IMPACTS OF LIMING AND FERTILIZATION WITH PHOSPHORUS AND POTASSIUM ON SOIL STATUS

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ABSTRACT

The stationary field experiment was conducted in spring 2004 on acid soil (pH in KCl = 3.80) of Bjelovar-Bilogora County. The fertilizer NPK 10:30:20 was applied in amounts 416 (*a*), 1249 (*b*), 2082 (*c*), 2916 (*d*) and 3748 (*e*) kg/ha, respectively. Nitrogen amount was equilized for all treatments by addition of adequate quantities of CAN (calcium ammonium nitrate: 27% N). The experiment was conducted in four replicates (basic plot 77 m^2). In the next years the experiment was fertilized uniformly in level of conventional fertilization. Additional intervention in the experiment was liming of the third and fourth replication by 10 t/ha of granulated fertdolomite (24.0 % CaO + 16.0 % MgO + 3.0 % N + 2.5 % P_2O_5 + 3.0 % K_2O). Soil samples (0-30 cm) were taken in term Sept. 3, 2009. Liming significantly influenced on soil pH increases for 0.69 and 0.76 units, for pH in H_2O and KCl, respectively, as well as decrease of hydrolitical acidity for 2.04 Cmol /kg, while humus, AL-soluble P and K were independent on liming. Also, application of NPK fertilizer resulted by considerable increases both AL-soluble P and K (mg/100 g: 11.9 and 19.1 mg P_2O_5,15.7 and 20.3 K_2O, for the treatments *a* and *e*, respectively), while soil pH, hydrolitical acidity and humus contents were similar for all applied treatments. By ameliorative PK-fertilization yields of field crops were increased up to 14 % (maize 2004), 32% (soybean 2005) and 7 % (soybean 2010).

Key words: Liming, Phosphorus and potassium fertilization, Soil pH, AL-soluble P and K status

Acknowledgments: These investigations have been supported by the Ministry of Science, Technology and Sport (the project 079-0730463-0447)

INTRODUCTION

Soil acidity is certainly one of the most damaging soil conditions affecting the growth of most crops. Estimates of the total area of topsoil affected by acidity through the world vary from 3.77 (Eswaran et al., 1997) to 3.95 (von Uexkull and Mutert (1995) billion ha representing approximately 30 % of the total ice-free land area of the world. The poor production of crops grown in acid soils is due to combinations of toxicity (Al, Mn, Fe, H) and deficiencies (N, P, Ca, Mg, K, Fe, Zn). Liming alone or in combination with fertilization is recommendation for improvement of these soils. P and K status in soils could be limiting factors of field crops yield under different soil and climatic conditions (Kovacevic and Basic, 1997; Fotyma and Gosek, 2000; Petosic et al., 2003; Cermak and Torma, 2006). Response of field crops to liming and P and K fertilization under conditions of eastern and central Croatia and northern Bosnia in the last decade period were reported by the previous studies (Komljenovic et al., 2006, 2008, 2010; Kovacevic and Rastija, 2010; Kovacevic et al., 2003, 2009, 2010, 2011; Loncaric et al., 2005; Markovic et al., 2006, 2008). Aim of this study was testing effects of liming and P and K fertilization on soil properties.

MATERIAL AND METHODS

<u>The field experiment</u>

The stationary field experiment was conducted in spring 2004 (April, 23) 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 year 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). Additional intervention in the experiment was liming of the third and fourth replicates by 10 t/ha 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.

<u>Soil characteristics</u>

Very acid reaction, low levels of AL-soluble P and K and high hydrolitical acidity are main chemical characteristics of tested soil. The first soil sampling was made in autumn 2005. 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 of soil: 11.57 and 21.42 P_2O_5, 17.31 and 25.55 K_2O, for the treatments a and e, respectively. However, humus contents (mean 2.21 %) and hydrolitical acidity (mean 5.79 cmol/kg) were independent on applied fertilization (Rastija et al., 2006).

