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Impacts of liming on soil status, yield and nutritional value of spring oats

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Abstract
The stationary field trial of liming by dolomite powder (0, 5, 10 and 15 t ha^{-1}) was started in spring 2003. The field trial was conducted in four blocks each of 370 m^2 area. Each block was divided in four subplots of 92.5 m^2 which represented four replicates. Aim of this study was testing response of oats in 2011 growing season. Using the highest lime rate resulted by oats yield increase for 16%, by increases of grain-P for 30%, -Mg for 29%, -Fe for 16%, and decreases of grain-Mn for 54%, -Zn for 36% and –Cu for 31%, while grain-K was independent on liming. Grain composition of the control was as follows (mg kg^{-1} in dry matter): 3242 P, 5048 K, 996 Mg, 57.3 Fe, 85.0 Mn, 30.8 Zn and 4.84 Cu.

Key words: liming, spring oats, grain yield, grain nutritional status

Introduction

Due to the high nutritional value oat is used in food for people and livestock. Oats have been discovered to help people reduce their risk of developing heart disease. Studies have found that eating oats has led to a reduction of bad and total cholesterol in people. One kind of soluble fiber called beta glucans has been seen as an effective factor in lowering a person's cholesterol (http://www.fitday.com/fitness-articles/nutrition/healthy-eating/the-nutrition-of-oats). However, these advances of oats are insufficient using in human diet of people in Croatia. According to the data of FAO statistics (FAOSTAT, 2012) harvested area of oats in Croatia has been only 21308 ha $year^{-1}$ (average 2001-2010). Aim of this study was testing liming effects on grain yield and nutritional composition of grain.

Material and methods

The field experiment

The stationary field experiment with increasing rates of dolomite meal (56% CaO + 40% MgO) was started at beginning May of 2003 on Badljevina (Pakrac municipality, Pozega-Slavonia County) acid soil (pH in 1n KCl 3.74). Total four treatments of dolomite were applied on ordinary fertilization (160 N + 100 P_2O_5 + 130 K_2O) as follows: *a* = control; *b* = a + 5 t ha^{-1}; *c* = a + 10 t h^{-1} and *d* = a + 15 t ha^{-1}. The field trial was conducted in four blocks each of 369.6 m^2 area ordered in sequence of treatments from *a* to *d*. Each block was divided in four subplots of 92.4 m^2 which represented four replicates. In the next years (2004 - 2009) the experiment was fertilized uniformly in level of the ordinary fertilization. Crop sequence for the 2003 - 2009 was as follows: maize (2003 – 2005) – spring barley (2006) – maize (2007). These results were elaborated in the previous study (Kovacevic and Rastija, 2010).

Winter wheat was grown for the 2009/2010 growing season and the results were shown in the study Iljkic et al. (2011).

Oats (the cultivar *Baranja* – Bc-Institute Zagreb) was sown 22^{nd} of February 2011 by pneumatic sowing machine and harvested 8 July 2012. The experiment was fertilized for oats in amount (kg ha^{-1}) 130 N + 45 P_2O_5 + 60 K_2O. The 1-m wide tracks were made among the treatments at beginning of stem elongation stage of oats. Immediately before harvesting, oats samples were taken for determination of yields and nutrients composition.

Four 0.25 m^2 areas (total 1.0 m^2) were harvested manually by cutting above half length of the stem with the panicle. The panicles from square meter area were enumerated before trashing by special threshing machine. Grain was weighed by the precise electronic balance. Grain yields were calculated on 13% grain moisture basis.

Sampling chemical and statistical analyses

The soil samples were taken by the auger to 30 cm of depth after harvesting of maize (October, 5, 2004).The grain samples of oats were taken from the portion of grains collected from 1-m area of trashed seeds and prepared for chemical analyses by grinding. Soil reaction and organic matter were determined according to ISO (1994, 1998). Mobile fraction of the individual elements in soil was extracted with ammonium lactate – EDTA (pH 4.65) according Lakanen and Ervio (1971). The total amounts of P, K, Mg, Fe, Mn, Zn and Cu in grain samples were determined using inductively coupled plasma (ICP) after their microwave digestion by concentrated HNO_3+H_2O_2. These analyses were made by Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the laboratory of the RISSAC, Budapest. The data were subjected to the analysis of variance (ANOVA) and treatment means were compared using t-test and subsequent least significant difference (LSD) at the 0.05 probability level.

The weather characteristics

Moderate storage of water in presowing period, only about third part in comparison with the long-term average, made possible sowing of oats in the optimal term at the second half of February. Moderate supplies of water continued in the March-April period (53 mm precipitation or 40% of average). However, precipitation in the remaining part of the growing season was adequate for normal growth and development of oats. Air-temperatures in March and May were in level of average, while in April and June they were for 1.6 and 1.4 °C higher of average (Table 1). In general, weather conditions in 2011were mainly favorable for oats growing.

