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Response of Rice Cultivars to Rates of Nitrogen and Potassium Application in Field and Pot Conditions

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Abstract: Nitrogen and potassium are the yield-limiting nutrients in rice production regions of Iran. Use of N and K efficient cultivars is an important complementary strategy in improving rice yield, increasing the quality properties of rice grains and reducing cost of production. In order to consider the effects of different amounts of N and K application on rice (*Oryza sativa* L.) yield and yield components in pot and field conditions these experiments were undertaken in 2004 at Sari Agricultural Station, Iran. Four levels of N (0, 50, 100 and 150 Kg N ha^{-1} in field and 0, 0.6, 1.2 and 1.8 g N pot^{-1} in pot) corresponding with four levels of K (0, 75, 150 and 225 kg K_2O ha^{-1} in field and 0, 0.5, 1 and 1.5 g K_2O pot^{-1} in pot) were applied in a split-factorial plot design with three replications in both pot and field experiments, variously. Grain yield, number of grain per panicle, number of tiller, plant height, length of flag leaf, total and shoot dry matter, 1000 grain weight and harvest index have been increased by N application in field conditions. However, in pot conditions grain yield, number of grain per panicle, number of tiller, plant height, width of flag leaf, total and shoot dry matter, leaf nitrogen contents and harvest index have significantly been increased ($p \leq 0.05$). Potassium application in field conditions has significantly affected on all characteristics but 1000 grain weight and leaf N and K contents. Simultaneous application of N and K have increasingly affected on grain yield, plant height, shoot dry matter and harvest index in field conditions and on plant height, length of flag leaf and shoot dry matter in pot conditions ($p \leq 0.05$).

Key words: Field conditions, nitrogen, potassium, pot conditions, rice

INTRODUCTION

Rice is well known as one of the most important food crops in Asia, Africa, South America and Australia (Yoshida, 1981). Application of suitable nutritional elements is a critical strategy for increasing rice yield (Fageria and Baligar, 1996). It has been proved that the N application can be increasingly effected some traits such as dry matter, panicle length, panicle number per square meter which are correlated with grain yield (Bansal *et al.*, 1993). Nitrogen deficiencies have been reported in most of the world regions of Riceland. Numbers of fertile tillers and 1000 grain weight have also been increased by application of N fertilizer, however, numbers of grain per panicle have been reduced (Qian *et al.*, 2004). Moreover, N application causes an increase in yield performance (Singh *et al.*, 1991; Novera *et al.*, 1992). There are positive correlations between some of yield components like shoot dry matter, N harvest index and efficiency of N application with grain yield (Fageria and Filho, 2001a, b; Shen *et al.*, 2003). Norman *et al.* (1992) reported that accumulation of N element in rice productive organs and its distribution is an important process for determination of grain yield.

Potassium is of frequent cation existed in cytoplasm and its salts help tremendously in osmotic potential protection of cells and tissues of glycophytes. Potassium has the most important roles in physiology and metabolism of plant, not only because of its frequency in plant tissues, but also for its physiological and chemical duties (Mangel and Kirby, 1987). Within past two decades, continuous rice cultivations, planting high yielding varieties which are more efficient in K uptake than previous cultivars, application of more phosphorous and limited consuming of potassium fertilizers, the amount of available K in soil has extensively been reduced (Ostan and Towfighi, 1997). Velayutham *et al.* (1992) reported an increase in rice grain yield with applying of 125 kg K_2O ha^{-1} fertilizer. Adding 200 kg K_2O ha^{-1} in experimental level has caused maximum production (Sreemannarayana and Sairam, 1993). So, potassium fertilizer application can increasingly affect on grain yield performance, number of panicles per square meter, grain number per panicle, number of filled grains and 1000 grain weight (Panday *et al.*, 1993; Kalita *et al.*, 1995; Bansal *et al.*, 1993; Ojha and Talukar, 2002). Moreover, increasing of dry matter and amount of potassium and

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nitrogen uptake in leaf were also influenced by potassium application (Bohri *et al.*, 2000). Simultaneous application of potassium and nitrogen in different years have significantly affected on performance of rice grain yield and dry matter (Zhang and Wang, 2005). The main objectives of the present study were to consider the effects of potassium and nitrogen on yield and yield components in two different conditions and rice cultivars.

