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MORPHOLOGICAL AND QUALITY PARAMETERS OF *ORYZA SATIVA* L. AS AFFECTED BY POPULATION DYNAMICS, NITROGEN FERTILIZATION AND IRRIGATION REGIMES

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Abstract

Quality of the produce is as much important as quantity in all walks of life and particularly in directly consuming commodities. The present study was conducted to compare the morphological and quality of the field grown rice as effected by population dynamics, nitrogen fertilization and irrigation regimes. Field experiments were carried out at University of Agriculture, Faisalabad (UAF), Pakistan for two years. The results revealed that population dynamics did not significantly effect the quality parameters. However, nitrogen fertilization and irrigation regimes have significant and linear impact upon quality attributes of fine transplanted rice under field conditions. From the two years data it can safely be recommended that application of 200 kg ha^{-1} of nitrogen and 48 plants m^{-2} is the most appropriate to obtain optimum response of yield and kernel quality under the prevailing conditions. Moreover, irrigation regime of 107.5 cm seems more appropriate than lower or higher rates of irrigation application under the water scarcity situations. In the present scenario the severity of water shortage is increasing in Pakistan, therefore, deficit irrigation should be applied. Simple correlation coefficients were also studied between grain yield and yield components of rice crop for both experiments, having highly positive and highly negative relation.

Introduction

Stability and growth of all nations in the world in present and future scenarios is only possible by using their resources efficiently and effectively to meet the burgeoning populations (Ahmad *et al*., 2009). That's why it is imperative to increase the production of agricultural produce both in terms of quantity and quality to meet the challenge of food security. In Pakistan, rice holds second pitch after wheat both in terms of production and consumption. Rice production constitutes the major economic activity and a key source of employment for the rural population of Pakistan (Baloch *et al*., 2006). It is grown on an area of 2515 thousands hectares with an annual production of 5563 thousands tones of grains and having average yield of 2211 kg ha^{-1} (Anon., 2008). In addition to low yield of rice as compared to the genetic potential, Pakistan also earns foreign exchange by exporting it. So, quality of rice grain is next to rice production in Pakistan.

Population dynamics exerts a strong influence on rice growth and grain yield, because of its competitive effect both on the vegetative and reproductive development, and ultimately quality. Density depended effects on yield are due to the competition between the adjacent plants for the necessary resources (Donald, 1963; Zia, 1987). Hu *et al*., (2000) reported that the photosynthetic characters of rice were affected by plant population. Janaki & Thiyagarajan (2005) observed that nitrogen uptake was significantly lower at lower plant densities as compared with highest plant densities. The growth and yield of a crop can be adversely affected by a deficient or excessive supply of any one of essential nutrients. However in intensive agriculture nitrogen is the major nutrient

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determining crop yield by effecting potential kernel setting in cereal crop (Waraich *et al.*, 2007). Nitrogen, the most deficient element in our soils being an integral part of structural and functional proteins, chlorophyll and nucleic acid plays a vital role in crop development (Tisdale *et al.*, 1990). Rajarathinam & Balasubramaniyan (1999) concluded that yield and quality parameters (panicles m^{-2}, panicle weight and length, grain $panicle^{-1}$, filled grain $panice^{-1}$, harvest index and 1000 grain weight) and grain yield were highest with the 200 kg N ha^{-1}. Crude protein concentration is frequently improved substantially by adequate nitrogen supply (Tisdale *et al.*, 1990). Lack of proper water management is probably the most wide spread constraint to higher rice yield and quality (Sharma & Sarkar, 1994). Irrigation has been shown to increase crop yield in arid climates (Sharma & Prasad, 1984) but yield varied greatly. Takami *et al.*, (1990) concluded that cereal crops often encounter drought during grain-filling stage, so yield reduces substantially and there is a limited chance for the crop to recover from the negative impact. Grain yield may be drastically reduced when water deficit coincides with the flowering period (O'Toole, 1982; Garrity & O'Toole, 1994). In recent years the severity of water shortage is increasing in Pakistan, therefore, deficit irrigation should be applied.

