IMPACTS OF LIMING AND PK-FERTILIZATION ON NUTRITIONAL STATUS OF SOIL AND MAIZE YIELD

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Abstract: The stationary field experiment was started in spring 2004 on very acid soil by the application of four levels of NPK 10:30:20 fertilizer up to 3748 kg ha^{-1}.The experiment was performed in four replicates and the basic plot size was 77 m^2. The third and fourth replicates of the experiment were limed with 10 t ha^{-1} granulated fertdolomite (24.0 % CaO + 16.0 % MgO + 3.0 % N + 2.5 % P_2O_5 + 3.0 % K_2O) in the November 13, 2007. Mobile fraction of the individual elements in soil (sampling in Sept. 2009) was extracted with NH_4-Acetate+EDTA solution (pH 4.65). Liming significantly influenced on soil pH increases for 0.69 and 0.75 units, for pH in H_2O and KCl, respectively, as well as decrease of hydrolitical acidity for 2.04 Cmol /kg^{-1}. However, ameliorative fertilization had low effects on these properties. By application of ameliorative fertilization and liming grain yields of maize were in the 2009 growing season significantly increased for 6% and 8%, respectively. As affected by the fertilization available P, K and Mg in the soil were increased for 29% and 9%, while the remaining tested elements status (Fe, Mn, Zn, Cu and Cd) was independent on the fertilization. However, liming considerably affected on Ca, Mg and Cd soil status (increases for 75%, 123%, and 36% respectively) as well as K, Zn and Cu status (decreses about 20%), while the impacts on P, Fe, and Mn status were lower.

Keywords: ameliorative PK-fertilization, liming, soil properties, yield, maize

Introduction

Soil acidity and inadequate nutritional status are oft limiting factors of the field crops yield on arable lands in Croatia (Kovacevic and Rastija, 2010; Kovacevic et al., 2011; Stojic et al., 2012; Basic, 2013). Aim of this study was testing impacts of PK-fertilization and liming on soil properties and maize yields in the 2009 growing season.

Material and methods

The field experiment

The stationary field experiment was started in April 24, 2004 on Pavlovac (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 was as follows: maize (2004) – soybean (2005) – maize (2006) – wheat (2007) – maize (2008) – maize (2009). The third and fourth replicates of the experiment were limed with 10 t ha^{-1} granulated fertdolomite (24.0% CaO + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O; product of the Fertilizer Factory Kutina, Croatia) in the November 13, 2007.

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Maize (the hybrid OsSK298P developed in Agricultural Institute Osijek) was sown in the April 18, 2009 by the pneumatic sowing machine (distance in row 21.0 cm, interrow spacing 70 cm = 68027 plants ha^{-1}). Maize was harvested manually (2 x 2 internal rows from each basic plot for receiving four replicates). Grain yields were calculated on 14% grain moisture basis.

Sampling and chemical analysis

The first soil sampling from each basic plot of NPK-fertilization was performed in November 15, 2005. The results were shown in the previous study (Rastija et al., 2006). The second soil sampling was performed in the September 3, 2009. Both sampling was performed by the pedologic auger to 0-30 cm of depth. Soil pH reaction was determined electrometrically in a suspension of soil in water and in a solution of 1 mol L^{-1} potassium chloride (ISO, 1994). Soil organic matter contents were analyzed according to determination of organic carbon by sulfochromic oxidation (ISO, 1998). These analyses were performed in the Department of Agroecology, Faculty of Agriculture in Osijek. Mobile fraction of the individual elements in soil was extracted with NH_4-Acetate+EDTA solution (pH 4.65) according to Lakanen and Erviö (1971). The soil samples for this procedure were prepared by combine equal parts of four replicates in level of the *a*, *c* and *e* treatments because of inadequate funds for these investigations. Analyses of the elements (P, K, Ca, Mg, Fe, Mn, Zn, Cu, Cd) in the soil extract were performed with a Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the laboratory of the RISSAC, Budapest, Hungary.

