RESPONSE OF MAIZE AND WHEAT TO FERTDOLOMITE APPLICATION

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Abstract: Granulated dolomite enriched with NPK (trade name fertdolomite: 24.0% CaO + 16.0% MgO + 3.0% N + 2.5% P_2O_5 + 3.0% K_2O) was applied (0, 5 t ha^{-1}, 10 t ha^{-1}, 20 t ha^{-1}, 30 t ha^{-1} and 40 t ha^{-1}) on standard fertilization. The field experiment was established in spring 2008. In the next years only standard fertilization was applied. In this study results of 3-year investigations (2011 -2013) were tested (rotation: maize – wheat – maize). Maize yields on the control were 10.84 and 10.04 t ha^{-1}, for 2011 and 2013, respectively. Maize in the 2011 responded to fertdolomite up to quantity of 10 t ha^{-1} by significant yield increases up to 9%, while by the rates 30 and 40 t ha^{-1} yields were decreased up to 14%. However, in the 2013 effective (up to 17% yield increases) were 20 t ha^{-1} and the higher doses. As affected by application of 20 t ha^{-1} and the higher doses of fertdolomite four years ago, yields of wheat in 2012 were decreased compared to the control for 7% (7.47 and 6.96 t ha^{-1}, respectively). Possible explanation of this phenomenon could be too high ears densities (871 vs. 982 ears square m^{-1}) under the highest fertdolomite conditions and water deficit in tillering and stem elongation phases of wheat. Thousand grain weight, hectoliter mass and starch contents were independent on fertdolomite. However, protein-, wet gluten contents and sedimentation in wheat grain were considerably increased as affected by fertdolomite application as follows: 13.8% and 15.7% (protein), 33.5% and 38.1% (wet gluten), 46.5 and 58.1% (sedimentation value), for the control and the highest fertolomite rate, respectively.

Keywords: maize, wheat, liming, fertdolomite, yield

Introduction

Soil acidity is a major yield-limiting factor for crop production. The land area affected by acidity is estimated at 4 billion hectare, representing approximately 30 % of the total ice-free land area of the world (Sumner and Noble, 2003). Also, over half of the world population currently lives in regions dominated by acid soils (Yang et al., 2004).

Soil acidity is accompanied with some plant growth-limiting factors affecting physical, chemical, and biological properties of soil. Calcium (Ca), magnesium (Mg), and phosphorus (P) deficiencies or unavailability and aluminum (Al) toxicity are considered major chemical constraints that limit plant growth on acid soils. Disorders in activities of beneficial microorganisms, decomposition of organic matter, nutrient mineralization and immobilization, uptake and utilization of nutrients by plants, are accompanied with soil acidity (Rengel, 2003; Kadar et al. 2007).

Liming is the most important and most effective practice to ameliorate soil acidity constraints for optimal crop production. Reduced soil acidity increases soil fertility by improvement of chemical, physical and biological properties of soil.

One of the benefits of liming acid soils are the increased utilization of P added by fertilizers because of reduced P fixation and increase of nitrogen (N) availability as affected by intensification of microbiological processes in soil (Rengel, 2003). Aim of this study was testing subsequent effects of fertdolomite application in spring 2008 on maize and wheat yields in 2011 - 2013 period. The results of the first three years of testing were shown in the previous study (Kovacevic et al., 2015).

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Material and methods

The field experiment, chemical and statistical analysis

Granulated dolomite enriched with nitrogen, phosphorus and potassium (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 improvement of soil fertility on Drkulec Family Farm in Badljevina (municipality Pakrac, Pozega-Slavonian County). Fertdolomite was applied on standard fertilization in the amounts 0 (the control) , 5 t ha^{-1}, 10 t ha^{-1}, 20 t ha^{-1}, 30 t ha^{-1} and 40 t ha^{-1} (Table 1). The field experiment was established at beginning of April 2008 in four replicates (basic plot 40 m^2). In the next years only standard fertilization of the experiment was applied and subsequent effects of fertdolomite were tested.

The crop rotation on the experiment was as follows: maize (2008) - winter barley (2009) - maize (2010) – maize (2011) – winter wheat (2012) – maize (2013). The standard fertilizations of the experiment were 175 N + 50 P_2O_5 + 50 K_2O (maize), 120 N + 35 P_2O_5 + 50 K_2O (barley) and 175 N + 70 P_2O_5 + 103 K_2O (wheat). The results of the first three years of the experiment (2008 – 2010) were shown in the previous study (Kovacevic et al., 2015).

