PHOSPHORUS AND POTASSIUM FERTILIZATION IMPACTS ON YIELD AND NUTRITIONAL STATUS OF MAIZE

Vlado KOVAČEVIĆ [1] – Mirta RASTIJA [1] – Branimir ŠIMIĆ [2] – Luka ANDRIĆ [2] – Dražen KAUČIĆ [3]

[1]University J. J. Strossmayer in Osijek, Faculty of Agriculture, Trg Sv. Trojstva 3, HR-31000, Osijek, Croatia; vkovacevic@pfos.hr
[2]Agricultural Institute, Juzno predgradje 17, HR-31000 Osijek, Croatia
[3]State Hydrometeorological Institute in Zagreb, Croatia

Abstract: The field experiment with three ameliorative rates of P (kg P_2O_5/ha^{-1}: 250 = P1, 500 = P2 and 750 = P3), rate of K (500 kg K_2O/ha = K2) and their combination (P2K2: 500 kg both P_2O_5 and K_2O ha^{-1}) was conducted on soil of moderate fertility. Maize was grown for 4-year period 2003-2006. Precipitation and temperature regimes were resposible for considerable differences of maize yield among years. For example, under drought stress of 2003 annualy yield was from 21 to 45% lower than annualy yields for remaining three years. In general, applied fertilization resulted by significant but moderate yield increases for 14% (2003: PK-treatment), 7% (2004: K-treatment), and up to 16% (2005 and 2006: PK and P-3, respectively). K fertilization resulted by decrease of leaf Mg for third part compared to the control. However, for the applied fertilization and the control nutritional status of maize (leaf and grain P, K, Ca, Mg and Zn) remained in normal ranges.

Keywords: ameliorative fertilization, maize, nutritional status, phosphorus, potassium, yield

Introduction

Soil degradation processes became serious environmental problem (Varallyay, 2006). Kadar (2007) reported about sustainability of soil nutrient levels, while Pepo (2007) and Nagy (2007) emphased role of fertilization and genotype in sustainable field crop growing. Low plant available phosphorus (P) and potassium (K) levels are in place limiting factor of the field crop yields in Croatia (Petošić et al., 2003; Kovačević et al., 2005. Application of the higher P and K rates could be solution for better efficiency of soil (Kovačević et al., 2006; Lončarić et al., 2005; Banaj et al., 2006; Rastija et al., 2006). Aim of this study was 4-year testing of maize response to P and K fertilization.

Material and methods

The field experiment, soil and weather characteristics

The field experiment with three ameliorative rates of P (kg P_2O_5 ha^{-1}: 250 = P1, 500 = P2 and 750 = P3), rate of K (500 kg K_2O/ha = K2) and their combination (P2K2: 500 kg both P_2O_5 and K_2O ha^{-1}) was conducted on soil of moderate fertility (Maslenjaca, Bjelovar-Bilogora County) in spring of 2003. Standard fertilization (kg ha^{-1}: 160 N + 125 P_2O_5+ 125 K_2O) used as the control treatment. P was added as MAP (monoammonium-phosphate 12% N and 52% P_2O_5) and K in KCl form (60% K_2O). Nitrogen was equalized for all treatments with addition of CAN (calcium ammonium nitrate: 27% N). For the next three years (2003-2006), residual effects were tested and the trial was fertilized in level of the control. The field trial was conducted by randomized block design in four replicates. Gross of the basic plot was 92.2 m^2.

Maize (OsSK552 hybrid) was sown at beginning of May by pneumatic sowing machine on theoretical (planned) plant densities (TPD: depended on the year, between 51948 and 62111 plants ha^{-1} - Table 3). Maize was harvested manually (4 internal rows from each basic plot) in the second half of October. Mass of cob was weighed by Kern electronic

balance (d=200 g). Ten cobs from each treatments was used for determination of grain moisture and grain share in cob (waiging by Kern electronic balance, d = 100g). Grain moisture was determined by electronic grain moisture instrument (WILE-55, Agroelectronics, Finland). Yield were calculated on 14% grain moisture basis.
The Maslenjaca soil is favourable for field crops growth regarding soil reaction (pH) and humus contents, but moderately supplied with plant available P and K (Table 1).

