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Research article/Araştırma makalesi

Potassium-use efficiency of some bread wheat cultivars

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Abstract

The experiment was carried out in two vegetation seasons, years of 2009/10 and 2010/11. The main purpose of the study was to investigate the effects of potassium (K) doses (a control-0, 25, 50 and 75 kg ha^{-1}) on grain yield, K-use efficiency, K-uptake efficiency and K-utilization efficiency of some bread wheat cultivars (Gerek-79, Gün-91, Harmankaya, Altay-2000, Yıldız and Sultan) under the semi-arid climatic conditions. The experiment was set up according to a randomized complete block design in a split-plot arrangement with three replicates, where potassium doses were main plots while the wheat cultivars were in subplots split within main plots. Of the wheat cultivars, the highest grain yield, the highest K-use efficiency and the highest K-utilization efficiency were obtained from Altay-2000 in both 2009/10 and 2010/11, the highest K-uptake efficiency from the Sultan during 2009/10 and Gerek-79 during 2010/11. Of the potassium doses, while the highest grain yield, the highest K-use efficiency and the highest K-utilization efficiency were determined from the 50 and 75 kg ha^{-1} K doses, the highest K-uptake efficiency was obtained from the 25 kg ha^{-1} K dose in both 2009/10 and 2010/11.

The effect of the cultivars x K dose interactions on grain yield, K-use efficiency, K-uptake efficiency and K-utilization efficiency of wheat were statistically ($p<0.05$ and $p<0.01$) significant in the both years. Of the interactions between the wheat cultivars and the K doses, the highest grain yield (3347 kg ha^{-1} in 2009/10 and 3509 kg ha^{-1} in 2010/11) and the highest K-use efficiency (33.4% in 2009/10 and 35.1% in 2010/11) were determined from the 50 kg ha^{-1} K in Altay-2000. The highest K uptake was obtained from the 25 kg ha^{-1} K in Sultan cultivar (76.2%) during 2009/10 and the 25 kg ha^{-1} K in Gün-91 (71.1%) during 2010/11. The highest K-utilization efficiency was determined from the 75 kg ha^{-1} K in Sultan cultivar (105.3% and 107.5%, respectively) in both years.

Key words: wheat, grain yield, potassium, K-use efficiency.

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Bazı ekmeklik buğday çeşitlerinin potasyum kullanım etkinliliği

Özet

Deneme 2009/10 ve 2010/11 yıllarında iki vejetasyon döneminde yürütülmüştür. Çalışmanın amacı yarı kurak iklim koşullarında bazı ekmeklik buğday çeşitlerinin tane verimi, K-kullanım etkinliği, K-alım etkinliği ve K'dan yararlanma etkinliğine potasyum (K) dozlarının (kontrol-0, 25, 50 ve 75 kg/ha) etkisini araştırma amacıyla yürütülmüştür. Deneme tesadüf bloklarında bölünmüş parseller deneme desenine göre 3 tekerrürlü olarak, ana parsellere potasyum dozları ve ana parselleri içerindeki alt parsellere buğday çeşitleri gelecek şekilde kurulmuştur. Buğday çeşitleri arasında hem 2009/10'da hem de 2010/11'de en yüksek tane verimi, K-kullanım etkinliği ve K'dan yararlanma etkinliği Altay-2000 çeşidinden, en yüksek K-alım etkinliği Sultan çeşidinden elde edilmiştir. Potasyum dozları arasında, hem 2009/10'da hem de 2010/11'de en yüksek tane verimi, K-kullanım etkinliği ve K'dan yararlanma etkinliği 50 ve 75 kg/ha K dozlarından, en yüksek K-alım etkinliği 25 kg/ha K dozunda tespit edilmiştir.

