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Efficiency of Potassium in Barley Genotypes

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Abstract

The variation in potassium uptake and utilization by Bulgarian malting barley genotypes was studied. Four varieties such as Obzor (state standard), Emon, Kaskadior and Krami and ten perspective breeding lines, selected by the Department of Genetics and Breeding at the Agricultural University-Plovdiv, were studied. It was established that the potassium concentration of straw was two times higher than the grain potassium concentration. Variety Krami and lines 17, 18, 31, 44 were distinguished with higher content of potassium in grain and variety Krami and lines 24 and 44 had higher straw potassium content. Accumulated potassium in straw represented eighty percents of the total potassium uptake in maturity. Kaskadior was characterized with the highest potassium harvest index and the lowest expense for 100 kg grain - 26.8% and 2,5 kg K_2O, respectively. Cultivar Emon and line 29 used most efficiently potassium for biomass and grain formation, and variety Krami and line 44 demonstrated the lowest values of KUEb and KUEg. The rest of the studied genotypes showed lower potassium use efficiency related to standard variety Obzor. A strong positive correlation was established between KUEb and KUEg with KHI, and between KUEg and KUEb. The efficiency of potassium use for biomass and grain was negatively related to the straw yield, the concentration and content of potassium in straw, the total potassium uptake and the expense of potassium for 100 kg grain.

Keywords: potassium use efficiency, barley, genotypes

Introduction

Potassium is an important nutrient for malting barley which affects the quality of the grain. Genotypic specificity of mineral nutrition has been established in cereals (Pettersson and Jensen 1983; Yang et al., 2003; Samal et al., 2010;) but studies in the world and in Bulgaria are conducted mainly with wheat (Zhang et al. 1999 ; Guoping et al., 1999; Kostadinova and Panayotova, 2012; Kostadinova et al., 2013). While planning the selection process, the specifics of the breeding forms related with mineral nutrition, are rarely taken into consideration and they are not predictable about possible results, which indicates insufficient participation of Physiology and Agrochemistry when new genotypes are created (Foulkes et al., 2009). The high prices of fertilizers related with the energy crisis and the negative impact of the intensive use of chemicals on the environment and the yield's quality more often are reason to focus on use of agrochemical efficient varieties, which rationally use nutrients. The study of specifics of mineral nutrition is in two directions: characterize the response of varieties and hybrids toward mineral nutrition in order to define precisely fertilization and to create systematically and purposefully new varieties and hybrids which are using mineral nutrients effectively and economically (Górny, 2009). Researches on genetic specificity of mineral nutrition are complexed because of the extreme complexity of processes, methodological difficulties and difficulties in usage and interpretation of the results. The new intensive varieties use more efficiently nutrients than the old ones. This is due not so much to the increased uptake as the improved utilization of absorbed nutrient for the formation of yield (Foulkes, 2009). It was established that plants absorb potassium exclusively from soil solution, which is in dynamic equilibrium with exchangeable and to a lesser extent with non-exchangeable potassium supply in soil (Steingrobe and Claassen 2000). The efficiency of mineral nutrition depends on two integrated groups of plant factors, namely the use efficiency and the efficiency of utilization. Use efficiency is the relative absorption of nutrients in a certain utilization or supply with it. Use efficiency is a general or primary production related to absorption of elements. Use efficiency of potassium depends on differences in varieties and genotypes (Trehan and Claassen 1998; Dessougi et al. 2002; Trehan and Sharma 2002; Zhang et al., 2007). Mechanisms which lead to higher use efficiency of potassium are size of the root system of the plants and their ability to increase the solubility of potassium in the rhizosphere (Steingrobe and Claassen 2000; Rengel and Damon 2008). The aim of the study was to establish the genotypic response of cultivars and breeding lines of malting barley related to the concentration of potassium in the primary and additional production, uptake and utilization of this nutrient by plants and possible usage for the purposes of selection.

