INFLUENCES OF LIMING ON NUTRITIONAL STATUS OF SOIL

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Introduction

Soil acidity and problems associated with it (elemental toxicities and deficiencies, primarily an inadequate level of phosphorus) are in many cases limiting factor of crops yield in Croatia (Kovacevic et al. 1993). Acidity in the surface soil can be corrected through liming and this solution has a long tradition. For example, the article dealing with liming recommendation on Croatian language was published more than 200 years ago (Anonymous, 1789). Besides common liming materials, the waste of sugar beet factory (carbocalk with total Ca contents about 340 g kg^{-1}) is also used for neutralizing soil acidity. It is well-known that mineral fertilization affects the availability of nutrients through the alteration of the soil pH and the interaction of nutrients (Blaskó at al., 2003). The same is relevant for liming, because the solubility of soil compounds and therefore, nutrient availability to plants is dependent on soil pH. The aim of this study was testing the impact of liming with carbocalk in five rates up to 90 t ha^{-1} on the nutritional status of soil surface layer on a stagnic albeluvisol. Response of maize, sunflower and winter barley to liming was elaborated in the previous study (Kovacevic et al. 2006).

Material and methods

Field experiment

Field experiment with increased rates of carbocalk was conducted in the autumn of 2000 on the stagnic albeluvisol on the lowland area of western Slavonian region in Croatia. Liming treatments were as follows: 0, 15, 30, 45, 60 and 90 t ha^{-1}. The field trial was set up in a randomized block design in four replicates. The size of experimental plot was 60 m^2. Crop rotation for the four-year period on the experimental field was as follows: maize (2001) – maize (2002) – sunflower (2003) – winter barley (2004). Response of these crops to liming was elaborated in the previous study (Kovacevic et al. 2006).

Sampling and chemical analysis

Soil sampling was made in 2004, after the harvest of winter barley. In total 24 mean samples were taken from each plot by auger up to 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). The soil samples were prepared for chemical analyses by extraction with NH_4-Acetate+EDTA solution (pH 4.65) according to Lakanen-Erviö (1971). Analyses of 23 elements in soil extract were performed with a Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the laboratory of the RISSAC, Budapest, Hungary. For determination of the mobile fraction of individual elements, carbocalk sample was also extracted with NH_4-Acetate+EDTA solution. Carbocalk contained very high level of mobile calcium (48.2% CaO), moderate

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levels of phosphorus (1.07% P_2O_5), low levels of potassium (0.17% K_2O) and magnesium (0.11% MgO) and considerable lower quantities of other elements (Table 1). The statistical analyses of the data were performed by the two-way ANOVA.

Table 1. Properties of liming material (carbocalk)

Mobile fraction in carbocalk (mg kg^{-1}) by NH_4-Acetate +EDTA extraction (pH 4.65)							
P_2O_5 10655	K_2O 1668	CaO 481744	MgO 18148	S 2660	Mn 152	Zn 38.5	Fe 2770
Cu 19.4	Al 3620	B 6.3	Ba 27.2	Co 0.76	Na 277	Ni 3.1	Pb 1.4
under detection limits: As (<0.08), Hg (<0.024), Cd (<0.04), Sr (<0.001), Mo (<0.008)							

Results and discussions

Liming with carbocalk significantly increased yields of tested crops at all treatments, except at the highest one. By application of 90 t ha^{-1} carbocalk, yields of all crops drastically decreased to the level of control due to overliming. (Kovacevic et al., 2006). Yields increases influenced by liming are closely related to soil pH increases to optimal values near the neutral. Application of very high amounts of carbocalk caused additional rising of pH value and consequently decreased yields. Effect of liming on increasing soil pH was statistically proved at all liming treatments as well as within them (Table 2). In the fourth year after application, $pH_{(KCl)}$ raised from initial 3.89 (no liming) to high value of 7.30 (90 t ha^{-1}). The organic matter contents significantly decreased only at the highest carbocalk rate.

Table 2. Influence of liming on soil pH value and organic matter contents

Soil property	Liming with carbocalk (t ha^{-1})						LSD	
	0	15	30	45	60	90	5%	1%
pH H_2O	5.33	5.81	6.52	7.12	7.35	7.72	0.25	0.34
pH KCl	3.89	4.71	5.80	6.62	6.95	7.30	0.32	0.44
Org. matter (%)	1.98	1.83	1.93	1.98	1.92	1.67	0.18	ns

Significant increases of NH_4-Acetate+EDTA soluble phosphorus were found by the application of 45 t ha^{-1} and the following higher rates. Moreover, the highest content (243 mg P_2O_5 kg^{-1}) was determined at the overliming rate, where slightly alkaline soil reaction occurred, although is widely acknowledged that phosphorus mobility declines in such conditions. At the same time, the potassium solubility significantly decreased at 45 t ha^{-1} and higher carbocalk rates (Table 3.). Similar effect regarding AL- soluble phosphorus and potassium contents were observed by Zsigrai and Ori (2006) in the sixth year after the liming. The contents of calcium and magnesium, as expected, remarkably increased with increasing liming rates. Especially high amount of calcium (4736 mg Ca kg^{-1}) was found at the highest rate, suggesting some nutrients disorders could appear. We presume that the antagonistic effects of calcium and magnesium could be responsible for potassium decreasing in the soil adsorption complex.

