

MINERAL FERTILIZATION AND LIMING IMPACT ON MAIZE AND WHEAT YIELD

Zdenko LONCARIC - Domagoj RASTIJA - Krunoslav KARALIC - Brigita POPOVIC

University J. J. Strossmayer in Osijek, Faculty of Agriculture, Trg Sv. Trojstva 3, HR-31000 Osijek, Croatia, e-mail: zdenkol@pfos.hr

Introduction

The process of soil acidifications is aided by water leaching base cations to lower horizons and acid soils are widespread in the Eastern Croatia with acidity as limiting factor of the field crops yield. Since numerous authors reported that liming of acid soils increased crops yield (Rahman et al., 2002, Zhang et al., 2004) and some of them concluded that the liming is more effective in combination with phosphorus fertilizer (Lopes et al., 1994, Rahman et al., 2002) or that the liming secondary effect is higher phosphorus fertilizer efficiency (Hughes et al., 2004), this paper was aimed to investigate the combined influence of liming and phosphorus mineral fertilization on soil pH reaction, wheat and maize yield, phosphorus and calcium concentrations and removal.

Material and methods

The soil analyses for the field trials started in the spring of 2003 at site Donji Miholjac in eastern Croatia. According to physical and chemical analyses, two different soil types were chosen with distance less than 1 km: silty loam dystric luvisol and silty loam calcaric regosol (limey substrate was excavated for the melioration canals and redeposited as top soil layer in 1986). The top soil layer (0-30 cm) were analyzed for pH_{KCl} , organic matter and phosphorus and potassium are extracted by Lakanen-Ervio (1971) method with $\text{NH}_4\text{-Acetate+EDTA}$ (pH 4.6). The dystric luvisol was very acid (pH_{KCl} 4,02) with 1,66 % humus, 149 mg kg^{-1} P_2O_5 and 167 mg kg^{-1} K_2O . The calcaric regosol was slightly alkaline (pH_{KCl} 7,14) with lower content of humus (1,42 %), phosphorus (139 mg kg^{-1}) and potassium (109 mg kg^{-1}).

In the spring of 2003 the dystric luvisol was limed with 0, 10 or 20 t ha^{-1} carbocalk (total Ca content 344 g kg^{-1} and P 4,6 g kg^{-1}) on soil depth 30 cm. In the autumn of 2003 and 2004 the both soils (dystric luvisol and calcaric regosol) were fertilized first for maize and in second year for wheat with three different nutrient amounts (Table 1): no fertilization (B1 treatment), standard mineral fertilization (B2) and doubled phosphorus fertilization (B3 treatment). The size of each plot was 70 m^2 (7×10 m) using a randomised block design with 3 replicates.

Table 1. Liming and fertilization treatment

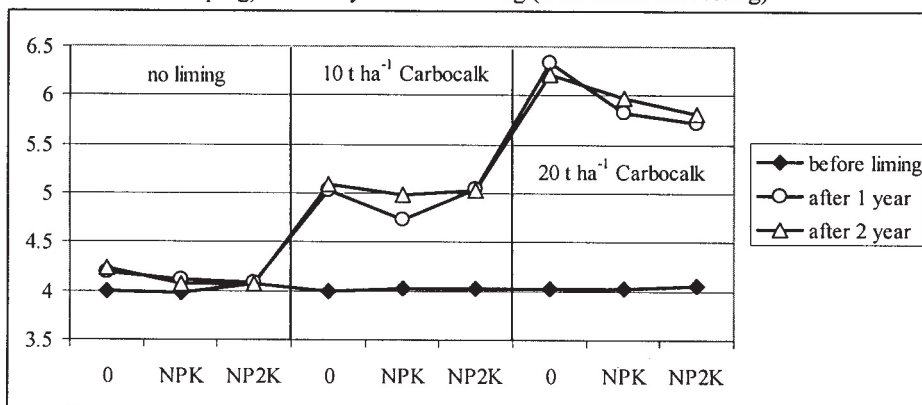
soil type	liming (treatment A)	fertilization (treatment B)		
dystric luvisol	no liming	B1	B2	B3
	10 t ha^{-1} carbocalk	no fertilization	standard	doubled P_2O_5
	20 t ha^{-1} carbocalk	N: P_2O_5 : K_2O 0: 0: 0	N: P_2O_5 : K_2O 200:150:300	N: P_2O_5 : K_2O 200:300:300
calcaric regosol	limed with substrate redeposition in 1986			

The statistic analyses for all data were done by analyses of variance using PC applications Microsoft Excel and StatSoft Statistica. The results were calculated as an experiment with two factors: liming (A) and fertilization (B).