Materials and Methods

The study includes ten straight lines two-row winter barley, a selection of the Department of Genetics and Breeding at the Agricultural University - Plovdiv and varieties such as Obzor (state standard), Emon, Kaskadior and Krami (widely spread and included in production by the Executive Agency for Variety Testing , Field Inspection and Seed Control system of variety testing as a control). Genotypes were grown in competitive variety trials under irrigated conditions on yield plots of 10 m^2 each in three iterations. The study was conducted in the educational and experimental base of Agricultural University - Plovdiv during 2012-2013 year on alluvial-meadow soil. More important agrochemical indicators of soil are: pH water = 7.2; mineral nitrogen 39.2 mg N min/kg; mobile phosphates 22.8 mg P_2O_5/100 g and available potassium 50 mg K_2O/100 g soil. A standard agrotechnics was applied in the region of South Bulgaria. Sowing fertilization with 60 kg N / ha was provided. Climatic conditions during barley vegetatiton for the investigated period were considered to be favourable for the air temperature and the sum of rainfalls. Samples were taken from every genotype in physiological maturity in three replications in order to report productivity. Air dry samples are divided into grain and overground biomass, in which the concentration of potassium (g $K_2O.kg^{-1}$) is defined by flame photometer after mineralization with sulfuric acid. The amount of available potassium in grain and straw was calculated as the dry weight of a particular plant part multiplied by the concentration of the element in it (kg K_2O ha^{-1}). On this basis use efficiency of potassium by barley genotypes was established (Gerloff, 1987). Potassium use efficiency was defined by different author (Gerloff, 1987; Yang et al., 2003; Dawson et al., 2008) as: 1) use efficiency for biomass production (KUEb), relation between overground biomass and potassium uptake in maturity (kg biomass/kg utilized K_2O) and 2) use efficiency for grain formation (KUEg), relation between grain yield and potassium uptake in maturity (kg grain/kg utilized K_2O). The distributed potassium is characterized by the harvest index of the element (KHI %) as a reference to potassium uptake of available K_2O in grain and available potassium in biomass, multiplied by 100.

Analysis of variance (ANOVA) is attached for statistical processing of the results and statistical significance was determined by Duncan's multiple range test. Only differences in the level of significance $\alpha = 0.95$ are accepted to be proven.

Results

At physiological maturity the average amount of potassium in grain and straw in barley genotypes differed significantly (Table. 1).

Table 1.Content of potassium in grain and straw in barley genotypes

Genotypes	Grain (g $K_2O.kg^{-1}$)	Straw (g $K_2O.kg^{-1}$)
Obzor	5.8 d*	15.3 gh
Emon	6.4 cd	14.9 h
Kaskadior	6.6 c	13.8 i
Krami	7.5 b	19.2 b
5	6.3 cd	18.4 c
13	6.6 c	18.6 c
16	6.3 cd	15.9 ef
17	7.6 b	17.7 d
18	8.4 a	16.2 e
24	6.2 cd	19.2 b
29	5.9 d	16.2 e
31	7.6 b	16.0 e
33	6.2 cd	15.5 fg
44	7.2 b	20.0 a
Average	6.76	16.92

* Values in each column followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test.

Variety Krami and lines 17, 18, 31 and 44 were distinguished with high potassium content in grain, and lines 5, 16, 24 and 33 had low content. The potassium content in the straw of barley was three to four times higher compared to that in the grain. Genotypes with higher percentage of potassium in straw are variety Krami and lines 5, 13, 24 and 44.