Material and Methods

Experimental site, design and treatments: Two field experiments were conducted on the Agronomic Research Area, University of Agriculture, Faisalabad (UAF), Pakistan (31.25°N, 73.09°E and 184.4 m altitude). Treatments for experiment I includes three plant densities viz., PD_1 = 16 plants m^{-2}, PD_2 = 32 plants m^{-2}, and PD_3 = 48 plants m^{-2}, and five nitrogen fertilizer (NF) levels viz., NF_0 = 0, NF_1 = 50, NF_2 = 100, NF_3 = 150, and NF_4 = 200 kg N ha^{-1}. Whilst, treatments for experiment II were three plant densities as in experiment I along with five irrigation regimes, viz., I_1 = 62.5 cm, I_2 = 77.5 cm, I_3 = 92.5 cm, I_4 = 107.5 cm and I_5 = 122.5 cm. The other detailed experimental methodology has been fully described by Ahmad *et al.*, (2008).

Protocols for determination of morphological and quality parameters

Kernel protein content (KPC): Kernel protein content of rice seed were estimated by micro kjeldahl digestion to determine nitrogen content, which is then converted to protein by multiplying with the factor 5.9 (Jacobe, 1958).

Kernel amylose content (KAC): Milled and grounded rice seed were used for the determination of amylase content according to method prescribed by Juliano (1971). The intensity of blue colour was read in a spectronic photometer 20 (Baush & Lomb) at 620 nm.

Kernel water absorption ratio (KWAR): The water absorption ratio was determined by the formula reported by Juliano *et al.*, (1965). Kernel water absorption ratio (KWAR) = weight of cooked rice/ weight of raw rice.

Sterility, abortiveness, opaqueness and normal kernels: Sterile spikelets (sterile spikelets are those which are not filled and fertilization in such cases does not take place), abortive (Fertilization takes place but the development of kernels starts taking place sluggishly, which eventually discontinues during early development stages of kernels), opaque (opaque kernels stop gaining weight at a little later stage than abortive kernels) and normal kernels (kernels which do not stop growing in any way during the ripening process and attain dimensions and full weight) were counted from ten panicles from primary tillers randomly selected from each treatment. The whole panicles were carefully sketched to differentiate between sterile spikelet, abortive, opaque and normal kernels (Nagato & Chaudhry, 1969). A common electric lamp with a flexible stand was used as a source of light. A panicle was positioned in front of the lamp so that light may pass through it in order to differentiate different stages of kernel development. Number of sterile spikelets, abortive, opaque and normal kernels from each sketch of all the treatments were counted, averaged and expressed in percent.

Dimensions of kernels (mm): Kernel dimensions (length and width) were taken on 100 normal kernels from each treatment with the help of a dial caliper. Length/width ratios were calculated from the values.

Statistical analysis: All sets of data were subjected to analysis of variance to assess the significant of treatment effects using "MSTAT' statistical computer package (Freed & Scot, 1986). The effect of plant density, N application levels and increasing irrigation regimes was analysed using polynomial contrast within the analysis of variance structure. Differences among treatments means were compared employing least significant difference (LSD) test at $p \leq 0.5$ (Steel *et al*., 1997).

Results and Discussion

Experiment I (Population dynamics and N levels)

Spikelet sterility (SS): The SS was not significantly affected by plant density during both the seasons and average SS was 12.51% in PD_1, 12.53 in PD_2 and 12.63% in PD_3 respectively (Table 1). Increasing rates of NF application significantly decreased SS as compare to nil (NF_0) or lower rate (NF_1) of NF application in both the study years. Application of 100 kg (NF_2) application rate also significantly decreased the SS than NF_0 or NF_1 application rates. Averaged over the two seasons the SS was 14.84%, 14.07%, 12.37%, 11.07% and 10.44% in NF_0, NF_1, NF_2, NF_3 and NF_4 respectively (Table 1).

