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The Role of Potassium in Improving Growth Indices and Increasing Amount of Grain Nutrient Elements of Wheat Cultivars

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Abstract: In order to consider potassium role in improvement of growth indices and increasing the amount of nutrient elements in wheat grain, a pot experiment has been undertaken in 2005. In this experiment cultivars Tajan and Nye 60 have been used in four levels of potassium (0, 100, 200 and 300 kg K_2O ha^{-1} from source of K_2SO_4) in form of factorial experiment based on a completely randomized design. Results showed that application of potassium increased dry matter, 1000 grain weight, tiller number, seed and leaf potassium content, seed Zn content, plant height, seed Iron and protein content. Also, grain yield, 1000 grain weight, seed potassium and Zn content in cultivar Nye 60 were higher than in cultivar Tajan and tiller number and seed protein content in cultivar Tajan were higher than in cultivar Nye 60.

Key words: Potassium, nutrition, iron, zinc, wheat

INTRODUCTION

Potassium has a critical role in plant growth and development and in human being healthiness. Due to intensive system of cultivation in agronomic lands and using high yielding cultivars, the every year potassium removal of soil is increasing and potassium depletion of soils have gradually been occurred. Fixed potassium quit and potassium availability from non exchangeable sources has been considered by several researchers (Ganeshamurthy and Biswas, 1985; Rao *et al.*, 1993). Potassium application can increase number of fertile tiller (Mehdi *et al.*, 2001), biomass production (Bhargava *et al.*, 1985; Roy *et al.*, 1989; Ehsan Akhtar *et al.*, 2002), number of grains per spike (Evans and Riedell, 2006), 1000 grain weight and wheat grain yield (Tariq and Shah, 2002; Sharma *et al.*, 2005; Evans and Riedell, 2006). However, extra application of potassium chloride may reduce number of grains per spike and grain yield (Evans and Riedell, 2006; De-Shui *et al.*, 2007). Potassium uptake in wheat leaves and grains may also increase using potassium fertilizers and its amount in wheat grains may increase even extra than 100 mg kg^{-1} (Patel *et al.*, 1989; Mehdi *et al.*, 2001; Tariq and Shah, 2002).

Application of potassium may enhance stress resistance mechanisms in wheat and other field crops. Nevertheless, the interactions between plant nutrient levels and stress repair mechanisms are recently being studied (Lavon *et al.*, 1999; Thalooth *et al.*, 2006). Potassium is an essential element in maintenance of osmotic potential and water uptake and had a positive impact on stomata closure which increases tolerance to water stress (Epstein, 1972). Moreover it is involved in activating a wide range of enzyme systems which regulate photosynthesis, water use efficiency and movement, nitrogen uptake and protein building (Nguyen *et al.*, 2002). Potassium application may improve the water content in the broad bean leaves and the plants showed more tolerance to drought stress (Thalooth *et al.*, 1990).

The present study has aimed to consider role of potassium in improving plant growth indices and in increasing potassium, zinc and iron contents of grains and leaves in wheat cultivars.

MATERIALS AND METHODS

In order to consider effects of potassium application on plant growth, grain yield, protein content and potassium accumulation in leaves and kernels, a pot experiment was undertaken on two wheat cultivars namely Tajan and Nye 60 in Sari agricultural sciences and natural resources university, Sari, Iran in 2006. A factorial experiment based on completely randomized design were used in glasshouse using 24 number of 10 inches diameter pots, including 2 cultivars, 4 levels of potassium treatment (K0 = 0, K1 = 100, K2 = 200 and K3 = 300 kg K_2O ha^{-1} from K_2SO_4 source) and 3 replications. Texture, total nitrogen, total organic matters, pH, lime and soil available potassium of prepared soils from surface horizon was determined (Table 1) and fertilizers were added into soil prior planting.