Sampling, chemicaland statistical analysis

The second soil sampling (0-30 cm) from each basic plot of applied fertilization was made at the end of the 2009 growing season (Sept. 3, 2009). Nutritional status of soil was determined by extractions with AL-solution (Egner et al. 1960) Soil reaction and organic matter was determined according to ISO (1994, 1998). The data were statistically analyzed by ANOVA and treatment means were compared using t-test and LSD at 0.05 and 0.01 probability levels.

RESULTS AND DISCUSSION

Liming of the half experiment area was made in autumn 2007(end of the third year of the experiment) with aim of possible improvement of applied fertilization effects for the next crops in crop rotation. Liming significantly influenced on soil pH increases for 0.69 and 0.76 units, for pH in H_2O and KCl, respectively, as well as decrease of hydrolitical acidity for 2.04 Cmol /kg, while humus, AL-soluble P and K were independent on liming. Also, application of NPK fertilizer resulted by increases both AL-soluble P and K (for 60% and 28%, respectively, for the control and the highest applied rate, respectively, while soil pH, hydrolitical acidity and humus contents were similar for all applied treatments (Table 1).

Table 1. Impacts of ameliorative fertilization and liming on soil (0-30 cm) properties

Factor B: Fertilization* (spring 2004)			Impacts of fertilization (factor B) and liming (factor A: 0 and 10 t/ha**) on soil status (HY = hydrolytical acidity) (soil sampling 0-30 cm in term Sept. 3, 2009)								
			Liming		Mean	Liming		Mean	Liming		Mean
	kg/ha		0	10 t	B	0	10 t	B	0	10 t	B
			Soil pH						Hydrolitical acidity HY (Cmol /kg)		
	P_2O_5	K_2O	pH (H_2O)			pH (1n KCl)					
a	125	82	4.92	5.67	*5.30*	3.80	4.44	*4.12*	6.82	4.85	*5.84*
b	375	248	4.97	5.46	*5.21*	3.87	4.32	*4.10*	6.54	5.20	*5.87*
c	625	414	4.94	5.73	*5.34*	3.80	4.67	*4.24*	6.56	4.64	*5.75*
d	875	582	4.98	5.58	*5.28*	3.81	4.55	*4.18*	7.12	4.92	*6.02*
e	1125	746	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*	*4.53*		*6.92*	*4.88*	
LSD 5% LSD 1%			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: ns 1.20 0.31		
	kg/ha		Plant available (AL-method): mg/100 g						Humus (%)		
	P_2O_5	K_2O	Phosphorus (P_2O_5)			Potassium (K_2O)					
a	125	82	11.1	12.7	*11.9*	15.8	15.7	*15.7*	1.89	1.98	*1.94*
b	375	248	11.5	13.2	*12.3*	17.7	16.6	*17.1*	2.09	1.91	*2.00*
c	625	414	11.5	17.8	*16.1*	19.7	17.8	*18.7*	1.95	2.00	*1.98*
d	875	582	16.6	16.7	*16.7*	21.4	18.8	*20.1*	1.95	2.01	*1.98*
e	1125	746	18.7	19.5	*19.1*	20.5	20.1	*20.3*	2.03	1.99	*2.01*
Mean A			*14.5*	*16.0*		*19.0*	*17.8*		*1.98*	*1.98*	
LSD 5% LSD 1%			A: ns B: 1.72 AB: ns 2.37			A: ns B: 1.61 AB: ns 2.21			A: ns B: ns AB: ns		

* N quantities were equalized by CAN (27% N); for 2005-2009 period ordinary fertilization only
** Nov. 13, 2007: granulated ferdolomite (24.0% CaO+16.0% Mg +3.0% N+2.5% P_2O_5 +3.0% K_2O) 10 t/ha

Rastija et al. (2006) reported results of the first two years of the field experiment. By application of the ameliorative rates of the fertilizer, grain yields of maize (the growing season 2004) significantly increased to level of 14% compared to standard fertilization (12.33 and 14.00 t/ha, 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. 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% (3.88 and 5.14 t/ha, for the treatments *a* and *e*, respectively. However, differences of yield among *b* – *e* treatments were non-significant (mean 4.93 t/ha: differences from 4.73 to 5.14 t/ha). Protein contents in soybean grain were independent on the fertilization, while oil contents were increased up to 0.66% compared to the control (Rastija et al. – Table 2).

