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MAIZE RESPONSE TO LIMING AND PHOSPHORUS FERTILIZATION IN LIJEVCE POLJE REGION OF BOSNIA AND HERZEGOVINA

Ilija KOMLJENOVIC[1*], Vlado KOVACEVIC[3], Mihajlo MARKOVIC[1], Goran DJURASINOVIC[2], Vojo RADIC[1]

[1]Faculty of Agriculture, University of Banja Luka, Sq. Vojvoda Bojovic bb, 78000 Banja Luka, Republic of Srpska (RS), Bosnia and Herzegovina
[2]Agricultural Institute of Republic of RS, Knjaza Milosa 18, 78000 Banja Luka, RS, Bosnia and Herzegovina
[3]Faculty of Agriculture of University J. J. Strossmayer in Osijek, V. Preloga 1, 31000 Osijek, Croatia
*Corresponding author: Ilija Komljenovic, ilijakom@teol.net

Abstract

The field experiment of liming (0 and 10 t ha^{-1} of powdered hydrated lime) and phosphorus (P) fertilization (monoammonium phosphate or MAP: 12% N + 52% P_2O_5) started in autumn 2008 on acid soil (pH in 1n KCl: 4.28) of Lijevce polje region (Laktasi municipality, Bosnia and Herzegovina). Three doses of P (0, 500, 1000 and 1500 kg P_2O_5 ha^{-1}) on the conventional fertilization (160 N + 75 P_2O_5 + 75 K_2O kg ha^{-1}) were applied in four replicates (basic plots of liming and P fertilization 640 m^2 and 40 m^2, respectively). The conventional fertilization was applied in the next years of the experiment. Soil of the experiment was low supplied with plant available P and adequate supplied with potassium (AL-method: 2.9 mg P_2O_5 and 23.4 mg K_2O in 100 g of soil). Maize was grown in monoculture from 2009 to 2013. Average grain yield of maize was considerable different among the years, ranging from 2.06 to 9.38 t ha^{-1}. Under less favorable weather conditions (drought and high temperature stress) in the 2011, 2012 and 2013, yields were considerably lower (mean 4.28 t ha^{-1}) than in the remaining two years (mean 9.20 t ha^{-1}). In general, liming effects on maize yields were stronger than P effects with considerable impacts of weather conditions. Affected by liming, yields were increased for 39%, 18%, 47%, 25% and 158%, for 2009, 2010, 2011, 2012 and 2013, respectively. However, P effects ranged, depending on the year, from non-significant differences (2012) to 32% (2013).

Keywords: *maize, liming, fertilization, phosphorus, grain yield*

Introduction

Acidic soil with low a level of humus, reduced accessibility of exchangeable forms of the most important plant nutrients such as phosphorus and calcium, as well as rather poor physical soil properties (poor water-air regime) are limiting factors for achieving higher and stable yields of cultivated plants. Low yields on these soil in recent years, despite the regular application of mineral fertilizers, indicate the blocking of individual nutrients in the soil under conditions of acid reaction. If such a bad agrochemical trait is added to drought, then the production of crop, fodder, vegetable plants and fruits stagnates year after year.
Marković and Supić (2013) are estimating that 25 % arable lands in B&H belong to pseudogley. Acid soils and low levels exchangeable phosphorus (P) as well as unfavourable physical properties are limiting factor of pseudogley fertility (Okiljevic et al., 1997, Resulovic and Custovic, 2002; Markovic et al., 2006).

Materials and methods

General description of the Lijevce Polje area

Lijevce polje is an area in the northern part of B&H, encompassing the Gradiska, Laktasi and Srbac municipalities. It is lowland area in the lower flow of the Vrbas river, extending from the Sava river to the north and the mountains Prosara to the west, Motajica to the east and Kozara to the southwest. Climate of this area is moderate continental. In general, soil is more fertile compared to the majority of agricultural areas in the country, although serious problems of aluminum toxicity were sporadically found (Okiljevic, 1982; Kovacevic et al., 1988). Climate of wide region area was elaborated by Komljenovic et al., 2014).