MATERIALS AND METHODS

This experiment has been undertaken on field and pot trial in soil that has been taken from surface horizon, on rice cultivars Neda and Tarrom (two Iranian improved and landrace rice cultivars, respectively) in 2004. The experimental soil had 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 percent lime. Plastic pots with 30 cm diameter have been filled up to 22 cm. In pot experiment four levels of potassium fertilizer (0.0, 0.5, 1.0 and 1.5 g K_2O per pot from potassium sulfate source) and four levels of nitrogen fertilizer (0.0, 0.6, 1.2 and 1.8 g nitrogen per pot from urea source) have been applied. Also, in field experiment four levels of potassium fertilizer (0, 75, 150 and 225 kg K_2O ha^{-1}) and four levels of nitrogen fertilizer (0, 50, 100 and 150 kg N ha^{-1}) both from the same source as in pot experiment have been applied. Half of the amount of potassium fertilizer was added in transplanting date and the rest was added in shooting stage and one third of the amount of nitrogen fertilizer was used in transplanting time, one third was added in tillering stage and the rest was added in flowering initiation stage in both of field and pot experiments. In both experiments a split-factorial plot design with 3 replications based on a randomized complete block design has been used. In field experiment sub-plot size was 3×4 m and plants have spaced 25 cm with 3 seedlings transplanted per hill in field or pot in pot experiment. Samples were taken from flag leaf in heading stage to determine the amount of leaf mineral elements. Amount of leaf potassium and nitrogen were measured and plant height, panicle length, length and width of flag leaf, number of tillers, number of grains per panicle, number of unfilled grains, 1000 grain weight, grain yield, total dry matter and shoot dry matter were also determined. Data analyses were conducted using statistical software of MSTATC and means were compared with Duncan's multiple range test.

RESULTS AND DISCUSSION

In the field experiment, grain yield, number of tillers, height, length of panicles, length of flag leaf, total dry matter, shoot dry matter, 1000 grain weight, K uptake in leaf, N uptake in leaf and grain harvest index were significantly affected by cultivars and N and K treatments (Table 1). However, pot experiment caused severely different results especially in case of K treatment (Table 1). Cultivar × N interaction of most traits in field were significantly affected, however, only shoot dry matter, K and N uptake in leaf have shown significant differences in pot conditions. Other interactions have illustrated significant grain yield differences in field but not in pot and most of traits were not significant in both conditions (Table 1).

Field and pot grain yields were significantly different among cultivars and varied from 4812 to 5069 kg ha^{-1} in the field and from 38.14 to 44.62 g pot^{-1} in the pot produced by cultivars Tarrom and Neda, respectively (Table 2). In both environments the higher grain yield producing cultivar, Neda, has had more tillers and 1000 grain weight than Tarrom. Hence, these characters seem to be the most important yield components which determined grain yield (Table 3). Report of Fageria and Filho (2001) has illustrated the same results for role of number of panicles per pot but minimum role for number of grain per panicle and 1000 grain weight in determining grain yield in their lowland rice genotypes. Maximum contribution of number of tiller in improving grain yield was also confirmed by having highest correlation of this component with grain yield, but because of existence of non-significant correlation between yield and 1000 grain weight in both environments, the influence of the latter character on yield is not quite obvious (Table 3).

The relationship between rice grain yield and yield components has extensively been studied at the phenotypic level (Fageria and Baligar, 1999; Gravois and Helms, 1992; Fageria and Filho, 2001a, b). Generally, increased number of tiller per unit area was the most important component of yield associated with rice yield and number of fertile tillers or percent filled grains per tiller are the other important factors. Plant height in field experiment has significant effects on grain yield but in most literatures breeders tried to reduce this trait for having higher N uptake with no problem. Why better performance produced by taller cultivar (Neda) in present work is behind in producing better results of semi dwarf improved cultivars in moderate fertile rice lands. Hence, plant height can not be accounted as a reliable trait for increasing grain yield performance in all conditions.