Soybean (domestic cultivar *Lucija* originating from Agricultural Institute Osijek) was grown on the experimental field for the 2010 growing season (Kovacevic et al., 2011). As affected by liming yields of soybean were increased for 18 % (means 3279 and 3854 kg ha^{-1}, for unlimed and limed plots, respectively. Also, grain quality parameters were improved by liming (protein contents: 35.24 and 39.06 %, respectively), while oil contents were decreased (23.84 and 22.62 %, respectively). Impacts of P and K fertilization on soybean properties were considerable lower in comparison with liming (Table 3).

Table 2. Response of maize and soybean to PK-fertilization (Rastija et al., 2006)

Fertilization (April 23, 2004)			Maize: 2004						Soybean: 2005				
	kg/ha		t/ha	Percent in dry matter					t/ha	Percent in dry matter			
	P_2O_5	K_2O	Grain				Leaves*		Grain			Leaves*	
			Yield	Protein	P	K	P	K	Yield	Protein	Oil	P	K
a	125	82	12.33	8.57	0.24	0.30	0.36	2.47	3.88	41.9	20.3	0.53	2.67
b	375	248	13.18	8.27	0.24	0.31	0.34	2.62	4.87	40.9	20.8	0.54	2.71
c	625	414	14.00	8.83	0.29	0.34	0.38	2.61	4.73	41.4	20.6	0.57	2.85
d	875	582	14.09	8.60	0.28	0.34	0.41	2.54	4.98	40.6	21.0	0.49	2.73
e	1125	746	13.73	9.33	0.30	0.36	0.41	2.56	5.14	41.9	20.7	0.50	2.69
LSD 5%			0.52	0.58	0.04	0.16	0.03	ns	0.72	n.s.	n.s.	n.s.	n.s.
LSD 1%			0.73	n.s.	n.s.	0.23	0.04		n.s.				

*the ear-leaf of maize at silking stage; the uppermost full-developed threefoliate leaf before anthesis

Table 3. Residual effects of PK-fertilization and liming on soybean status (Kovacevic et al., 2011)

Residual effects of fertilization (April 2004) and liming (Nov. 2007) on soybean (cultivar *Lucija*) grain yield and grain quality in the 2010 growing season											
Factor B*: Fertilization			Factor A**: Liming		Mean B	Factor A**: Liming		Mean B	Factor A**: Liming		Mean B
	P_2O_5	K_2O	0	10 t		0	10 t		0	10 t	
	kg ha^{-1}		Grain yield (kg/ha)			Protein contents (%)			Oil contents (%)		
a	125	82	3141	3703	3422	36.12	39.24	37.68	23.70	22.49	23.10
b	375	248	3231	3837	3534	34.92	38.75	36.84	23.58	22.61	23.09
c	625	414	3285	4047	3666	35.73	39.44	37.59	23.58	22.29	22.94
d	875	582	3352	3826	3589	34.59	38.92	36.76	24.32	22.90	23.61
e	1125	746	3387	3860	3624	34.83	38.93	36.88	24.02	22.79	23.41
	Mean A		***3279***	***3854***	***3567***	***35.24***	***39.06***	***37.15***	***23.84***	***22.62***	***23.23***
	LSD 5% LSD 1%		A: 209 B: 156 AB: ns 482 ns			A: 0.63 B: ns AB: ns 1.46 ns			A: 0.53 B: ns AB: ns 1.23		
* NPK 10:30:20; N added by NPK-fertilizer were equalized with CAN (calcium ammonium nitrate: 27% N); ** 10 t/ha of granulated ferdolomite (24.0 % CaO + 16.0 % MgO + 3.0 % N + 2.5 % P_2O_5 + 3.0 % K_2O) *** yield calculation on 13 % grain and plant density 600000 plants ha^{-1}											

Field experiment with increasing rates of carbocalk (by-product of Osijek Sugar Factory containing 39% CaO) in amounts 0, 15, 30, 45, 60 and 90 t/ha) was conducted in autumn 2000 on arable land of Kutjevo Agricultural Holding in Pozega-Slavonian County (Kovacevic et al., 2006; Jurkovic et al., 2008; Kovacevic et al., 2010). In general, carbocalk application had considerably influenced on the field crop yields as follows: 50%, 36% and 40 % (maize: 2001, 2002 and 2006), 49% (sunflower: 2003) 30% (barley: 2004), 40 % and 42% (wheat: 2006/2007 and 2008/2009).