Abortive kernels (AK): In both years plant density did not affect the percentage of AK (Table 1). Averaged over the two-years percentage of AK ranged from 11.13% to 12.45% between different densities. Increasing rates of NF application significantly decreased the percentage of AK as compared to nil or lower rates of application. In both seasons differences in the percentage of AK between NF_3 and NF_4 treatment were statistically at par. Averaged over the two years data the percentage of AK was 15.45%, 13.92%, 11.93%, 9.43%, and 7.59% in NF_0, NF_1, NF_2, NF_3 and NF_4 application rates, respectively (Table 1).

Opaque kernels (OK): Table 1 presents the effect of plant density and fertilizer levels on percentage of OK. In both years plant density did not affect the percentage of OK and it varied from 14.73% to 14.99% among different densities. Increasing rates of NF application significantly decreased the percentage of OK as compared to nil or lower rates of application. Differences in the percentage of OK between NF_3 and NF_4 treatments were however non significant in both the seasons. Averaged over the two seasons the percentage of OK was 16.29%, 15.96%, 14.95%, 13.72% and 13.39% in NF_0, NF_1, NF_2, NF_3 and NF_4 application rates, respectively (Table 1).

Table 1. Morphological and quality parameters of rice as affected by population dynamics and nitrogen fertilization.

Treatments	Spikelet sterility (%)	Abortive kernels (%)	Opaque kernels (%)	Normal kernels (%)	Kernel length (mm)	Kernel width (mm)	Water absorption ratio	Kernel protein content	Kernel amylose content	Grain yield (g m^{-2})
	Population dynamics (plants m^{-2})									
PD_1=16	12.51	11.41	14.73	67.59	6.71	1.84	4.04	8.93	22.18	360.0
PD_2=32	12.53	11.13	14.79	67.81	6.71	1.84	4.10	8.93	22.42	402.0
PD_3=48	12.63	12.45	14.99	67.73	6.70	1.84	4.03	8.90	22.11	381.0
LSD 5%	0.83	1.50	2.06	6.50	0.07	0.05	0.42	0.33	0.50	0.20
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
Linear	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
	Fertilizer N application rates									
NF_0 = 0	14.84	15.45	16.29	61.20	6.63	1.79	3.74	8.20	20.85	306.0
NF_1 = 50	14.07	13.92	15.96	65.87	6.68	1.82	3.88	8.66	22.28	336.0
NF_2 = 100	12.37	11.93	14.95	67.62	6.72	1.85	4.04	9.08	22.49	371.0
NF_3 = 150	11.07	9.43	13.72	70.50	6.75	1.87	4.28	9.26	22.70	434.0
NF_4 = 200	10.44	7.59	13.39	73.35	6.76	1.88	4.34	9.41	22.87	459.0
LSD 5%	1.07	1.94	2.66	8.40	0.10	0.06	0.55	0.43	0.57	0.26
Significance	**	**	*	**	*	*	*	**	**	**
Linear	**	**	**	**	**	**	**	**	**	**
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	**	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Normal kernels (NK): Plant density did not affect the percentage of NK during both the study years. Averaged over the two years data the percentage of NK varied from 67.59% to 67.81% among different densities. In both years increasing rates of NF application significantly increased the percentage of NK as over nil or lower rates of application. Averaged over the two years data mean percentage of NK was 61.20%, 65.87%, 67.62%, 70.50% and 73.35% in NF_0, NF_1, NF_2, NF_3 and NF_4 application rates, respectively.

Kernel length (KL): Table 1 showed that plant density had no significant affect on KL in both the seasons. The average KL varied from 6.70 mm to 6.71 mm among different densities. Increasing NF application rate significantly increased the KL as compared to nil (NF_0) treatment. Differences in the KL among different rates of NF application were non-significant in both the years. Averaged over the two years the KL varied between 6.63 to 6.76 mm among different rates of NF application.