Table 1. Precipitation and mean air-temperatures (Daruvar Weather Bureau)

Daruvar Weather Bureau: precipitation (mm) and mean-air-temperature (°C)							
		The growing season of oats				March -June	
	Jan. –Febr.	March	April	May	June	Σ	X
	The 2011 growing season						
mm	33.4	34.2	19.2	55.1	121.1	229.6	
°C	1.2	6.4	12.6	15.6	20.3		13.7
	The long-term (30-years) averages (1961-1990)						
mm	104.3	58.4	76.9	85.5	99.4	320.0	
°C	0.9	6.2	11.0	15.7	18.9		12.9

Results and discussion

Survey of the previous investigations on the experimental field

The grain yield of maize was influenced by liming in all four years and yield was significantly increased at all liming treatments compared with the control. However, between rates of 15 and 10 t ha^{-1} dolomite no significant difference was found. In the first year of research maize responded to lime application by increasing grain yield for 15%, and in the second year by 25%. The best response was observed in 2005 and 2007 when grain yields increased by 150% and 50%, respectively. Also, liming significantly affected grain yield of barley four years after dolomite application, but only at the highest rate, where yield increase for 20% is achieved (Table 2).

In general, very low yields of wheat, especially on the control treatment, were achieved in the experiment. Low realization of spikes per area unit is the main reason for low yield on the unlimed treatment. However, due to liming number of spike/m^2 was increased up to 50% (Iljkic et al., 2011) and grain yield for 18% compared to the control treatment (Table 2). Also, liming resulted by improving of the parameters of grain quality but differences of sedimentation values and protein contents were non-significant (Iljkic et al., 2011).

Table 2. Impacts of liming on yields of maize and barley (Kovacevic and Rastija, 2010) and wheat (Iljkic e al., 2011)

Impacts of liming (spring 2003) by dolomite on grain yields						
Lime	Grain yield (t ha^{-1}) and growing season					
t/ha	Maize				Barley	Wheat
	2003	2004	2005	2007	2006	2011
0	6.75	9.82	3.72	3.60	2.70	2.92
5	7.49	11.76	8.05	4.04	2.94	3.44
10	7.53	12.29	9.35	4.72	2.86	3.34
15	7.76	12.01	8.72	5.40	3.24	3.24
LSD 5%	0.93	0.68	0.90	0.72	0.30	0.40

Response of oats to liming

Liming by the highest lime rate resulted by oats yield increase for 16%, by increases of grain phosphorus for 30%, magnesium for 29%, iron for 16%, and decreases of grain manganese for 54%, zinc for 36% and copper for 31%, while grain potassium was independent on liming. For this reason, the lower contents of grain micronutrients manganese, zinc and copper by food intake from limed soils need be substituted by the other sources. Grain composition of the control was as follows (mg kg^{-1} on dry matter basis): 3242 P, 5048 K, 996 Mg, 57.3 Fe, 85.0 Mn, 30.8 Zn and 4.84 Cu.

Table 3. Impacts of liming in spring 2003 on spring oats properties in 2011

Impacts of liming by dolomite (spring 2003) on oats (the growing season 2011)									
Liming	Grain yield	Panicle number	Grain composition (mg kg^{-1} on dry matter basis)						
(t ha^{-1})	(t ha^{-1})	per m^2	P	K	Mg	Fe	Mn	Zn	Cu
0	6.26	381	3242	5048	996	57.3	85.0	30.8	4.84
5	6.25	368	3897	4805	1303	60.4	67.8	28.6	4.76
10	6.96	389	3792	4648	1266	60.4	46.2	22.9	3.81
15	7.25	383	4202	4859	1283	66.6	39.3	19.8	3.35
Average	*6.68*	*380*	*3783*	*4840*	*1212*	*61.2*	*59.6*	*25.5*	*4.19*
LSD 5%	0.55	ns	302	ns	152	6.3	6.7	3.0	0.42
LSD 1%	0.80		455		246	8.2	8.7	4.2	0.66

According to available data (http://www.eatmoreoats.com/health.html) grain of oats contains (mg kg^{-1}) 5230 P, 4290 K, 1770 Mg, 47 Fe, 49 Mn, 39.7 Zn and 6.3 Cu. In our study, considerably lower grain phosphorus, magnesium, zinc and copper were found, while grain potassium, iron and manganese were higher. This difference could be affected by correspondingly amounts of plant available nutrients in the soil.

Impacts of liming on soil status

Liming with dolomite meal significantly increase the soil pH from initial 3.74 to 6.36 as affected by application of the highest rate of dolomite. Liming considerably affected on availability of magnesium (about 9-fold), calcium (about 4-fold), phosphorus (+38%), zinc (-22%) and copper (+26%). In general, impacts of liming on the nutrients availability (Table 4) mainly correspondingly affected on grain composition (Table 3).