Soil acidity and low AL-soluble P contents considerable limit yield of field crops in Bosnia (Markovic and Supic, 2003; Markovic et al., 2006). In general, ameliorative fertilization by P and liming had considerably effects on yields of field crops and chemical properties of soil under ecological conditions of Bosnia. With that regard effects of liming are mainly higher in comparison with P fertilization. Markovic et al., (2008) applied four rates of hydratized dolomite meal (47% CaO + 34% MgO) up to 20 t/ ha in spring 2005. By application of the highest rate of lime yield for 2005 was increased two-fold. In 2006, liming resulted by yield increases up to 44%. Under drought stress conditions of 2007 low maize yields and yield depression as affected by the highest rate of lime were found. Application 15 t lime/ha resulted by yield increase for 42% compared to the control. Komljenovic et al. (2006, 2008) applied ameliorative P fertilization up to 1500 kg P_2O_5/ha on Knespolje soil in the northern Bosnia. Yield increases compared to the control were up to 32% (2004), 17% (2005) and 20% (2006). Komljenovic et al. (2010) applied increasing ameliorative rates of phosphorus fertilizers up to 1750 kg P_2O_5 /ha on hydromorphic soil of Sava lowland area in Bosnia. In general, low maize yields were achieved in the experiment (4-year mean 4.84 t/ha), mainly as result of low plant density realization (mean 74.7 %). Phosphorus fertilization resulted mainly by considerable yield increase in level 17 % (4-year means: 4.30 and 5.02 t/ha, for control and ameliorative P-fertilized treatments, respectively). Yield increases were achieved mainly by application of the first step o P in level of 750 kg P_2O_5/ha. Also, significant P fertilization impacts on grain moisture were found only in the 2006 growing season because the highest P rate resulted by 4.6% reduction of grain moisture (26.9 and 22.3 %, for the control and 1750 kg kg P_2O_5/ha, respectively). Protein, starch and oil contents in maize grain (2-year means: 8.83%, 72.04% and 3.78%, respectively) were independent on applied P fertilization.

Cermak and Torma (2006) noted that the current supply of K and other nutrients for crop production reflects the many economical problems. The average applications of K fertilizers in Slovakai and in the Czech Republic are, with less than 10 kg K_2O/ha, at the level of 60 years ago.

Losak et al., (2009) noted that in Czech Republic at the present time is necessary to fertilize about 40% of the acreage of agricultural land (1.2 mil. ha) with K. Probably, similar situation concerning fertilizer consumption is in other Central- and East- European countries. For example, according data of State Bureau for Statistics (DZS, 2010) mean consumption of mineral fertilizer in Croatia (status 2009) is 259 kg/ha (337028 t consumption / 1299582 ha utilized agricultural land) or 114 kg active ingredients (52 N + 25 P_2O_5 + 37 K_2O).

Madaras et al. (2010) investigated time-trends of available K in an arable land within long-term field fertilization experiments established in 1979 at nine sites across climatic and soil conditions of the Czech Republic. Annual K application rates necessary for a stabilization of available K at levels of 108-283 mg K/ kg soil, ranged from 84-506 kg K/ha. According to the multiple regression analysis, climatic factors were found to be more important than soil properties in explanation of variability among the sites. The results confirm that in the Czech Republic, actual agricultural praxis of K-deficient management is highly dependent on soil K reserves. Sustainable K fertilization should respect climatic and soil characteristics of the site.

CONCLUSIONS

Soil acidity and low supplies of one or more nutrients are considerable factors of field crop yield under different environmental conditions. Based on numerous field experiments in continental part of Croatia and in the northern Bosnia, liming and application of the higher rates of phosphorus alone or in combination with potassium, was shown as useful soil management practice. However, previous soil testing could be indication of these recommendations.

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