Although grain weight is one of the important characters in determining grain yield performance, it is not as important as the number of grain which is determined by the number of fertile panicle or tiller (Gravois and Helms, 1992). It has been reported in most of literatures that lowest grain yield genotype in some case are able to produce larger grains with highest 1000 grain weight, however, is of minor importance in increasing rice yield (Yoshida, 1981). Fageria and Baligar (1999) emphasized

Table 1: Analysis of variance of yield and yield components and N and K uptake parameters of field and pot experiments in four N and K levels

Variables	C	N	K	CN	CK	NK	CNK	CV
Field								
Grain yield	**	**	**	**	*	**	**	5.27
Grain per panicle	**	**	**	**	ns	ns	ns	9.27
Number of tiller	**	**	*	**	ns	ns	ns	10.34
Plant height	**	**	*	**	**	*	ns	3.51
Length of panicle	**	**	**	**	ns	ns	ns	7.44
Length of flag leaf	**	**	**	**	ns	ns	ns	7.79
Width of flag leaf	ns	ns	*	ns	ns	ns	ns	3.08
Total dry matter	**	**	**	ns	ns	ns	ns	9.43
Shoot dry matter	**	**	**	**	ns	*	*	6.51
1000 grain weight	**	*	ns	ns	ns	ns	ns	2.16
K uptake in leaf	*	ns	ns	**	**	ns	ns	5.9
N uptake in leaf	**	ns	ns	ns	*	ns	ns	5.35
Harvest index	**	**	**	*	ns	**	**	3.89
Pot								
Grain yield	**	**	**	ns	ns	ns	ns	6.29
Grain per panicle	**	**	ns	ns	ns	ns	ns	11.96
Number of tiller	**	**	ns	ns	ns	ns	ns	5.41
Plant height	ns	**	ns	ns	*	*	**	4.96
Length of panicle	**	ns	ns	ns	ns	ns	ns	8.07
Length of flag leaf	ns	ns	ns	ns	ns	**	ns	12.35
Width of flag leaf	ns	**	ns	ns	*	ns	ns	9.42
Total dry matter	**	**	*	ns	ns	ns	ns	11.4
Shoot dry matter	**	**	ns	**	*	*	ns	6.89
1000 grain weight	**	ns	ns	ns	ns	ns	ns	7
K uptake in leaf	**	ns	ns	**	*	ns	ns	7.75
N uptake in leaf	ns	**	ns	*	ns	ns	ns	5.56
Harvest index	**	**	ns	ns	**	ns	ns	6.21

C = Cultivar N = Nitrogen K = Potassium ** = ($p<0.01$) * = ($p<0.05$) ns = not significant

Table 2: Grain yield and yield components of rice cultivars across nitrogen and potassium application

	Field		Pot	
Variables	Neda	Tarrom	Neda	Tarrom
Grain yield (kg ha^{-1})	5069	4812	44.62	38.14
Grain per panicle	126.58	57.44	98.57	121.75
Number of tiller	29.46	17.21	5.83	5.26
Plant height (cm)	101.22	75.03	63.69	92.16
Length of panicle (cm)	25.42	22.98	24.34	25.98
Length of flag leaf (cm)	27	25	27.12	27.09
Width 0f flag leaf (cm)	1.31	1.32	1.18	1.14
Total dry matter (kg ha^{-1})	10969	10325	89.23	75.79
Shoot dry weight (kg ha^{-1})	6099	5495	44.46	37.58
1000 grain weight (g)	28.7	24.1	26.76	22.96
K uptake in leaf (%)	1.94	1.99	1.9	2.01
N uptake in leaf (%)	2.44	2.95	2.81	2.87
Harvest index	0.45	0.459	0.498	0.503