Kernel width (KW): KW was not significantly affected by the plant density in both the seasons and it varied from 1.84 mm to 1.85 mm. Increasing rates of NF application significantly increased the KW as compared to nil (NF_0) treatment in both the years. Averaged over the two years data the KW was 1.79 mm in NF_0, 1.82 mm in NF_1, 1.85 mm in NF_2, 1.87 mm in NF_3 and 1.88 mm in NF_4 application rate (Table 1).

Kernel water absorption ratio (KWAR): Table 1 presents the effect of treatments on KWAR. In both seasons KWAR was not significantly affected by plant density and it ranged from 3.97 to 4.19 among different densities. Increasing rates of NF application significantly enhanced KWAR than nil (NF_0) treatment in both the years. Differences in KWAR among different rates of N application were however statistically at par in both the seasons. Averaged over, the two years mean KWAR varied from 3.74 to 4.34 among different rates of NF application.

Kernel protein contents (KPC): Plant density did not affect significantly the KPC in both the seasons and it varied from 8.90 to 8.93 among various densities (Table 1). Increasing rates of NF application significantly increased the KPC as compare to NF_0 (nil) or lower rates of NF application (NF_1) in both the years. Differences in KPC among NF_2, NF_3 and NF_4 application rates were however significant. Averaged over the two years, KPC was 8.20%, 8.66%, 9.08%, 9.26%, and 9.41% respectively in NF_0, NF_1, NF_2, NF_3 and NF_4 application rates (Table 1).

Kernel amylose content (KAC): Table 1 shows that plant density did not affect the significantly the KAC in both the years, and it varied 22.11% to 22.42% among various densities. Increasing rates of NF application from NF_0 to NF_4 significantly increased the KAC. However, differences between NF_2, NF_3 and NF_4 application rates were non-significant. Averaged over the two years data, KAC were 20.85% in NF_0, 22.28% in NF_1, 22.49% in NF_2, 22.70% in NF_3 and 22.87% in NF_4 application rate. Overall KAC was 22.08% in year I and 20.40% in year II which are similar to the values (23.52% - 24.44%) reported in literature.

Correlation between grain yield and components of yield: Simple linear correlation analysis between grain yield and different components of yield are presented in Table 3. The data showed highly positive correlation between grain yield and different components of yield such as total number of tillers hill^{-1}, number of panicle bearing tillers hill^{-1}, number of spikelets panicle^{-1} and 1000-grain weight in both the years. The pooled data also showed similar trend between grain yield and its components. Data in Table 3 also showed that quality parameters such as SS, AK, and OK were highly negatively correlated with the grain yield. However, kernel dimensions and KPC were positively and significantly correlated with grain yield.

Experiment II (Population dynamics and Irrigation regimes)

Spikelet sterility (SS): Table presents the effect of treatments on percentage of SS. In both the seasons plant density did not affect significantly the percentage of SS and it ranged from 6.0 to 6.27% among different densities. In both seasons increasing irrigation levels significantly reduced the percentage of SS and it was minimum at 5.28% in first season and 5.39% in I_5 (16 irrigation) treatment. However both I_4 and I_5 treatments were statistically at par in SS. Averaged over the two years data percentage of SS was 6.60%, 6.41%, 6.28%, 5.94% and 5.34% in I_1, I_2, I_3, I_4 and I_5 treatment, respectively. Overall mean percentage of SS was 6.05% in first season and 6.18% in second season (Table 2).

Abortive kernels (AK): In both seasons PD_1 and PD_3 density significantly increased percentage of AK over PD_2 density, whereas differences in abortive kernels between PD_1 and PD_3 were however non- significant. Averaged over the two years data percentage of AK was 6.86% in PD_1, 6.73% in PD_2 and 6.86% in PD_3 density (Table 2). Increasing levels of irrigation significantly reduced the percentage of AK. In both seasons differences in the percentage of AK between I_1 and I_2 treatment were non- significant. In first year percentage of abortive kernels was 7.0%, 6.93%, 6.78%, 6.58% and 6.39% in I_1, I_2, I_3, I_4 and I_5 treatment, respectively. Equivalent figures in second year were 7.17%, 7.10%, 6.94%, 6.73% and 6.55%, respectively. Overall mean percentage of AK was 6.74% and 6.90% in first and second year, respectively (Table 2).