Table 2. Uptake and allocation of potassium (kg K_2O ha^{-1}) in barley genotype

Genotypes	Potassium uptake (kg K_20 ha^{-1})			KHI, %	Expense for 100kg grain
	Grain	Straw	Total		
Obzor	31,0 cde	146,8 b	177,8 b	17,3 e	3,4 e
Emon	30,0 de	111,2 c	141,1 c	21,2 c	3,0 g
Kaskadior	28,4 def	77,7 d	106,0 d	26,8 a	2,5 i
Krami	26,7 ef	155,9 b	182,6 b	14,6 f	5,1 a
5	32,5 bcde	158,6 b	191,1 b	17,0 e	3,7 d
13	38,0 abc	217,9 a	255,9 a	14,9 f	4,4 b
16	31,4 cde	159,6 b	190,9 b	16,4 e	3,8 c
17	44,7 a	215,1 a	259,8 a	17,2 e	4,4 b
18	33,3 bcde	138,8 bc	172,1 bc	19,3 d	4,4 b
24	32,9 bcde	195,0 a	227,9 a	14,4 f	4,3 b
29	22,2 f	76,4 d	98,5 d	22,5 b	4,7 h
31	38,5 abc	134,3 bc	172,8 bc	22,3 b	4,9 e
33	36,0 bcd	150,8 b	186,8 b	19,3 d	5,0 f
44	39,7 ab	204,4 a	244,1 a	16,3 e	5,2 b
Average	33,2	153,0	186,2	18,5	4,2

* Values in each column followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test.

Table 3. Potassium utilization efficiency for biomass (KUEb) and grain (KUEg) in barley genotypes

Genotypes	KUEb (kg biomass.kg K_20 [1])	%	KUEg (kg grain.kg K_20^{-1})	%
Obzor	83,8	100	29,6	100
Kaskadior	86,2	102,9	33,3	112,5
Emon	115,4	137,7	40,4	136,5
Krami	64,0	76,4	19,5	66,0
5	72,2	86,1	27,0	91,3
13	68,6	81,8	22,7	76,8
16	78,6	93,8	26,0	87,9
17	69,3	82,7	22,6	76,5
18	72,6	86,6	22,9	77,5
24	67,8	80,9	23,1	78,1
29	113,0	134,9	38,1	128,7
31	77,7	92,8	29,3	99,1
33	83,3	99,4	31,0	104,9
44	64,6	77,1	22,7	76,6
Average	79.8		27.7	

Table 4. Correlation between potassium use efficiency and some parameters in barley genotypes

Parameters	Straw dry mass	g K_2O.kg- straw	K taken up straw	Total K maturity	Expense for 100 kg grain	KHI	KUEb
KUEb	-0.786**	-0.752**	-0.857**	-0.849**	-0.896**	0.849**	
KUEg	-0.752**	-0.784**	-0.845**	-0.827**	-0.978**	0.876**	0.957**

**Correlation is significant at the 0.01 level

This study demonstrated varietal reaction in utilization efficiency of potassium in soil well supplied with available potassium. The average amount of utilized potassium in studied genotypes was 186.2 kg $K_2O.ha^{-1}$ (Table. 2). Line 27 assimilated the highest content of potassium in grain (44.7 kg $K_2O.ha^{-1}$), and in straw - lines 13 and 17 (217.9 and 215.1 kg $K2O.ha^{-1}$). Line 29 absorbed the lowest content of potassium, in both grain and straw.

Potassium harvest index values varied widely in studied genotypes and were in the range from 14.4 to 26.8%. Variety Kaskadior was characterized with the highest potassium harvest index and line 24 with the lowest. Variety Krami, line 33 and 44 were distinguished with the highest expense of potassium for 100 kg grain.

The average total yield (grain and straw) formed per unit potassium, utilized by malting barley genotypes, was 79.8 units (Table. 3). Variety Emon and line 29 used most effectively the utilized potassium to form biomass and grain and variety Cultivar Krami and line 44 had the lowest values of KUEb and KUEg compared with the standard cultivar Obzor.

It has been established a strong positive correlation of KUEb and KUEg with KHI, and KUEb with KUEg. Efficiency of use of utilized potassium for biomass or grain was in strong negative relation with the yield of straw, concentration and content of potassium in straw, total expense of potassium for 100 kg grain (Table. 4).

