LIMING AND PK-FERTILIZATION IMPACTS ON MAIZE YIELDS AND GRAIN QUALITY

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Abstract: The stationary field experiment was conducted in spring 2004 (April, 23) on Pavlovac very acid soil by the application treatments as follows: a = conventional fertilization, b = a + NPK-1, c = a + NPK-2, d = a + NPK-3 and e = a + NPK-4. The fertilizer NPK 10:30:20 was source of P and K (using in amounts 416, 1249, 2082, 2916 and 3748 kg ha^{-1}, for the treatments a, b, c, d and e, respectively). Nitrogen amount was equalized for all treatments by the addition of adequate quantities of CAN (calcium ammonium nitrate containing 27% N). The experiment was conducted in four replicates and the basic plot size was 77 m^2. In the following years the plots was fertilized uniformly in the level of conventional fertilization. Additional intervention in the experiment was liming of the third and fourth replicates by 10 t ha^{-1} with granulated fertdolomite (24.0% CaO + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O). In this study, response of maize (the hybrid OsSK 2893) was shown. Liming and ameliorative PK-fertilization in spring 2004 had significantly ubsequent effects on yield because of yield increases for 8% (liming effects) and 11% (PK-effects), respetively. With that regard, the PK-2 rate was adequate. Liming had considerably effects on increase of protein contents in grain from 9.9% (the control) to 10.6% (liming), while by the using ameliorative PK-fertilization there is tendency to increases of grain protein contents. Grain starch contents was independent on liming and PK-treatments.

Keywords: liming, PK-fertilization, grain yield, maize, protein contents, starch contents

Introduction

Acid reaction and nutritional unbalances, mainly low level of plant available phosphorus (P) as well as unfavorable physical properties are oft limiting factor of soil fertility. Liming and increased fertilization (mainly with P, occasionally both P and K) are usually recommendations for these soils improvement (Petosic et al., 2003; Komljenović et al., 2008; Kovacevic et al., 2011a, 2011c, 2012; Andric et al., 2012; Stojic et al., 2012). Aim of this study was testing maize response to ameliorative PK-fertilization on acid soil of Bjelovar-Bilogora County in Croatia.

Material and methods

The field experiment

The stationary field experiment was conducted in spring 2004 on Pavlovac (municipality V. Grdjevac, Bjelovar-Bilogora County very acid soil by the application treatments as follows: a = conventional fertilization, b = a + NPK-1, c = a + NPK-2, d = a + NPK-3 and e = a + NPK-4. The fertilizer NPK 10:30:20 was source of P and K (using in amounts 416, 1249, 2082, 2916 and 3748 kg ha^{-1}, for the treatments a, b, c, d and e, respectively). Nitrogen amount was equalized for all treatments by the addition of adequate quantities of CAN (calcium ammonium nitrate containing 27% N). The experiment was conducted in four replicates and the basic plot size was 77 m^2. In the following years the plots was fertilized uniformly in the level of conventional fertilization. Crop rotation on the experimental field has been as follows: maize (2004) – soybean (2005) – maize (2006) – wheat (2007) – maize (2008) – maize (2009) – soybean (2010) – maize (2011). Additional intervention in the experiment was liming of

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the third and fourth replicates by 10 t ha^{-1} with granulated fertdolomite (24.0% CaO + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O: product of Petrokemija Fertilizer Factory Kutina, Croatia) in Nov. 13, 2007. The some results of these investigations were shown in detail by the previous studies (Rastija et al., 2006; Kovacevic et al., 2006, 2011b). In this study, response of maize (the growing season 2011) was shown.
Maize hybrid OsSK2983 was sown in term April 19, 2011 by pneumatic sowing machine on the planned (theoretical) plant density (TPD: plants ha^{-1}) 71429 plants ha^{-1}. Maize was harvested manually (4 internal rows from each basic plot) in term September 15, 2011. Mass of cob was weighed by Kern electronic balance (d=50 g). Ten cobs from each treatments were used for determination of grain moisture and grain share in cob weighing by Kern electronic balance, d = 5g). Grain moisture was determined by electronic grain moisture instrument (WILE-55, Agroelectronics, Finland). Grain yields were calculated on the realized plant density and 14% grain moisture basis.

The chemical and statistical analysis
Protein and starch contents in the grain were determined by Near Infrared Transmittance spectroscopic method on Grain Analyzer (Infratec 1241, Foss Tecator). The data of yields, protein and starch contents were statistically analyzed by ANOVA and treatment means were compared using t-test and LSD at 0.05 and 0.01 probability levels.

Weather characteristics
The growing season 2011 was less favorable for maize (*Table 1.*). Supplies of water in soil during soil preparing and sowing were low because of insufficient precipitation (January-March: only 37 mm or fourth part compared to usual). Low supplies of water continued in the next three months (April-June: 88 mm or close to 40% of usual). Also, August was especially unfavorable because of drought and the high air–temperatures (26 mm and 22.°C, respectively).

