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POTASSIUM FERTILIZATION AND GENOTYPE EFFECTS ON THE FIELD CROPS IN CROP ROTATION

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Abstract

Review of KCl fertilization effects on the field crops status (four experiments starting from 2001 to 2004) was aim of this study. Five maize hybrids (the experiment A) were grown on Gundinci gleysol on two K rates (500 and 1250 kg K_2O ha^{-1}). Considerable effects of genotype on leaf-nutritional status (% in dry matter) were found as follows: the hybrid effects = from 1.44% to 1.79% K, from 0.64 to 0.71% Ca and from 0.49% to 0.61% Mg; fertilization effects = 1.26% and 1.93% K, 0.73% and 0.64% Ca, 0.67% and 0.43% Mg, for the control and 1250 kg K_2O ha^{-1}, respectively). As affected by KCl yields of maize were increased up to 13% (8.36 and 9.42 t ha^{-1}, respectively). By the KCl fertilization in the experiment B (625 kg K_2O ha^{-1}) yields of maize were significantly increased for 7% (2004), 13% (2005) and 10% (2006). In the experiment C (1100 kg K_2O ha^{-1}) maize responded by non-significant differences of yield (4-y mean 10.89 t ha^{-1}), while yields of wheat and barley were increased up to 11% and 12%, respectively. Application of KCl up to 1582 kg K_2O ha^{-1} in the experiment D had moderate effects on maize yields (up to 5% increases only), while yields of soybean and wheat were increased up to 17% and 14%, respectively. Acid reaction of soil and adequate leaf-K could be responsible for relative low response of the field crops to KCl fertilization.

Key words: potassium, ameliorative fertilization, genotype, leaf nutritional status, maize, wheat, soybean, barley

Introduction

Nutritional disorders closely connected with potassium (K) deficiency alone or in combination with low phosphorus (P) supplies were found on some clay hydromorphic soils in Croatia. Details of this problem were elaborated in the previous studies (Bertić et al. 1989; Katušić 1992; Kovačević 1993, 1994; Kovačević and Brkić, 2003; Kovačević and Grgić 1995; Kovačević and Vujević, 1993; Kovačević and Vukadinović 1990, 1992; Kovačević et al. 1990, 1991, 1991a, 1991b, 1996, 1997; 2003, 2006; Kristek et al., 1996; Richter et al. 1990; Vukadinović et al. 1988). Similar K nutrition problem was found on calcaric soils in Hungary (Kadar et al., 1991, 1997). Aim of this study was review our new researches of ameliorative KCl fertilization effects on the field crops properties, while the earlier investigations of the same subject were reviewed in the other studies (Kovačević, 2001, 2002, 2009; Kovačević and Petošić, 2005; Kovačević et al., 2005, 2006a).

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Material and methods

Four field experiments with ameliorative fertilization by different rates of P and K were started on less fertile soils in the eastern and northwestern part of Croatia in the period from 2001 to 2004. The experiments were conducted by randomized block designee in four replicates. The results of these experiments were shown in the previous studies (Lončarić et al., 2005; Kovačević et al., 2006b, 2007, 2008, 2009). For this study was made choice of K fertilization (KCl form) treatments and their effects on maize nutritional status (the experiment A) and yields of the field crops in rotation on these stationary experiments (the exp. A, B, C and D). The ear-leaves of maize were collected for chemical analysis at silking.

The total amount of the elements (K, P, Ca, Mg, Zn, Fe, Mn and B) in maize leaves (the ear-leaf at silking) were determined using ICP (Jobin-Yvon Ultrace 238 ICP-OES spectrometer) after their microwave digestion by conc. HNO_3+H_2O_2. Soil K status was determined by the AL-method (Egner et al., 1960). Data obtained from the measurements and analyses were evaluated statistically by the analyses of variance and F-test, using limited significant difference (LSD) test for comparison of means.

The experiment A

Five maize (Zea mays L.) hybrids (OsSK444, OsSK458, OsSK552, Bc5982 and Florencia) were grown on Gundinci K-deficient gleysol of Brod-Posavina County in Croatia for four growing seasons (2001, 2002, 2003 and 2004). Two ameliorative rates of K on KCl form in amounts 500 and 1250 kg K_2O ha^{-1} on conventional fertilization (kg/ha: 170 N + 100 P_2O_5 + 150 K_2O) were applied at 2nd April 2001. Conventional fertilization was applied for the complete experiment in the next three years. Experimental plots measured 165 m^2 and 33 m^2, for fertilization and hybrid, respectively. The ear-leaves of maize were collected for chemical analysis at beginning of silking (July 3, 2002) from each basic plot of the control and the 1250 kg K_2O/ha treatments.

