RESPONSE OF MAIZE TO LIMING AND PHOSPHORUS FERTILIZATION WITH EMPHASIS ON WEATHER PROPERTIES EFFECTS

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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 of Laktasi municipality (Republic of Srpska, Bosnia and Herzegovina). Three doses of P (0, 500, 1000 and 1500 kg P_2O_5 ha^{-1}) on ordinary fertilization were applied. The experiment was conducted in four replicates. Basic plots of liming and P fertilization were 640 m^2 and 40 m^2, respectively. Maize was grown in monoculture. Under drought stress of 2011 and 2012 yields were considerably lower (mean 3.86 t ha^{-1}) than in the remaining two years (mean 9.20 t ha^{-1}). As affected by drought and high air-temperature, particularly in August, the 2012 growing season was especially unfavorable for maize growth because mean yield in the experiment was only 2.06 t ha^{-1} or 22% of yield realized in the 2010 growing season. As affected by liming yield of maize was increased by 31% (4-year mean), while P effect was considerably lower (6.14 and 6.65 t ha^{-1}, for the control and average of ameliorative P treatments, respectively).

Keywords: liming, phosphorus fertilization, maize, grain yield. Lijevce polje area

Introduction

Bosnia and Herzegovina (B&H) has 2.159 million hectares of agricultural area. Arable land covers 1.006 million hectares or about 46% of agricultural land and 0.53 million hectares is covered by temporary crops. Maize and wheat are the most frequently grown field crops on arable land of B&H. Annual harvested area (5-years average 2008-2012) of maize was 194 836 ha and for wheat 61 180 ha and both crops covered close to 50% of temporary crops area (FAO, 2013).

Grain yields of the field crops in B&H (averages 2008-2012) are mainly low (4.24 t ha^{-1} for maize and 3.50 t ha^{-1} for wheat) with considerable differences of yield among the years (from 2.75 to 4.92 t ha^{-1} and from 2.66 to 3.78 t ha^{-1}, for maize and wheat, respectively: FAO, 2013).

Acid reaction and nutritional unbalances, mainly low levels of plant available phosphorus (P) as well as unfavorable physical properties are oft limiting factor of soil fertility in B&H (Okiljevic et al., 1997, Resulovic and Custovic, 2002). These characteristics of soils in combination with very low consumption of mineral fertilizers (19.5 kg ha^{-1} on 1022000 ha: The World Bank, 2012) are main factors of low yields of field crops in B&H.

Aim of this study was testing the maize response to P fertilization and liming in Lijevce Polje area (RS, B&H) with emphasis on the growing season ("year") effects, while response of maize in consecutive four years of testing were shown in two previous studies (Komljenovic et al., 2013, 2015).

Materials and methods

General description of the Lijevce Polje area

Lijevce polje (Lijevce field) is an area in the northern part of B&H, encompassing the Gradiska, Laktasi and Srbac municipalities in the entity of Republic of Srpska (RS). 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

DOI: 10.18380/SZIE.COLUM.2015.1.29.

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).

Description of the field experiment area

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 2012, 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. The experiment was conducted in four replicates (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, weather characteristics, statistical analysis, grain yield, grain moisture, protein-, starch- and oil-determinations, were shown in the previous study (Komljenovic et al., 2013).

Collection of the weather data and calculation of water balance

Statistical Yearbook of RS (SY, 2013), Hydrometerorological Service of RS in Banja Luka (HSRS, 2012) and TuTiempo (2012) and Saric et al., (1996) were the sources of meteorological data. Calculations of potential evapotranspiration (PET), actual evapotranspiration (AEV), water deficit (WD) and WS (water surplus) were made according to Thornthwaite and Mather (1955) and (1957) as follows:

$$PET = 16\left(\frac{10T}{I}\right)^{a} \quad (1)$$

$$I = \sum_{1}^{12} i \quad (2)$$

$$i = \left(\frac{T}{5}\right)^{1.514} \quad (3)$$

$$a = 0.00000075\ x\ I^{3} - 0.0000771\ x\ I^{2} + 0.01792\ x\ I + 0.49239 \quad (4)$$

Where:

- PET = mean monthly potential evapotranspiration (mm)
- T = mean monthly air temperature (ºC)
- I = annual heat index;
- i = monthly heat index

Results and discussion

Average grain yield of maize in the experiment was considerable different among the years, ranging from 2.06 to 9.38 t ha^{-1}. Under drought stress of 2011 and 2012 yields were considerably lower (mean 3.86 t ha^{-1}) than in the remaining two years (mean 9.20 t ha^{-1}). As affected by drought and high air-temperature, particularly in August, the 2012 growing season was especially unfavorable because mean yield in the experiment was only 2.06 t ha^{-1} or 22% of yield realized in the best 2010 growing season (Table 1). Low yield in the experiment was accompanied by a very high contribution (about 50%) of barren plants (Komljenovic et al., 2015) due to drought and high temperatures at flowering stage.