Çeşit x K dozu interaksiyonunun buğdayın tane verimi, K-kullanım etkinliği, K-alım etkinliği ve K' dan yararlanma etkinliği üzerine etkisi her iki yılda da istatistiksel olarak ($p<0.05$ ve $p<0.01$) önemli olmuştur. Çeşit ve K dozu interaksiyonunda, en yüksek tane verimi (2009/10' da 3347 kg/ha ve 2010/11' de 3509 kg/ha) ve en yüksek K-kullanım etkinliği (2009/10' da %33.4 ve 2010/11' de %35.1) 50 kg/ha K dozu x Altay-2000 interaksiyonunda belirlenmiştir. En yüksek K-alım etkinliği 2009/10 da 25 kg/ha K dozunda Sultan-91 çeşidinde (%76.2), 2010/11 de

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aynı K dozunda Gün-91 çeşidinden (%71.1) elde edilmiştir. En yüksek K'dan yararlanma etkinliği her iki yılda da 75 kg/ha K dozu x Sultan çeşidi interaksiyonunda (sırasıyla, %105.3 ve %107.5) tespit edilmiştir.

Anahtar kelimeler: buğday, tane verimi, potasyum, K- kullanım etkinliği

1. Introduction

Potassium (K) is one of the macro elements required for plants. There are significant functions at plant tissues of K such as regulate the osmotic pressure of plant cells (Makhdum et al., 2007), promoting enzyme activation in plants, improving efficiency of photosynthesis and transport of assimilated products (Lin, 2010). K plays important roles at resistance to disease of plants, reduces fungal and pathogenic populations in the soil (Fageria et al., 2001). K affects the transport of water, nutrients and sugars, it also increases protein content of plants, maintains turgor, water loss and wilting. K increases root growth, improves drought and cold resistance, reduces lodging, affects the harvest time, improves the availability of nitrogen, and increases the yield and the quality in the crop plants (Kacar and Katkat, 1988). According to Saurbeck and Helal (1990) efficient use of nutrition is plant yield per unit of nutrient supply. Nutrient use efficiency comprises uptake efficiency and utilization efficiency (George et al., 2002). Uptake efficiency is expressed as the total nutrition content in plants per unit surface area. On the other hand, utilization efficiency is defined as dry matter production per unit potassium in the dry matter (Dessougi et al., 2002). Uptake efficiency is nutrient uptake relative and supply, and utilization efficiency represents plant yield to nutrient uptake (George et al., 2002). K use efficiency is largely depends to genetic potential and physiological mechanisms (Yang et al., 2003). Nutrient efficient genotypes are important in modern agriculture because they can produce greater yields on soils where the effectiveness nutrient (Rengel and Marschner, 2005). Breeding new nutrient-efficient genotypes adapted to low nutrient environments that would reduce land degradation by reducing the use of machinery and minimizing application of chemicals on agricultural land (Thongbai et al., 1993).

Taking previous studies conducted years before as reference, it is believed that Turkey's soils are generally sufficient in terms of potassium and this belief continues even today (Kacar and Katkat, 1988). Soil is a dynamic structure and is significantly affected from climate conditions and agricultural practices. Agriculture techniques such as irrigation, cultivars, tillage systems, seeds quality, weed and pesticides control has changed from the past to the present day. The available amount of K is often insufficient in soils contrary to what is believed and in order to maintain soil productivity must be supplied as fertilizers (Saurbeck and Helal, 1990; Kacar and Katkat, 1988; Ibrahim et al., 2012). The aim of the study was to determine the effects of different K doses on the grain yield, K-use efficiency, K-uptake efficiency and K-utilization efficiency of some bread wheat cultivars under semi-arid climatic conditions..

2. Materials and methods

2.1. Materials

The experiment was conducted during the growing seasons of 2009/2010 and 2010/2011 at the Experimental Station of Faculty of Agriculture in Süleyman Demirel University, Isparta, Turkey. In the study, proposed bread wheat cultivars (Gerek-79, Gün-91, Harmankaya, Altay-2000, Yıldız and Sultan) for the semi-arid climatic conditions by the breeder institution were used.