Farmyard in amount 35 t ha^{-1} was ploughed in spring of 2012. Maize (the hybrid *Drava 404* developed on Agricultural Institute Osijek) was sown in the second half of April (2011 and 2013) by pneumatic sowing machine at planned plant densities (PPD) 70 391 plants ha^{-1} and 68027 plants ha^{-1}, for 2011 and 2013, respectively. Four internal rows from each basic plot were harvested manually at the first half of October. After harvest enumerated plants and mass of cob weighed by precise Kern electronic balance. Grain yields were calculated on 14% grain moisture basis.

Winter wheat (the cultivar *Srpanjka* developed on Agricultural Institute Osijek) was sown at middle part of October 2011 and harvested at beginning of July 2012. 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.

Protein, starch, wet gluten and sedimentation value was determined by Near Infrared transmission spectroscopic method on Foss Tecator Infratec 1241 Grain Analyzer in Agrochemical laboratory of Agricultural Institute Osijek. The data were statistically analyzed by ANOVA and treatment means were compared using t-test and at 0.05 probability levels (LSD 5%).

Table 1. Quantities of the nutrients added by fertdolomite

Quantities of the nutrients added by fertdolomite (April 9, 2008) in Badljevina field experiment (four replicates, randomized block design, basic plot 40 m^2)						
Fertdolomite* (t ha^{-1})		Added nutrients by fertdolomite (kg ha^{-1})				
		N	P_2O_5	K_2O	CaO	MgO
a	0	0	0	0	0	0
b	5	150	125	150	1200	800
c	10	300	250	300	2400	1600
d	20	600	500	600	4800	3200
e	30	900	750	900	7200	4800
f	40	1200	1000	1200	9600	6400
* added to the standard fertilization (SF); in the next years only SF of the experiment as follows (kg ha^{-1}): 175 N + 50 P_2O_5 + 50 K_2O (maize), 175 N + 70 P_2O_5 + 103 K_2O (wheat).						

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Soil and weather characteristics

The surface soil layer up to 30 cm depth at starting of the experiment characterized by acid reaction (pH in 1nKCl 4.69), low levels of organic matter (2.12%) and plant available P (3.1 mg P_2O_5 100 g^{-1}) determined by the AL-method (Egner et al., 1960). Hydrolitical acidity was 2.41 Cmol kg^{-1}.

mainly because adequate and mainly good distributed precipitation. Both growing season characterized temperatures above the usual and these data are in harmony with the global warming (Table 2).

The growing season 2011/2012 was mainly favorable for winter wheat. Precipitation in the October-June period was 504 mm or

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

Daruvar*: Precipitation and air-temperatures during maize and wheat growing seasons														
Year	Monthly precipitation (mm)							Monthly mean air-temperatures (°C)						
	The growing seasons of maize (2011 and 2013) and the long-term means (LTM): 1961-1990													
	Apr.	May	June	July	Aug	Sept	Σ	Apr.	May	June	July	Aug	Sept	X
2011	19	55	44	121	40	27	*306*	12.6	15.6	20.3	21.7	21.6	18.7	*18.4*
2013	69	82	55	61	54	106	*427*	12.5	15.8	19.2	22.1	21.7	17.3	*18.1*
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 winter wheat (2011/2012) and the long-term means (LTM): 1961-1990										
	2011			2012							
	Oct.	Nov.	Dec.	Jan.	Febr.	March	April	May	June	Total	Mean
mm	65	1	94	32	48	7	56	111	90	504	
°C	9.7	2.1	3.6	2.1	-2.7	8.4	11.9	15.9	21.4		8.0
	The long-term means (LTM): 1961-1990										
mm	64	82	66	55	49	58	77	86	99	635	7.9
°C	10.9	5.8	1.4	-0.4	2.1	6.2	11.0	15.7	18.9		
* 10 km from the experiment site in the N direction											

The growing season 2011 was less favorable for maize growth mainly because of stress affected by combination of drought and high air-temperatures. In general, low yields of maize are in connection with water deficit and the high temperature, particularly in summer months (Markulj et al., 2010; Kovacevic et al., 2013). In the April-Sept. period of 2011 precipitation was 306 mm or about 40% lower than usual (LTM – Table 2). At the same period, mean air-temperature was 18.4 °C or the higher for 1.4 °C. This type of stress was the most effective in June and August because of precipitation quantities below 50% and the higher temperatures for 1.4 °C (June) and 1.1 °C (August). The growing season 2013 was more favorable for maize compared to 2011

for 21% lower than usual, while at the same period temperature was in level of the LTM. Deviations of the weather characteristic were drought periods in November and March (total 8 mm or only 6% of LTM), considerable colder November and February, as well as the higher temperatures in December and January (Table 2). In general, moderate lower precipitation, particularly in autumn / winter period and mild winter are favorable weather conditions for winter wheat (Marijanovic et al., 2010; Pepo and Kovacevic, 2011).

