MAIZE AND BARLEY RESPONSE TO FERTDOLOMITE LIMING

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Reakcija kukuruza i ječma na kalcizaciju fertdolomitom

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SUMMARY

Aim of this study was testing of maize and barley response to Fertdolomite (24.0% CaO + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O) application (crop rotation: maize 2008 – barley 2009 - maize 2010). Grain yield was increased by 12% (maize 2010) and 22% (barley). Mean concentrations 0.347% P, 2.44% K, 0.492% Ca and 0.176% Mg (leaves), 0.294% P, 0.334% K, 0.006% Ca and 0.093% Mg (grain) were found and due to Fertdolomite they were increased by 12% (P), 8% (K) and 19% (Ca) in leaves and by 14% (P) in grain.

Key-words: maize, barley, Fertdolomite, yield, nutritional status

INTRODUCTION

Acid soils that limit crop production are found throughout the world (Rengel, 2003). There is an estimate that 30-40% of the world's arable soil has a pH below 5.5 (von Uexküll and Mutert, 1995). In Croatia it was estimated that acid soils covered 831.704 ha, representing about 32% of total agricultural land (Mesić et al., 2009). Improvement of these soils are possible by liming and correspondingly mineral fertilization, particularly by the higher rates of phosphorus (Jurković et al., 2008; Kovačević et al., 2006, 2011; Marković et al., 2008; Mesić et al., 2009; Kovačević and Rastija, 2010; Andrić et al., 2012; Komljenović et al., 2010, 2013). Aim of this study was testing of maize and barley response to liming with dolomite enriched in nitrogen, phosphorus and potassium (trade name Fertdolomite).

Also mainly positive effects of liming on field crops yield were found by the other studies in Croatia. Antunović (2008) found positive effects of carbocalk (by-product of sugar factory containing 39% CaO) application on maize yields in the Virovitica-Podravina County. As affected by liming yield of maize was increased in four years by 26% on the average with these effects variation from 7% to 50% among the years. The field trial with application of increasing rates of dolomite (0, 5, 10 and 15 t ha^{-1}) was conducted on the very acid soil in the central Croatia. Maize crops were grown four years during the experiment. The grain yield of maize was influenced by liming in all four years and yield was significantly increased at all liming treatments. However, no significant difference was found between rates of 15 and 10 t ha^{-1} dolomite. Maize yield, due to liming, were increased by depending on the year (by 15%, 25%, 50% and 50%, respectively) while spring barley responded in yield increase by 20% (Kovačević and Rastija, 2010). Andric et al. (2012) applied the hydrated lime up to 20 t ha^{-1}. As affected by liming grain yields of maize, in two years of testing, were increased by 33% and 35%, respectively, while soybeans responded in yield increase in third year of testing by 44%.

Also, in the northern Bosnia considerable effects of liming were found on soil improvement fertility. Markovic et al. (2008) applied dolomite up to 20 t ha^{-1} on the acid and hydromorphic soil in the northern Bosnia. Maize was grown for three years during the experiment and yield was increased by 48% on the average. In autumn of 2008 Komljenovic et al. (2013) conducted stationary field experiment on acid soil in Lijevče polje area in Bosnia aiming to test liming effects (0 and 10 t ha^{-1} of hydrated lime) and three steps of phosphorus fertilization up to 1500 kg P_2O_5 ha^{-1} as monoammonium phosphate (12% N + 52% P_2O_5) on maize. As affected by liming yield of maize was increased by 32% (3-year averages: 6.90 and 9.12 t ha^{-1}, for the control and liming, respectively) with differences of liming effects

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among the years from 18% to 47%. The differences of yields were non-significant among the three rates of P applications, while increases of yields were, depending on the year from 5% to 18% by comparing P treatments with the control.

MATERIAL AND METHODS

The field experiment

The stationary field experiment was conducted in April 9, 2008 on arable land of Drkulec Family Farm in Badljevina (Pakrac municipality; Požega-Slavonia County). Selection of the soil for the experiment was made based on the previous soil test. Granulated dolomite enriched with nutrients (trade name Fertdolomite – product of Petrokemija Fertilizer Factory in Kutina, Croatia: 24.0% CaO + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O) was used for liming and improvement of soil nutritional status in the amounts as follows: a = 0 (the control: usual fertilization), b = a + 5 t ha^{-1}, c = a + 10 t ha^{-1}, d = a + 20 t ha^{-1}, e = a + 30 t ha^{-1}, f = a + 40 t ha^{-1} (Table 1). The experiment was conducted by randomized block design in four replicates (basic plot 40 m^2). Crop rotation was conducted as follows: maize (2008) - spring barley (2009) - maize (2010). In the next two years the experiment was fertilized uniformly (in kg ha^{-1}: for maize 175 N + 50 P_2O_5 + 50 K_2O, for barley 120 N + 35 P_2O_5 + 50 K_2O). Farmyard in amount 35 t ha^{-1} was distributed and ploughed in autumn 2008.