2.2. Methods

The experiment land, one-year fallow field, was plowed, cultivated and then prepared for planting with a single pass of a disk-harrow. Sowing was made on 15th and 18th October (autumn) in 2009/2010 and 2010/2011, respectively. Distance between rows was 17 cm and intra row spaces were 5 cm. Each subplot area was 10.8 m^2 (8 m x 1.36 m) and consisted of 8 rows. Seeds were sown at 3-4 cm depth using a parcel sowing machine.

Soil N, P and K were analyzed before planting. Nitrogen and phosphorus fertilizers were applied at a rate of 80 kg ha^{-1} and 60 kg ha^{-1} in the form of ammonium sulphate and P_2O_4, respectively. The total quantity of phosphorus was applied at the time of sowing. Total nitrogen fertilization was applied in two equal doses at the time of seed sowing and tillering stage. In the experiment, four potassium (K_2O) doses (a control-0, 25, 50 and 75 kg ha^{-1}) were applied at the time of sowing. Potassium doses and wheat cultivars were arranged according to a Randomized Complete Block Design by a split-plot arrangement with three replicates. Potassium doses were main plots, and the wheat cultivars were in subplots split within the main blocks.

The experiment was conducted in the semi-arid climatic conditions of Isparta, in Turkey. Regular cultural practices were kept for all treatments. The experiments were non-irrigated at any growing stage. When the kernel moisture was about 14-15%, plants from 6 rows in the center of each plot were harvested manually and were threshed with threshing machine. Grain yield, K-use, K- uptake and K-utilization efficiency were determined in the following

ways: Grain yield was calculated by multiplying by 10000/plot sizes (m^2). K content was analyzed using a Flame Emission Spectrophotetry.

The following K-efficiency parameters were calculated for each treatment (Manske et al., 2001):

K-use efficiency = Kt x Grain yield (kg ha^{-1}) / Kt

K-uptake efficiency = Kt / applied K (kg ha^{-1})

K-utilization efficiency = Grain yield (kg ha^{-1}) / K uptake

Kt =Kg+Ks

Kg = Grain K content (%) x Grain yield (kg ha^{-1})

Ks= Total aboveground plant K (%) x Dry matter weight (kg ha^{-1})

All the data were analyzed according to the analysis of variance (ANOVA) using SAS Statistical Package Program, the significant differences between the group means were separated by a DUNCAN test.

2.3. Climatic data of the experimental area

Meteorological data for the growing seasons are shown in Table 1. The long-term annual mean temperature, relative humidity, total annual precipitation, wind speed and sunshine duration per day in the area were 10.2 ^{0}C, 55%, 477.7 mm, 2.4 m s^{-1} and 7.6 h, respectively. During the vegetative periods (from October to July) in 2009/10 and in 2010/11 an average temperature of 12.1 and 11.3 ^{0}C, total precipitation of 530.3 and 526.1 mm were recorded, respectively. Meteorological data of wheat growing seasons were higher compared to long-term meteorological data.

Table 1. Climatic data of the experimental region (2009-2011 growing seasons)*

	Years	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Mean/Total
Mean Temperature (^{o}C)	2009/10	15.1	7.5	5.7	4.3	5.6	8.6	11.5	16.5	21.9	24.4	12.1
	2010/11	12.7	10.8	6.8	2.9	3.7	6.3	10.3	14.4	19.8	25.0	11.3
	Long term	12.8	6.9	3.0	1.7	2.6	5.9	10.5	15.5	20.1	23.4	10.2
Precipitation (mm)	2009/10	18.1	51.6	68.6	68.0	106.8	33.2	47.0	32.4	64.5	40.1	530.3
	2010/11	79.1	13.6	84.2	34.6	51.8	50.4	54.7	43.1	62.2	52.4	526.1
	Long term	38.0	51.5	70.9	64.2	54.9	52.8	58.8	46.0	27.8	12.8	477.7

*Records of the Meteorology Station, Isparta

2.4. Soil structure

Soil at a depth of 60 cm was sampled before the experiment and subjected to a physicochemical analysis. The soil was low in nitrogen (1.3 kg NH_4^+ ha^{-1}), P_2O_5 (20.5 kg ha^{-1}) and K_2O (2.4 kg ha^{-1}). The soil was alkaline (pH: 7.9) and limy (1.3 $CaCO_3$%).