The field experiment

This research was carried out on the Djurasinovic Family Farm in Mahovljani (Laktasi municipality, RS, B&H) during four consecutive growing seasons, from 2009 to 2013, on pseudogley soil (pH $_{1nKCl}$ = 4.28) low supplied with plant available P and rich in potassium (K). The treatments included liming and P fertilization. P distribution as monoammonium phosphate (MAP: 12% N + 52% P_2O_5) was conducted on November 10th, 2008 before ploughing. The rates of P on basic fertilization (160 N + 75 P_2O_5 + 75 K_2O kg ha^{-1}) were as follows: 0, 500, 1000 and 1500 kg P_2O_5 ha^{-1}. Immediately after P fertilization the experiment plot was ploughed up to 30 cm in depth. Liming of the experiment by 10 t ha^{-1} of powdered hydratized lime (73% CaO + 2-3% MgO + 21% of bound water) was made on November 16th, 2008 (four replicates and basic plots 40 m^2 and 640 m^2 for P and liming treatments, respectively). Maize (the hybrid NS444) was grown in monoculture. Detailed information regarding crop management practice, soil properties, weather characteristics, statistical analysis, grain yield, grain moisture, protein-, starch- and oil- determinations until 2012, were shown in the previous studies (Komljenovic et al., 2013, 2015a, 2015b). Maize was sown in April 30 and harvested in November 2, 2013.

Weather conditions for maize growth in the 2013 growing season

Table 1. Precipitation and air-temperatures in Banja Luka (SY, 2014)

Year	The weather data (Banja Luka* Weather Bureau: LTM = long-term averages 1961-1990)							
	Jan.-April	May	June	July	Aug.	Sept.	Oct.	May-Oct.
	Precipitation (mm)							
2013	362	120	54	27	36	70	68	375
LTM**	298	98	111	95	93	82	72	551
	Mean air-temperatures (°C)							
2013	6.2	16.6	20.4	23.0	23.5	16.7	13.1	18.9
LTM	4.9	15.6	18.9	20.6	19.7	15.9	10.8	16.9

Absolute and average maximum air-temperatures (°C), PET, AET, WD and WS (mm) in Banja Luka**										
Year	Absolute maximal temp.			Average maximal temp.			PET	AET	WD	WS
	June	July	August	June	July	August	June –August (sum)			
2013	36.0	41.6	41.1	26.4	30.7	31.3	101.54	67.52	34.01	0

* air-distance from the experiment site: Banja Luka = about 20 km in S direction
** PET = potential (PET) and actual (AET) evapotranspiration, water deficit (WD) and water surplus (WS)

The 2013 growing season was less favorable for maize growing, mainly due to precipitation deficit in July and August (Fig 1). According data for Banja Luka Weather Bureau precipitation in amount 63 mm was only about third part in comparison with the average 1961-1990. At the same period air temperature was for 3.0 °C higher and absolute maximal temperatures were above 41 °C (Table 1).

