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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 10 (11): 1880-1884, 2007
ISSN 1028-8880

Response of Rice (*Oryza sativa* L.) Cooking Quality Properties to Nitrogen and Potassium Application

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Abstract: In order to consider effects of various levels of nitrogen and potassium application on cooking quality traits of rice cultivars, an experiment was conducted in 2004 and 2005 using Tarrom (a local Iranian landrace) and Neda (an Iranian improved cultivar). In this experiment four levels of nitrogen fertilizer (0, 50, 100 and 150 kg N ha^{-1} from urea source) and four levels of potassium fertilizer (0, 75, 150 and 225 kg K_2O ha^{-1} from potassium sulfate source) have been applied using a split factorial design with three replications. Nitrogen fertilizer have been applied in three stages (1/3 in transplanting stage, 1/3 in tillering stage and finally 1/3 in flowering initiation stage) and potassium fertilizer have been applied in two stages (½ in transplanting stage and ½ in shooting stage). Results showed that application of nitrogen increased gel consistency and decreased amylose content of rice kernel; however, had not significantly affected gelatinization temperature and grain protein content. Application of potassium increased gel consistency and grain protein content but had not significantly affected gelatinization temperature and kernel amylose content. Gel consistency and gelatinization temperature of Tarrom were higher than Neda; whilst, inversely, grain amylose and protein contents of Neda were higher than Tarrom. Simultaneous application of nitrogen and potassium has no significant effects on gel consistency, gelatinization temperature and grain protein content; But maximum amylose content was achieved using none of fertilizers in Neda and 75 kg K_2O ha^{-1} with no nitrogen fertilizer in Tarrom genotypes, respectively.

Key words: Gel consistency, gelatinization temperature, amylose content, protein content, nitrogen, potassium

INTRODUCTION

Although one of the best quality landrace rice with very long slender grain, cooking, taste, aroma and milling properties is cultivated in parts of Gilan province here in Iran, its low yield performance is the most important barrier for restricting its area of cultivation. Tarrom is the other high quality landrace rice that is cultivated in most area of Iran's Northern provinces, especially in Mazandaran. Information regarding the quality of this landrace rice is steel little known to us. Biswase *et al.* (2001) studied the quality of some sticky rice cultivars. Dipti *et al.* (2003) also studied quality of a different sticky cultivar. The amylose content, volume expansion, water absorption are critical parameters for cooking and eating qualities of milled rice (Juliano, 1972; 1979; 1985; Dipti *et al*., 2003).

In Philippine it was hypothesized that the low of yields and protein contents of rice at the IRRI farm were partly related to a change in the N supplying capacity of soil which results in low N concentration in the leaf canopy during the grain filling period, early senescence of leaves and low rates of photosynthesis (Kropff *et al.*, 1993; Cassman *et al.*, 1995; Perez *et al.*, 1996). Fertilizer-N application showed to be effective for increasing rice grain protein content when applied up to panicle initiation stage (IRRI, 1964; Nangju and De Datta, 1970; Taira, 1970; Taira *et al*., 1970; Seetanum and De Datta, 1973; Patrick and Hoskins, 1974). High protein contents improve the whole-grain or head rice content (Nangju and De Datta, 1970; Seetanum and De Datta, 1973; Blakeney, 1979; Jongkaewwattana *et al*., 1993) and milled-rice translucency (IRRI, 1964; Cagampang *et al*., 1966). The present study has been focused on comparison of cooking quality properties of two Iranian rice genotypes in response to nitrogen and potassium fertilizers application.

MATERIALS AND METHODS

The present experiment was conducted at Sari experimental station of Iran in year 2004 and 2005. The farm soil contained 515 g kg^{-1} clay, 295 g kg^{-1} silt, 90 g kg^{-1} sand, 23.4 g kg^{-1} total nitrogen, 213 mg kg^{-1} available potassium and 23.6% lime. Four levels of potassium fertilizer (0, 75, 150 and 225 kg K_2O ha^{-1} from potassium sulfate source) and four levels of nitrogen fertilizer (0, 50, 100 and 150 kg N ha^{-1} from urea source)

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have been applied. Half of the amount of potassium fertilizer was added in transplanting date and the rest was added in shooting stage and 1/3 of the amount of nitrogen fertilizer was used in transplanting time, 1/3 was added in tillering stage and the rest was added in flowering initiation stage. A split plot design with 3 replications based on a randomized complete block design with sub-plot size of 3×4 m and plant space of 25 cm have been used and 3 seedlings were transplanted per a hill.

For measuring gel consistency, gelatinization temperature and amylose content methods of Cagampang *et al*. (1973), Little *et al.* (1958) and Juliano and Villareal (1993) have been used, respectively. Kernel protein also was defined as percentage of protein content of kernel. For analysis of variance of data MSTATC statistical software was used.