3. Results

The results belong to effects of potassium doses on grain yield, K-use, uptake and utilization efficiency of bread wheat cultivars are shown in Table 2. The effects of the potassium doses on the grain yield, K-use, uptake and utilization efficiency of wheat cultivars were significant found for both years. No significant differences between two subsequent years in grain yield, K-use and uptake were found. K utilization efficiency of wheat cultivars were significant ($P<0.05$) found between two subsequent years. The mean K utilization efficiency of the second year was higher than those of fist year (Table 2).

Of the wheat cultivars, the highest grain yield (2910 and 2989 kg ha^{-1}, respectively), the highest KUE (29.1 and 29.5%, respectively) were obtained from Altay-2000 in both subsequent years (2009/10 and 2010/11). The highest K-uptake was attained from Sultan (54.5%) during 2009/10 and Gerek-79 (50.1%) during 2010/11. The highest K-utilization efficiency was determined in Altay-2000 (69.1%) during 2009/10 and Sultan (78.6%) during 2010/11. Of the potassium doses, the highest grain yield (3133 and 3145 kg ha^{-1}, respectively), the highest KUE (31.3 and 31.5%, respectively) and the highest K-utilization (93.8 and 95.9%, respectively) were determined from the 75 kg ha^{-1} K in the both years. The highest K-uptake was obtained from 25 kg ha^{-1} potassium dose (68.2 and 67.5%, respectively) in both 2009/10 and 2010/11. The grain yield, K-use and utilization decreased in the low potassium practices in both 2009/10 and 2010/11. Of the interactions of cultivar by potassium doses, the highest grain yield (3347 and 3509 kg ha^{-1}, respectively), the highest K-use efficiency (33.4 and 35.1%, respectively) were obtained from the 50 kg ha^{-1} K in Altay-2000 in 2009/10 and 2010/11. The highest K uptake was obtained from the 25 kg ha^{-1} K in Sultan cultivar (76.2%) in 2009/10 and Gün-91 (71.1%) in 2010/11. The highest K-utilization efficiency (105.3 and 107.5%, respectively) was determined from the 75 kg ha^{-1} K in Sultan cultivar in both years (Table 2). In generally, higher grain yield, K-use and utilization efficiency in all wheat cultivars were obtained by increasing of potassium doses.

Table 2. Effect of potassium doses on grain yield (kg ha^{-1}), K use efficiency (%), K uptake efficiency (%) and K Utilization Efficiency (%) of wheat