The experiment B

The field experiment with three ameliorative rates of P and K fertilization of maize was started on Maslenjaca soil of moderate fertility (Bjelovar-Bilogora County) in spring of 2003. For the next three years (2004-2006), residual effects were tested and the trial was fertilized in level of the control. Choice of the control and K fertilization treatments (625 kg K_2O ha^{-1}) was made for this study. Gross of the basic plot was 92.2 m^2.

The experiment C

The experiment with increasing rates of P and K fertilization was conducted in April 2003 in Badljevina (Pozega-Slavonian County). Total seven treatments were applied and results of three rates of K (0, 500, and 1000 kg K_2O ha^{-1} in form of KCl) on conventional fertilization was shown in this study. Gross of the individual plot of fertilization was 46.2 m^2. Crop rotation has been as follows: maize (2003-2004) – wheat (2005) – maize (2006) - winter barley (2007) – maize (2008).

The experiment D

The experiment with increasing rates of P and K fertilization was conducted in spring of April 2004 on Pavlovac acid soil (Bjelovar-Bilogora County). Four rates of K application (0, 500, 1000 and 1500 kg K_2O ha^{-1} in form of KCl) was shown in this study. Gross of the individual plot of fertilization was 77.0 m^2. Crop rotation was as follows: maize (2004) – soybean (2005) – maize (2006) – wheat (2007).

Results and discussion

Bergmann (1992) reported adequate ranges of the ear-leaf nutrient status at silking stage as follows: (% dry matter): from 2.0 to 3.5 (K), from 0.25 to 0.50 (P), from 0.25 to 1.00 (Ca), from 0.2 to 0.5 (Mg), from 25 to 70 mg kg^{-1} (Zn) and from 35 to 100 mg/kg (Mn), while according to Christensen (cited by Gollmick et al. 1970), an adequate Fe and B concentrations are from 10 to 300 mg /kg (Fe) and from 6 to 40 mg kg^{-1} (B). Ameliorative fertilization resulted by significant increases of leaf-K, and decreases of leaf-Ca and leaf-Mg (1.26% and 1.93% K, 0.73% and 0.64% Ca, 0.67% and 0.43% Mg, for the control and 1250 kg K_2O ha^{-1}, respectively). Also, leaf-P and leaf-Mn were low decreased by the fertilization. Also, considerable effects of genotype on leaf-nutritional status were found. Depending on the hybrids the ranges were as follows (from 1.44% to 1.79% K, from 0.31% to 0.34 % P from 0.64 to 0.71% Ca, from 0.49% to 0.61% Mg, from 28.9 to 35.3 mg Mn kg^{-1} (Table 1). Inadequate levels of K, Mn, Zn and B in maize of the experiment A were found.

Table 1. Residual impacts of KCl- fertilization (the experiment A) on nutritional status of maize in the 2002 growing season (Kovačević et al., 2007)