Grain yield, Total dry matter and Shoot dry weight in pot were g pot^{-1}

Table 3: Correlation between grain yield and yield components

	Grain yield	
Variables	Field	Pot
Number of tiller	0.596**	0.714**
Grain per panicle	0.467**	0.206*
Plant height (cm)	0.390**	0.357**
Length of panicle (cm)	0.654**	0.059^{ns}
Length of flag leaf (cm)	0.679**	-0.009^{ns}
Width 0f flag leaf (cm)	0.184^{ns}	0.466**
Total dry matter (kg ha^{-1})	0.877**	0.975**
Shoot dry weight (kg ha^{-1})	0.723**	0.898**
1000 grain weight (g)	0.145^{ns}	0.184^{ns}
K uptake in leaf (%)	0.209*	0.045^{ns}
N uptake in leaf (%)	0.016^{ns}	0.665**
Harvest index	0.458**	0.404**

Grain yield, Total dry matter and Shoot dry weight in pot were g pot^{-1}, ** = ($p<0.01$) * = ($p<0.05$) ns = not significant that number of panicle per unit area was the most important, while spikelet sterility and 1000 grain weight have lower importance which accounting for 87, 7 and 3% of the variation in yield, respectively. Grain harvest index in both conditions for both cultivars were highly closed together and only ranged from 0.450 to 0.459 in field and from 0.498 to 0.503 in pot conditions for Neda and Tarrom, respectively (Table 2). However, it was having significant correlation with grain yield. Importance of harvest index is due to its critical role in expressing the efficiency of grain production in crop plants. It determines how efficiently the total production can be changed into grain form as the ultimate target of production. Sinclair (1998) and Hay (1995) have mentioned that harvest index is a critical character associated with the dramatic increase in grain yield that have occurred in recent century. This trait actually reflects the partitioning of photosynthate between the grain and vegetative part of plant and improvements in harvest index emphasize the importance of carbon allocation in grain production (Table 3).

Shoot dry matter in both cultivars has systematically been increased by increasing N application level. One reason behind increasing dry matter is that N application may reduce the amount of spikelet sterility (Table 4). This result was supported by Fageria and Baligar (1999) in lowland rice grown on a Brazilian inceptisol. Ordinarily, reduction in the number of sterile spikelet increases the number of grain and, it in, turn, will increase the grain yield performance. Increased yield, in turn, will produce more grain, shoot and total dry matter in both conditions and cultivars (Table 4).

Application of K showed different effects on studied characters between cultivars and conditions. Neda has illustrated significant differences in both environments but Tarrom showed non significant effects in both conditions for shoot dry matter. Features of significance are similar in both environments and cultivars for grain and total dry matter. Cultivars illustrate significant differences for both characters in field conditions but demonstrated non significant effects in pot trial. Cultivars are different in unfilled grain production in various conditions. For hollow grain production, Neda has illustrated significant differences in pot but not in field conditions, while Tarrom has shown reversely significant effects in pot and field conditions (Table 4). Some literatures have reported that phenomenon of hollow grain production is definitely correlated with source and sink relationships (Yang *et al*., 2000, 2001, 2002, 2003; Senesweer *et al*., 2001; Cao *et al*., 1992). This effect can be organized by application of N fertilizer in different time of vegetative growth periods (Balasubramanian *et al*., 1993). Hollow or semi filled grain production has been considered as a physiological trait which is mainly under influence of source restriction, is, in turn, under influence of climatic conditions, soil type and N fertilizer achievement (Yang *et al*., 2002). Lu *et al*. (1994) have proposed two hypotheses for weak grain filling of rice cultivars: 1) less photosynthetic products and early senescence of leaves which cause restriction in dry matter productionand 2) low source on sink ratio and dry matter limitation due to low photosynthetic rate during grain filling period. Since grain yield has negatively correlated with number of hollow grain per panicle, nitrogen fertilizer which is able to provide suitable conditions for producing extra source and improving source on sink ratio, can play an important role in increasing grain yield performance (Honarnedjad, 2002).