Table 4. Impacts of liming on the soil (0-30 cm depth) status (October 5. 2004)

	The soil (0-30 cm) status (sampling in October 5, 2004)										
Lime	pH		%	Mobile fraction of the elements (mg kg^{-1})*							
t ha^{-1}	H_2O	KCl	Humus	P	K	Ca	Mg	Fe	Mn	Zn	Cu
0	4.50	3.74	2.75	68	162	476	104	800	191	5.0	4.2
5	5.68	4.90	2.67	75	180	1019	421	784	202	4.0	4.4
10	6.29	5.71	2.88	89	184	1552	766	812	185	4.1	5.2
15	6.86	6.36	2.78	94	185	1950	923	819	189	3.9	5.3
Mean	*5.83*	*5.18*	*2.77*	*82*	*178*	*1249*	*554*	*804*	*192*	*4.3*	*4.8*
$P_{0.05}$	0.27	0.37	ns	6	16	55	14	ns	ns	0.8	0.7

* NH_4Acetate – EDTA extraction (pH 4.65) according Lakanen and Ervio (1971)

Kovačević and Banaj (2007) found considerable effects of increasing rates of NPK 7:20:30 fertilization on acid soil up to 900 kg ha^{-1} on yields of oats. Yield on the control was very low (3.80 t ha^{-1}) while by applications of the fertilizer in amounts 600 and 900 kg ha^{-1} yields were increased for 29% and 56%, respectively. However, by using the lower rate of the fertilizer (300 kg ha^{-1}) yield was in level of the control.

Besides fertilization, sowing date is important factor of spring oats yield. Jukić et al. (2011) tested impacts of three sowing date on yields of two varieties of the spring oats over two years. Over the year's effects of sowing dates, cultivars and their interaction on yields have been examined. Variety *Flamingsstern* achieved a significantly higher yield at all planting dates and years in relation to the variety of *Baranja*. In 2010 average yield of 3.76 t ha^{-1} was significantly lower compared to the 2011 (4.32 t ha^{-1}). The highest yield of oats grain was achieved in early planting dates in both years.

Conclusions

Liming was useful soil management practice for increases the field crops yields, including oats. However, decreases of micronutrients manganese, zinc and copper in grain as affected by liming reducing nutritional value of oats.

References

ISO (1994). Soil quality. Determination of pH. ISO 10390:1994

ISO (1998). Soil quality. Determination of organic carbon by sulfochromic oxidation. ISO 14235:1998.

Iljkic D., Rastija M., Drezner G., Karalic K., Sudar R. (2011). Impacts of liming with dolomite on the wheat yield. Proceedings of International Conference „Soil, Plant and Food Interactions", 6 – 8 Sept. 2011, Faculty of Agronomy, Mendel University in Brno, Czech Republic, p. 141-146.

Jukić G., Varnica I., Šunjić K., Mijić Z., Beraković I. (2011). Utjecaj roka sjetve na prinos kultivara jare zobi. Sjemenarstvo 28 (1-2): 17-23.

Kovačević V., Banaj Đ. (2007). Reakcija kukuruza i zobi na gnojidbu fosforom i kalijem. Agroznanje, Vol. 8, No 2, 21-26.

Kovacevic V., Rastija M. (2010). Impacts of liming by dolomite on the maize and barley grain yields, Poljoprivreda , Vol 16, No 2: 3-8.

Lakanen E., Ervio R. (1971). A comparison of eight extractans for the determination of plant available micronutrients in soils. Acta Agr. Fenn. 123, 223-232.

FAOSTAT (2012). http://faostat.fao.org/site/567(Area Harvested of Oats in Croatia).

http://www.fitday.com/fitness-articles/nutrition/healthy-eating/the-nutrition-of-oats

Utjecaj kalcizacije na tlo, prinos i hranidbenu vrijednost zrna jare zobi

Sažetak

Stacionirani poljski pokus kalcizacije dolomitnim prahom (0, 5, 10 i 15 t ha^{-1}) je postavljen u proljeće 2003. Pokus je postavljen u četiri bloka površine po 370 m^2. Svaki od njih je podijeljen u četiri manje parcele površine 92.5 m^2 koje predstavljaju ponavljanja.
U ovome radu analizirani su učinci kalcizacije na prinos i elementarni sastav zrna zobi vegetacije 2011. te na svojstva tla. Primjenom najveće količine vapna je prinos zobi povećan za 16%. Istovremeno, povećane su koncentracije P za 30%, Mg za 29%, Fe za 16%, a smanjene konmcentracije Mn za 54%, Zn za 36% i Cu za 31%, dok su koncentracije K u zrnu ostale nepromijenjene. Prosječne koncentracije u zrnu zobi uzgajane na kontroli (mg kg^{-1} suhe tvari) bile su sljedeće: 3242 P, 5048 K, 996 Mg, 57.3 Fe, 85.0 Mn, 30.8 Zn i 4.84 Cu.

Ključne riječi: kalcizacija, jara zob, prinos zrna, hranidbena vrijednost