K doses (kg ha^{-1})	Cultivars	Grain yield		K use efficiency		K uptake efficiency		K utilization efficiency	
		2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
0	Gerek-79	2480fg**	2379 h**	24.8gh**	23.8 e*				
	Gün-91	2441 fg	2348 h	24.4 gh	23.5 e				
	Harmankaya	2329 g	2334 h	23.3 h	23.3 e				
	Altay-2000	2434 fg	2424 gh	24.3 gh	24.2 de				
	Yıldız	2390 g	2462 fgh	23.9 h	24.6 de				
	Sultan	2447 fg	2479 fgh	24.5 gh	24.8 de				
25	Gerek-79	2587 efg	2486 fgh	25.9 e-h	24.9 de	62.0cd*	69.4 a*	41.7f**	36.1f**
	Gün-91	2614 d-g	2488 fgh	26.1 d-h	24.8 de	70.1 ab	71.1 a	37.5 f	35.1 f
	Harmankaya	2569 efg	2441 gh	25.7 e-h	24.4 de	72.9 a	67.8 a	35.3 f	36.2 f
	Altay-2000	2540 efg	2517 e-h	25.3 fgh	25.2 cde	64.5 bc	65.7 a	39.4 f	38.7 f
	Yıldız	2397 g	2425 gh	24.0 h	24.3 de	63.5 bc	65.8 a	37.7 f	36.9 f
	Sultan	2557 efg	2452 fgh	25.5 e-h	24.5 de	76.2 a	65.6 a	33.7 f	37.4 f
50	Gerek-79	2927 b-e	2893 cde	29.3 b-e	28.9 b-e	44.5 e	44.8 b	66.1 de	64.7 e
	Gün-91	2887 b-e	2784 d-g	28.8 b-f	27.9 b-e	43.9 e	41.4 bc	65.9 de	67.9 de
	Harmankaya	2809 c-f	3081 bcd	28.1 c-g	33.5 ab	41.7 ef	41.5 bc	67.4 de	73.9 de
	Altay-2000	3347 a	3509 a	33.4 a	35.1 a	47.7 e	46.5 b	70.1 d	76.5 d
	Yıldız	3204 ab	3142 a-d	32.0 ab	31.4 ab	48.0 e	41.3 bc	66.5 de	76.7 d
	Sultan	3260 ab	3326 ab	32.6 ab	33.2 ab	56.7 d	36.7 cd	58.0 e	90.9 bc
75	Gerek-79	3074 abc	3170 a-d	30.7 abc	31.7 ab	36.1 fg	36.0 cd	85.1 c	88.1 c
	Gün-91	2979 a-d	3121 bcd	29.8 a-d	31.2 abc	35.7 fg	34.9 cd	83.4 c	89.5 c
	Harmankaya	3038 abc	3025 bcd	30.4abc	30.3 a-d	33.8 g	31.4 d	89.0 bc	96.4 bc
	Altay-2000	3318 a	3504 a	33.2 a	33.5 ab	33.9 g	34.8 cd	98.0 ab	100.8ab
	Yıldız	3170 abc	2830 def	31.7abc	28.3 b-e	31.3 g	30.3 d	102.4 a	93.1 bc
	Sultan	3217 ab	3213 abc	32.1 ab	32.1 ab	30.7 g	29.9 d	105.3 a	107.5 a
Years		2793	2785	27.9	27.8	49.6	47.4	65.6 b	69.2 a
K doses	0	2421 b**	2404b**	24.2b**	24.0b**				
	25	2544 b	2468 b	25.4 b	24.6 b	68.2a**	67.5a**	37.5c**	36.7c**
	50	3072 a	3123 a	30.7 a	31.4 a	47.1 b	42.0 b	65.6 b	75.1 b
	75	3133 a	3145 a	31.3 a	31.5 a	33.6 c	32.9 c	93.8 a	95.9 a
Cultivars	Gerek-79	2767ab**	2732b**	27.7ab**	27.3ab*	47.5 b*	50.1a**	64.3b**	62.9c**
	Gün-91	2731 ab	2688 b	27.3 ab	26.9 b	49.9 b	49.1 ab	62.3 c	64.1 bc
	Harmankaya	2686 b	2721 b	26.9 b	27.9 ab	49.5 b	46.9 abc	63.9 bc	68.8 bc
	Altay-2000	2910 a	2989 a	29.1 a	29.5 a	48.7 b	49.0 ab	69.1 a	72.0 ab
	Yıldız	2790 ab	2715 b	27.9 ab	27.1 ab	47.6 b	45.8 bc	68.8 a	68.9 bc
	Sultan	2871 ab	2867ab	28.7 ab	28.7 ab	54.5 a	44.1 c	65.7 b	78.6 a
CV (%) value		8.45	8.34	8.23	6.88	7.99	9.51	10.59	9.19