Maize (the hybrid *Drava 404* developed on Agricultural Institute Osijek) was sown in the second part of April by pneumatic sowing machine at planned plant density (PPD) 59 525 plants ha^{-1}.

Four internal rows, from each basic plot, were harvested manually at the beginning of October. After harvesting enumerated plants and mass of cob were weighed by precise Kern electronic balance. Grain yields were calculated on 14% grain moisture basis.

Spring barley (the cultivar *Fran* developed on Agricultural Institute Osijek) was sown at the end of February and harvested at the beginning of July 2009. The ears of four quadrate areas (4 x 0.25 m^2) were harvested by shears, enumerated, dried on open and thrashed by special combine for field experiments. Yields were calculated on 13% grain moisture basis.

Sampling, chemical and statistical analysis

Mean soil sample from the experimental plot was taken at the end of March 2008 by the auger to 30 cm of depth. Mobile fractions of phosphorus and potassium in soil were extracted with AL-solution (Egner et al., 1960). Soil pH and organic matter contents were determined according to ISO standards (ISO, 1994, 1998).

Twenty ear-leaves were taken at the beginning of silking stage (middle of July 2010) from each basic plot for chemical analysis. The leaves were air dried and ground.

Ten cobs from each basic plot were used for determination of grain moisture and contribution grain in mass of cob. Grain moisture was determined *in situ* by portable electronic grain moisture instrument. Also, these samples were used for determination nutritional status and quality parameters of grain.

The total amounts of individual elements in maize leaves and grain were determined using ICP after their microwave digestion by conc. HNO_3+H_2O_2. Plant material analyses were made by Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the laboratory of the Research Institute for Soil Science and Agricultural Chemistry in Budapest.

Oil content in the grain was determined by nuclear magnetic resonance (NMR) spectroscopy method, protein and starch content in grain by Near Infrared spectroscopic method on Foss Tecator ("Infratec 1241 Grain Analyzer") in the Agrochemical laboratory of the Agricultural Institute in Osijek.

The data were statistically analyzed by ANOVA and treatment means were compared using t-test and LSD at 0.05 and 0.01 probability level.

Soil and weather characteristics

By the soil test, acid reaction, low levels of organic matter and mobile phosphorus, as well as moderate level of mobile potassium were found (Table 1). Also, hydrolytic acidity value is indication for possible useful effects of liming on the field crops yield.

Table 1. Soil characteristics before start of the experiment and quantities of nutrients added by Fertdolomite

Tablica 1. Svojstva tla prije početku eksperimenta (travanj 2008.) i količine hraniva dodane Fertdolomitom

Properties of soil (0-30 cm; March 2008) *Svojstva tla (0-30 cm; ožujak 2008.)*		Nutrients (kg ha^{-1}) added by Fertdolomite (F t ha^{-1}) * in April 2008 *Hraniva (kg ha^{-1}) dodana Fertdolomitom (F t ha^{-1}) u travnju 2008.*					
pH (H_2O)	5.65		b) F 5	c) F 10	d) F 20	e) F 30	f) F 40
pH (1n KCl)	4.69	N	150	300	600	900	1200
Org. matter / *Organska tvar* (%)	2.12	P_2O_5	125	250	500	750	1000
AL- P_2O (mg 100 g^{-1})	3.1	K_2O	150	300	600	900	1200
AL- K_2O (mg 100 g^{-1})	8.7	CaO	1200	2400	4800	7200	9600
HA** (Cmol kg^{-1})	2.41	MgO	800	1600	3200	4800	6400

*composition/*sastav*: 24.0% CaO + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O; additional fertilization /*dodatna gnojidba*: farmyard (autumn 2008) /*stajski gnoj (jesen 2008.)* 35 t ha^{-1}; mineral fertilization/*mineralna gnojidba*: 175 N + 50 P_2O_5 + 50 K_2O kg ha^{-1} (maize-*kukuruz*), 120 N + 35 P_2O_5 + 50 K_2O kg ha^{-1} (barley-*ječam*); ** hydrolitical acidity/*hidrolitička kiselost*

Table 2. The meteorological data for Daruvar (SHS, 2014)

Tablica 2. Meteorološki podaci za Daruvar (SHS, 2014.)

