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RESPONSE OF MAIZE TO LIMING AND AMELIORATIVE PHOSPHORUS FERTILIZATION

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The field experiment of liming (0 and 10 t ha-1 of powdered hydrated lime) and phosphorus fertilization (monoammonium phosphate or MAP: 12% N + 52% P2O5) were conducted on Mahovljani acid soil in November 2008. The rates of P on basic fertilization were as follows: 0, 500, 1000 and 1500 kg P2O5 ha-1. Basic plots of liming and P fertilization were 640 m2 and 40 m2, respectively. The average yield of maize grain was 8.03 t ha-1. The yield of maize was increased by liming 32% (3-year averages: 6.90 and 9.12 t ha-1, for the control and liming, respectively) with differences of liming effects among the years by 18% to 47%. The differences of yields were nonn-significant among three rates of P applications, while increases of yields were 5% (2009), 6 % (2010) and 18% (2011) respectively by comparing these treatments with the control. Protein and oil contents were independent on liming and P fertilization in maize grain, while effects of these treatments on starch contents found only in 2009 growing season: as affected by liming starch contents were increased by 1.3%, while P fertilization resulted by decreases of starch contents by 0.9%.

1- Introduction

The soils of Bosnia and Herzegovina (B&H) are mainly less favourable for physical and chemical properties. It is estimated that about 25% of agricultural land of B&H are pseudogley or similar soils (Markovic and Supic, 2003). Acid reaction and nutritional unbalances, mainly low levels of plant available 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). In general, low yields of the field crops have been found in B&H. For example, in Republic of Srpska (RS) the enthity of B&H average yields (5-y means 2006-2010: SYRS, 2011) were as follows: maize 4.60 t ha-1 (141427 ha), wheat 3.28 t ha-1 (44017 ha), barley 3.28 t ha-1 (12447 ha) oats 2.46 t ha-1 (10740 ha), soybean 2.46 t ha-1 (3566 ha) and rye 2.58 t ha-1 (2103 ha). The similar status of yields exists is in the remaining part of B&H (Statistical SYFBH, 2011). Low soil fertility and inadequate fertilization are main responsible factors for inadequate efficiency of soil in B&H. According to the data of The World Bank (2012) the mean consumption of mineral fertilizer per hectare of arable land was 19.5 kg ha-1 on 1022000 ha in B&H for 2005-2009 periods. Liming, enrichment with organic matter by ploughing of manure and crop residues adequate P fertilization as well are usually recommendations for improvement of physical and chemical properties of pseudogley and other acid soils (Janekovic, 1971; Moniz et al., 1997; Petosic et al., 2003; Kovacevic et al., 2006b, 2011; Rastija et al., 2006; Komljenovic et al., 2010). The positive effects of liming and ameliorative P fertilization were found in our earlier studies int he northern Bosnia. For example, as affected by liming maize yield increases were up to 48% (Markovic et al., 2008), while P fertilization was up to 32% resulted by maize yield increases (Komljenovic et al., 2006, 2008). Also, pseudogley soil and similar soil types are common in central Serbia (Dugalic et al., 2005; Jovanovic et al., 2007).

2- Materials and methods

- Study site and plot design

This research was carried out in Lijevce polje (Republik of Srpska, B&H). This is a lowland area situating close to the Vrbas river among river Sava on north, and mountains of Prosara on west, Motajica on east and Kozara on south-west. The stationary field experiment was conducted in Mahovljani (municipality Laktasi) during three consecutive growing seasons, from 2009 to 2011, at pseudogley soil (pH H2O = 5.38, pH 1nKCl = 4.28; 2.91 mg P2O5 and 23.24 mg K2O 100 g-1) of Djurasinovic family farm. This soil indicates acid reaction, very low in plants available phosphorus but adequate in plants available potassium.