Discussion

The efficiency of utilization of nutrients is often defined as the ability of plants to absorb a certain element in low level of availability in soil or nutrient environment (Dawson et al., 2008). Usually, however, the selection of the cultures was performed in agrochemical conditions which did not limit their growth and productivity (Abeledo et al., 2008). The results of present study demonstrated genotypic reaction of 14 Bulgarian cultivars and breeding lines in potassium uptake.

The potassium content in the straw of studied barley was three to four times higher compared to that in the grain. Genotypes with higher percentage of potassium in straw are variety Krami and lines 5, 13, 24 and 44. Our data confirmed the results reported by different authors (Woodend and Glass, 1987; Yan et al., 1995; Swaider and Chyan, 1994) that reported higher potassium concentration in the stem compared to that in other plant parts and potassium accumulation in straw constituted on average about 70% of its total quantity in cereals. In this connection it is important that the straw of cereals can be used as organic fertilizer in order to improve the supply of potassium in soil.

Potassium harvest index (KHI) indicated the participation of total potassium uptake, distributed in grain yield and in cereals it was characterized with the lowest value compared to those of nitrogen and phosphorus (Wignarajah, 1995). In our study potassium harvest index values varied widely in studied genotypes and were in the range from 14.4 to 26.8%. These values were two to three times lower than citied harvest indexes of nitrogen and phosphorus in barley (Kostadinova and Ganusheva, 2014).

It has been established in field trial of 25 winter wheat genotypes, that biomass (KUEb) or grain yield (KUEg) formed per unit of utilized potassium in biomass were in positive correlation with the grain yield and HI, and a strong negative correlation with the concentration of potassium in stem in maturity (Guoping et al., 1999). Investigation of 134 genotypes of rice established a strong positive correlation between the use effeciency of potassium biomass (KUEb) and dry mass of the plants, and also negative correlation of KUEb with the percentage of potassium in plants and with accumulated potassium in straw (Yang et al., 2003). Only for nine varieties it has been proven that KUEg in physiological maturity is strongly and positively related with HI in low potassium levels, strongly and negatively correlated with the concentration of potassium in straw and potassium uptake.

For studied Bulgarian genotypes we established a strong positive correlation of KUEb and KUEg with KHI, and KUEb with KUEg. Utilization efficiency of potassium for biomass or grain was in strong negative relation with the yield of straw, concentration and content of potassium in straw, total expense of potassium for 100 kg grain. This indicated that utilization efficiency of potassium mainly depended on straw dry mass, potassium concentration and uptake in straw, and KHI and these characteristics are important for future selection program of barley effective in potassium.

Conclusion

It was established that the potassium concentration of straw was two times higher than the grain potassium concentration in studied barley genotypes. Variety Krami and lines 17, 18, 31, 44 were distinguished with higher content of potassium in grain and variety Krami and lines 24 and 44 had higher straw potassium content. Accumulated potassium in straw represented eighty percents of the total potassium uptake in maturity. Kaskadior was characterized with the highest potassium harvest index and the lowest expense for 100 kg grain - 26.8% and 2,5 kg K_2O, respectively. Average for the studied genotypes 80% of total expense of potassium accumulated in straw. The use efficiency of potassium was strongly and negatively related to straw dry mass and slightly depended on the concentration of potassium in biomass.

Cultivar Emon and line 29 used most efficiently potassium to form biomass and grain formation, and variety Krami and line 44 demonstrated the lowest values of KUEb and KUEg. The rest of the studied genotypes showed lower potassium use efficiency related to standard variety Obzor. A strong positive correlation was established between KUEb and KUEg with KHI, and between KUEg and KUEb. The efficiency of potassium use for biomass and grain was negatively related to the straw yield, the concentration and content of potassium in straw, the total potassium uptake and the expense of potassium for 100 kg grain.

The formation of grain or biomass per unit potassium, utilized by plants, can be used as an index in the selection of effective in potassium barley genotypes.

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