Results and discussion

Dystric luvisol pH reaction was influenced by liming and fertilization and changes are measured one year after liming (before maize sowing) and two year after liming (after wheat harvest). As it was expected according to soil properties before liming, 10 t ha⁻¹ carbocalk raised pH value for approximately 1 pH unit and 20 t ha⁻¹ for 2 pH units (Graph 1). Influence of mineral fertilization on soil pH is evident especially on liming treatment with 20 t ha⁻¹ carbocalk. Liming without fertilization resulted in increased pH_{KCl} from 4.02 to 6.33 and 6.22 after first and second year, respectively. At the same time, liming with standard fertilization raised pH_{KCl} up to 5.83 and 5.98, and with doubled phosphorus fertilization reached pH_{KCl} was 5.72 after first year and 5.81 after second year.

Graph 1. Dystric luvisol pH_{KCl} reaction before liming, one year after liming (before maize cropping) and two years after liming (after wheat harvesting)



The grain and straw yield of maize and winter wheat was influenced by fertilization and liming, but not so evident as soil pH reaction was. The lowest maize grain yield was on plots without fertilization and without liming, and the highest yield was on treatment with highest liming and mineral fertilization with doubled phosphorus amount (Table 2). Still, statistically significant ($P < 0.001$) impact on yield had just fertilization comparing to yield achieved without fertilizers. There wasn't significant influence of liming or doubled phosphorus fertilization on maize grain yield. Almost the same relations are determined with fertilization, liming and maize above ground mass.

Table 2. Influences of liming and fertilization on maize yield in 2004

Maize grain yield in t DM ha ⁻¹					
fertilization	dystric luvisol & liming			calcaric regosol	average
	no lime	10 t ha ⁻¹	20 t ha ⁻¹	limed 1986	
no fertilizer	5,0	5,3	6,3	5,5	5,5 a
200:150:300	10,7	10,5	10,6	9,9	10,4 b
200:300:300	10,6	10,4	11,2	9,7	10,5 b
avearge (ns)	8,7	8,7	9,4	8,4	

differences between values with the same letters are not significant at the 1% level

In year 2005 significantly ($P < 0.001$) lowest wheat grain and straw yield was on treatments without fertilization and the lowest yield was without liming (Table 3). Although doubled

phosphorus fertilization and highest liming resulted in the highest grain yield and straw mass, there was hardly significant ($P = 0.027$) liming impact comparing grain yield on calcaric regosol or dystric luvisol without liming to grain yield on dystric luvisol with highest liming treatment. Rahman et al. (2002) and Zhang et al. (2004) also reported that liming is solution for soil acidity due to increasing wheat yield. The grain yield increasing in average 0.4 t ha^{-1} with doubled phosphorus comparing to standard phosphorus amount wasn't significant.

Table 3. Influences of liming and fertilization on winter wheat yield in 2005

grain yield in t DM ha^{-1}					
	dystic luvisol & liming			calcaric regosol	average
fertilization	no lime	10 t ha^{-1}	20 t ha^{-1}	limed 1986	
no fertilizer	1,7	2,0	2,4	2,1	2,0 a
200:150:300	6,1	6,1	6,9	5,4	6,1 b
200:300:300	6,5	6,6	7,1	5,8	6,5 b
avearge	4,7 a	4,9 ab	5,5 b	4,4 a	

differences between values with the same letters are not significant at the 1% level

The concentrations of phosphorus and calcium in grain and straw weren't influenced by liming or fertilization although there were some differences. The phosphorus concentrations in wheat grain was $3.2\text{-}3.5 \text{ g kg}^{-1}$, in maize $2.4\text{-}2.5 \text{ g kg}^{-1}$, in wheat straw $0.8\text{-}1.0$ and maize straw $0.7\text{-}1.0 \text{ mg kg}^{-1}$. The calcium concentrations comparing to phosphorus was lower in grains ($0.44\text{-}0.60$ wheat and $0.34\text{-}0.41 \text{ g kg}^{-1}$ maize) but considerable higher in straw ($2.1\text{-}3.1$ wheat and $3.7\text{-}4.1 \text{ g kg}^{-1}$ maize). The concentrations could be compared with other results since Alam et al. (2003) reported the P concentration in wheat grain $3.5\text{-}4.2 \text{ g kg}^{-1}$ and Buerkert et al. (2005) found $2.5\text{-}2.8 \text{ g P kg}^{-1}$. Buerkert et al. (2005) also found lower concentration of P in wheat straw ($0.3\text{-}0.5 \text{ g kg}^{-1}$) and higher P concentration in maize straw ($1.9\text{-}2.8 \text{ g kg}^{-1}$) than the values presented in this paper.