The treatments included liming and phosphorus fertilization. Phosphorus distribution in the form of monoammonium phosphate (MAP: 12% N + 52% P2O5) was conducted on November 10, 2008 before ploughing. The rates of P on basic fertilization (160 N + 75 P2O5 + 75 K2O kg ha-1) were as follows: 0, 500, 1000 and 1500 kg P2O5 ha-1. Different N rates added by MAP were equalized for the fertilization treatments by addition of CAN (calcium ammonium nitrate 27% N). The phosphorus fertilization was made in four replicates and duplicated for 2 x 640 m2 (eight replicates) areas. The basic plot of P fertilization was 40 m2. The experiment plot was ploughed up to 30 cm of depth immediately after P fertilization. Liming of the experiment by powdered hydratized lime (73% CaO + 2-3% MgO + 21% of bound water) was made in November 16, 2008. Lime was originally packed in the 40-kg sacks. Each sack was distributed by hand on 16 basic plots of P fertilization (10 t of lime ha-1) and remaining 16 basic plots of P fertilization was used as non-limed P treatments. The experiment was conducted as two-factorial experiment (the factor A= liming; the factor B: phosphorus fertilization).

- Maize crop management practice

Mineral fertilizer NPK 8:26:26 (200 kg ha-1) was ploughed down, while NPK 15:15:15 (150 kg ha-1) and urea (100 kg ha-1) were incorporated in soil by seedbed preparation. Band top-dressing was accomplished CAN (200 kg ha-1) with cultivation at early growth stage of maize.

Maize hybrid NS444 originating from Institute for the field crops and Vegetables Novi Sad (Serbia) was sown manually by the planter (inter-row spacing 70 cm and distance in the rows 25 cm (theoretical plant density 57143 plants ha-1) in depth of 6-8 cm at the end of April/beginning of May. A total 2-3 seed were sown and the maize crop thinned out at 3-5 leaf stages (1 plant for 25 cm distance). Herbicide Lumax (3.5 l ha-1) was applied by pre-emergence treatment. Internal four of total six 7.5 m long rows of maize were harvested manually at the beginning of November.

- Determining of sampling, yield, grain moisture and quality parameters

The mass of cob was weighed by Kern electronic balance (d=100 g). The yields were calculated based on 14% grain moisture and realized plant density.

Mean soil sample (0-30 cm depth) was taken by the auger at the end of August 2008 from approximately 0.20 ha of area planned for the experiment conduction.

Ten random cobs from each treatments waa taken at maize harvest for grain moisture, grain share in cob and grain quality parameters (protein, starch and oil contents) determinations. The soil reaction was determined according to ISO (1994), while plant available P and K were extracted by the ammonium-lactate solution (AL-method) according to Egner et al., (1960). P was determined spectrophotometrically and K by atomic absorption.

The grain moisture was determined by electronic grain moisture instrument (WILE-55, Agroelectronics, Finland). Oil content in grain was determined by nuclear magnetic resonance (NMR) spectroscopy method while the protein and starch contents were determined by Near Infrared spectroscopic method on Foss Tecator ("Infratec 1241 Grain Analyzer").

- Weather characteristics

Precipitation quantities in May-October period were 489 mm, 816 mm and 310 mm for 2009, 2010 and 2011, respectively. In the August-September period of 2011 the precipitation was five-fold lower and air-temperature for 4.2 oC higher as compared to 30-year average (Table 1).

- Statistical analysis

Data were analyzed statisticall by a double-factors (A: liming; B: P fertilization) ANOVA using SAS software (SAS Institute, Cary, N.C.; PROC ANOVA) and tested parameters were evaluated based on t-test and LSD at 0.05 and 0.01 probability levels.

3- Results

The average yield of maize grain in our investigation was 8.03 t ha-1 for 3-year period, however, differences of average yields among the years were from 5.65 to 9.38 t ha-1 (Table 2). Under drought and hot stress conditions of the 2011 growing season (Table 1) yields were close to 40% lower than under weather conditions of two remaining years (mean 9.22 t ha-1).

In general, the grain yield of maize was increased for liming by 32% (3-year averages: 6.90 and 9.12 t ha-1, for the control and limed treatment, respectively) with differences of liming effects among the years by 18% to 47%. The most effective impacts of liming on maize yield was found under unfavorable weather conditions of the 2011 growing season, while it was the lowest under excess of precipitation of 2010 (Table 2).