RESULTS AND DISCUSSION

Rice quality is under influence of characteristics under genetic control, environmental factors and processing technologies. The genetic makeup of a particular genotype dictates to a large degree the grain quality characteristics. Selection for improving milling, cooking, eating and processing qualities is a required part of breeding programs to get industry standards or taste and cooking desirable for consumers. Furthermore, environmental factors and cultural practices during growth have key roles for determining rice ultimate quality. Moreover, there are factors influencing quality independent of genetics or the environment which are associated with handling, storage and presence of foreign material. Prolonged periods of storage under unfavorable circumstances can result in objectionable flavors or odors. Gel consistency, gelatinization temperature, amylose content and protein content are rice kernel genetically controlled factors that are under influence of environmental factors, cultural practices during growth, storage conditions and physically moving with machines which have been considered in present study.

Gel consistency and gelatinization temperature: Table 1 show that varieties are significantly different for all quality traits of rice kernel including gel consistency, gelatinization temperature. Nitrogen application was effectively significant for gel consistency (Table 1).

Tarrom genotype with gel consistency of 75.25 mm and gelatinization temperature of 6.78°C has illustrated much better cooking quality than Neda cultivar (Table 2). Cooking time of the rice depends on coarseness of the grain and its gelatinization temperature.

Higher levels of nitrogen application were more effective for gel consistency, so that, the best result was achieved with maximum amount of nitrogen (150 kg nitrogen ha^{-1}) applied in current experiment (Table 2). In contrast, potassium application showed better results for traits gel consistency (75.68 mm) applying 75 kg K_2O ha^{-1} (Table 2).

Table 1: Analysis of variance of cooking qualities of two Iranian rice genotypes for N and K application

		Means of squares			
Source of variation	df	Gel consistency (mm)	Gelatinization temperature (°C)	Amylose content (%)	Protein content (%)
Replication	2	215.18	0.39	0.03	0.06
Variety	1	178.46**	145.78**	171.98**	23.39**
Error (a)	2	50.63	0.23	0.66	0.01
Nitrogen	3	527.75**	0.02	27.96**	0.02
Var×Nitr	3	68.17	0.11	22.16**	0.13
Potassium	3	389.84**	0.22	3.57	0.19*
V×P	3	514.52**	0.06	3.22	0.14
N×P	9	84.01	0.09	7.25*	0.18*
V×N×P	9	79.53	0.14	12.49**	0.08
Error (bc)	60	68.18	0.09	3.43	0.06
CV		11.18	5.49	8.84	3.00

V = Variety, N = Nitrogen, K = Potassium, *, **Significant at 5 and 1% levels, respectively, df = Degree of Freedom

Table 2: Means of cooking qualities of two Iranian rice genotypes for N and K application

Treatments	Gel consistency (mm)	Gelatinization temperature (°C)	Amylose content (%)	Protein content (%)
Tarrom	75.25a	6.78a	19.62b	7.83b
Neda	72.52b	4.32b	22.30a	8.82a
N_0	7.02ab	5.05a	22.47a	8.36a
N_1	68.50c	5.58a	19.93b	8.30a
N_2	71.50bc	5.51a	20.84b	8.31a
N_3	78.51a	5.56a	20.59b	8.33a
K0	73.18a	5.62a	20.87a	8.29b
K1	75.68a	5.56a	21.38a	8.46a
K2	72.91ab	5.41a	21.11a	8.30b
K3	68.77b	5.60a	20.47a	8.27b
Mean	73.89	5.55	20.98	8.33

In each column different letter(s) shows significant effect

Table 3: Interactions of cultivar and nitrogen for cooking qualities of two Iranian rice genotypes

Treatments	Gel consistency (mm)	Gelatinization temperature (°C)	Amylose content (%)	Protein content (%)
Tarrom				
N0	74.75b	6.85a	19.98a	7.65a
N1	77.61b	6.79a	18.73a	7.79a
N2	74.75b	6.77a	19.33a	7.75a
N3	80.05a	6.70a	20.43a	7.74a
K0	73.31b	6.90a	20.08a	7.64b
K1	76.52a	6.75a	19.86a	7.75a
K2	72.40b	6.69a	19.53a	7.76a
K3	74.92b	6.78a	19.01a	7.78a
Neda				
N0	73.37a	4.25a	24.96a	8.73b
N1	64.56a	4.36a	22.13ab	8.77b
N2	70.00a	4.24a	22.35ab	8.80ab
N3	76.32a	4.40a	20.49b	8.89a
K0	65.87b	4.35a	21.66a	8.73b
K1	74.50a	4.37a	22.90a	8.81ab
K2	71.25b	4.13a	22.43a	8.79ab
K3	69.62b	4.41a	21.93a	8.86a