Results and discussion

In two tested growing seasons, response of maize to fertdolomite were specific (Table 3),

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Table 3. Impacts of fertdolomite application on maize properties

Impacts of fertdolomite * (Badljevina, April 9, 2008) on maize (the hybrid *Drava 404*)									
Fert-dolomite ($t\ ha^{-1}$)		Plant density (PD) realization (PDR in % of planned PD*), unfertile plants (UP), grain moisture (GM) at harvest and grain yield (on 14% GM basis) of maize							
		The growing season 2011				The growing season 2013			
		Percent			Yield $t\ ha^{-1}$	Percent			Yield $t\ ha^{-1}$
		PDR	UP	GM		PDR	UP	GM	
a	0	95.5	15.8	22.7	10.84	89.6	5.9	28.2	10.04
b	5	95.5	11.6	23.0	11.85	90.0	3.3	28.8	10.31
c	10	95.5	26.1	23.4	11.66	89.6	6.1	29.0	10.65
d	20	96.1	26.0	24.0	10.70	89.6	4.2	27.3	11.29
e	30	96.5	35.0	23.5	9.50	93.0	4.4	27.0	11.68
f	40	96.5	34.7	23.8	9.36	91.8	2.5	27.4	11.78
Average		95.9	24.9	23.4	10.65	90.6	4.4	27.9	10.96
			LSD 5%	ns	0.70		LSD 5%	ns	0.80
		Planned PD (100% PDR): 73261 plants ha^{-1}				Planned PD (100% PDR): 68027 plants ha^{-1}			
* composition: 24.0 % CaO + 16.0 % MgO + 3.0 % N + 2.5 % P_2O_5 + 3.0 % K_2O									

Table 4. Impacts of fertdolomite application (spring 2008) on winter wheat (the cultivar *Srpanjka*) status (the growing season 2011/2012)

Winter wheat status (2012) following fertdolomite (Fertd.) application (spring 2008): grain yield, ear number in unit of area, thousand grains weight (TGW), hectoliter mass (HM) and grain quality parameters (proteins, starch, moist gluten and sedimentation value contents)								
Fertd. $t\ ha^{-1}$	Yield $t\ ha^{-1}$	Ears per sqm^{-1}	TGW g	HM kg	Grain quality parameters			
					Protein %	Starch %	Wet gluten %	Sedimentation value (mL)
0	7.47	871	30.5	77.3	13.8	65.4	33.5	46.5
5	7.77	934	31.4	78.0	13.4	66.2	32.5	45.0
10	7.41	927	30.1	77.1	14.9	64.6	36.1	54.5
20	7.01	956	29.3	76.6	15.2	64.5	37.1	55.0
30	7.06	982	30.6	76.8	15.5	64.1	37.7	56.6
40	6.96	977	31.1	77.1	15.7	63.9	38.1	58.1
Mean	7.28	941	30.5	77.2	14.8	64.8	35.8	52.6
LSD 5%	0.38	65	ns	ns	0.8	1.3	2.5	3.1

probably because of weather characteristic differences (Table 2). Maize in the 2011 responded positively to fertdolomite up to applied 10 t ha^{-1} by significant yield increases up to 9%, while by the rates 30 and 40 t ha^{-1} yields were decreased up to 14%. Explanation of this phenomenon could be in considerable increases of the unfertile plants, probably by the higher plant densities and more exposure to drought in flowering as affected by observed about week earlier starting of flowering stage compared to plants on the control. The second possible explanation is restricted water supplies by precipitation in the first half of growing period (April - June 118 mm or 45% compared to the LTM) and following this more concentrated soil solution as affected by the very high applied fertdolomite doses. However, in the 2013 non-significant differences of yield between the

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Table 5. Survey results of the first three years (2008 – 2010) of the field experiment (Kovacevic et al., 2015)