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Table 1: Some physico-chemical properties of soil applied in present experiment

Available K (μg g^{-1})	Available P (μg g^{-1})	Total N (%)	pH	$CaCO_3$ (%)	OM (%)	Clay (%)	Silt (%)	Sand (%)
210	9.6	0.14	7.53	17.8	2.11	44	49	7

Ten seeds were firstly planted in each pot and then after germination the rest but five green plants were removed. Also, 100 kg super phosphate ha^{-1} and 150 kg urea ha^{-1} were applied. All super phosphate together with 1/3 urea have been applied pre-planting and 1/3 of urea at tillering time and the rest at shooting time have been added on the field. Number of fertile tiller, plant height, length and width of flag leaf, number of nodes, spike length, awn length, dry matter, 1000 grain weight, seed number and grain yield were measured at maturity stage. Grain protein (using Kjeltech method), harvest index, zinc, iron and potassium contents were measured in flag leaves and kernels. Meanwhile, to determine potassium contents in wheat leaves and kernels, ashes were prepared by drying samples in 60°C, then milled in 550°C for 8 h and then ashes were saluted into 3% HCl. Iron and potassium contents were measured using Atomic Absorption and Flame Photometer apparatus, respectively. Statistical analyses were conducted using MSTATC statistical software and means comparisons were done by Duncan's Multiple Range Tests.

RESULTS AND DISCUSSION

Potassium application has significant effects on number of fertile tiller, dry matter, 1000 grain weight, leaf and grain potassium contents, grain zinc and iron concentration, plant height and grain protein contents. Also, both of studied cultivars showed significant differences for number of fertile tiller, 1000 grain weight, leaves and grain potassium contents, grain zinc and grain protein contents. Cultivar×potassium interaction was significant only for kernel potassium contents (Table 2).

Means comparisons showed that grain yield, 1000 grain weight, grain and leaf potassium contents and grain zinc content in cultivar Nye 60 were higher than in cultivar Tajan. Meanwhile, tiller number and grain protein content of cultivar Tajan were higher than Nye 60; however, dry matter weight, grain iron content, plant height, harvest index, spike length, awn length and flag leaf length and width have demonstrated no significant differences between studied cultivars (Table 3).

Although grain yield was not significantly increased by application of potassium, its amount has increased from 11.25 g pot^{-1} in K0 to 12.31 g pot^{-1} in K3 treatment. Amount of dry matter has increased from 23.96 g pot^{-1} in K0 to maximum 28.14 g pot^{-1} in K3 treatment. A number of researchers have concluded that potassium application may result in additional yield of wheat over ground organs (Bhargava *et al*., 1985; Roy *et al*., 1989; Ehsan Akhtar *et al*., 2002). Also, applying potassium fertilizer increased significantly 1000 grain weight from 45.05 to 49.66 g (Tariq and Shah, 2002; Sharma *et al*., 2005; Evans and Riedell, 2006). Potassium also increased significantly number of fertile tiller from 13.17 in control to 16.83 in K3 treatment (Table 3) (Mehdi *et al*., 2001).

Table 2: Analysis of variance for bread wheat grain yield and its components applying various levels of potassium fertilizer

Characters	cv	K	CK	CV (%)
Grain yield	*	ns	ns	7.18
Total dry matter	ns	**	ns	6.88
1000 grain weight	**	*	ns	4.70
No. of tillers	**	*	ns	12.66
Grain K content	**	**	*	2.30
Flag leaf K content	**	**	ns	6.24
Grain Zn content	*	**	ns	5.19
Flag leaf Zn content	ns	ns	ns	12.65
Grain Fe content	ns	*	ns	7.85
Height	ns	**	ns	3.85
Harvest index	ns	ns	ns	7.76
Spike length	ns	ns	ns	6.38
Awn length	ns	ns	ns	7.05
Flag leaf length	ns	ns	ns	14.19
Flag leaf width	ns	ns	ns	6.81
No. of nodes	ns	ns	ns	6.75
Grain protein content	**	*	ns	2.52

*, **Significant differences at 1 and 5% levels, Ns: Non significant difference, cv: Cultivar, K: Potassium

Potassium concentration in wheat was influenced by potassium fertilizer application and kernel potassium indicated an increase from 4.13 to 4.83% and also leaf potassium amount demonstrated an increase from 2.64 to 3.24%. Although wheat grain zinc contents increased, wheat flag leaf zinc contents showed no influence using potassium application (Table 3).

These results coincide with those obtained by Basole *et al*. (2003), Gupta *et al*. (2003) and Kassab (2005). Potassium application may have a stimulatory effect on spike number per plant, spike dry weight, number of seeds per spike, seed dry weight per plant, seed index and seed yield like what Thalooth *et al*. (2006) found in mungbean.

Application of potassium increased plant height but had no effect on harvest index, spike length, awn length, flag leaf length and width and number of node. Treatment K2 showed maximum kernel protein contents (18.71%). Meanwhile, potassium application has a tremendous effect on increasing wheat grain iron contents, so that, treatment K3 was yielded maximum grain iron (36.61 mg kg^{-1}).