As affected by liming yield of maize was increased by 31% (4-year mean), with considerable differences among years (from 18% in 2010 to 47% in 2011). Ameliorative P fertilization impact on maize yield was considerably lower compared to liming effect because yields were increased in three years

DOI: 10.18380/SZIE.COLUM.2015.1.29.

Table 1. Response of maize to liming and P fertilization

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 (Komljenovic et al., 2013, 2015)												
	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		

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}, 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 1).

Positive effects of either liming or ameliorative P fertilization on yields of field crops in B&H, as well as in the neighboring Croatia, were found by the earlier studies (Kovacevic et al., 2006, 2014; Antunovic, 2008; Markovic et al., 2008; Mesic et al., 2010; Komljenovic et al., 2010; Kovacevic and Rastija, 2010; Andric et al., 2012).

Precipitation quantity and distribution, as well as temperature regime during growing season, considerably affected the yields of crops under field conditions (Shaw, 1988, Kovacevic et al., 2013). With that regard, in our experiment two growing season were favorable for maize growth (2009 and particularly 2010), while remaining two were less favorable, particularly the 2012 growing season (Table 2).

Precipitation in May-September period was in three growing seasons below LTM, while only in 2010 precipitation was close to 50% higher. In accordance with the trend of global warming (Komljenovic et al., 2014), average temperatures in the mentioned period were in all four growing seasons higher than usual, particularly in July and August (Table 2).

The 2009 growing season was characterized in total by moderate and considerable deviations of monthly precipitation compared to usual (LTM). However, majority precipitation was in June-August (335 mm or close to 70% of total precipitation in May-September period) when maize has very high needs for water. Mean air-temperatures in May-Sept. was 19.2°C or 2.3°C higher than usual. July and August were warmer compared to LTM for 2.7°C and 3.1°C, respectively.

The growing season 2010 was especially favorable for maize because of adequate precipitation for maize growth in all stages of development and something lower temperatures.

The growing season 2011 was moderate in precipitation (May-Sept.: 310 mm or only 56% from LTM) with adequate amount only in July and considerable deficit in June, August and September (total 72 mm or only 25% from

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Table 2. Precipitation and air-temperatures in Banja Luka (SY, 2013; HSRS, 2012; TuTiempo 2012)

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)							
2009	235	49	153	44	138	33	73	489
2010	419	148	235	66	87	196	84	816
2011	153	63	37	113	9	26	62	310
2012	244	168	70	53	2	92	88	473
LTM**	298	98	111	95	93	82	72	551
	Mean air-temperatures (°C)							
2009	5.9	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
2012	5.3	16.1	23.0	25.2	24.4	18.9	12.5	20.0
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)			
2009	33	37	38	29.9	25.1	29.5	366.6	326.4	40.2	0.0
2010	34	38	35	27.9	24.9	27.7	361.0	329.1	32.0	119.0
2011	33	37	36	28.4	27.0	30.2	379.6	213.2	166.4	0.0
2012	35	40	37	31.1	28.4	32.6	414.7	219.3	195.3	0.0

* 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)

LTM). Aggravating circumstance was low reserve of water in soil before sowing (153 mm precipitation in Jan.-April or about 50% lower than usual). Water deficit in August in combination with average temperature 4.0°C higher than LTM are the most responsible for low yield of maize in the experiment. The 2012 growing season was very unfavorable for maize growth. Weather in Banja Luka during 2012 was characterized by water deficit in August (2 mm precipitation) accompanied by mean air-temperature of 24.4°C or 3.1°C higher compared to the long-term mean. Also, air-temperature in July was 25.2°C or 3.4°C higher than average. Absolute maximum air-temperature increased to enormous level of 40°C and average maximum temperature to 32.6°C (Table 2). Observing a long-term average for Banja Luka area (2009-2012), the state of soil moisture, PET and AET, for the period June-August, the most evident water surplus was in 2010. On the other hand, in case of deficiency of moisture, as opposed to the year 2010, in the analyzed 2012, there was a very significant deficit of moisture (WD) and significant difference between PET and AET. This led to a very dry period and the lack of moisture in the soil (Table 2).