Daruvar*: Precipitation and mean air-temperatures in 2010, 2010 and average 1961-1990 (*61-90*) *Daruvar*: Oborine i srednje temperature zraka u 2010., 2012. i prosjek 1961.-1990. (61.-90.)*														
Year *Godina*	Monthly precipitation (mm) *Mjesečne količine oborina (mm)*							Monthly mean air-temperatures (°C) *Mjesečne srednje temperature zraka (°C)*						
	The growing seasons of maize (2008 and 2010) / *Vegetacije kukuruza (2008. i 2010.)*													
	Apr. *Tra.*	May *Svi.*	June *Lip.*	July *Srp.*	Aug. *Kol.*	Sept. *Ruj.*	Σ	Apr. *Tra.*	May *Svi.*	June *Lip.*	July *Srp.*	Aug. *Kol.*	Sept. *Ruj.*	$\bar{x}$
2008	57	21	163	102	48	95	*486*	11.7	16.7	20.7	21.0	20.5	14.3	*17.5*
2010	80	197	262	71	67	212	*889*	11.5	15.8	19.7	22.3	20.4	14.7	*17.4*
61-90	77	86	99	86	91	65	*504*	11.0	15.7	18.9	20.6	19.7	16.1	*17.0*

	The growing season of spring barley (2009) / *Vegetacija jarog ječma (2009.)*									
	March *Ožujak*	April *Travanj*	May *Svibanj*	June *Lipanj*	Σ	March *Ožujak*	April *Travanj*	May *Svibanj*	June *Lipanj*	$\bar{x}$
2009	49	28	57	72	*206*	6.8	13.7	17.5	19.0	*14.3*
61-90	58	77	86	99	*320*	6.2	11.0	15.7	18.9	*13.0*

*10 km from the experiment site in the N direction / *10 km sjeverno od mjesta eksperimenta*

Weather characteristics are important factor of maize and other field crops yield. In general, the low precipitation and the higher air-temperature compared to the long-term mean (LTM), especially in summer, are often in connection with the lower grain yield of maize (Shaw, 1988; Kovačević et al., 2013). With aspect of this criterion, both crop years were mainly favorable for maize growth regarding weather characteristics because of adequate precipitation in April-September period, particularly in July and August. Also, monthly temperature regimes were close to LTM (Table 2). Owing to moderate precipitation soil preparing and sowing of barley was possible in optimal sowing term, but continuation of below the long-term average monthly precipitation, particularly in April, was less favorable for growth of the spring barley.

RESULTS AND DISCUSSION

As affected by mainly favorable weather conditions (Table 2), high yields of maize were achieved in both years of the research. In general, under more favorable environment, potential soil fertility are more emphasized. So, applied management practice, including liming and fertilization, are ineffective or have lower impact. For example, in the first year of testing, non-significant differences of maize yields among the control and limed treatments until 30 t ha^{-1} were found, but overliming by 40 t ha^{-1} resulted in yield decreases by 7%, mainly due to reduction of plant density (Table 3). Main reason of plant density reduction is application of enormous rate of Fertdolomite in spring and impossibility of deeper incorporation by soil tillage managements before sowing.

In the third year of the research as affected by Fertdolomite yields of maize were increased to 12%. With that regard, non-significant yield differences of limed treatments from level between 5 and 30 t ha^{-1} were found, while by the highest step (overliming) yield was decreased to level of the control. Liming treatments were without impacts on grain moisture at harvest (Table 3).

Average yield of spring barley in our investigations was 4.62 t ha^{-1} and it was considerably lower compared to yield potential of *Fran* high-yielding spring barely cultivar. Moderate precipitation during the growing season (Table 2) is probably reason of the yield reduction. Even the lowest rates of Fertdolomite in amount of 5 t ha^{-1} were adequate for considerable yield increase of barley by 22% compared to the control. Also, by the next step of Fertdolomite application at the level of 10 t ha^{-1}, yield was decreased but increased compared to the control by 14%, while by the higher rates yield additionally reduced to the level of the control (Table 3).