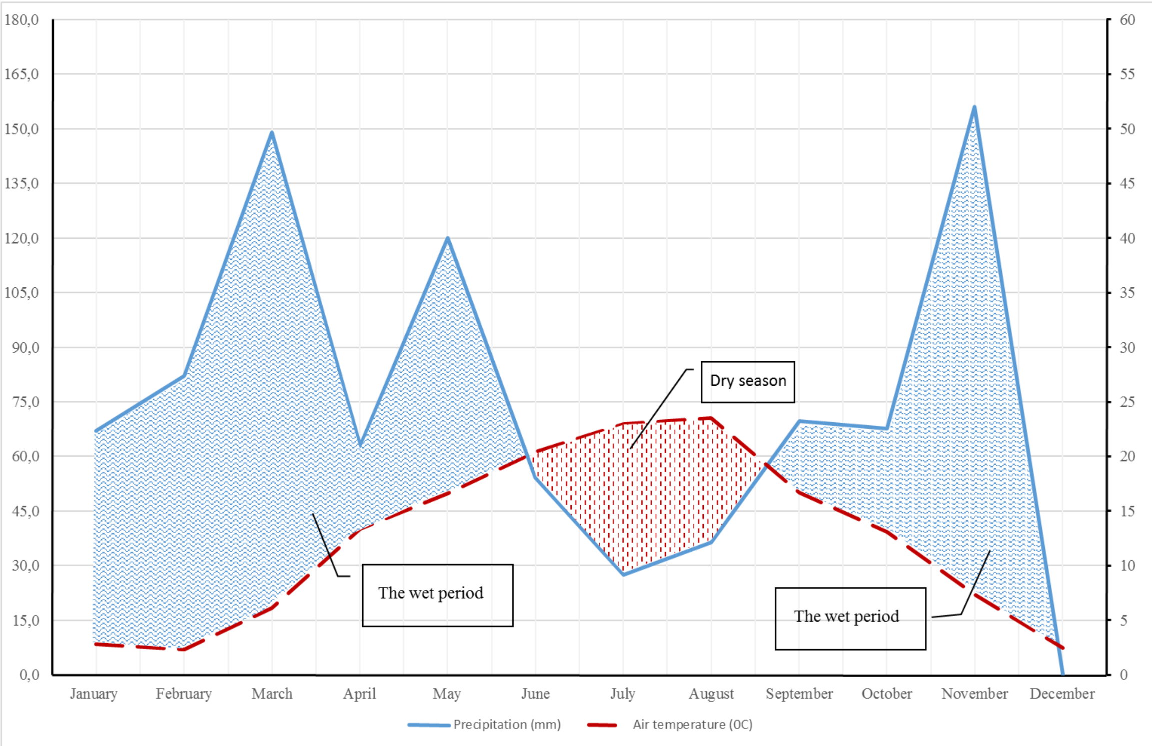

Fig. 1. Climate diagram by H. Walther for 2013 growing season for Banja Luka area

There is a noticeable lack of moisture in the period from the beginning of June to the first half of September in 2013 growing season, therefore in the critical period from the beginning of flowering, fertilization, and filling of grains. This was reflected in the yield of corn grain in the 2013 growing season (Table 1, Fig 1 and Table 3).

Results and discussion

Average grain yield of maize in the experiment for the 2013 growing season was 5.12 t ha^{-1} with considerably liming effects (2.86 and 7.38 t ha^{-1}, for control and limed treatment, respectively. Main reasons of low yield of maize under control treatment compared to lime application were considerable lower realized plant density (averages 70.8% and 94.5%) and the higher rate of barren plants (averages 37.6% and 7.6%) under acid stress conditions. Grain moisture at harvest was independent on liming (Table 2).
However, P effect was considerably lower compared to liming effect. With that regard, significant yield increases for 32% was realized by application the highest rate of P fertilizer. Realized plant density was independent on P fertilization, while barren plants contribution was significantly decreased (25.0% and 19.8%, respectively) by application of the highest P rate (Table 2).
Impacts of liming on grain quality parameters (protein, oil and starch contents) in 2013 were non-significant, while P use resulted by significant increases only oil contents (Table 3).
Josipovic et.al. (2013) are reported that liming had considerably effects on increase of protein contents in maize grain from 9.9% (the control) to 10.6% (lime 10 t ha^{-1}), while by the using ameliorative PK-fertilization there is tendency to increases of maize grain protein contents. Grain starch contents was independent on liming and PK-treatments on very acid soil located near Pavlovac in Croatia.

Table 2. Response of maize (the 2013 growing season) to liming and phosphorus fertilization (November 2008).

Liming (the factor A) by the hydrated lime (A1 = 0, A2 = 10 t ha^{-1}) and ameliorative phosphorus (P_2O_5 kg ha^{-1}: B1= 0, B2 = 500, B3 = 1000, B4 = 1500) fertilization (the factor B) in autumn 2008: impacts on maize status in the 2013 growing season (realized plant density:100% = 57143 plants ha^{-1})												
P_2O_5* kg ha^{-1}	Lime			Lime			Lime			Lime		
	A1	A2	x B	A1	A2	x B	A1	A2	x B	A1	A2	x B
	Grain yield (t ha^{-1})			Grain moisture at harvest (%)			Realized plant density (% of planned)			Barren plants (%)		
B1	2.50	6.55	4.52	18.5	18.5	18.5	64.3	96.5	80.4	39.4	10.7	25.0
B2	2.74	7.00	4.87	18.4	18.7	18.6	70.0	95.4	82.7	39.3	9.4	24.3
B3	2.90	7.33	5.15	18.4	18.7	18.6	73.9	93.6	83.7	39.6	9.6	24.6
B4	3.29	8.65	5.97	18.5	18.0	18.3	75.2	92.5	83.8	32.0	7.6	19.8
x A	2.86	7.38		18.5	18.5		70.8	94.5		37.6	9.3	
	$P_{0.05}$	$P_{0.01}$		$P_{0.05}$	$P_{0.01}$		$P_{0.05}$	$P_{0.01}$		$P_{0.05}$	$P_{0.01}$	
A	0.85	1.22		ns			8.8	12.3		8.7	11.3	
B	0.53	0.76		ns			ns			4.6	ns	
AB	1.92	1.38		ns			ns			13.9	19.4	
* basic fertilization of all treatments (160 N + 75 P_2O_5 + 75 K_2O kg ha^{-1}); in the next years (2009-2013) only basic fertilization of the experiment.												

Table 3. Response of maize (the 2013 growing season) to liming and phosphorus fertilization (November 2008).

