PHOSPHORUS FERTILIZATION IMPACTS ON SOIL NUTRITIONAL STATUS

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Introduction

Grain yields of field crops in the mountain region of Croatia are considerably lower than in lowland area of Croatia, mainly as affected by soil and climatic limitations. For example, mean grain yields in Lika-Senj County (LSC) and Croatia (state mean) were as follows (3-year means: 2001-2003): wheat 2.41 and 3.74 t/ha, maize 1.872 and 5.15 t/ha, respectively. Shortage of plant available phosphorus (P) and soil acidity have been found as main nutritional problems in this area. Aim of this study was ameliorative P fertilization influences on nutritional status of soil situating in Lika (continental part of LSC) region. Response of maize to applied fertilization were elaborated in previous studies (Kovacevic et al., 2002; Kovacevic and Buzasi, 2005).

Material and methods

General information about Lika region with emphasis on wheat and maize yields

Lika region is southern part of the mountain region of Croatia. According territorial division until end of 1992 it covered five municipalities (Donji Lapac, Gospic, Gracac, T. Korenica and Otocac) of total area 5563 km^2 or 9.8% of state territory. Since 1992 this region has been majority integrated in the LSC. Yields in the LSC for the 1996-2003 period were 2.53 t ha^{-1} (wheat) and 2.03 t ha^{-1} (maize), and they were for 43% (wheat) and 67% (maize) lower than in eastern Croatia (Table 1).

Table 1. Wheat and maize production (data of State Bureau for Statistics Zagreb)

Year	The harvested areas (ha) and grain yields (t /ha)							
	Wheat				Maize			
	Eastern Croatia*		Lika-Senj County		Eastern Croatia*		Lika-Senj County	
	ha	t ha^{-1}	ha	t ha^{-1}	ha	t ha^{-1}	ha	t ha^{-1}
	The 5-year period (1996-2000)							
Mean	117421	4.51	1600	2.60	168 288	6.06	503	2.12
	The 2001-2003 period							
2001	145365	4.70	1984	2.55	190 136	6.63	524	1.69
2002	141835	4.73	2085	2.67	185 651	7.21	474	2.64
2003	127747	3.30	2104	2.01	184 270	4.49	444	1.29
Area (km^2)					12466		5350	
Agricultural land (ha): status 2003					734536		268126	
Arable land and gardens (ha): status 2003					620870		56184	

* five counties as follows: Vukovar-Syrmium, Osijek-Baranya, Brod-Posavina, Pozega-Slavonia and Virovitica-Podravina County

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Plant growing in the LSC is forage based and the narrow crop selection is dominated by maize, (early maturing group of hybrids), and then potato, rye and vegetables. Haplic acrisol and chromic cambisol are main soil types in this region. Chemical properties of haplic acrisol are less favourable, mainly because of the high active and potential acidity, occurrence of free phytotoxic Al^{+++} ions, low cation exchange capacity, lack of bases, raw humus and a low content of available nutrients, notably phosphorus (Kovacevic and Basic, 1997).

The field experiment, soil sampling, chemical and statistical analysis

The field experiment with increased rates of P fertilization was conducted on Brinje soil of moderate fertility at the beginning of May 2001. Soil is acid reaction with low levels of plant available phosphorus and based on its hydrolitical acidity, liming could be useful for increase of soil fertility (Table 2.). Four rates of ameliorative P fertilization were applied in form of monoammonium phosphate (MAP: 12% N + 52% P_2O_5) as follows (kg P_2O_5 ha^{-1}): a) control, b) a + 500 , c) a + 1000, d) a + 1500 and f) a + 2000. The standard fertilization included NPK 10:30:20 (416 kg ha^{-1}) and urea (46% N) 200 kg ha^{-1} (total kg ha^{-1}: 134 N + 125 P_2O_5 + 83 K_2O). The field experiment was conducted in four replicates (experimental plot of fertilization = 64.26 m^2) Maize was grown on the experimental plot for the 2001 growing season (Kovacevic et al. 2002).

Soil sampling (15 individual sampling wit the auger to depth of 30 cm) was made in May 2005 from each plot (total 20 samples). Nutritional status of P and K in soil was made by extractions with AL-solution (Egner et al. 1960.) Soil reaction and organic matter were determined according to ISO (1994, 1998). Mobile fraction of the individual elements were extracted with ammonium lactate – EDTA (pH 4.65) according to Lakanen and Ervio (1971) and their concentrations were determined by inductively coupled plasma.

Table 2. Chemical properties of Brinje experimental soil (the surface 0-30 cm layer)

Preliminary soil test (2000)				Control of the field experiment (June 2005)					
pH (KCl)	% Humus	*mg 100 g^{-1}		pH		% Humus	*mg 100 g^{-1}		cmol kg^{-1}
		P_2O_5	K_2O	H_2O	KCl		P_2O_5	K_2O	Hydr. ac**
5.3	3.8	0.70	11.4	5.75	4.71	3.5	3.34	11.37	5.08

*AL-method; ** hydrolitical acidity

Results and discussion

Applied fertilization considerably influenced soil pH, and hydrolitical acidity, available phosphorus status as well. For example, by application of 2000 kg P_2O_5 ha^{-1} pH in KCl was decreased to level 3.95 or 0.76 unit. At the same time hydrolitical acidity was increased to 7.13 cmol kg^{-1} or for 2.05 units. In general, influences of P fertilization on mobile fractions of tested elements in soil were low. For example, significant influence of P fertilization was only found on P, Cr and Ba status. Also, status of harmful elements in soil was low and this phenomenon is an indication of sustainability of Lika region and applied fertilization as well (Table 3). In our experiment with increased P fertilization, corn grain yields were increased for 30% compared to the control and they were as follows: 6.87, 7.89, 7.81, 8.96 and 9.02 t ha^{-1}, for 0, 500, 100, 1500 and 2000 kg P_2O_5 ha^{-1} (Kovacevic et al., 2002).