Sometimes application of potassium can create an adverse effect of water stress on photosynthesis and photosynthesis related parameters, yield and yield components through mitigating the nutrient demands of

Table 3: Mean comparison of cultivars and various treatments for yield, growth indices, accumulation K and Fe in grain and leaf

Characters	Tajan	Ny60	K0	K1	K2	K3	LSD (5%)
Grain yield (g)	11.39b	12.30a	11.25	11.72	12.09	12.30	1.05
Total dry matter (g)	26.10a	25.657a	23.96	26.12	27.12	28.14	2.24
1000 grain weight (g)	45.40b	50.15a	45.05	47.85	48.54	49.66	2.78
No. of tillers	16.67a	13.75b	13.17	15.00	15.83	16.83	2.38
Grain K content (%)	4.28b	4.70a	4.13	4.41	4.60	4.83	0.13
Flag leaf K content (%)	2.67b	3.27a	2.64	2.93	3.06	3.24	0.24
Grain Zn content (μg g^{-1})	47.84b	50.14a	45.45	47.79	49.78	52.94	3.15
Flag leaf Zn content (μg g^{-1})	55.33a	54.86a	53.38	57.83	53.33	55.83	8.63
Grain Fe content (μg g^{-1})	36.74a	37.49a	34.09	36.34	38.41	39.61	3.61
Height (cm)	64.95a	64.88a	61.51	64.31	67.35	66.48	3.10
Harvest index	0.45a	0.43a	0.43	0.45	0.44	0.45	0.04
Spike length (cm)	10.05a	10.15a	9.94	9.96	10.34	10.15	0.80
Awn length (cm)	6.17a	6.21a	6.16	6.26	6.16	6.17	1.31
Flag leaf length (cm)	18.53a	19.49a	18.16	18.77	19.21	19.90	3.34
Flag leaf width (cm)	1.43a	1.47a	1.41	1.47	1.44	1.48	0.12
No. of nodes	4.05a	4.10a	3.89	4.17	4.06	4.18	0.34
Protein content (%)	18.68a	17.98b	17.94	18.05	18.71	18.51	0.47

Table 4: Interactions of various levels of K application by cultivar on yield and some growth characters

	Tajan				Ney 60				
Characters	K0	K1	K2	K3	K0	K1	K2	K3	LSD (5%)
Grain yield (g)	11.01	11.07	11.50	11.96	11.49	12.36	12.68	12.67	1.49
Total dry matter (g)	23.80	25.80	26.60	28.19	24.12	26.43	27.63	28.08	3.17
1000 grain weight (g)	42.39	46.69	45.58	46.96	47.72	49.01	51.50	52.37	3.93
No. of tiller	15.00	16.67	17.33	17.67	11.33	13.33	14.33	16.00	3.72
Grain K content (%)	3.97	4.08	4.38	4.69	4.28	4.74	4.82	4.98	0.18
Flag leaf K content (%)	2.25	2.62	2.78	3.03	3.04	3.25	3.34	3.46	0.33
Grain Zn content (μg g^{-1})	44.84	46.77	47.84	51.89	46.06	48.80	51.72	53.98	4.45
Flag leaf Zn content (μg g^{-1})	53.00	58.00	52.67	57.67	53.77	57.67	54.00	54.00	12.20
Grain Fe content (μg g^{-1})	34.57	36.77	37.88	37.74	33.61	35.91	38.94	41.48	5.10
Height (cm)	61.65	64.70	66.85	66.58	61.36	63.92	62.86	66.38	4.37
Harvest index	0.43	0.44	0.45	0.46	0.42	0.45	0.43	0.44	0.06
Spike length (cm)	9.93	9.62	10.33	10.01	9.95	10.00	10.35	10.29	1.13
Awn length (cm)	6.17	6.52	6.05	5.94	6.15	6.01	6.27	6.39	1.85
Flag leaf length (cm)	17.34	18.16	18.62	20.00	18.98	19.38	19.80	19.80	4.72
Flag leaf width (cm)	1.40	1.43	1.39	1.48	1.41	1.50	1.49	1.48	0.18
No. of node	3.89	4.11	4.00	4.22	3.89	4.22	4.13	4.15	0.48
Grain protein content (%)	18.25	18.42	19.21	18.82	17.64	17.67	18.21	18.40	0.81

water-stressed plants. Since potassium has favorable influence on metabolism and biological activity and stimulating photosynthetic pigments and enzyme activity, these effects, in turn, encourage vegetative growth and yield of plants and consequently protein content (Michail *et al*., 2004; Thalooth *et al*., 2006).