Liming (the factor A) by the hydrated lime (A1 = 0, A2 = 10 t ha^{-1}) and ameliorative phosphorus (P_2O_5 kg ha^{-1}: B1= 0, B2 = 500, B3 = 1000, B4 = 1500) fertilization (the factor B) in autumn 2008: impacts on grain quality parameters in the 2013 growing season									
P_2O_5* kg ha^{-1}	Lime			Lime			Lime		
	A1	A2	x B	A1	A2	x B	A1	A2	x B
	Protein (%)			Oil (%)			Starch (%)		
B1	8.95	9.25	9.10	3.38	3.30		67.85	66.43	
B2	9.33	9.43	9.38	3.73	3.55		68.00	67.80	
B3	9.23	9.34	9.29	3.69	3.73		68.13	68.00	
B4	9.38	9.35	9.37	3.63	3.58		68.83	69.52	
x A	9.22	9.34		3.68	3.62		68.32	68.44	
	$P_{0.05}$	$P_{0.01}$		$P_{0.05}$	$P_{0.01}$		$P_{0.05}$	$P_{0.01}$	
A	ns			ns			ns		
B	ns			0.18	0.25		ns		
AB	ns						ns		
* basic fertilization of all treatments (160 N + 75 P_2O_5 + 75 K_2O kg ha^{-1}); in the next years (2009-2013) only basic fertilization of the experiment.									

Also, in the 4-year period of 2009-2012 liming considerably affected on grain yield of maize by average yield increase for 31% with differences among years from 18% in 2010 to 47% in 2011. As in 2013 growing season, P fertilization impact was considerably lower because yields were increased in three years from 6% in 2009 to 19% in 2011, while in 2012 differences of yield among P treatments were non-significant. By comparison of yield realized by three ameliorative P rates and the control, P effect on maize yield was only 8% (4-year averages: 6.14 and 6.65 t ha^{-1}, for control and P rates, respectively). With exception of the first year of testing, for significant increase of maize yield was adequate the lowest rate of applied P in amount 500 kg P_2O_5 ha^{-1} (Table 4). Response of maize to liming and P fertilization in 2009-2012 period elaborated in our earlier studies (Komljenovic et al., 2013, 2015a, 2015b).

Table 4. Response of maize to liming and P fertilization in the 2009-2012 period (Komljenovic et al., 2013, 2015a, 2015b)

Liming (the factor A) by the hydrated lime (A1 = 0, A2 = 10 t ha^{-1}) and ameliorative phosphorus (P_2O_5 kg ha^{-1}: B1= 0, B2 = 500, B3 = 1000, B4 = 1500) fertilization (the factor B) in autumn 2008: impacts on grain yield of maize in four consecutive growing seasons 2009 -2012												
	2009			2010			2011			2012		
	A1	A2	x B	A1	A2	x B	A1	A2	x B	A1	A2	x B
	Grain yield (t ha^{-1})			Grain yield (t ha^{-1})			Grain yield (t ha^{-1})			Grain yield (t ha^{-1})		
B1	7.30	10.07	*8.68*	7.97	9.92	*8.94*	4.40	5.53	*4.97*	1.82	2.08	*1.95*
B2	7.37	10.65	*9.01*	8.66	10.28	*9.47*	4.59	7.19	*5.89*	1.98	2.24	*2.11*
B3	7.61	10.66	*9.13*	9.23	10.24	*9.73*	4.60	7.09	*5.85*	1.85	2.36	*2.11*
B4	7.82	10.60	*9.21*	8.55	10.17	*9.36*	4.68	7.06	*5.87*	1.67	2.49	*2.08*
x A	*7.52*	*10.49*	**9.00**	*8.60*	*10.15*	**9.38**	*4.57*	*6.72*	**5.65**	*1.83*	*2.29*	**2.06**
A effect		+39%			+18%			+47%			+25%	
B effect			+6%			+9%			+19%			ns
	A	B	AB	A	B	AB	A	B	AB	A	B	AB
P 0.05	0.81	0.43	ns	0.32	0.33	ns	0.45	0.34	0.49	0.17	ns	ns
P 0.01	1.49	ns	ns	0.59	0.45		0.83	0.47	0.67	0.30		

Conclusions

The results of the study of the impact of liming and P fertilization in 2013 growing season in the Mahovljani (the fifth year of research), clearly show the extended effect of the applied agroemeliorative measures on maize grain yield. On the treatment where is applied 10 t ha^{-1} lime material and phosphorus fertilizer, the yield of maize was 7.86 t ha^{-1} which was higher for 4.52 t ha^{-1} or 258% than the control variant (2.586 t ha^{-1}). However, the same effect was not reflected on the quality properties of corn grains.

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