Table 1. Soil characteristics at start of the experiment

Soil propertis (0-30 cm depth) at start of the experiment before fertilization (April 17, 2003)									
pH		%	mg kg^{-1}						
H_2O	KCl	Humus	AL-method		NH_4Acetate+EDTA (pH=4.6) extraction				
			P_2O_5	K_2O	P_2O_5	K_2O	Ca	Mg	Zn
6.90	6.48	2.1	76.0	97.8	56.0	97.6	3591	336	4.5

Table 2. Weather characteristics for the maize growing seasons

The data of State Hydrometeorological Institute in Zagreb												
Year	Precipitation (mm)						Mean air-temperatures (^oC)					
	May	June	July	Aug.	Sept.		May	June	July	Aug.	Sept	Mean
	Daruvar * Weather Bureau (the 2003-2006 growing seasons)											
2003	35	36	38	46	111	*266*	18.5	23.6	22.2	23.7	15.0	*20.6*
2004	55	97	65	63	103	*383*	14.2	18.7	20.4	20.2	14.9	*17.7*
2005	69	45	106	166	110	*496*	15.9	18.9	20.8	18.5	16.1	*18.0*
2006	106	95	19	160	27	*407*	15.2	19.1	22.5	18.6	16.6	*18.4*
	Daruvar* Weather Bureau: lomg-term mean (LTM) 1961-1990											
LTM	86	99	86	91	65	*427*	15.7	18.9	20.6	19.7	16.1	*18.2*

* air-disatnces from the experiment: Daruvar = 12 km in SW direction

Drought stress is main characteristic of the 2003-growing season. Precipitation for 4-month period (May-August) was 155 mm or only 50% compared to the LTM. At the same time, air-temperatures were for 3.5 ^oC higher (Table 2). Under these conditions plant density reduction and low grain yields were found (Table 3). However, the remaining three years were favourable for maize. In general, low maize yields are in connection with drought and the higher air-temperatures, especially in July and August (Josipovic et al., 2005).

Sampling and analyses of plant and soil samples from the experimental field

The ear-leaf at flowering (middle of July 2004 and 2005: 25 leaves in the mean sample) and grain at maturity (five cobs in mean sample) were taken for chemical analysis. Soil sampling (depth 0-30 cm) was made at start of the experiment. Mobile fractions of elements in soil were extracted by the AL-method and NH_4-Acetate + EDTA (Lakanen-Ervio, 1971). The total amounts of P, K, Ca, Mg and Zn in maize leaves and grain were determined using ICP after their microwave digestion by conc. HNO_3+H_2O_2. Plant analyses were made by Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the laboratory of the Research Institute for Soil Science and Agricultural Chemistry (RISSAC) Budapest. Statistical calculations were made according Mead et al. (1996).

Results and discussion

Precipitation and temperature regimes were responsible for considerable differences of maize yield and realized plant densities among the years. For example, under drought stress of 2003 mean yield was from 21 to 45% lower than the yields for remaining three years. In general, applied fertilization resulted by significant yield increases for 14% (2003: PK- treatment), 7% (2004: K-treatment), and up to 16% (2005 and 2006: PK and P-3, respectively) compared to the control (Table 3). Izsaki (2007) also found moderate effects of P fertilization in a long-term trial on chernozem soil in Hungary and it was detected in approximately 50% of the years over ten years period.

Table 3. Response of maize to P and K fertilization – Maslenjača experiment 2003-2006.

Fertilization (kg ha^{-1}) in spring 2003			Grain yields of maize (t ha^{-1})* and plant density realization (PDR in % TPD)							
			2003		2004		2005		2006	
	P_2O_5	K_2O	t ha^{-1}	%TPD	t ha^{-1}	%TPD	t ha^{-1}	%TPD	t ha^{-1}	%TPD
a	125	125	7.37	63.6	13.33	91.4	10.71	94.9	8.70	73.7
b	375	125	7.44	57.5	13.33	93.0	11.11	95.4	9.66	72.4
c	625	125	7.57	56.5	13.70	94.5	11.09	92.1	9.64	75.0
d	825	125	8.07	60.6	13.76	95.4	12.23	95.4	10.10	70.6
e	125	625	7.21	64.2	14.28	93.0	12.10	94.0	9.57	72.4
f	625	625	8.46	65.6	14.07	96.0	12.51	93.0	9.55	70.0
Average			7.69	61.3	13.75	93.9	11.63	94.1	9.70	72.4
LSD 5%			0.46		0.50		0.82		0.77	
LSD 1%			0.63		ns		1.13		ns	
TPD plants ha^{-1}				51948		58333		62111		54945

* yield calculations on 14% grain moisture and TPD %: 60, 90, 90 and 70, for 2003, 2004, 2005 and 2006

Table 4. P and K fertilization influences on nutritional status of maize for 2004 and 2005