Table 4. Fertilization influence on phosphorus and calcium removal by wheat and maize

Phosphorus removal in kg P ha^{-1}						
	Winter wheat			Maize		
	no fertilizer	200:150:300	200:300:300	no fertilizer	200:150:300	200:300:300
grain	7,0 a	20,1 b	21,4 b	13,4 a	25,4 b	25,6 b
straw	2,0 a	5,5 b	7,2 c	4,1 a	6,1 b	6,6 b
total	9,0 a	25,6 b	28,6 b	17,5 a	31,5 b	32,2 b
Calcium removal in kg Ca ha^{-1}						
	Winter wheat			Maize		
	no fertilizer	200:150:300	200:300:300	no fertilizer	200:150:300	200:300:300
grain	1,1 a	3,2 b	3,7 b	2,1 a	3,8 b	4,0 b
straw	4,8 a	16,1 b	17,6 b	19,6 a	24,5 b	25,8 b
total	5,9 a	19,3 b	21,3 b	22,3 a	28,3 b	29,8 b

differences between values with the same letters are not significant at the 1% level

The removal of phosphorus and calcium by grain yield and straw of wheat and maize was significantly ($P < 0.001$) influenced by fertilization, almost exclusively as difference between control treatment (without fertilization) and fertilized treatments regardless to standard or doubled phosphorus amount (Table 4). Only exception was significant ($P < 0.001$) influence of doubled phosphorus fertilization comparing to standard treatment on increasing of phosphorus removal with wheat straw (7.2 comparing to 5.5 kg P ha^{-1}). Differences between wheat and maize were: maize removed slightly more phosphorus (up to $32.2 \text{ kg P ha}^{-1}$) than wheat (up to

28.6 kg P ha⁻¹) and considerable more calcium (up to 29.8 kg Ca ha⁻¹) than wheat (up to 21.3 kg Ca ha⁻¹). The relations between removal by grain and straw was the same for wheat and maize: more phosphorus removed by grain (up to 21.4 and 25.6 kg P ha⁻¹, wheat and maize, respectively) than by straw (up to 7.2 and 6.6 kg P ha⁻¹). On the other hand, more calcium was removed by straw (up to 17.6 and 25.8 kg Ca ha⁻¹, wheat and maize, respectively) than by grain (up to 3.7 and 4.0 kg Ca ha⁻¹).

Liming influenced significantly ($P = 0.047$) only on phosphorus removal by winter wheat grain, comparing the highest removal (18.2 kg P ha⁻¹ after liming with 20 t ha⁻¹) to lowest removal without liming (15.9 kg P ha⁻¹).

Conclusions

The increasing liming significantly increased the soil pH and increasing mineral fertilization decreased soil pH with small changes during second year after liming comparing to pH after first year. Liming did not affect maize yield but did slightly increased wheat grain yield and phosphorus removal by wheat grain.

Mineral fertilization influenced significantly on yield and phosphorus and calcium removal comparing to production without fertilization. Although doubled phosphorus fertilization increased wheat yield and nutrient removal, only significant increasing comparing to lower phosphorus fertilization was phosphorus removal by wheat straw.

Wheat and maize grains removed much more phosphorus and less calcium than straws.

References

- Alam, S.M., Azam Shah, S., Akthar, M. (2003): Varietal Differences in Wheat Yield and Phosphorus Use Efficiency as Influenced by Method of Phosphorus Application. Songklanakarin J. Sci. Technol., 25(2): 175-181.
- Buerkert, A., Nagieb, M., Siebert, S., Khan, I., Al-Maskri, A. (2005): Nutrient cycling and field-based partial nutrient balances in two mountain oases of Oman. Field Crops Research, 94(2-3): 149-164.
- Hughes, B., Payne, R., Hannam, B. (2004): Soil acidity and the benefits of liming. The department of Primary Industries and Resources South Australia.
- Lakanen E., Ervio R. (1971): A comparison of eight extractants for the determination of plant available micronutrients in soils. Acta Agr. Fenn. 123, 223-232.
- Lopes, A.S., Guilherme, L.R.G. (1994): Solos sob cerrado: manejo da fertilidade para producao agropecuaria. ANDA. SP. Boletim Tecnico 5: 62. Sao Paulo. Brasil.
- Rahman, M.A., Meisner, C.A., Duxbury, J.M., Lauren, J., Hossain, A.B.S. (200): Yield response and change in soil nutrient availability by application of lime, fertilizer and micronutrients in an acidic soil in a rice-wheat cropping system. In: Proceedings 17th WCSS Symposium Thailand. no. 5. 773: 1-7.
- Zhang, H., Edwards, J., Carver, B., Raun, B. (2004): Managing Acid Soils for Wheat Production. Oklahoma Cooperative Extension Service. F-2240: 1-4.