K_2O kg/ha (A)	The ear-leaf composition (on dry matter basis) at beginning of silking stage (3rd July 2002): fertilization (the Factor A) and hybrid (B: H1=OsSK444, H2=OsSK458, H3=OsSK552, H4=Bc5982, H5=Florencia) effects*									
	The hybrid effects (the factor B)					Mean	Statistical analysis			
	H1	H2	H3	H4	H5	A	LSD	A	B	AB
	Potassium (% K)									
150	1.18	1.32	1.28	1.37	1.13	*1.26*	5%	0.16	0.10	0.22
1400	1.70	1.99	1.88	2.22	1.85	*1.93*	1%	0.36	0.14	ns
Mean B	*1.44*	*1.66*	*1.58*	*1.79*	*1.49*					
	Phosphorus (% P)									
150	0.344	0.357	0.345	0.338	0.310	*0.339*	5%	0.017	0.017	0.024
1400	0.338	0.309	0.315	0.320	0.318	*0.320*	1%	0.023	ns	ns
Mean B	*0.341*	*0.330*	*0.330*	*0.329*	*0.314*					
	Calcium (% Ca)									
150	0.670	0.703	0.757	0.810	0.686	*0.725*	5%	0.015	0.030	0.042
1400	0.606	0.627	0.676	0.672	0.641	*0.644*	1%	0.035	0.041	ns
Mean B	*0.638*	*0.665*	*0.717*	*0.741*	*0.663*					
	Magnesium (% Mg)									
150	0.589	0.635	0.735	0.701	0.687	*0.671*	5%	0.044	0.054	ns
1400	0.387	0.434	0.481	0.433	0.427	*0.432*	1%	1.01	0.074	ns
Mean B	*0.488*	*0.535*	*0.609*	*0.571*	*0.557*					
	Manganese (mg Mn/kg)									
150	36.9	37.5	36.7	31.5	30.8	*34.7*	5%	1.2	2.7	ns
1400	33.6	28.6	31.3	26.3	28.2	*29.6*	1%	2.7	3.7	ns
Mean B	*35.3*	*33.1*	*33.9*	*28.9*	*29.5*					

* non-significant differences between fertilization treatments for zinc, iron and boron (means in mg kg^{-1}: 18.5 Zn, 202 Fe and 5.4 B)

Table 2. Influences of year, KCl fertilization (spring 2001) and hybrid on maize yields and stalk lodging at maturity stage (Kovačević et al., 2006b)

Year (A), fertilization (kg K_2O/ha: B**) and hybrid (C) effects and their interactions											
Year	K_2O	Maize hybrid (factor C) *					Year	kg K_2O/ha (B)**			Mean
(A)	(B)	H1	H2	H3	H4	H5	(A)	150	650	1400	A
		Maize yield (t ha^{-1})									
2001		11.02	11.34	10.55	10.66	10.88	2001	10.09	11.04	11.54	*10.89*
2002		9.74	10.18	10.84	10.44	10.52	2002	9.13	10.63	11.28	*10.35*
2003		5.06	5.51	4.53	4.12	6.00	2003	4.72	5.28	5.10	*5.03*
2004		10.07	9.65	8.85	9.53	10.08	2004	9.49	9.64	9.77	*9.63*
Mean C		*8.97*	*9.17*	*8.70*	*8.69*	*9.37*	Mean B	*8.36*	*9.15*	*9.42*	
	150	8.33	8.38	7.98	8.01	9.09	* factor C: H1=OsSK444, H2=OsSK458,				
	650	8.89	9.40	9.12	8.87	9.47	H3=OsSK552, H4=Bc5982, H5=Florencia				
	1400	9.68	9.72	8.99	9.20	9.54	** in spring 2001 only				
				Statistical analysis	A	B	C	AB		AC	BC
				LSD 5%	0.30	0.23	0.31	0.49		0.68	0.57
				LSD 1%	0.39	0.30	0.40	0.67		0.96	ns
		Stalk lodging (SL) at maturity stage (%)						kg K_2O/ha (B)**			
	Hybrid	H1	H2	H3	H4	H5	KCl	150	650	1400	
	effect	2.6	15.7	16.5	12.0	4.1	effect	15.5	8.4	6.6	
Year effect		SL = 26.5 (2001), 7.3 (2002), 0.0 (2003) and 6.9 (2004)									

Connection of leaf composition and yield of maize hybrids in the 2002 growing season was mainly low. However, the lowest yield of the OsSK444 hybrid could be in connection with lower both K and Mg concentrations in comparison with remaining four hybrids (Table 1).
Significant effects of KCl fertilization on maize yields were found in three years of testing by yield increases up to 14% (2001), 22% (2002) and 12% (2003). Drought stress was responsible for low yields in 2003 (Table 2).
The yields of individual hybrids (4-year means) were in the range from 8.69 and 9.37 t/ha. The OsSK552 and Bc5982 hybrids could be attributed as more susceptible to soil stress caused with moderate K supplies. In that respect, the OsSK444 and OsSK458 are moderate tolerant, while Florencia hybrid is more suitable for this soil in comparison with remaining four hybrids. Also, K deficiency is promoting factor of inclination for stalk lodging at maturity. With that respect heredity factors have considerable role (Table 2).