Year	2003* (kg ha^{-1})		The ear-leaf at flowering and grain at maturity stage (mg kg^{-1} on dry matter basis)									
			Leaf					Grain				
	P_2O_5	K_2O	**P**	**K**	**Ca**	**Mg**	**Zn**	**P**	**K**	**Ca**	**Mg**	**Zn**
2004	125	125	3602	16212	10455	4146	46.9	2817	3440	54.2	848	18.5
	375	125	-	-	-	-	-	3034	3484	43.1	967	18.8
	625	125	3529	16015	10764	4169	42.4	2942	3562	58.4	906	16.5
	875	125	3859	18543	10953	3947	39.0	3108	3532	67.0	947	17.0
	125	625	3604	22211	10411	3137	61.9	2779	3526	55.2	847	18.4
	625	625	3664	19854	10908	3350	45.6	3102	3720	57.7	921	19.0
	LSD 5%		250	3194	ns	719	7.9	155	ns	ns	77	ns
2005	125	125	3350	17900	8900	3100	38.6	2816	3360	49.0	844	15.4
	375	125	3480	17700	9800	2900	41.1	2906	3423	40.6	856	18.4
	625	125	3970	16200	10700	3000	42.3	3083	3682	84.9	879	16.0
	875	125	3600	18500	9800	2900	39.1	2939	3519	24.1	876	18.8
	125	625	3610	18600	9600	2500	44.2	2651	3660	14.9	811	18.6
	625	625	3660	18700	9600	2500	43.7	3034	3638	27.5	856	18.2
	LSD 5%		290	ns	ns	500	ns	63	40	4.4	ns	0.8

* ordinary fertilization of all treatments for the growing seasons 2004 and 2005

Mengel and Kirkby (2001) cited data regarding appraisal of the nutrient status in dry matter of ear leaf of maize at flowering Adequate ranges are from 0.2 to 0.5% P, from 1.5 to 3.0% K, from 0.2 to 1.0% for Ca and Mg and 20 to 70 mg kg^{-1} Zn. K 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 investigated soil. Loncaric et al. (2005) reported similar observation in 2-year study of application ameliorative P and K rates. Also, Rastija et al. (2006) applied four rates of NPK 10:30:20 up to 3748 kg ha^{-1} for maize –soybean rotation. Yield increases were up to 14% and up to 32%, for maize and soybean, respectively. Banaj et al. (2006) used three P_2O_5 rates up to 2000 kg ha^{-1} and tested response of maize for three-year period. As in our study, the growing season was the most influencing factor of yield.

Conclusion

In general, in our study yield differences of maize among the years were greater than among ameliorative P and K fertilizations. Water deficit and the higher air-temperatures are responsible for the lower maize yields under our environmental conditions. Nutritional status of maize regarding contents of P, K, Ca, Mg and Zn was in adequate ranges for the applied fertilizations.

References

Banaj D., Kovačević V., Šimić D., Šeput M., Stojić B.: 2006. Phosphorus impacts on yield and nutritional status of maize. Cereal Research Communications **34**: 1. 393-396.

Izsaki Z.: 2007. N and P impact on the yield of maize in a long-term trial. Cereal Research Communications **35**:4 1701-1711.

Josipović M., Kovačević V., Petosic D. and Šostarić J.: 2005. Wheat and maize yield variations in the Brod-Posavina area. Cereal Research Communications **33:** 1. 229-233.

Kádár I.: 2007. Sustainability of soil fertility nutrient levels. Cereal Research Commun., **35:** 2. 573-576.

Kovačević V., D. Petosic D. and M. Josipović M.: 2005. Potassium availability in hydromorphic soils of Eastern Croatia. Cereal Research Communications **33**: 1. 247-250.

Kovačević V., Rastija M., Rastija D., Josipović M., Šeput M.: 2006. Response of maize to fertilization with KCl on gleysol of Sava valley area. Cereal Research Communication **34**: 2-3. 1129-1135.

Lakanen E., Ervio R. (1971): A comparison of eight extractans for the determination of plant available micronutrients in soils. Acta Agr. Fenn. 123, 223-232.

Lončarić Z., Kovačević V., Šeput Miranda, Šimić B. and Stojic B.: 2005. Influences of fertilization on yield and nutritional status of maize. Cereal Research Communications **33**: 1.259-262.

Mead R., Curnow R. N., Hasted A.M.:1996. Statistical methods in agriculture and experimental biology. Chapman & Hall, London.

Mengel K., Kirkby E. A.: 2001. Principles of plant nutrition. Kluwer Academic Publishers Dordrecht/Boston/London.

Nagy J.: 2007. Evaluating the effect of year and fertilisation on the yield of mid ripening (FAO 400–499) maize hybrids. Cereal Research Communications **35**: 3.1497-1507.

Pepó P.: 2007.The role of fertilization and genotype in sustainable winter wheat (Triticum aestivum L.) production. Cereal Research Communications, Vol. 35, No. 2 pp 917-920

Petosic D., Kovačević V., Josipović M.: 2003. Phosphorus availability in hydromorphic soils oh Eastern Croatia. Plant, Soil and Environment, **49**: 9. 394-401.

Rastija M., Kovačević V., Vratarić M., Sudarić A,, Krizmanić M.:2006. Response of maize and soybeans to ameliorative fertilization in Bjelovar-Bilogora county. Cereal Research Communications **34** :1. 641-644.

Várallyay, Gy., 2006. Soil degradation processes and extreme soil moisture regime as environmental problems in the Carpathian Basin. Agrokémia és Talajtan. **55**. (1-2) 9-18.