Phosphorus fertilization effects on grain yields of maize was considerably lower in comparison with liming effects. For example, differences of yields among three rates of P applications were non-significant, while by comparison of these treatments with the control, the increases of yields were 5% (2009), 6 % (2010) and 18% (2011) respectively. As in the case of liming, phosphorus was the most effective element under less favoruable conditions of 2011 (Table 2).

The protein and oil contents in maize grain were independent on liming and P fertilization, while the effects of these treatments on starch contets were found only in the 2009 growing season: as affected by liming starch contents were increased by 1.3%, while P fertilization resulted by decreases of starch contents for 0.9% (B2-B4 average) as compared to the control, while differences among three ameliorative P fertilization treatments were non-significant. However, the growing season (year effects) was more influencing factor on grain and oil contents in maize grain. Under drought stress conditions of 2011 protein contents were 2.90% and 2.22% higher than those in 2009 and 2010, respectively. Also, the average oil contents were the lower and reciprocal similar in 2010 and 2011 (mean 3.60%) as compared with 2009 (4.09%). However, the starch contents in maize grain were less dependent on the growing season compared to protein and oil contents. Grain moisture at harvesting were independent on P fertilization, while liming had slight effects on grain moisture as follows: decreasing effects for 1.2% in 2009, increasing effects for 1.0% in 2010 and non-significant differences in 2011. Plant density realization in the trial was for three tested years over 95% as compared to planned plant density (Table 2).

4- Discussion

Weather conditions, especially precipitation amounts and their distribution through the growing season, along with air temperatures are mainly most important environmental factors affecting the maize development and yield. In general, large quantities of well-distributed precipitation and lower air temperatures during three summer months benefits maize growing (Shaw, 1988). The water shortage is among the most important factors for optimum production of maize wordwide (Araus et al., 2002), especially under semiarid conditions (Payer et al., 2006; Hammad et al., 2012).

Many previous studies elaborated the impact of precipitation and air temperatures regime on maize yield variations under conditions of continental part of Croatia (Josipovic et al., 2005; Kovacevic and Josipovic, 2005; Markulj et al., 2010; Rastija et al., 2012; Stojic et al., 2012) and it was confirmed that low yields are associated with water shortage and higher air temperatures during July/August. The growing seasons 2009 and 2010 were more favourable for maize growing compared to 2011. Maize crop was especially under drought and hot stress during August-September period of 2011.

Positive effects of liming were found in the other studies in B&H and neighbouring countries. Markovic et al. (2008) applied dolomite powder up to 20 t ha-1 on Gradiska hydromorphic soil in the northern Bosnia in spring of 2005 and tested the maize response in the following three growing seasons. Liming resulted by yield increases for 48% (3-year means: 4.19 and 6.23 t ha-1, for 0 and 20 t of lime, respectively). Under drought and high air-temperature stress in July and August of 2007 yield of maize in the experiment was 30% lower than in the previous year characterizing relative normal weather conditions. Also, by applying of 5 t ha-1 of lime leaf-P, -Ca, -Mg and -S were increased as compared to the control for 12%, 18%, 25% and 22%, respectively. Especially influences of liming were found for Mo status in maize leaf because by using 5 t ha-1 limes it was increased nearly three-fold as compared to the control. Antunovic (2008) found considerably effects of carbocalk (by-product of sugar factory; 39% CaO) application on maize yields for 26% (4-year mean) in the Virovitica-Podravina County in Croatia with variation in these effects among the years from 7% to even 50%. In the other experiment the arbocalk application resulted by yield increases themaize and sunflower for 50% and barley for 30% (Kovacevic et al., 2006b). Kovacevic and Rastija (2010) examined in a five year experiment the effect of liming with dolomite powder rates up to 15 t ha-1 (spring of 2003) on maize and spring barley grain yields. Maize crops were grown during 2003-2005 and 2007, whereas spring barley was grown in 2006. The highest average maize grain yield (11.47 t ha-1) was achieved in 2004 which was characterized by an adequate amount of evenly distributed rainfall and somewhat lower air temperatures during the growing season. On the contrary, the average maize grain yield under drought stress of 2007 was only 4.44 t ha-1. The grain yield of maize was influenced by liming in all four years and yield was significantly increased at all liming treatments as compared with control. The best response was observed in 2005 and 2007 when grain yields increased by 50%. Liming significantly affected barley ears number and grain yield four years after dolomite application, but it was achieved only at the highest rate, where the yield increase by 20%. Barley is particularly sensitive to soil acidity and a number of authors reported about positive effects of liming on barley grain yield (Tang et al., 2003.; Kovacevic et al., 2006a). The liming considerably influenced on the increase of soil pH in the experiment (pH in 1nKCl = 4.20 and 6.87, respectively) and elimination of hydrological acidity (Kovacevic et al., 2010). Andric et al. (2012) reported about the effects of liming with the hydrated lime on maize and soybean yields in Croatia. Grain yield of maize by using 20 t ha-1 of lime were increased for 33% and 35%, in 2006 and 2007, respectively, while soybean yield by liming were increased in the third year of testing for 44%. As seen in our study, the maize yields under drought stress conditions of 2007 were considerably lower than in 2006 (7.19 and 9.04 t ha-1, respectively).