In each column different letter(s) shows significant effect

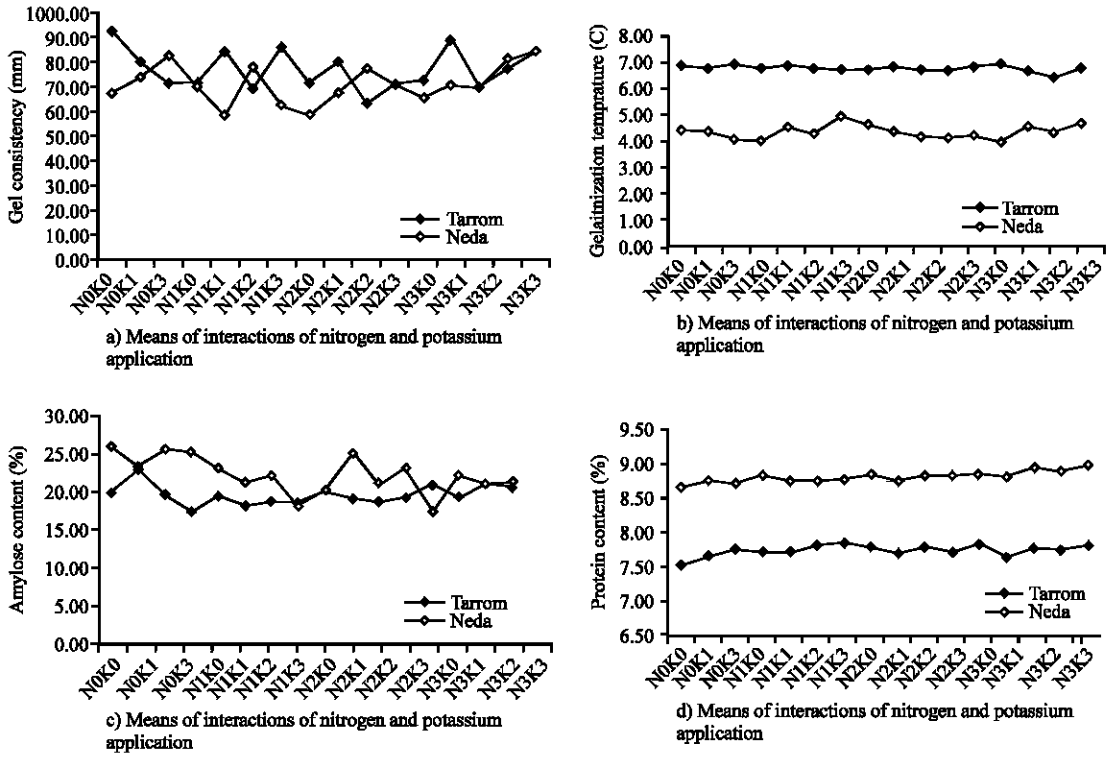

Fig. 1: Effects of various levels of simultaneous application of nitrogen and potassium fertilizers on cooking quality traits of Iranian rice genotypes

Gel consistency showed no changes due to application of nitrogen and potassium in Neda cultivar; however, in Tarrom, it has been significantly increased up to 80.05 mm genotype using 150 kg nitrogen ha^{-1} and up to 76.52 mm using 75 kg K_20 ha^{-1}, but decreased by increasing in application of potassium fertilizer (Table 3). Simultaneous application of nitrogen and potassium showed no effects on gel consistency in both genotypes (Fig. 1a).

Gelatinization temperature in Tarrom genotype with 6.78°C was higher than in Neda cultivar with 4.32°C, whilst application of nitrogen and potassium demonstrated no significant effect on gelatinization temperature (Table 2). Meanwhile, gelatinization temperature in Tarrom and Neda genotypes demonstrated no significant effects using nitrogen or potassium fertilizers (Table 3). Despite insignificant effects of simultaneous application of nitrogen and potassium on trait gelatinization temperature, treatments N0K0 and N3K2 for Tarrom and N1K2 and N3K0 for Neda showed the most and the least gelatinization temperature, respectively (Fig. 1b).