Application of nitrogen in pot experiment has increased plant height non-significantly from 90.78 to 93.63 cm in Tarrom, but significantly from 90.04 to 95.22 cm in Neda cultivar. However, in field experiment there were significant differences between both cultivars using various levels of N fertilizer (Table 5). Totally, Neda has shown taller than Tarrom in all N levels in field experiment. Also, for length of panicle, length and width of flag leaf, 1000 grain weight and harvest index there were significant differences in field experiment but no significant in pot experiment using various levels of N fertilizers (Table 5). The amount of N application in semi dwarf cultivar, Neda, can be increased due to its resistance against lodging problem which is a serious constriction in tall susceptible cultivars. There is a straight relationship between N application and yield increasing. According to such a hypothesis plant breeders have severely attempted to find dwarf genes in wild species or foreign resources and transfer them into commercial common cultivars. So, dwarf genes play a critical role in reducing plant height in several agronomic crops and because of ability for higher amount of N application in semi dwarf, cultivars grain yield has extensively increased within last centuries. Despite introducing Tarrom as a landrace, both of the present used cultivars seem to be improved for height reduction and are not landraces. Only due to similarity existed between the Tarrom cultivar and landraces for characters like aroma, grain size and heated grain water uptake, people have accepted it and probably made a mistake in their definite identification with their own landraces.

For 1000 grain weight there are different results for Neda and Tarrom in both conditions. Neda has shown significant differences in field experiment by increasing N application levels but no significant effects in pot trial. Tarrom has shown no significant differences in both conditions. The N uptake in leaf in Neda field trial was similar in all levels of N application but showed significant differences in pot conditions, so that it showed significant effects in Tarrom pot trials (Table 5).

Potassium application added the number of tillers in both cultivars so that this trait is grown up from 3.58 to 7.04 per pot in Tarrom genotype and from 4.12 to

7.87 per pot in Neda genotype, so, number of tiller is added by 55% in Tarrom; however, in Neda this increase was more than 91% (Table 5). Higher use of N in both cultivars and conditions have resulted higher harvest index, however, only Tarrom cultivar in pot conditions showed differences with higher application of K fertilizer (Table 5). This result confirms accordingly the conclusion of Fageria and Filho (2001a, b).

Interaction effects of N and K application on yield and most of yield components were different in field in both cultivars, but in pot experiment these differences were significant only for length and width of flag leaf (Fig. 1 and 2). As it is demonstrated in these graphs grain yield, plant height, length of flag leaf, total and shoot dry matter and grain number per panicle were significantly affected when N and K were used simultaneously in field experiment. These interactions mostly showed significant differences in Neda while in some cases were not significant in Tarrom. Except in grain yield the trend of variation were smoothly increased in both cultivars by increasing N and K levels of application. In pot experiment, the effects of N and K interactions on characters length and width of flag leaf showed to be significant, while even this effect on grain yield was not significant (Fig. 2). Neda and Tarrom in both characters showed similar trends of variation when increasing N and K levels of application.

Table 4: Shoot, grain and total dry matter of two rice cultivars across four N and K levels in field and pot environments