Table 1. Precipitation and mean air-temperatures (Bjelovar Weather Bureau)

Period	Bjelovar Weather Bureau (LTM = long-term averages 1961-1990)							April – Sept.	
	Jan.-March	April	May	June	July	Aug.	Sept.	Total	Mean
	Precipitation (mm)							mm	°C
2011	37	34	30	24	59	26	47	220	
LTM	150	63	79	96	78	82	65	463	
	Mean air-temperature (°C)								
2011	3.1	13.5	16.9	21.3	22.0	23.0	19.9		19.4
LTM	2.2	10.8	15.6	18.7	20.4	19.5	15.8		16.8

* air-distance from the experimental field: 25 km in NW direction

Results and discussion

Response of maize in the 2011 growing season to the applied treatments
As affected by less favorable weather conditions (*Table 1.*) maize yields in the experiment was about 9.0 t ha^{-1} and considerably lower compared to grain yield potential of the OsSK2983 hybrid. However, liming and ameliorative PK-fertilization in spring 2004 had significantly subsequent effects on yield because of yield increases for

8% (liming effects) and 11% (PK-effects), respectively (*Table 2.*). With that regard, the second PK- rate (the treatment c) was adequate.

Table 2. Subsequent effects of PK- fertilization and liming on maize (OsSK2983) in the 2011 growing season

PK-fertilization (spring 2004; the factor B) and liming* (autumn 2007; the factor A: 0 and 10 t ha^{-1})												
PK-fertilization (B)			Liming (A)		Mean	Liming (A)		Mean	Liming (A)		Mean
			0	10	B	0	10	B	0	10	B
	P_2O_5	K_2O	Grain yield (t ha^{-1})			Grain protein contents (%)			Grain starch contents (%)		
	kg/ha										
a	0	0	8.37	8.64	*8.50*	9.4	10.5	*4.1*	71.2	70.4	*70.8*
b	250	168	8.77	8.97	*8.87*						
c	500	336	9.11	9.78	*9.44*	9.8	10.4	*4.5*	71.0	70.3	*70.7*
d	750	504	8.44	9.78	*9.11*						
e	1000	672	8.64	9.71	*9.18*	10.5	10.7	*4.5*	70.1	70.2	*70.2*
	Mean A		*8.67*	*9.38*		*9.9*	*10.6*		*70.8*	*70.3*	
			Statistics			Statistics			Statistics		
			A	B	AB	A	B	AB	A	B	AB
	LSD 5%		0.57	0.52	ns	0.6	ns	ns	ns	ns	ns
	LSD 1%		ns	ns		ns					

* granulated fertdolomite (24.0 % CaO + 16.0 % MgO + 3.0 % N + 2.5 % P_2O_5 + 3.0 % K_2O)

Liming had considerably effects on increase of protein contents in grain from 9.9% (the control) to 10.6% (lime 10 t ha^{-1}), while by the using ameliorative PK-fertilization there is tendency to increases of grain protein contents. Grain starch contents was independent on liming and PK-treatments (*Table 2.*).

The previous investigations

Rastija et al. (2006) reported the results of the two first years of the experiment. By application of the ameliorative rates of NPK fertilizer, grain yields of maize (the growing season 2004) were significantly increased to level of 14% compared to standard fertilization (12.33 and 14.00 t ha^{-1}), for the control and the second rate of NPK fertilization, respectively. Only the highest rate of NPK fertilizer resulted by significant increase of protein in grain. Subsequent response of soybean (the growing season 2005) to the fertilization was considerably higher compared to maize, because yields of soybeans were increased up to 32%. Protein contents in soybean grain were independent on the fertilization, while oil contents were increased up to 0.66% compared to the control.

Significant influences of the fertilization on maize grain composition (the 2004 growing season) were found only for P, K and Mn (increases for 27%, 20% and 60%, respectively). Concentrations of Ni, Se, As, Co, Hg. Mo, Pb and Co were bellow detection limits of ICP-AES method. Mean concentrations of the elements in maize grain were as follows: (mg/kg on dry matter basis): 2695 (P), 3324 (K), 41.9 (Ca), 945 (Mg), 943 (S), 22.0 (Fe), 7.73 (Mn), 19.8 (Zn), 1.90 (Cu), 011 (Sr), 0.025 (Cd), 5.6 (Na), 1.6 (Al), 1.15 (B) and 0.40 (Ba). The above mentioned values are in normal ranges with aspect of sustainable agriculture and applied fertilization did not influenced on environment pollution (Kovacevic et al., 2006).

Very acid reaction and low levels of AL-soluble P and K are main chemical characteristics of the soil. The first soil sampling was made in autumn 2005.

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Ameliorative fertilization resulted by significant decrease of soil pH (KCl) from 3.77 (*a*) to 3.42 (*e*) and decrease both AL-soluble P and (mg 100 g^{-1} of soil: 11.57 and 21.42 P_2O_5, 17.31 and 25.55 K_2O, for the treatments *a* and *e*, respectively (Rastija et al., 2006). The analogous values of the second soil sampling (autumn 2009) were as follows: soil pH 3.80 and 3.75; soil P_2O_5 11.1 and 18.7, soil K_2O 15.8 and 20.5. As affected by liming, soil pH was increased (4.53), while humus, phosphorus and potassium contents were independent on liming (Kovacevic et al., 2011).

Conclusions

Ameliorative PK-fertilization and liming had mainly moderate but the long-term impacts on yields of the field crops in rotation. Intensity of these effects was considerably affected by weather characteristics of the individual growing season. In general, under stress conditions due to drought and the high air-temperature, yield variation over years are sometimes lower under liming and ameliorative PK-fertilization in comparison to usual soil management practice.

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