Amylose and protein contents: Table 1 shows significant difference between genotypes Tarrom and Neda for amylose and protein content of rice grain. Neda cultivar with 22.30 and 8.82% was superior than Tarrom genotype with 19.62 and 7.83% amylose and protein content, respectively (Table 2). Rao and Siddiq (1976) showed that differences between amylose content of rice varieties have tremendously role in cooking and eating quality of rice. Low amylose content rice cooks moist and sticky and very few expansion of volume will happened during cooking. In contrast, high amylose content rice shows high volume expansion (not necessarily elongation) and high degree of flakiness. The grains cook dry, are less tender and become hard upon cooling (Normita, 1978; Dipti *et al*., 2003). Therefore, intermediate amylose contents rice are the most suitable rice to get soft and not getting hard upon cooling. According to their amylose content, rice varieties are classified into four groups, waxy with no amylose, non-waxy with 10-20% amylose, intermediate amylose with 20-25% and high amylose with 25-30% (Juliano *et al*., 1965; Juliano, 1971, 1979). In spite of influence of gel consistency and gelatinization temperature on cooking quality, cultivars including in one group demonstrate roughly similar cooking quality. Indian and Pakistani Basmati and Iranian Sadri group of rice are similar to intermediate amylose rice group. Today most people like to consume intermediate type rice in most universal rice growing areas. Neda is classified into intermediate group and Tarrom with less than 20% amylose is classified into non-waxy group but its amylose content is too close to be accounted as intermediate group. Tarrom genotype has several types of landraces amongst farmers and is known as high quality rice. Therefore, it can not be classified into non-waxy group and should be included into intermediate group. It is quite possible having types of Tarrom genotypes with more amylose content than Neda cultivar. Moreover, one of the environmental factors affecting amylose content of varieties is temperature during maturity period of rice grain. The increase the temperature during maturity the decrease the amylose content of varieties and response of various genotypes is different because of their heritability level of amylose (Puri and Siddiq, 1983).

Application of no nitrogen has demonstrated higher amylose content than any other treatments: however, it has been decreased using nitrogen fertilizer (Table 2). Amylose content in Neda cultivar without application of nitrogen was 24.96% whilst, increasing in nitrogen application up to 150 kg N ha^{-1}, reduced amylose content to 20.49%; But in Tarrom genotype using nitrogen fertilizer showed no significant effects on its amylose contents (Table 3). Also, it is demonstrated that amylose contents in both genotypes have not been significantly affected by application of potassium (Table 3). Using nitrogen may improve cooking quality in both genotypes because of its increasing effects on Tarrom's amylose content from 19.98 to 20.43 and decreasing effects on Neda's amylose content from 24.96 to 20.49 (Table 3).

Simultaneous applications of nitrogen and potassium have significantly affected grain amylose content of Neda cultivar. Maximum amylose content was achieved using none of fertilizers in Tarrom and 75 kg K_2O ha^{-1} in Neda, respectively (Fig. 1c). The highest amylose content in Neda (25.51%) and Tarrom (22.89%) genotypes have been obtained using 150 and 75 kg K_2O ha^{-1} with no nitrogen, respectively. It seems that two genotypes showed different direction of cooking quality when applying potassium. Maximum potassium application with no nitrogen destroys Neda's cooking quality, however, this trait getting improve when potassium have been applied 75 kg K_2O ha^{-1} with no nitrogen.

Application of nitrogen fertilizer plays various roles in Tarrom and Neda genotypes for grain protein contents, so that, it has insignificantly increased in Tarrom but significantly increased in Neda genotypes, respectively. Maximum grain protein content in Neda was obtained using 150 kg N ha^{-1} (Table 3). Potassium application has significantly affected grain protein content of Tarrom and Neda, so that, both genotypes have produced maximum grain protein contents (7.78 and 8.86% for Tarrom and Neda, respectively) using 225 kg K_2O ha^{-1} (Table 3). Simultaneous application of nitrogen and potassium was insignificant for grain protein content of both genotypes (Fig. 1d).

CONCLUSION

Moreover the genetic and climatic characteristics, soil mineral nutrient elements are also influencing rice cooking quality. While rice genotypes are obviously different for factors affecting cooking characteristics, they have differently shown reactions for nutrient elements like nitrogen and potassium. Tarrom has demonstrated higher gel consistency and gelatinization temperature than Neda, but the trend vice versa for amylose and grain protein contents. Nitrogen application increased gel consistency but decreased amylose and grain protein contents in both genotypes. Using nitrogen affected none of studied cultivars for gelatinization temperature. Application of 75 kg K_2O ha^{-1} increased gel consistency of both genotypes; however, extra potassium application reduced this trait. Although potassium utilization has not significantly affected on gelatinization temperature and amylose content, grain protein content have significantly been increased. Simultaneous application of nitrogen and potassium fertilizers has not significantly influenced gel consistency, gelatinization temperature and grain protein content. The highest amylose content in Neda (25.51%) and Tarrom (22.89%) genotypes have been obtained using 150 and 75 kg K_2O ha^{-1} with no nitrogen, respectively. It seems that two genotypes showed different direction of cooking quality when applying potassium. Increasing potassium application with no nitrogen destroys Neda's cooking quality; However, its increasing application improves firstly Tarrom's cooking quality, whilst reduced the quality with more potassium application.

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