Roles of potassium in yield indices and accumulation of elements in plant organs of studied cultivars were different. Interaction of different levels of potassium application by cultivar on grain yield was significant ($p<0.05$). Maximum yield was produced in treatment K2 of Nye 60 with 12.68 g pot^{-1}. Also, maximum amounts of dry matter and 1000 grain weight, percentages of grain potassium and leaf potassium and flag leaf zinc and grain iron contents were obtained from Nye 60 in treatment K3, which were 28.08, 52.37 g pot^{-1}, 4.98 and 34.46% and 53.98 and 41.48 mg kg^{-1}, respectively. However, maximum amounts of number of fertile tiller, plant height and grain protein contents were produced by Tajan in treatment K2 with 17.33 number pot^{-1} and 66.85 and 19.21%, respectively (Table 4). Also, interaction of cultivar× potassium application on flag leaf Zn contents, harvest index, spike length, flag leaf length and width, awn length and number of node were not significant (Table 4). Grain yield of wheat cultivars is significantly correlated with traits grain and leaf K accumulation and grain Zn at 0.01 level; however, it is correlated with total dry matter, 1000 grain weight, grain Fe and height at 0.05 level. Grain K content is also significantly correlated with leaf K, grain Zn, grain Fe contents, plant height and flag leaf length and width (Table 5).

The results of our previous study on application of potassium and zinc on wheat cultivars also are in full agreement with these results (Ranjbar and Bahmaniar, 2007).

Potassium application causes an increase on potassium contents of flag leaf in both cultivars as Nye 60 compared with Tajan cultivar showed higher (Fig. 1a). Also, the amount of potassium uptake and its accumulation in kernels of Nye 60 was more than Tajan

Table 5: Correlations amongst studied traits for affecting potassium application on wheat cultivars

	GY	TDM	1000 W	NT	GK	FLK	GZn	FLZn	GFe	He	HI	SL	AL	FLL	FLW	NN	Pr
Grain yield	1																
Total dry matter	0.45*	1															
1000 grain weight	0.49*	0.19	1														
No. of tillers	0.08	0.32	-0.14	1													
Grain K content	0.67**	0.35	0.72**	0.10	1												
Flag leaf K content	0.65**	0.57**	0.67**	-0.15	0.75**	1											
Grain Zn content	0.56**	0.32	0.53**	0.08	0.75**	0.52**	1										
Flag leaf Zn content	-0.15	0.18	-0.19	0.13	-0.19	0.16	-0.24	1									
Grain Fe content	0.46*	0.16	0.49*	0.11	0.42*	-0.22	0.64**	-0.22	1								
Height	0.42*	0.39	0.39	0.32	0.60**	0.37	0.53**	-0.20	0.42*	1							
Harvest index	0.21	-0.18	0.10	0.39	0.18	-0.22	0.17	-0.26	0.50*	0.13	1						
Spike length	-0.04	0.16	0.14	0.19	0.13	0.18	-0.17	0.35	0.05	-0.15	0.02	1					
Awn length	0.02	-0.05	0.12	-0.34	0.01	-0.11	0.42*	-0.54**	0.37	0.15	-0.03	-0.68**	1				
Flag leaf length	0.07	0.11	0.39	-0.16	0.47**	0.21	0.55**	-0.49**	0.38	0.31	0.18	-0.23	0.58**	1			
Flag leaf width	0.24	0.04	0.40	-0.09	0.50**	0.15	0.61**	-0.50**	0.47*	0.22	0.41*	-0.25	0.58**	0.84**	1		
No. of nodes	0.06	0.14	0.25	0.02	0.05	0.20	0.21	0.15	0.16	-0.06	-0.06	-0.23	0.22	0.01	0.13	1	
Protein content	-0.19	0.06	-0.06	0.39	0.08	-0.29	0.29	-0.34	0.38	0.45*	0.16	-0.13	0.36	0.30	0.19	0.05	1

GY: Grain Yield, TDM: Total Dry matter, 1000 W: 1000 grain weight, NT: No. of Tillers, GK: Grain K content, FLK: Flag leaf K content, Gzn: Grain Zn content, FLZn: Flag Leaf Zn content, GFe: Grain Fe content, He: Height, HI: Harvest Index, SL: Spike Length, AL: Awn Length, FLL: Flag Leaf Length, FLW: Flag Leaf Width, NN: No. of Nodes, Pr: Protein content; *,**Significant differences at 0.05 and 0.01 levels, respectively