Table 3. Impacts of Fertdolomite application on maize and spring barley properties

Tablica 3. Utjecaj primjene Fertdolomita na svojstva kukuruza i jaroga ječma

Impacts of Fertdolomite (Badljevina, 2008) on maize (the hybrid Drava 404) and spring barley (cultivar Fran) *Utjecaj fertdolomita (Badljevina, 2008.) na kukuruz (hibrid Drava 404 i jari ječam (sorta Fran)*											
Fertd. (t ha^{-1})		Plant density (PD plants ha^{-1}) and plant density realization (PDR), grain moisture (GM) at harvest and grain yield (TPD = theoretical PD = 100% PDR); Ears density (ED: number of ears per square m) *Ostvareni sklop (PD biljaka ha^{-1}) i postotak realizacije planiranoga sklopa (PDR), vlaga zrna u berbi (GM) i prinos zrna (TPD = teoretski sklop = 100% PDR); ED: Broj klasova po m^2*									
		Year of the experiment / *Godina pokusa*									
		2008 (Maize / *kukuruz*)				2009 (Barley / *ječam*)		2010 (Maize / *kukuruz*)			
		PD	PDR % TPD*	GM %	Yield *Prinos* t ha^{-1}	Yield *Prinos* t ha^{-1}	ED	PDR	PDR %TPD*	GM %	Yield *Prinos* t ha^{-1}
a	0	50172	91.3	29.2	13.59	4.22	573	57339	83.8	25.3	12.38
b	5	50172	91.3	29.0	13.66	5.14	665	57339	83.8	25.0	13.60
c	10	48696	88.6	29.3	13.44	4.81	629	58882	86.1	25.5	13.90
d	20	48900	90.0	29.2	13.30	4.54	633	60305	88.2	25.8	13.59
e	30	48696	88.6	29.4	13.32	4.52	646	58575	85.6	25.9	13.30
f	40	46729	85.0	29.4	12.69	4.53	653	55609	81.3	26.0	12.57
Mean *Prosjek*		48894	81.6	29.3	13.33	4.62	633	58008	84.8	25.6	13.22
		LSD 5%		ns	0.42	0.38	49	LSD 5%		ns	0.40
		LSD 1%			0.57	0.52	68	LSD 1%			0.56

*TPD (100% PDR) = 59 525 plants/*biljaka* ha^{-1}

Mean concentrations of the nutrients in leaves of maize in our experiment during the 2010 growing season were 0.347% P, 2.44% K, 0.492% Ca and 0.176% Mg. Golmick et al. (1970) reported about adequate concentrations of nutrients in dry matter of the ear-leaf of maize at silking stage as follows: P from 0.2 to 0.5%, K from 1.5 to 3.0% and Ca and Mg from 0.2 to 1.0%. Deficit of these nutrients were mainly found to be below concentrations 0.1% for P, Ca and Mg, and below 1.0% for K. Similar findings were stated by Bergmann (1988, 1992). According to these criteria, in our investigations P, K and Ca status in maize leaves were in adequate ranges while concentrations of Mg were below adequate levels but close to adequate limit (Table 5). Also, as affected by Fertdolomite application, concentrations of P, K and Ca in maize leaves were significantly increased up to 12% (P), 8% (K) and 19% (Ca). With that regard, for significant response to P, K and Ca uptake in leaves were found at levels of applied Fertdolomite in amounts 5 t ha^{-1}, 10 t ha^{-1}, and 40 t ha^{-1}, respectively.

In our research, concentrations of tested nutrients in dry matter of maize grain were as follows: 0.294% P, 0.334% K, 0.006% Ca and 0.093% Mg. As affected by Fertdolomite application, only P concentrations in grain were significantly increased up to 14% compared to the control.

Also, oil contents in grain were increased due to Fertdolomite application (3.53% and 3.71%, for the control and average of Fertdolomite treatments, respectively) while differences of starch and protein contents among treatments were non-significant (Table 4).