Table 3. Influence of liming on nutritional status of soil

Element	Liming with carbocalk (t ha^{-1})						LSD	
	0	15	30	45	60	90	5%	1%
	mg kg^{-1}							
Phosphorus (P_2O_5)	132	125	152	185	178	243	30	42
Potassium (K_2O)	186	173	163	158	153	139	28	ns
Calcium (Ca)	568	1143	1504	2140	2484	4736	292	405
Magnesium (Mg)	74	86	90	102	98	103	12	16
Sulphur (S)	13.5	16.6	15.8	18.3	16.0	18.2	2.7	3.8
Manganese (Mn)	146.3	102.8	102.5	92.0	92.2	81.5	10.2	14.1
Zinc (Zn)	1.52	0.94	0.72	0.75	0.69	0.64	0.45	0.62
Iron (Fe)	283	235	230	242	239	242	26	37
Cooper (Cu)	1.88	1.90	1.88	2.04	2.12	2.15	ns	
Aluminum (Al)	288	191	181	187	182	184	23	32
Boron (B)	0.41	0.47	0.40	0.47	0.43	0.47	0.04	0.06
Barium (Ba)	26.8	26.0	23.9	23.3	23.6	23.0	2.4	ns
Cobalt (Co)	2.07	1.40	1.32	1.27	1.26	1.12	0.30	ns
Sodium (Na)	13.9	16.6	13.8	18.3	16.0	18.7	3.4	ns
Nickel (Ni)	0.79	0.31	0.27	0.16	0.16	0.06	0.11	0.15
Under detectable range:	As = <0.08; Hg = < 0.024; Se = < 0.12; Mo = <0.008; Sr = <0.001; Cd = < 0.04							

Micronutrients status was also mainly depended on liming. Plant available manganese gradually decreased by increasing lime rates, at the most for 44% compared to unlimed plots. However, available zinc quantities decreased for 38% by application of only 15 t carbocalk per hectare. The average zinc level at the remaining four treatments was 0.7 mg kg^{-1}, indicating possible zinc availability problems. Zn deficiency mainly occurs on soils with high pH, especially calcareous soils (Bergmann 1992; Kovacevic et al. 1988; Cakmak et al. 1996,) and could be expected after heavy lime application (Kamprath and Foy, 1971). Musac et al. (1982) reported that by ameliorative soil tillage of acid soil on calcareous loess substrate, $pH_{(KCl)}$ increased from initial 4.5 to 6.7, while exchangeable Zn decreased for 55%. Influences of liming on iron contents were found by application of the first rate, when iron availability decreased for 14% compared to the control. At the higher rates iron status differences were under statistical error and similar to the rate of 15 t ha^{-1}. Application of the lowest carbocalk rate resulted in severely declining of mobile aluminum contents in soil for 34%, but analogous iron, aluminum levels remained similar at all other liming treatments. Nickel availability was drastically reduced by liming for about 63% (treatments 15 and 30 t ha^{-1}), 80% (treatments 45 and 60 t ha^{-1}) and for 92% (treatment 90 t ha^{-1}), compared to the control. In general, liming had lesser influence on mobile fractions of copper, boron, barium and sodium in soil. Quantities of arsenic, mercury, selenium, molybdenum, strontium and cadmium in soil extracts were under detectable ranges of ICP-OES method.

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Conclusions

Increasing rates of carbocalk gradually raised soil pH value and that effect was significant at all treatments in the fourth year after liming. Overall, increased soil pH had the positive impact on phosphorus availability, whilst the micronutrients solubility mostly was reduced. Due to antagonism with Ca-ions, whose contents were considerably increased, potassium availability were declined, but that effect were significant only at the higher liming rates. As regards Fe, Al and Zn status, there weren't notable differences among liming treatments. It can be concluded, that the most positive effect on nutritional status of investigated stagnic albeluvisol had the carbocalk rates of 30 and 45 t ha^{-1}, while the higher rates led to nutrient unbalances.

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