After harvest mass of cobs was weighed by precise electronic balance. Than ten cobs from each treatments was used for determination of grain moisture and grain share in cob. Grain moisture was determined by electronic grain moisture instrument.

Data were statistically analyzed by ANOVA and treatment means were compared using t-test and LSD at 0.05 probability level.

The soil and weather characteristics

The soil of the experiment is very acid and low supplied with available calcium and magnesium and adequate in remaining tested nutrients. Also, harmful heavy metal cadmium status is low and production of health food is possible on this soil (*Table 1.*).

Table 1. Chemical properties of the soil at starting of the experiment (Kovacevic et al., 2011)

Soil characteristics (0-30 cm) at the start of the experiment before fertilization (April 23, 2004)											
pH		%	Concentrations (mg kg^{-1}) in NH_4-Acetate+EDTA solution (pH 4.65)								
H_2O	1n KCl	Humus	P_2O_5	K_2O	Ca	Mg	Fe	Mn	Zn	Cu	Cd
5.44	3.99	1.93	90	171	456	77	496	296	2.45	3.56	0.086

The growing season 2009 was unfavorable for maize because of two long dry periods. In the 30-day period from July 11 to August 10, was only 17 mm precipitation. In the next 10-days period the field crops received rain in amount 40 mm. Then again was the next 40 days long drought period with only 4 mm precipitation. The precipitation in the May-September period was about 50% of average. At the same time, air-temperature was for 1.3 ^{o}C higher (Stojic et al., 2012).

In general, the higher yields of maize were found in the growing seasons characterizing the higher precipitation and the lower temperatures, especially in two summer months July and August (Markulj et al., 2010).

Results and discussion

By application of ameliorative fertilization and liming grain yields of maize were in the 2009 growing season significantly increased for 6% and 8%, respectively (*Table 2.*). Effect of liming on maize yieds was found also in the other study (Kovacevic and Rastija, 2010). By application of the ameliorative rates the fertilizer, grain yields of maize significantly increased to level of 14% in 2004 and 7% in 2006. Response of soybean (2005) to the fertilization was considerably higher compared to maize, because yields of soybeans were increased up to 32% (*Table 2.*).

Table 2. Impacts of PK-fertilization (spring 2004) and liming (autumn 2007) on the field crop yields

Fertilization in 2004 (B) and liming with fertdolomite* (10 t ha^{-1}) in 2007 (A); RPD = realized plant density in % of planned (PPD 68027 plants ha^{-1})										PK-fertilization effects (2004-2006)		
Fertilization (B)			Liming (A)		Mean	Liming (A)		Mean	RPD	Maize	Soybean	Maize
			0	10	B	0	10	B				
	P_2O_5	K_2O	Maize (the growing season 2009)							2004	2005	2006
	kg/ha		Grain moisture (%)			Grain yield (t ha^{-1})			%	Grain yield (t ha^{-1})		
a	0	0	20.4	90.7	20.5	9.9	10.5	10.2	90.7	12.33	3.88	10.88
b	250	168	21.3	91.2	20.6	10.3	10.8	10.5	91.2	13.18	4.87	11.16
c	500	336	20.2	90.0	20.0	10.6	11.1	10.9	90.0	14.00	4.73	11.27
d	750	504	20.0	90.5	20.0	10.6	11.3	10.9	90.5	14.09	4.98	11.60
e	1000	672	20.5	90.0	20.3	10.8	11.2	11.0	90.0	13.73	5.14	11.52
	Mean A		*20.5*	*20.1*	*90.4*	*10.4*	*11.0*	*10.7*	*90.5*	*13.47*	*4.72*	*11.28*
* Fertdolomite composition:						A	B	AB				
24.0 % CaO + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O					$P_{0.05}$ $P_{0.01}$	0.47 ns	0.40 0.55	ns	$P_{0.05}$ $P_{0.01}$	0.52 0.73	0.72 ns	0.38 ns

Table 3. Soil pH and hydrolitical acidity (Kovacevic et al., 2011)