Opaque kernels (OK): Data in Table 2 showed non significant effect of plant density on the percentage of OK. Averaged over the two years data percentage of OK was 6.15% PD_1, 6.11% in PD_2 and 6.21% in PD_3 density. In both seasons increasing levels of irrigation application from I_1 to I_5 significantly decreased the percentage of OK. Averaged over the two seasons percentage of OK was 6.81%, 6.49%, 6.03%, 5.85% and 5.59% in I_1, I_2, I_3, I_4 and I_5 treatment, respectively. Overall mean percentage of OK was 6.09% in first and 6.22% in second year (Table 2).

Normal kernels (NK): Table 2 presents the effect of treatments on percentage of NK. In both seasons PD_2 density significantly increased the percentage of NK as compared to PD_1 density. Differences in the percentage of NK between PD_2 and PD_3 density were however non-significant. Averaged over, the two seasons mean percentage of NK varied from 65.04% to 67.06% among different densities. In both seasons increasing levels of irrigation application significantly and linearly increased the percentage of NK. Differences in the percentage of NK between I_4 and I_5 treatment were however non-significant. In both seasons I_3 (92.5 cm) treatment was also superior in the percentage of NK than I_1 and I_2 treatments. Averaged over the two seasons percentage of NK was 57.36%, 60.13%, 65.09%, 73.78% and 73.82% in I_1, I_2, I_3, I_4 and I_5 treatment, respectively. Overall mean percentage of NK was 64.71% and 67.36% in first and second year, respectively (Table 2).

Table 2. Morphological and quality parameters of rice as affected by population dynamics and irrigation regimes.

Treatments	Spikelet sterility (%)	Abortive kernels (%)	Opaque kernels (%)	Normal kernels (%)	Kernel length (mm)	Kernel width (mm)	Water absorption ratio	Kernel protein content	Kernel amylose content	Grain yield (g m^{-2})
	Population dynamics (plants m^{-2})									
PD_1 = 16	6.08	6.86	6.15	65.04	6.65	1.66	3.06	8.29	22.21	408.0
PD_2 = 32	6.00	6.73	6.11	67.06	6.70	1.67	3.15	8.37	22.24	436.0
PD_3 = 48	6.27	6.86	6.21	66.01	6.70	1.67	3.11	8.32	22.15	421.0
LSD 5%	0.59	0.12	0.64	1.35	0.052	0.02	0.38	0.56	1.07	0.16
Significance	NS	*	NS	**	NS	NS	NS	NS	NS	**
Linear	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quadratic	NS	*	NS	*	NS	NS	NS	NS	NS	**
	Irrigation regimes (cm)									
I_1 = 62.5	6.60	7.09	6.81	57.36	6.60	1.64	2.83	7.75	21.26	360.0
I_2 = 77.5	6.41	7.02	6.49	60.13	6.69	1.66	2.88	8.03	21.42	390.0
I_3 = 92.5	6.28	6.86	6.03	65.09	6.70	1.67	3.10	8.41	22.21	427.0
I_4 = 107.5	5.94	6.66	5.85	73.78	6.71	1.67	3.35	8.66	22.99	461.0
I_5 = 122.5	5.34	6.47	5.59	73.82	6.71	1.68	3.37	8.75	23.13	470.0
LSD 5%	0.78	0.21	0.84	1.74	0.10	0.06	0.49	0.74	1.43	0.21
Significance	*	**	*	**	**	*	*	*	*	**
Linear	**	**	**	**	**	**	**	**	**	**
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	**	NS	NS	NS	NS	NS	NS

Kernel length (KL): Table 2 presents the effect of treatments on KL. Plant density did not significantly affect KL in both seasons and it varied from 6.65% to 6.70% among different densities. In both seasons I_2, I_3, I_4 and I_5 treatment significantly increased KL as compared to I_1 (62.5cm). Differences in KL between I_2, I_3, I_4 and I_5 treatment were non-significant in both seasons. Averaged over the two seasons mean KL varied from 6.60 mm to 6.71 mm among different irrigation levels (Table 2).