Impacts of fertdolomite * application (spring 2008) added to standard mineral fertilization on maize and barley: grain moisture at harvest (GM), grain yield, ears density in square m, P and K status in leaves (the ear-leaves at silking stage) and grain (maturity stage)						
	Maize (2008)		Spring barley (2009)		Maize (2010)	
Fertdolomite* t ha^{-1}	GM %	Yield t ha^{-1}	Ears (E) E m^{-2}	Yield t ha^{-1}	GM %	Yield t ha^{-1}
0	29.2	13.59	573	4.22	25.3	12.38
5	29.0	13.66	665	5.14	25.0	13.60
10	29.3	13.44	629	4.81	25.5	13.90
20	29.2	13.30	633	4.54	25.8	13.59
30	29.4	13.32	646	4.52	25.9	13.30
40	29.4	12.69	653	4.53	26.0	12.57
Mean	29.3	13.33	633	4.62	25.6	13.22
LSD 5%	ns	0.42	49	0.38	ns	0.40
LSD 1%		0.57	68	0.52		0.56
* composition of fertdolomite: 24.0 % CaO + 16.0 % MgO + 3.0 % N + 2.5 % P_2O_5 + 3.0 % K_2Ofertilization: 175 N + 50 P_2O_5 + 50 K_2O kg ha^{-1} (maize), 120 N + 35 P_2O_5 + 50 K_2O kg ha^{-1} (barley)						

control and two the lower doses (5 and 10 t ha^{-1}) were found and by applied the higher rates yields were increased up to 17% compared to the control. In the both growing season, fertdolomite did not impacts on grain moisture at harvest (Table 3).

As affected by application of 20 t ha^{-1} and the higher fertdolomite doses four years ago, yields of wheat in 2012 were decreased up to 7%, while by applied the lower rates yields were in level of the control. Possible explanation could be too high ears densities and water deficit in tillering and stem elongation phases of wheat plants under the higher fertdolomite conditions.

Thousand grain weight and hectoliter mass and starch contents were independent on fertdolomite. However, protein-, wet gluten contents and sedimentation value in wheat grain were considerably increased as affected by fertdolomite application as follows: 13.8% and 15.7% (protein), 33.5% and 38.1% (wet gluten), 46.5 and 58.1% (sedimentation value), for the control and the highest fertolomite rate, respectively (Table 4).

Grain yield and grain protein concentration are important traits affecting the economic value of common wheat. There is an inverse relationship between grain yield and protein content which is corroborated by our study. Wheat proteins and wet gluten is a primary quality component that influences the most of wheat grain baking quality characteristics and applied fertilization affected positively to these properties.

Kovacevic et al. (2015) reported about results of the first three years of the experiment (2008 -2010). In 2008, non-significant differences of maize yields among the control and limed treatments until 30 t ha^{-1} were found, but over liming by 40 t ha^{-1} resulted by yield decreases for 7% (13.59 and 12.69 t ha^{-1}, respectively), mainly due to reduction of plant density. However, in 2010, as affected by fertdolomite yields of maize were increased until 12% compared to the control (12.38 and 13.90 t ha^{-1}, respectively). 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 (over liming) yield was decreased to level of the control. Even the lowest rates of fertdolomite in amount of 5 t ha^{-1} was adequate for considerable yield increase of spring barley in 2009 for 22% compared to the control (4.22 and 5.14 t ha^{-1}, respectively), but by the highest treatment yield was reduced to level of the control.

By the other experiments realized in the last 15 years in the northern Croatia (Antunovic, 2008; Jurkovic et al., 2008; Mesic et al., 2009; Kovacevic and Rastija, 2010; Andric et al., 2012; Kovacevic et al., 2006; Kovacevic and Loncaric, 2014) and the northern Bosnia (Markovic et al., 2008; Komljenovic et al., 2013) were found also mainly positive effects of liming on field crops yield. With that regard, as in our study, considerable effects of the growing season characteristics (the factor "year") on field crops yield and liming efficiency were found.

Conclusions

Based on the results of our study and majority studies realized in Croatia, liming had positive effects on field crops yield with considerable influences of growing season impacts of liming efficiency, mainly due to weather characteristics. Maize in the 2011 responded to fertdolomite up to quantity of 10 t ha^{-1} by significant yield increases up to 9%, while by the rates 30 and 40 t ha^{-1} yields were decreased up to 14%. However, in the 2013 effective (up to 17% yield increases) were 20 t ha^{-1} and the higher doses. As affected by application of 20 t ha^{-1} and the higher doses of fertdolomite four years ago, yields of wheat in 2012 were decreased compared to the control for 7%, probably due to too high ears densities under the highest fertdolomite conditions and water deficit in tillering and stem elongation phases of wheat.

However, fertdolomite positively affected on backing quality parameters of wheat grain as follows: 13.8% and 15.7% (protein), 33.5% and 38.1% (wet gluten), 46.5 and 58.1% (sedimentation value), for the control and the highest fertolomite rate, respectively.

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