	Shoot dry matter†		Grain dry matter†		Total dry matter†		Unfilled grains (%)	
Cultivars	Neda*	Tarrom	Neda	Tarrom	Neda	Tarrom	Neda	Tarrom
Field								
N_0	4536c	5329c	3206c	3066c	7743d	8396c	6.90a	23.44a
N_1	6041b	4862b	5085b	4389b	11126c	9252b	6.85a	2057a
N_2	6914a	5905a	6664a	5826a	13495a	11731a	5.71ab	9.92b
N_3	6906a	5967a	6322b	5954a	12228b	11839a	4.91b	9.65b
Pot								
N_0	32.17c	25.83d	29.38d	23.60c	61.55d	49.43d	8.05a	8.08a
N_1	37.59c	34.23c	36.60c	35.27b	74.19c	69.50c	8.82a	7.45a
N_2	50.68b	40.72	52.28b	45.09a	102.96b	85.81b	7.90a	5.67a
N_3	57.40a	49.54a	60.78a	48.84a	118.19a	98.34	6.09a	6.21a
Field								
K_0	5888b	5361a	4670b	4613b	10558b	9974b	6.66a	19.85a
K_1	5958b	5458a	5113a	4877a	10988b	10335ab	5.85a	16.53ab
K_2	6375a	5567a	5438a	7834a	11814a	10402a	5.84a	14.67bc
K_3	6176ab	5678a	5256a	4911a	11232a	10507a	5.83a	12.52c
Pot								
K_0	41.30b	41.06a	43.76a	36.80a	85.06a	77.83a	9.77a	8.04a
K_1	45.88a	36.39a	44.11a	37.47a	89.99a	73.86a	7.72ab	6.91a
K_2	46.51a	36.24a	45.95a	38.96a	92.45a	75.20a	7.48b	6.34a
K_3	44.15ab	36.62a	45.24a	39.57a	89.38a	76.19a	5.90b	6.13a

† kg ha^{-1} for field and g pot^{-1} for pot experiments; *Each column with same letter(s) has not significantly difference at 0.05 probability level

Table 5: Yield and yield components of two rice cultivars across four N and K levels in field and pot conditions

	Plant height (cm)		Number of tiller		Length of panicle		Length of flag leaf		Width of flag leaf	
Cultivars	Neda*	Tarrom	Neda	Tarrom	Neda	Tarrom	Neda	Tarrom	Neda	Tarrom
Field										
N_0	92.58c	67.67c	23.08c	10.67d	22.75b	17.83c	25.00b	19.92d	1.29d	1.31ab
N_1	101.8b	74.46b	29.08b	15.92c	25.92a	23.50b	27.25ab	23.92c	1.30a	1.29b
N_2	102.4b	78.08a	33.07a	19.17b	26.08a	23.08a	28.42a	26.67b	1.31b	1.33ab
N_3	108.3a	79.92a	32.67a	23.08a	26.92a	27.50a	27.33ab	29.50a	1.30c	1.35a
Pot										
N_0	90.04b	90.78a	5.83a	5.75a	24.50a	25.61a	28.04a	26.96a	1.22a	1.06a
N_1	94.38a	90.53a	5.96a	5.21ab	24.26a	26.13a	26.83a	26.37a	1.17a	1.14a
N_2	95.22a	92.83a	5.96a	4.79b	23.74a	26.83a	27.73a	27.18a	1.17a	1.19a
N_3	94.27a	93.63a	5.75a	5.08b	24.57a	25.33a	26.38a	28.01a	1.15a	1.16a
Field										
K_0	94.67a	72.54a	27.50b	16.00b	24.41a	21.08b	25.67b	23.67c	1.29a	1.31a
K_1	102.90a	75.25ab	29.17ab	17.08ab	26.00a	23.08ab	27.42ab	24.17b	1.32a	1.33a
K_2	103.10a	77.00a	30.00a	17.83a	25.42a	24.00a	28.25a	25.83ab	1.31a	1.32a
K_3	104.30a	75.33ab	31.17a	17.92a	25.83a	23.75a	26.60ab	26.33a	1.30a	1.32a
Pot										
K_0	90.59b	93.01a	4.12c	3.58d	23.89a	26.15a	26.92a	27.80a	1.06a	1.09a
K_1	89.92b	91.85a	5.00c	4.58c	23.97a	25.69a	27.45a	27.34a	1.17ab	1.11a
K_2	96.88a	91.76a	6.29b	5.62b	24.02a	25.82a	27.54a	27.80a	1.22a	1.16a
K_3	96.51a	91.17a	7.87a	7.04a	25.18a	26.25a	27.08a	28.54a	1.25a	1.19a

*Each column with same letter(s) has not significantly difference at 0.05 probability level