Kernel width (KW): Plant density did not affect significantly KW in both seasons and it ranged from 1.66 to 1.67 mm among different densities. In both seasons increasing levels of irrigation application significantly increased KW, as compared to I_1 irrigation treatment. The I_1, I_2, I_3, and I_4 irrigation levels were however statistically at par in KW during both the seasons. Averaged over the two years data KW ranged from 1.64 to 1.68 among different irrigation levels (Table 2).

Kernel water absorption ratio (KWAR): Plant density did not affect significantly KWAR in both the seasons and it varied from 3.06 to 3.15 among different densities (Table 2). Increasing levels of irrigation application significantly increased KWAR during first but not in second year (Table 2). Differences in KWAR between I_2, I_3, I_4 and I_5 treatment were however non-significant. Averaged over the two seasons KWAR was 2.83, 2.88, 3.10, 3.35 and 3.37 in I_1, I_2, I_3, I_4 and I_5 treatment, respectively.

Kernel protein content (KPC): Table 2 showed that plant density did not affect percentage of KPC. Averaged over the two season's KPC were 8.29%, 8.37% and 8.32% in PD_1, PD_2 and PD_3 density, respectively. Increasing level of irrigation significantly increased the percentage of KPC in both the seasons. Lowest percentage of KPC was produced in I_1 treatment in both the seasons. Differences in percentage of KPC between I_4 and I_5 treatments were however statistically at par. Averaged over the two seasons percentage of KPC was 7.75%, 8.03%, 8.41%, 8.66% and 8.75% in I_1, I_2, I_3, I_4 and I_5 treatment, respectively. Overall mean percentage of KPC was 8.24% in first and 8.40% in second year, respectively (Table 2).

Kernel amylose content (KAC): In both seasons plant density did not affect significantly percentage of KAC and it ranged from 22.15% to 22.24% among different densities (Table 2). Increasing levels of irrigation application significantly increased the percentage of KAC. Differences in percentage of KAC between I_3, I_4 and I_5 treatments were statistically at par in both the seasons. Difference in KAC between I_1 and I_2 treatments were however non-significant. Averaged over the two seasons percentage of KAC was 21.26%, 21.42%, 22.21%, 22.99% and 23.13% in I_1, I_2, I_3, I_4 and I_5 treatments, respectively. Overall mean percentage of KAC was 22.07% in first and 22.33% in second year (Table 2).

Correlation between grain yield and components of yield: Table 4 shows the simple linear correlation coefficients between grain yield and different components of rice. All the yield components such as total number of tillers hill^{-1}, number of panicle bearing tillers hill^{-1}, number of spikelet's panicle^{-1} were highly positively related with the grain yield. The relationship between grain yield and 1000-grain weight was highly significant in first year but non significant in second year. Correlation between quality parameters such as SS, AK and OK with grain yield was highly significant but negative. NK and kernel dimensions were also highly positively correlated with grain yield. Both KPC and KAC were highly related with the grain yield in both the seasons. A similar trend between grain yield and its components was shown by the pool data.

Table 3. The relationship between grain yield and yield components of rice.

Character	Correlation co-efficient (r)		
	Season I	Season II	Pool
Plant height vs grain yield	0.88**	0.90**	0.90**
Total number of tillers hill^{-1} vs grain yield	0.93**	0.94**	0.92**
Panicle bearing tillers hill^{-1} vs grain yield	0.96**	0.97**	0.92**
Spikelets vs grain yield	0.97**	0.98**	0.97**
1000-grain weight vs grain yield	0.92**	0.88**	0.90**
Straw yield vs grain yield	0.95**	0.95**	0.95**
Harvest index vs grain yield	0.95**	0.96**	0.96**
Spikelet sterility vs grain yield	-0.96**	-0.96**	-0.92**
Abortive kernels vs grain yield	-0.97**	-0.96**	-0.92**
Opaque kernels vs grain yield	-0.97**	-0.96**	-0.83**
Normal kernels vs grain yield	0.95**	0.95**	0.94**
Kernel length vs grain yield	0.93**	0.91**	0.87**
Kernel width vs grain yield	0.92**	0.45NS	0.87**
Kernel protein content vs grain yield	0.93**	0.92**	0.91**
Kernel amylase content vs grain yield	0.83**	0.82**	0.84**
Kernel water absorption ratio vs grain yield	0.97**	0.99**	0.98**