Table 3. Response of maize to KCl fertilization – the experiment B (Kovačević et al., 2008)

K_2O (kg ha^{-1})	Grain yields of maize (t ha^{-1})* and plant density realization (PDR in % TPD)							
in spring 2003	2003		2004		2005		2006	
	t ha^{-1}	%TPD	t ha^{-1}	%TPD	t ha^{-1}	%TPD	t ha^{-1}	%TPD
125	7.37	63.6	13.33	91.4	10.71	94.9	8.70	73.7
625	7.21	64.2	14.28	93.0	12.10	94.0	9.57	72.4
LSD 5%	ns		0.50		0.82		0.77	
TPD plants ha^{-1}		51948		58333		62111		54945

By the KCl fertilization grain yields of maize were significantly increased for 7% (2004), 13% (2005) and 10% (2006), while in the first year of the experiment (2003) difference of yield in comparison to the control was non-significant. We presume that fertilizers application in spring of 2003 and their shallow incorporation in the soil accompanied with drought could be responsible for absence of KCl effects on yield in 2003 (Table 3).
The fertilization resulted by decrease of leaf Mg for 22 % compared to the control. However, for the applied treatments nutritional status of maize remained in normal ranges (Table 4).

This finding could be used as explanation for moderate response of maize to the fertilization. However, low levels of P and K were found by the soil testing. For this reason, in question is scientific application of AL-method in interpretation of soil nutritional status for the investigated soil.

In the experiment C (KCl application up to 1100 kg K_2O ha^{-1}) maize responded by non-significant differences of yield (4-y mean 10.89 t ha^{-1}), while yields of wheat and barley were increased up to 11% and 12%, respectively (Table 5). Application of KCl resulted by the considerable increases AL-soluble K in soil. Also, as affected by the fertilization considerably increases of leaf-K and decreases of leaf-Mg were found (Table 6).

Table 4. K fertilization impacts (the experiment B) on nutritional status of maize (Kovačević et al., 2008)

Year	2003* (kg ha^{-1}) K_2O	The ear-leaf at flowering and grain at maturity stage (% on dry matter basis)							
		Leaf				Grain			
		P	K	Ca	Mg	P	K	Ca	Mg
2004	125	0.360	1.62	1.04	0.414	0.282	0.344	0.0054	0.085
	625	0.360	2.22	1.04	0.314	0.278	0.353	0.0055	0.085
	LSD 5%	ns	0.32	ns	0.072	ns	ns	ns	0.008
2005	125	0.335	1.79	0.89	0.310	0.282	0.336	0.0049	0.084
	625	0.361	1.86	0.96	0.250	0.265	0.366	0.0015	0.081
	LSD 5%	ns	ns	ns	0.050	ns	0.004	0.0004	ns

* conventional fertilization for the growing seasons 2004 and 2005

Table 5. Effects of fertilization (the experiment C) on grain yields of field crops (Lončarić et al., 2005; Kovačević et al., 2009)

Fertilization (spring 2003) K_2O kg ha^{-1}	Realized plant densities (RD for maize = % of planned or PD; for wheat and barley = number of ears per m^2) and grain yields (Y in t ha^{-1}) for 2003-2008 period											
	Maize (2003)		Maize (2004)		W. Wheat (2005)		Maize (2006)		W. Barley (2007)		Maize (2008)	
	RD	Y	RD	Y	RD	Y	RD	Y	RD	Y	RD	Y
100	89.3	9.77	88.4	11.9	642	6.14	98.4	9.47	696	6.19	89.6	12.2
600	83.2	9.77	90.0	12.1	601	6.80	98.4	9.10	681	6.74	89.6	12.1
1100	85.6	10.3	89.5	12.0	567	6.53	99.6	9.64	741	6.91	92.5	12.4
LSD 5%		ns		ns		0.60		ns		0.69		ns

* 100 % RD or RD (plants ha^{-1}) = 54946 (2003 and 2004), 57143 (2006) and 58310 (2008).