Table 5: Continued

	1000 grain weight (g)		N uptake in leaf (%)		K uptake in leaf (%)		Harvest index		Grain per panicle	
Cultivars	Neda*	Tarrom	Neda	Tarrom	Neda	Tarrom	Neda	Tarrom	Neda	Tarrom
Field										
N_0	28.24b	23.93a	2.47a	2.96a	1.91a	1.95c	0.367c	0.417d	109.70c	39.25c
N_1	28.88a	24.10a	2.45a	2.98a	1.91a	1.98ab	0.474b	0.457b	124.00b	44.75b
N_2	28.40ab	24.05a	2.38a	2.90a	2.00a	2.02a	0.497a	0.493a	145.10a	71.08a
	29.03a	24.21a	2.45a	2.97a	1.91a	2.02a	0.499a	0.432c	127.60b	74.67a
Pot										
N_0	26.36a	22.31a	2.46a	2.65c	1.89c	1.99a	0.477b	0.477b	105.75a	118.8bc
N_1	26.90a	23.47a	2.73c	2.77bc	1.87c	2.01a	0.493ab	0.509ab	99.08a	115.3c
N_2	26.69a	23.72a	2.94b	2.96ab	1.94b	2.05a	0.507a	0.527a	100.33a	125.6ab
N_3	27.44a	23.28a	3.11a	3.08a	1.99a	2.07a	0.514a	0.498ab	102.50a	129.3a
Field										
K_0	28.63a	24.16a	2.45a	2.85b	1.73c	1.87d	0.455a	0.440a	119.58a	51.17b
K_1	28.63a	23.95a	2.50a	2.99a	1.86bc	1.96c	0.465a	0.458a	126.67a	57.92a
K_2	28.75a	24.14	2.34a	3.01a	1.94b	2.02b	0.459a	0.455a	129.75a	60.67a
K_3	28.90a	24.04a	2.46a	2.97ab	2.19a	2.11a	0.458a	0.446	130.33a	60.00a
Pot										
K_0	27.26a	23.04a	2.75b	2.79a	1.75d	1.81c	0.511a	0.474b	91.92b	112.3b
K_1	26.75a	24.07a	2.77b	2.86a	1.86c	1.98b	0.483a	0.503ab	98.17ab	114.5b
K_2	26.56a	22.76a	2.85a	2.86a	1.99b	2.08b	0.194a	0.516a	104.20ab	129.9a
K_3	27.02a	22.91a	2.86a	2.95a	2.09a	2.25a	0.506a	0.518a	113.10a	132.2a

*Each column with same letter(s) has not significantly difference at 0.05 probability level