Table 4. The relationship between grain yield and yield components of rice.

Character	Correlation co-efficient (r)		
	Season I	Season II	Pool
Plant height vs grain yield	0.98**	0.98**	0.97**
Total number of tillers hill^{-1} vs grain yield	1.00**	1.00**	0.99**
Panicle bearing tillers hill^{-1} vs grain yield	0.99**	0.99**	0.97**
Spikelets vs grain yield	0.99**	0.99**	0.99**
1000-grain weight vs grain yield	0.94**	0.94**	0.94**
Straw yield vs grain yield	0.99**	0.99**	0.99**
Harvest index vs grain yield	1.00**	1.00**	1.00**
Spikelet sterility vs grain yield	-0.87**	-0.87**	-0.76**
Abortive kernels vs grain yield	-0.95**	-0.96**	-0.71**
Opaque kernels vs grain yield	-0.97**	-0.97**	-0.85**
Normal kernels vs grain yield	0.98**	0.98**	0.98**
Kernel length vs grain yield	0.83**	0.83**	0.79**
Kernel width vs grain yield	0.92**	0.92**	0.86**
Kernel protein content vs grain yield	0.99**	0.99**	0.99**
Kernel amylase content vs grain yield	0.96**	0.97**	0.96**
Kernel water absorption ratio vs grain yield	0.98**	0.98**	0.97**

Discussion

Analysis of quality parameters and relationship studies between grain and other parameters of transplanted rice as affected by plant population and N fertilization (Exp-I) and plant population and irrigation regimes (Exp-II) were studied. Transplanting is the most popular crop establishment method in Asia’s irrigated rice growing areas and most of agronomic research has concentrated on it (Schnier *et al*., 1990). Among all treatments in both experiments similar response was recorded. Plant population in both experiments did not significantly affect the quality parameters. Probably these factors are mainly controlled by genetic factors. However, all of these quality parameters along with grain yield were statistically affected by nitrogen rates and different irrigation regimes. Generally significant results in terms of nitrogenous and irrigation regimes were due to increase in nitrogen use and nitrogen use efficiency (NUE) in exp-I and higher water use and water use efficiency (WUE) in exp-II. Similar results were reported by others who also stated that application of optimum nitrogen fertilizer reduced the rate of occurrence spikelet sterility (%), abortive kernels, opaque kernels and increased the number of normal kernels (head rice), kernel dimensions, kernel protein contents and kernel water absorption ratio (Takami *et al*., 1990; Schnier *et al*., 1990; Gravois & Helms, 1996; Maqsood, 1998). The higher percentage of normal kernels with the increasing rate of nitrogen fertilizer application may be due to adequate supply of N that enhance the availability of other nutrients like P and K and partly due to low competition among different population densities. Thus kernels under such conditions develop in the absence of any competition. Under normal condition the kernel parameter (length, width) are genetically determined in the rice plant, unless, the environment is changed to such an extent where severe stress occurs. Treatments such as NF_0 (nil) or NF_1 (50 kg N per hectare) were probably too low to create a nutritional stress which caused reduction in kernel dimensions. Our results substantiate the findings of Ali *et al*., (1992) who also reported that nitrogen fertilizer increases the kernel protein content of cereals and improves the milling quality of rice. Takami *et al*., (1990) concluded that cereal crops often encounter drought during grain-filling stage, so yield reduces substantially and there is a limited chance for the crop to recover from the negative impact.

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