Table 6. Influences of KCl fertilization (the experiment C) on soil K status (AL-method) and the earl-leaf composition at silking stage (Lončarić et al., 2005)

K_2O kg ha^{-1}	Impact of KCl fertilization (spring 2003) on the ear-leaf composition (silking stage) and soil K status								
	% on dry matter basis								
	The growing season 2003				The growing season 2004				Soil K_2O mg 100 g^{-1}
	P	K	Ca	Mg	P	K	Ca	Mg	
100	0.24	2.29	0.65	0.38	0.34	2.25	0.70	0.303	92
1100	0.25	2.83	0.55	0.24	0.32	2.80	0.63	0.204	182
LSD 5%	n.s.	0.19	0.05	0.03	n.s.	0.24	n.s.	0.074	37

* non-significant effects on leaf -Zn, -Mn and -Fe (2-year means in mg kg^{-1}): 64.2 Zn, 333 Mn and 138 Fe, respectively

Table 7. Soil properties and yields of the field crops (Kovačević et al., 2007, 2009) as affected by KCl fertilization (the experiment D)

Treatment (2004)	Grain yield of the field crops in rotation ($t\ ha^{-1}$)*				Soil in autumn 2005 (0-30 cm)		Leaf-K (% in dry matter)	
K_2O $kg\ ha^{-1}$	Maize (2004)	Soyb. (2005)	Maize (2006)	Wheat (2006)	pH (KCl)	K_2O** $mg\ 100\ g^{-1}$	Maize (2004)	Soybean (2005)
82	12.28	3.60	10.37	5.08	3.67	20.1	2.58	2.81
582	12.58	4.01	10.90	5.35	3.61	23.6	2.66	2.87
1082	12.73	4.20	10.58	5.48	3.71	33.8	2.67	2.95
1582	12.95	4.08	10.97	5.81	3.64	34.8	2.70	3.29
LSD 5%	0.52	0.37	ns	0.44	n.s.	3.6	0.09	0.30

* residual effects of the fertilization in the 2005-2007 period (conventional fertilization only)

Application of KCl up to 1582 kg $K_2O\ ha^{-1}$ in the experiment D had moderate effects on maize yields (increases of yields up to 5% only), while yields of soybean and wheat were increased up to 17% and 14%, respectively. Acid reaction of soil and adequate leaf-K could be responsible for relative low response of the field crops to KCl fertilization (Table 7).

Conclusions

Efficacy of applied K fertilization was different depending on the field crop, growing season and locality of the experiment. Also, by choice of more tolerant genotypes to less favorable soil conditions is possible to minimize problem of low yields of the field crops under conditions of the lower K supplies.

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UTICAJ ĐUBRENJA KALIJUMOM I GENOTIPA NA RATARSKE KULTURE U PLODOREDU

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Rezime

Cilj ovoga istraživanja je pregled uticaja đubrenja kalijumovim kloridom (četiri stacionirana poljska ogleda postavljena u periodu 2001.-2004.) na ratarske kulture gajene u plodoredu. Pet hibrida kukuruza (ogled A) gajeno je na glejsolu u Gundincima na dva nivoa dodanog kalijuma (500 i 1250 kg K_2O ha^{-1}). Ustanovljene su pri tome značajni uticaji na sastav lista ispod klipa kukuruza u svilanju (uticaj hibrida = od 1.44% do 1.79% K, od 0.64 do 0.71% Ca i od 0.49% do 0.61% Mg; uticaj đubrenja = 1.26% i 1.93% K, 0.73% i 0.64% Ca, 0.67% i 0.43% Mg, za kontrolu, odnosno 1250 kg K_2O ha^{-1}). Prinosi kukuruza su đubrenjem kalijumom povećani do 13% (8.36, odnosno 9.42 t ha^{-1}). U ogledu B je dodano na standardno đubrenje 500 kg K_2O ha^{-1}, a prinosi kukuruza su signifikantno povećani za 7% (2004), 13% (2005) i 10% (2006). U ogledu C kukuruz nije reagovao na đubrenje do 1100 kg K_2O ha^{-1}.(4-god prosek 10.89 t ha^{-1}),dok su prinosi pšenice povećani za 11% i ječma za 12% prema kontroli. Primena do 1582 kg K_2O ha^{-1} u ogledu D imala je skroman uticaj na prinose kukuruza (samo do 5% povećanja prinosa), dok su soja i pšenica reagovale povećanjem prinosa do 17%, odnosno 14%. Kisela reakcija tla i dovoljno kalijuma u listu mogle bi se povezati s relativno skromnim efektima đubrenja kalijumom u ogledu D.

Ključne reči: kalijum, meliorativno đubrenje, genotip, stanje mineralne ishrane lista, kukuruz, pšenica, soja, ječam,

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