ISSN 1330-7142
UDK = 633.15:631.811.2:631.445.1(497.6)

RESPONSE OF MAIZE TO PHOSPHORUS FERTILIZATION ON HYDROMORPHIC SOIL OF BOSNIAN POSAVINA AREA

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Original scientific paper
Izvorni znanstveni članak

SUMMARY

In a four year experiment the effect of ameliorative phosphorus (P) fertilization (0, 750, 1250 and 1750 P_2O_5 kg ha^{-1} in the form of triple superphosphate containing 45 % P_2O_5) on maize grain yields and maize nutrient status (the ear-leaf at silking) was examined. 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). Yield increases were achieved mainly by application of the first step of P in level of 750 kg P_2O_5 ha^{-1}, while differences among P treatments were significant only in the second year of testing. P application had significantly influence on P, Mg, Mn and Zn status in maize leaves (0.36 and 0.56% P, 0.61 and 0.77% Mg, 53.3 and 69.2 mg Mn kg^{-1}, 68.0 and 41.1 mg Zn kg^{-1}, for control and 1750 kg P_2O_5 kg ha^{-1}, respectively), while differences in leaf K, Ca, S Fe and Cu were non-significant (means 1.05% K, 0.83% Ca, 0.23% S, 148 mg Fe kg^{-1} and 11.1 mg Cu kg^{-1}). Protein, starch and oil contents in maize grain (2-year means: 8.83%, 72.04% and 3.78%, respectively) were independent on P fertilization.

Key-words: phosphorus fertilization, maize, grain yield, protein, starch, oil, maize leaf nutrients

INTRODUCTION

Acid reaction and nutritional unbalances, mainly low level of plant available phosphorus (P) as well as unfavorable physical properties are limiting factor of soil fertility in Bosnia (Okiljević et al., 1997; Resulović and Čustović, 2002). It is estimated that about 25% of agricultural land of Bosnia and Herzegovina are pseudogley or similar soils (Marković and Supić, 2003).

P as a limiting factor of the field crop yield under conditions of the northwern Bosnia was object of survey article Marković et al. (2006). Liming and increased fertilization (mainly with P) are usually recommendations for these soils improvement (Kovačević et al., 2004, Petosic et al., 2003, Komljenović et al., 2006, 2008). Aim of this study was testing maize response to ameliorative P fertilization on acid hydromorphic soil in Bosnian Posavina (Sava river valley) area.

MATERIAL AND METHODS

The field experiment

The field experiment with increasing rates of P fertilization (0, 750, 1250 and 1750 $_2O_5$ kg ha^{-1}) was conducted on April 14, 2005 on Catrnja (Gradiska municipality, Republic of Srpska, Bosnia and Herzegovina) hydromorhic soil (small family farm). These amounts of P were added to the earlier applied fertilization (60 N + 60 P_2O_5 + 60 K_2O kg ha^{-1}). Triple superphoshate (45 % P_2O_5) was used as source of P. The trial was conducted in a randomized block design with four replicates (basic experimental plot 7.0 x 8.5 m = 59.5 m^{-2}). Maize (hybrid NS444 – creation of Novi Sad Scientific Institute for Field and Vegetable Crops, Serbia) was sown in the first half of May (row distance 28.0 cm; interrow spacing 70 cm = theoretical density or TD = 51021 plants ha^{-1}). Maize was harvested manually (4 internal rows from each basic plot). Mass of cob was weighed by Kern electronic balance (d=200 g). Ten cobs from each treatments were used for determination of grain moisture and grain share in cob weighing by Kern electronic balance, d = 100g). Grain moisture was determined by electronic grain moisture instrument

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(WILE-55, Agroelectronics, Finland). Grain yields were calculated on the realized plant density and 14% grain moisture basis. In the period 2006-2008 the trial was fertilized uniformly at ordinary level and residual effects of ameliorative P fertilization were tested.

Sampling and chemical and statistical analysis

Mean soil sample was taken by auger to 30 cm of depth at the end of March 2005. Nutritional status of soil was made by extractions with AL-solution (Egner et al., 1960). The ear-leaf (25 leaves in mean sample) was taken at the beginning of silking stage (middle of July 2005). Grain samples were taken at maturity stage by choosing five cobs from each basic plot. The total amount of individual elements in maize leaves was 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 (RISSAC) Budapest. Oil content in the grain was determined by nuclear magnetic resonance (NMR) spectroscopy method. Protein and starch content in grain was determined by Near Infrared spectroscopic method on Foss Tecator ("Infratec 1241 Grain Analyzer"). 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 characteristics

Gradiska hydromorhic soil is characterized by very acid reaction (pH in 1n KCl less than 4.5), very low level less than 5 mg P_2O_5 100g^{-1} of plant available P and low level of plant available potassium (less than 10 mg K_2O 100 g^{-1}) – Table 1.