Table 3. Influences of phosphorus fertilization (May 2001) on soil status (June 2005)

P_2O_5 (t ha^{-1}) May 2001	Soil status (0-30 cm) of Brinje experiment (sampling in May 2005)									
	Mobile fraction of elements (NH4-Acetate + EDTA, pH 4.65): mg kg^{-1}									
	P_2O_5	K_2O	Ca	Mg	S	Fe	Mn	Zn	Cu	Mo
STD	31.3	145.0	2658	93	12.1	272	500	2.49	5.61	0.070
500	56.0	168.3	2316	104	13.7	312	482	2.87	5.23	0.074
1000	92.7	170.7	2626	115	13.6	305	535	2.96	5.25	0.077
1500	111.3	157.0	2112	91	13.0	314	459	3.40	5.12	0.079
2000	139.7	161.7	2026	102	13.8	322	414	2.60	4.76	0.069
LSD5%	17.1	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
LSD1%	24.9									
Mean	86.2	160.5	2348	101	13.2	305	478	2.86	5.19	0.074
	Sr	Cr	Ni	Na	Al	B	Ba	Cd	Co	Pb
STD	1.52	0.10	2.50	47.4	202	0.31	15.6	0.48	7.06	7.75
500	1.46	0.12	2.35	47.8	263	0.21	15.9	0.43	6.91	7.67
1000	1.74	0.11	2.47	47.1	247	0.27	15.2	0.49	7.21	7.81
1500	1.56	0.13	2.27	43.1	301	0.13	14.9	0.42	6.44	7.51
2000	1.61	0.15	2.14	47.7	347	0.09	14.6	0.43	6.01	8.55
LSD5%	n.s.	0.03	n.s.	n.s.	n.s.	n.s.	0.67	n.s.	n.s.	n.s.
LSD1%		n.s.					n.s.			
Mean	1.58	0.12	2.35	46.6	272	0.20	15.2	0.45	6.72	7.86
Under detectable range: Selenium (Se): < Arsen (As): < Mercury (Hg): <										

	Other chemical properties					
	pH		%	*mg 100 g^{-1} (AL-method)		cmol kg^{-1}
	H_2O	KCl	Humus	P_2O_5	K_2O	Hydr. ac**
STD	5.75	4.71	3.46	3.34	11.37	5.08
500	5.27	4.17	3.26	6.93	12.67	6.27
1000	5.48	4.39	3.51	12.33	14.25	5.74
1500	5.23	4.04	3.49	15.71	12.18	6.81
2000	5.08	3.95	3.45	19.83	11.80	7.13
LSD 5%	0.33	0.45	0.20	1.65	3.73	1.13
LSD 1%	0.47	0.63	0.28	2.31	5.23	1.59

Similar nutritional problems have been found in northern Bosnia (Komljenovic et al. 2006). For example, by four rates of P and K fertilization up to 1500 kg P_2O_5 ha^{-1} in Knespolje area maize grain yields were increased up to 32% in comparison to the control. Loncaric et al. (2005) applied 500 and 1000 kg ha^{-1} P_2O_5 and K_2O alone and in their combination + standard fertilization in spring 2003 on soil of moderate fertility. Although low levels of P and K were found by the soil test, maize yields were similar for applied treatments for the 2003 and 2004 growing seasons. In this study, adequate levels of P, K, S, Ca and Mg, as well as high levels of Mn in maize leaves (the ear-leaf at silking stage) were found. K fertilization significantly increased K concentrations, while Ca and Mg

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concentrations were decreased. Also, P concentrations were increased as affected by P fertilization. Zinc concentrations in maize were decreased due to application of P, while S, Fe and Mn status in plants were mainly independent on applied fertilization.
Banaj et al. (2006) applied three rates of P fertilization up to 2000 kg P_2O_5 ha^{-1} on hydromorphic soil of Sava valley area. Leaf P, Mg, Mn and Fe concentrations increased by application of the highest rate of P. At the same time, K, Ca, Zn, Cu and Fe concentrations significantly decreased. Especially influences of P fertilization were found for Zn status in maize leaves (70 and 40 ppm Zn, for the control and 2000 kg P_2O_5 ha^{-1}, respectively). However, low influences of applied fertilization on maize yields over 3-year period were found. We presume that mainly favourable weather conditions could be responsible for low influences of fertilization on maize yields.

Conclusion
Ameliorative fertilization with P fertilizer resulted by positive (increases of mobile fraction of P up to more than 4-fold, and AL-soluble P up to 6-fold) and negative (hydrolitical acidity increases up to 2.05 cmol kg^{-1}) effects in soil. It is important that mobile fraction of harmful elements, especially Cd, were in all applied treatment in level of the control. For alleviation of negative effects we recommend combination ameliorative fertilization with liming.

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