Factor B: Fertilization (2004)			Impacts of fertilization (factor B) and liming (factor A) on soil status (HY = hydrolytical acidity): sampling 0-30 cm in term Sept 3, 2009								
			Liming (t ha^{-1})		Mean	Liming (t ha^{-1})		Mean	Liming (t ha^{-1})		Mean
	kg/ha		0	10	B	0	10	B	0	10	B
	P_2O_5	K_2O	pH (H_2O)			pH (1n KCl)			HY (Cmol /kg)		
a	0	0	4.92	5.67	*5.30*	3.80	4.44	*4.12*	6.82	4.85	*5.84*
b	250	168	4.97	5.46	*5.21*	3.87	4.32	*4.10*	6.54	5.20	*5.87*
c	500	336	4.94	5.73	*5.34*	3.80	4.80	*4.30*	6.56	4.64	*5.60*
d	750	504	4.98	5.58	*5.28*	3.81	4.55	*4.18*	7.12	4.92	*6.02*
e	1000	672	4.90	5.69	*5.30*	3.75	4.67	*4.21*	7.57	4.78	*6.17*
Mean A			*4.94*	*5.63*		*3.81*	*4.56*		*6.92*	*4.88*	
$P_{0.05}$ $P_{0.01}$			A: 0.10 B: ns AB: ns 0.24			A: 0.10 B: ns AB:0.23 0.24 0.32			A: 0.52 B: 0.23 AB: 0.63 1.20 0.31 1.30		

Liming significantly influenced on soil pH increases for 0.69 and 0.75 units, for pH in H_2O and KCl, respectively, as well as decrease of hydrolitical acidity for 2.04 Cmol /kg^{-1}. However, ameliorative fertilization had low effects on these properties (*Table 3.*).

Table 4. Mobile fraction of individual elements in the soil

Fertilization (2004)			Impacts of fertilization and liming on soil status (sampling 0-30 cm in Sept 3, 2009)								
	kg/ha		Liming (t ha^{-1})		Mean	Liming (t ha^{-1})		Mean	Liming (t ha^{-1})		Mean
	P_2O_5	K_2O	0	10		0	10		0	10	
			Concentrations (mg kg^{-1}) in NH_4-Acetate+EDTA solution (pH 4.65)								
			Phosphorus (P_2O_5)			Potassium (K_2O)			Calcium (Ca)		
a	0	0	94	104	*99*	132	121	*127*	461	732	*597*
c	500	336	101	112	*106*	151	124	*138*	502	818	*660*
e	1000	672	116	140	*128*	165	112	*139*	427	874	*651*
Mean			*105*	*119*		*149*	*119*		*463*	*808*	
			Magnesium (Mg)			Iron (Fe)			Manganese (Mn)		
a	0	0	75	151	*113*	335	381	*358*	183	208	196
c	500	336	89	175	*132*	289	326	*308*	177	213	195
e	1000	672	66	191	*129*	414	267	*341*	192	177	185
Mean			*77*	*172*		*346*	*325*		*184*	*199*	
			Zinc (Zn)			Copper (Cu)			Cadmium (Cd)		
a	0	0	1.63	1.23	*1.43*	3.42	2.57	*3.00*	0.064	0.087	*76*
c	500	336	1.00	1.58	*1.29*	3.11	2.76	*2.94*	0.061	0.094	*78*
e	1000	672	1.28	1.32	*1.30*	3.58	2.75	*3.17*	0.072	0.088	*80*
Mean			*1.30*	*101*		*337*	*269*		*0.066*	*0.090*	

As affected by the fertilization available P, K and Mg in the soil were increased for 29% and 9%, while the remaining elements (*Table 4.*) status was independent on the fertilization. However, liming considerably affected on Ca, Mg and Cd soil status (increases for 75%, 123%, and 36% respectively) as well as K, Zn and Cu status (decreses about 20%), while the impacts on P, Fe, and Mn status were the lower. However, Cd status in the soil was very low with aspect of helth food production.

Conclusions

In general, maize responded moderately to the fertilization and liming by yield increases below 10%, probably becuse of drought in the 2009 growing season. Also, liming had the higher effects on the soil properties than PK-fertilization with exception of soil P and K status.

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