*, **: significant at P<0.05 and P<0.01 probability levels, respectively

Means in the same columns followed by the same letters are not significantly different as statistically

4. Conclusions

Potassium nutrient is very much significant in plant production as cell division, photosynthesis formation of carbohydrates and mineral nutrition. On the other hand, using of excessive synthetic and chemical manure in modern agriculture in spoil of soil component, pollution of environmental and resides in the plants. Nutrient use efficiency is increase in plants when proper choosing and application of variety, manure type, application time and amount, climate, soil structure, irrigation, rotation and plant growing regulate. Therefore, the improvement of nutrient efficiency in crops is important due to for reducing cost in agricultural production, healthy foods and protecting the environment (George and Zhou, 2002). This study, conducted with the objective to investigate the effects of different K doses on grain yield, potassium use, uptake and utilization efficiency of some bread wheat genotypes. Effect of the potassium doses on the grain yield, K-use, uptake and utilization efficiency of wheat cultivars were significant found for both years. The grain yield, K-use and utilization efficiency were higher by increasing of potassium doses. However, between 50 and 75 kg ha^{-1} on grain yield, K-use and utilization efficiency were not statistically significantly different from at the P<0.01 level on the basis of the DUNCAN test. K uptake was reduced by increasing of potassium doses. Mengel (1992) stated that nutrient use efficiency decreases with increment in fertilizer nutrient addition.

Significant differences in grain yield, K-use, uptake and utilization efficiency of wheat cultivars were observed. The grain yield, K-use, uptake and utilization efficiency varied between 2686-2910 kg ha^{-1}, 26.9-29.1%, 47.5-54.5%, 62.3-69.1% during 2009/10 and 2688-2989 kg ha^{-1}, 26.9-29.5%, 44.1-50.1%, 62.9-78.6% during 2010/11, respectively. The Altay-2000 and Sultan cultivars had higher grain yield, K-use and utilization efficiency as compare to the others cultivar. Differences in grain yield and nutrient use efficiency among the cultivars might result from the genetic structures of variety, root lengths (Dessougi et al., 2002), absorption of ion, ecological factors, management practices (Bellidoa et al., 2005). Zhang et al. (1999) reported that K use efficiency in wheat varied depending on genotypic. Similar studies on genotypic differences in grain yield and K use, utilization and uptake were studied by many workers in different crops (Swaider et al., 1994). Significant variation in K utilization efficiency was reported among genotypes for a number of crop species, including wheat (Zhang et al., 1999; Damon and Rengel, 2007). George et al. (2002) stated that K utilization efficiency was correlated with total plant biomass and root yield. Nutrient use in plants is largely due to variation in the utilization of accumulated nutrient before anthesis, especially under low nutrient supply (Moll et al., 1982). Nutrient-efficient genotypes are important in modern agriculture because they can produce greater yields on soils where the effectiveness of fertilizers may be limited by chemical and biological reactions, topsoil drying and subsoil constraints (Rengel and Marschner, 2005).

The results obtained from present study indicated that K doses had significant effects on grain yield, K-use, uptake and utilization efficiency of wheat cultivars. The grain yield, K-use and utilization efficiency were higher by increasing of potassium doses. K uptake was reduced by increasing of potassium doses. The highest grain yield, K-use and utilization efficiency were obtained from 50-75 kg ha^{-1} K dose. The highest K-uptake was obtained from 25 kg ha^{-1} K dose. The Altay-2000 and Sultan cultivars had higher grain yield, K-use and utilization efficiency as compare to the others cultivar.

Based on the results of the research: 1- K nutrient should be applied 50 kg ha^{-1} to the wheat because the differences between 50 kg ha^{-1} and 75 kg ha^{-1} K doses were not statistically significant, 2- we could recommend Altay-2000 and Sultan cultivars in Isparta's ecological conditions and similar ecological regions because of the higher grain yield, K-use and utilization efficiency.

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