50, 3.80, 4.15, 4.49 and 4.57 Mg ha^{-1} respectively for I_1 through I_5. Equivalent figures in 2001 were 3.7, 4.0, 4.38, 4.73 and 4.82 Mg ha^{-1} respectively. Similar results were reported by others that found higher yield with optimum irrigation level (Sharma *et al*., 1987; Choudhry, 1997). Data showed that increasing density from D_1 to D_3 significantly increased the straw yield in both the seasons (Table I). Differences in straw yield between D_2 and D_3 were statistically at par in the both years and it ranged from 8.53 to 8.93 Mg ha^{-1}. Increasing levels of irrigation significantly increased straw yield and the response was linear for this parameter during both the seasons. In 2000 averaged straw yield was 7.99, 8.40, 8.69, 8.67 and 9.03 Mg ha^{-1} for respectively for all irrigation treatments. Equivalent figures in 2001 were 8.15, 8.57, 8.86, 9.15 and 9.20 Mg ha $^{-1}$, respectively.

Plant density significantly affected the harvest index in both the seasons but the difference in D_2 and D_3 densities non-significant (Table I). In first year increased application of irrigation levels significantly and linearly enhanced harvest index ranging from 30.49 to 33.63 % among different irrigation levels, while this range for 2001 was 31.18 to 34.40 %. Differences in harvest index between I_4 to I_5 were, however, not evident in both the seasons. Overall harvest index was 32.20 % in 2000 and 32.93 % in 2001 (Table II).

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}	126.19	17.1b	15.47	16.85	3.96b	8.53b	31.68b	127.58	17.66b	15.89	17.20b	4.19b	8.70b	32.40b
Two hill^{-1}	127.16	17.97a	16.56	17.34	4.24a	8.75a	32.60a	128.57	18.56a	16.99	17.70a	4.48a	8.93a	33.35a
Three hill^{-1}	126.69	17.64ab	16.23	16.93	4.10ab	8.57ab	32.31a	128.10	18.22ab	16.66	17.29ab	4.32ab	8.74ab	33.05a
LSD (5%)	2.08	0.64	1.20	0.47	0.16	0.20	0.42	2.17	0.66	1.27	0.48	0.16	0.20	0.43
Significance	ns	*	ns	ns	**	*	**	ns	*	ns	*	**	*	**
Linear	ns	ns	ns	ns	Ns	ns	**	ns	ns	ns	ns	ns	ns	**
Quadratic	ns	*	ns	*	**	**	**	ns	*	ns	*	**	*	**
Mean	126.68	17.57	16.09	17.04	4.10	8.62	32.20	128.08	18.15	16.52	17.40	4.33	8.79	32.93

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

Table II. Effect of irrigation regimes 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						
Irrigations	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 (%)
Eight	119.74c	14.77d	13.44c	16.56bc	3.50d	7.99d	30.49d	121.07d	15.25d	13.44c	16.91c	3.70d	8.15d	31.18d
Ten	122.66c	16.26c	14.76c	16.85bc	3.80c	8.40c	31.11c	124.02c	16.79c	14.76c	17.20bc	4.00c	8.57c	31.82c
Twelve	126.86b	17.63b	17.23b	17.01ab	4.15b	8.69b	32.38b	128.27b	18.21b	17.23b	17.37abc	4.38b	8.86b	33.12b
Fourteen	131.02a	19.35a	18.29ab	17.26ab	4.49a	8.97a	33.38a	132.47a	19.99a	18.29ab	16.62ab	4.73a	9.15a	34.14d
Sixteen	133.12a	19.84a	18.85a	17.53a	4.57a	9.03a	33.63a	134.60a	20.49a	18.85a	17.89a	4.82a	9.20a	34.40a
LSD 5%	2.68	0.83	1.60	0.61	0.20	0.25	0.55	2.71	0.85	1.60	0.62	0.21	0.25	0.56
Significance	**	**	**	*	**	**	**	**	**	**	*	**	**	**
Linear	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Quadratic	ns	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	ns	*	ns
Cubic	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	*
Mean	126.68	17.57	16.09	17.04	4.10	8.62	32.20	128.08	18.15	16.52	17.40	4.33	8.79	32.93

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

CONCLUSIONS

It is concluded that growth and grain yield of rice (Basmati-385) significantly influenced by plant density and irrigation. The maximum yield was achieved with plant stand of two seedlings hill^{-1} with 14-irrigations and these responses were quadratic in nature. From the above discussion it can be suggested that application of 14-irrigations and density of two seedlings hill^{-1} is a most appropriate combination to obtain optimum response of rice yield under the climatic conditions of Faisalabad.

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(Received 10 February 2005; Accepted 26 March 2005)