Also, ameliorative P fertilization has been found as useful for yield increases but these effects are mainly lower compared to liming. In a four year experiment the effect of ameliorative phosphorus fertilization (triple superphoshate) was examined up to 1750 P2O5 kg ha-1 on maize grain yields and maize nutrient status. P fertilization resulted mainly in considerable yield increase being 17% (4-year means 2005-2008: 4.30 and 5.02 t ha-1, for control and ameliorative P-fertilized treatments, respectively). The yield increases were achieved mainly by application of the first step of P in level of 750 kg P2O5 ha-1, while differences among P treatments were significant only in the second year of testing (Komljenovic et al., 2010). In the previous studies, Komljenović et al. (2006, 2008) applied ameliorative P fertilization up to 1500 kg P2O5 ha-1 on Knespolje soil in the northern Bosnia and reported about maize response for three growing seasons. The yield increased as compared to the control was up to 32% (2004), 17% (2005) and 20% (2006). Under drougth conditions of 2007 the maize yield was even 60% lower than in 2006 (means 3.41 and 7.63 t ha-1, respectively). Kovacevic et al. (2011) applied increasing rates of P and K fertilization and liming with 10 t ha-1 of granulated fertdolomite (24.0 % CaO + 16.0% MgO + 3.0% N + 2.5% P2O5 + 3.0% K2O) on acid soil moderately supplied with plant available phosphorus. As affected by liming yields of soybean were increased for 18 %. Also, grain quality parameters were improved by liming (thousand grain weight were 151.8 and 168.3 g; protein contents were 35.24 and 39.06 %, respectively), while oil contents were decreased (23.84 and 22.62 %, respectively). However, an impact of P and K fertilization was considerably lower in comparison with liming. However, in some studies there was no effect of liming on soybean grain yield, as well as on oil or protein contents (Caires et al., 2006).

5- Conclusions

Both liming and increasing P fertilization could be recommend as useful soil management practice on acid soil characterizing low supplies of plant available P, but these effects were under considerable influences of the growing season characteristics, especially precipitation and temperature regimes.

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Table 1- Weather characteristics for the maize growing seasons.

The weather data (Banja Luka Weather Bureau: LTM = long-term averages 1961-1990)								
	1	2	3	4	5	6	7	
Year	Jan.-April	May	June	July	Aug.	Sept.	Oct.	
	Precipitation (mm)							Sum 2-7
2009	235	49	153	43	138	33	73	489
2010	419	148	235	66	87	196	84	816
2011	153	63	37	113	9	26	62	310
LTM	298	98	111	95	93	82	72	551
	Mean air-temperatures (^oC)							Mean 2-7
2009	6.0	18.9	20.0	23.3	22.8	18.6	11.4	19.2
2010	5.5	16.5	20.3	23.1	21.8	15.7	9.4	17.8
2011	5.9	16.0	21.2	23.1	23.7	20.2	11.0	19.2
LTM	4.9	15.6	18.9	20.6	19.7	15.9	10.8	16.9

* air-distance from the experiment: Banja Luka = about 20 km in S direction.