As affected by these stress conditions, maize was dried at the end of August without green color of leaves.

Maize covers about 26% (status 2012 according FAO, 2013) of arable land in the countries of the region. It is main field crop in Serbia (37.2%), Romania (28.7%), Hungary (26.8%), Croatia (21.5%) and B&H (19.4%). For this reason, unfavorable weather conditions for maize, for example in 2012, are a considerable negative factor for agriculture and economy development in these countries. As affected by unfavorable weather conditions in 2012, yield reduction of maize in the countries of the region compared to normal 2010 was as follows: 53% in Serbia, 49% in Romania, 40% in B&H and 38% in Hungary and Croatia (Kovacevic et al., 2013). Based on FAO (2013), in level of the region covering

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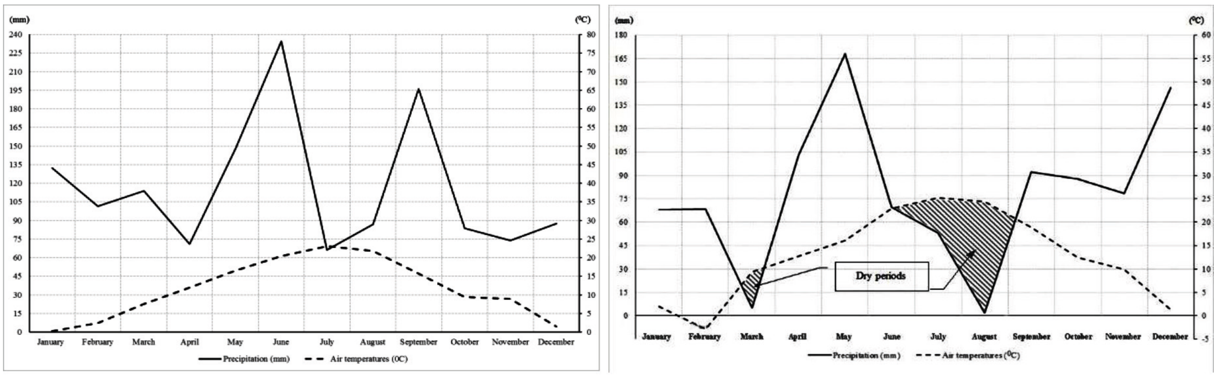
Figure 1. Climate diagram by Walter in Banja Luka for the period 2010 (left) and 2012 (right)



these five countries, maize yield reduction in 2012 was about 47% compared to 2010 (2.89 and 5.41 t ha^{-1}, on the harvested areas 5.21 and 6.14 million ha, respectively).

Based on Walter's climate diagram for Banja Luka area for the two tested periods (2010 and 2012), it can be clearly noted that in 2010 during mid-June to late August there was enough rainfall and even surplus, in contrast to the same period in 2012 with extreme drought, (Fig. 1). This is the most critical period for flowering, fertilization and grain filling of maize. Lack of moisture during this period caused a significant drop in the yield of corn. This suggests that irrigation of cultivated crops, with their growing period coinciding with the mentioned period of the lack of water, becomes necessary in the agricultural production within the area (Komljenovic et al., 2014) Irrigation in the critical periods is a direct management practice for overcoming drought stress in plants (Josipovic et al., 2012). Indirect managements for alleviation of this stress is ploughing for spring crops in autumn/winter period instead in spring together with incorporation of adequate quantities of mineral fertilizers, weed control etc.

Conclusion

In our study, precipitation quantity and temperature regime ("year effects") were the influencing factors on maize yield under environmental conditions of northern Bosnia. The second-ranked tested factor was liming, while P fertilization had mainly moderate impact on yield. Both liming and P fertilization effects were in high interaction with weather characteristics, particularly in two summer months July and August. Irrigation is a direct management practice for overcoming drought stress in arable crops. Also, alleviation of negative effects of drought is possible by adequate soil tillage and adequate fertilization and weed control.

Acknowledgements

The investigations for publication of this study were supported by the project "Agricultural Adaptation to Climate Change" (Networking, Education, Research and Extension in the West Balkans, approved by Norwegian funded Program in Higher Education, and Development, Research (HERD) in the Western Balkan.

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