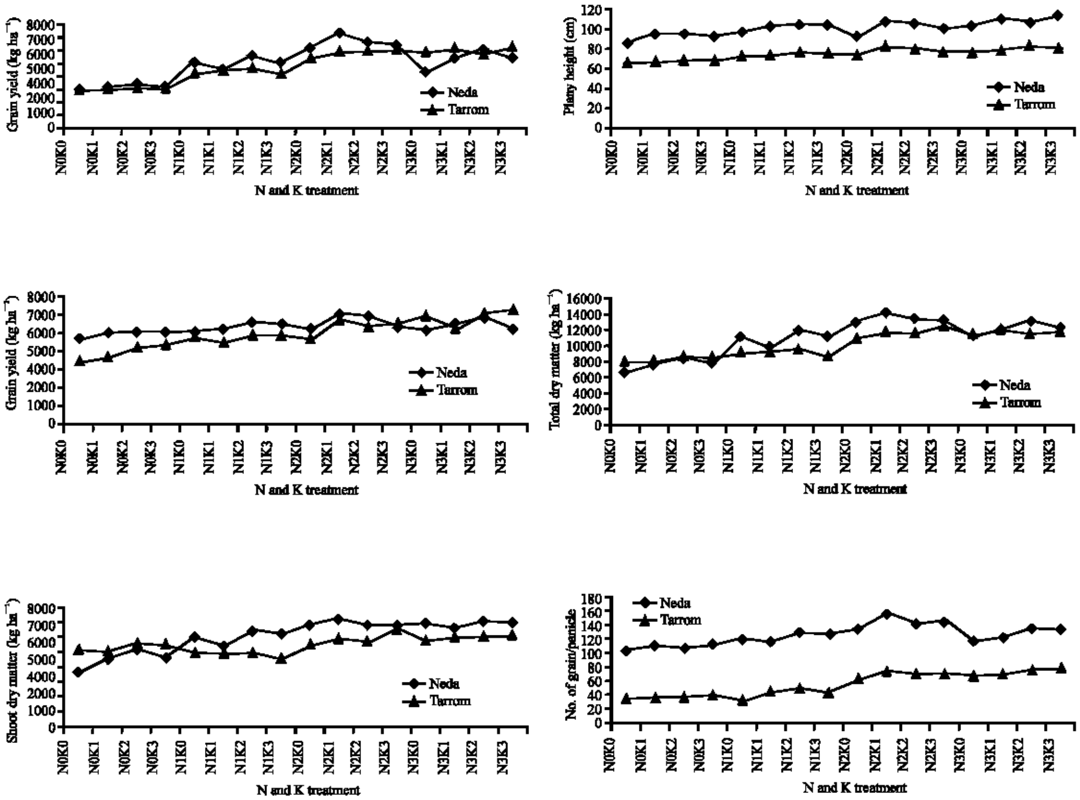

Fig. 1: Interaction effects of N and K application simultaneously on grain yield and some of yield components in field experiment (only significant components are shown) * Legend with no asterisk sign means non significant at 0.05 probability level

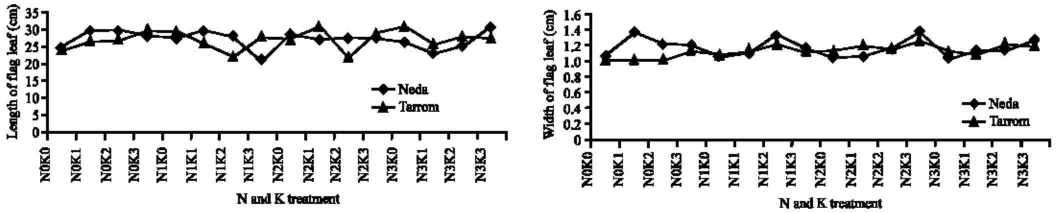

Fig. 2: Interaction effects of N and K application simultaneously on grain yield and some of yield components in pot experiment (only significant components are shown) * Legend with no asterisk sign means non significant at 0.05 probability level

CONCLUSIONS

In field conditions, different amount of nitrogen application increased characteristics plant height, flag leaf length and width, grain yield, total and shoot dry matter, 1000 grain weight, grain number per panicle, number of tiller and harvest index. These increases in Neda cultivar were higher than in Tarrom cultivar. Also, grain yield, plant height, leaf potassium, total and shoot dry matter, harvest index and number of grains per panicle have been increased by application of potassium. These increasing were more in Neda than in Tarrom. Simultaneous application of K and N made increase in flag leaf length, amount of total and shoot dry matter, 1000 grain weight and accumulated nitrogen in leaf. These interaction effects of K and N were more in Neda than Tarrom. Overall, higher yielding cultivar has illustrated smoothly more positive response for yield and some of yield components to simultaneous application of potassium and nitrogen than the other tested cultivar.

However, grain yield, grain number per panicle, number of tiller, plant height, flag leaf width, total and shoot dry matter, leaf nitrogen contents and harvest index have also significantly been increased in pot conditions ($p \leq 0.05$). Potassium application in field conditions has significantly affected on all characteristics but 1000 grain weight and leaf N and K contents. Simultaneous applications of N and K have increasingly affected on plant height, length of flag leaf and shoot dry matter in pot conditions ($p \leq 0.05$).

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