Table 2- Response of maize (the hybrid NSSK444) on liming and phosphorus fertilization.

Liming (the factor A) by the hydrated lime (A1 = 0, A2 = 10 t ha^{-1}) and phosphorus (P_2O_5 kg ha^{-1}: B1= 0, B2 = 500, B3 = 1000, B4 = 1500) fertilization (the factor B) in autumn 2008									
Phosphorus treatment	The growing season 2009			The growing season 2010			The growing season 2011		
	A1	A2	Mean B	A1	A2	Mean B	A1	A2	Mean B
Grain yield (t ha^{-1})									
B1	7.30	10.07	8.68	7.97	9.92	8.94	4.40	5.53	4.97
B2	7.37	10.65	9.01	8.66	10.28	9.47	4.59	7.19	5.89
B3	7.61	10.66	9.13	9.223	10.24	9.73	4.60	7.09	5.85
B4	7.82	10.60	9.21	8.55	10.17	9.36	4.68	7.06	5.87
x B	7.52	10.49		8.60	10.15		4.57	6.72	
ANOVA	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
P 0.01	1.49	ns	ns	0.59	0.45		0.83	0.47	0.67
Protein contents (%) in grain (ANOVA: non-significant differences)									
B1	9.03	8.80	8.91	9.68	9.50	9.59	12.00	12.05	12.02
B2	9.21	9.11	9.16	9.70	9.55	9.63	11.78	11.83	11.80
B3	9.05	8.90	8.98	9.75	9.42	9.59	11.80	12.10	11.95
B4	9.10	8.75	8.93	10.07	9.82	9.95	11.78	11.98	11.88
x B	9.10	8.89		9.80	9.58		11.84	11.99	
Starch contents (%) in grain									
B1	71.7	71.7	71.7	71.3	71.3	71.3	69.4	69.6	69.5
B2	69.6	71.5	70.5	71.4	71.4	71.4	69.7	69.9	69.8
B3	70.5	71.6	71.0	71.6	71.5	71.5	70.0	69.6	69.8
B4	70.0	71.8	70.9	71.1	71.5	71.3	69.6	69.8	69.7
x B	70.4	71.7		71.3	71.4		69.7	69.7	
ANOVA	A	B	AB	A	B	AB	A	B	AB
P 0.05	0.38	0.55	0.78	ns	ns	ns	ns	ns	ns
Oil contents (%) in grain (ANOVA: non-significant differences)									
B1	4.04	4.10	4.07	3.70	3.75	3.78	3.35	3.52	3.43
B2	4.19	4.20	4.19	3.80	3.82	3.81	3.38	3.40	3.39
B3	4.00	4.10	4.05	3.80	3.80	3.80	3.40	3.48	3.44
B4	4.03	4.03	4.03	3.80	3.80	3.80	3.38	3.40	3.39
x B	4.07	4.11		3.78	3.79		3.38	3.45	
Grain moisture (%) at harvest									
B1	19.2	18.1	18.6	18.8	20.0	19.4	16.6	17.2	16.9
B2	19.8	17.7	18.7	19.3	20.6	19.9	17.3	17.0	17.2
B3	19.3	18.4	18.8	19.1	20.6	19.8	17.6	17.2	17.4
B4	19.4	18.8	19.1	19.6	19.6	19.6	17.1	17.2	17.2
x B	19.4	18.2		19.2	20.2		17.1	17.2	
ANOVA	A	B	AB	A	B	AB	A	B	AB
P 0.05	0.8	ns	ns	0.7	ns	ns	ns	ns	ns
Plant density realization (PDR %: 100% = 57 143 plants ha^{-1})									
PDR %	Mean of the trial		95.7	Mean of the trial		95.5	Mean of the trial		97.3