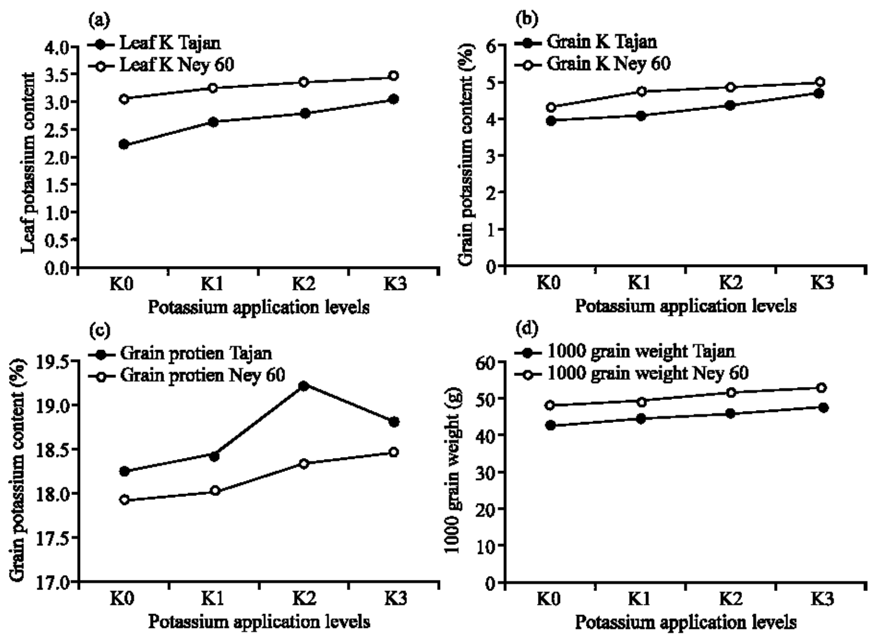

Fig. 1: Difference of cultivars Tajan and Ney 60 for (a) leaf potassium content, (b) grain potassium content, (c) grain protein content and (d) 1000 grain weight affected by various levels of potassium application

cultivar (Fig. 1b). Kernel protein contents have been increased by increasing potassium application level and the amount of increase in Tajan was higher than Nye 60 (Fig. 1c). Also, potassium application influenced the seed size by producing heavier 1000 grain weight, so that by increasing in potassium application level, seed size (or 1000 grain weight) was increased and Nye 60 produced greater seed size than Tajan (Fig. 1d). This phenomenon, in turn, may mean that 1000 grain weight is affected by seed size as the capacity of sink which can be filled by photosynthetic assimilation of sources. So, increasing the levels of potassium application has promoted greater seed size in cultivar Nye 60 or filled better by transferring the photosynthetic assimilates from sources into sink in comparison with cultivar Tajan. Grain yield as the ultimate goal of wheat production is mostly influenced by the number of seeds per plant and the seed size. Potassium application increases grain yield by increasing both characters i.e., seed number and seed size. Increasing in seed number may produce a higher capacity of sink providing better situation for filling by photosynthetic assimilates. Increasing in seed size showed that the provided sink filled well during filling period of wheat cultivars. The superior cultivar (Nye 60) in 1000 grain weight showed that its ability of assimilate movement from source (mostly leaves) to sink (seeds) is higher than the inferior cultivar (Tajan). Grain Zn content is influenced by several factors when applying potassium fertilizer, so that, increasing in levels of potassium application added leaf K content and it is, in turn, increased wheat grain Zn content (Table 5). Meanwhile, by increasing 1000 grain weight which is positively correlated with grain and leaf K, grain Zn and grain Fe, wheat grain Zn contents is also increased.

CONCLUSIONS

The growth parameters i.e., plant height; number of tiller and total dry matter are all under influence of potassium application. Potassium application has considerable effects on wheat grain weight; however, has no significant effect on grain yield. More potassium uptake in leaf and grain and also increasing in grain protein content are of potassium application effects on improving wheat grain quality. Although zinc uptake and its accumulation in grain was not under influence of potassium application, iron uptake and its accumulation in wheat grain was affected by potassium utilization. Therefore, suitable usage of potassium not only improves growth indices but also enriches wheat grain by elements of potassium and iron. The result of this study indicated that for increasing wheat grain K, Zn and Fe content, increasing the grain size can be considered as a possible solution.

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