Table 4. Impact of Fertdolomite on nutritional status of maize

Tablica 4. Utjecaj Fertdolomita na stanje ishrane kukuruza

Impacts of Fertdolomite (April 9, 2008) on nutritional status of maize (the hybrid Drava 404) and grain quality *Utjecaj Fertdolomita (9. travnja 2008.) na stanje ishrane kukuruza (hibrid Drava 404) i kvalitetu zrna*												
Fertd. (t ha^{-1})		Concentrations in leaf and grain (the growing season 2010): % in dry matter *Koncentracija u suhoj tvari lista i zrna (vegetacija 2010.): % suhe tvari*										
		The ear-leaf at silking *List ispod klipa u svilanju*				Grain at maturity (P, K, Ca, Mg, starch, proteins and oil) *Zrno u zriobi (P. K, Ca, Mg, škrob, proteini i ulje)*						
		Nutritional status / *stanje ishrane*								Quality / *Kvaliteta*		
		P	K	Ca	Mg	P	K	Ca	Mg	Starch	Prot.	Oil
a	0	0.324	2.34	0.462	0.177	0.276	0.331	0.005	0.093	71.83	8.60	3.53
b	5	0.346	2.33	0.498	0.184	0.288	0.333	0.005	0.090	72.17	8.60	3.70
c	10	0.345	2.52	0.463	0.168	0.284	0.315	0.005	0.086	71.90	8.53	3.67
d	20	0.350	2.47	0.500	0.170	0.304	0.339	0.006	0.097	72.03	8.50	3.70
e	30	0.362	2.50	0.478	0.170	0.315	0.341	0.006	0.098	71.43	8.83	3.77
f	40	0.356	2.48	0.549	0.185	0.299	0.346	0.006	0.096	71.93	8.87	3.73
Mean *Prosjek*		0.347	2.44	0.492	0.176	0.294	0.334	0.006	0.093	71.88	8.66	3.68
LSD 5% LSD 1%		0.013 0.191	0.13 ns	0.058 Ns	ns	0.019 0.024	ns	ns	ns	ns	ns	0.13 ns

Identical field experiment, with exception of treatment 30 t ha^{-1} of Fertdolomite application, was started in autumn 2008 on more fertile soil (pH in 1n KCl 5.08; AL-method: 8.3 mg P_2O_5 and 13.2 mg K_2O 100 g of soil) compared to our study, being about 2 km air-distanced from our experiment. By using the highest rate of Fertdolomite maize yield in the first year of testing (2009) was reduced by 12% due to overliming. Wheat yields in 2010 were moderately increased by 10%, while in 2011 and 2013 barley responded in yield increases by 20% and 41%, by 15% and 44%, using Fertdolomite rates of 20 and 40 t ha^{-1}, respectively (Kovačević et al., 2012a; 2014).

In our study also considerable effects of growing season was found on efficiency of liming on yields of maize as in the earlier studies under conditions of eastern and central Croatia (Antunovic et al., 2008; Kovacevic and Rastija, 2010; Andric et al., 2011).

CONCLUSION

In general, liming is useful management practice because of increases yields of maize and other field crops. However, effects of liming are different depending on year, mainly as affected by interaction with weather characteristics, particularly precipitation and temperature regimes during individual growing season. For example, in 2008 non-significant differences of maize yields were found to be level at 30 t ha^{-1} applied Fertdolomite while by the over liming (40 t ha^{-1}) yield was decreased by 7%. However, in 2010 maize yield was increased by 12% applying 10 t ha^{-1} Fertdolomite, but using the highest rate, yield was also decreased as in 2008. Yield of barley was increased by the lowest rate of Fertdolomite (5 t ha^{-1}) by 21% and the 20 t ha^{-1} and the higher rates yields were decreased to the control level.

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REAKCIJA KUKURUZA I JEČMA NA KALCIZACIJU FERTDOLOMITOM

SAŽETAK

Cilj ovoga rada bio je istraživanje reakcije kukuruza i ječma na primjenu Fertdolomita (24,0% CaO + 16,0% MgO + 3,0% N + 2,5% P_2O_5 + 3,0% K_2O) u stacionarnome poljskome pokusu (plodored: kukuruz 2008. – jari ječam 2009. - kukuruz 2010). Prinos kukuruza u 2010. povećan je za 12%, a ječma za 22%. Prosječne koncentracije u kukuruzu 2010. godine bile su 0,347% P, 2,44% K, 0,492% Ca i 0,176% Mg (listovi), 0,294% P, 0,334% K, 0,006% Ca i 0,093% Mg (zrno, a uslijed Fertdolomita povećane su za 12% (P), 8% (K) i 19% (Ca) u listu i za 14% (P) u zrnu.

Ključne riječi: kukuruz, ječam, Fertdolomit, prinos, mineralna ishrana

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