Table 1. Soil characteristics at the beginning of the experiment (April, 2005)

Tablica 1. Svojstva tla na početku eksperimenta (travanj 2005.)

Soil depth *Dubina tla*	Soil pH *pH tla*		Org. Matter *Org. tvar*	Mobile fraction (AL-method : mg 100 g $^{-1}$) *Mobilna frakcija (AL-metoda: mg 100 g $^{-1}$)*	
(cm)	H_2O	KCl	(%)	P_2O_5	K_2O
0-30	5.35	4.41	2.06	2.0	9.1

Weather characteristics

The growing seasons 2005, 2006 and 2008 were mainly favourable because precipitation was adequate for maize need, while drought stress was main weather characteristic of the 2007 growing season (Table 2). Higher frequency of drought stress and higher air-temperatures are general trend of climatic changes in recent period. For example, in tested four maize growing seasons 2005-2008, three years were characterized by lower precipitation and higher air-temperatures in comparison with the long term mean (LTM). With that regards, the most unfavorable weather characteristics were in the 2007 growing season. In the critical period of maize need for water (July and August) precipitation amount in 2007 was 60 mm i.e. 44% in comparison with LTM (136 mm), while precipitation in May-August period was178 mm or 35% lower than LTM (276 mm). At the same time, air-temperatures were higher (24.0 and 22.4 ^oC, respectively) in comparison with LTM (21.7 and 20.3 ^oC, respectively). Under these stress conditions mean maize yield in the experiment was only 3.93 t ha^{-1} i.e. 23 % lower than mean yield in three remaining years (Table 3). Global climatic changes and their impact on field crops growing have been discussed in the recent studies (Mikulec and Stehlova, 2006; Balla et al., 2006; Stekauerova and Nagy, 2007).

Table 2. Precipitation and mean air-temperature for the maize growing seasons (Gradiska, RS, BiH)

Tablica 2. Oborine i srednje temperature zraka tijekom vegetacije (Gradiška, RS, BiH)

The data of Hydrometeorological Institute in Banja Luka: Gradiska* Weather Bureau *Podaci Hidrometeorološkog zavoda u Banjoj Luci: meteorološka postaja Gradiška*												
Year	Precipitation (mm) / *Oborine* (mm)						Mean air-temp. (^oC) / *Prosječne temp. zraka (^oC)*					
God.	May *Svib.*	June *Lip.*	July *Srp.*	Aug. *Kol.*	Sept. *Rujan*	Σ	May *Svib.*	June *Lip.*	July *Srp.*	Aug. *Kol.*	Sept. *Rujan*	$\bar{X}$
	The 2005-2008 growing seasons *Vegetacije 2005.-2008.*						The 2005-2008 growing seasons *Vegetacije 2005.-2008.*					
2005	58	39	61	140	68	366	16.9	19.1	21.9	19.5	16.6	18.8
2006	64	67	23	134	35	323	16.1	20.6	23.8	19.8	17.9	19.6
2007	54	63	15	46	111	289	18.6	23.0	24.7	23.2	15.5	21.0
2008	37	77	45	17	59	235	18.8	22.2	22.9	23.0	16.1	20.6
	Long-term (LTM) means (1931-2005) *Višegodišnji (LTM) prosjeci (1931.-2005.)*						Long-term (LTM) means (1931-2005) *Višegodišnji (LTM) prosjeci (1931.-2005.)*					
LTM	72	68	57	79	77	353	17.5	20.3	22.4	20.9	16.5	19.5

* Gradiska = 5 km from the experiment in E-direction / * *Gradiška = 5 km od eksperimenta prema istoku*

RESULTS AND DISCUSSION

In general, low maize yields were achieved in the experiment (4-year mean 4.84 t ha^{-1}), mainly as a result of low plant density realization (mean 74.7 %). Reason for the poor density could be low quality of sowing (differences of sowing deep) due to inadequate soil preparing by tillage as a result of unfavorable soil characteristics and inadequate agricultural machinery on the small farms in t he northern Bosnia. Phosphorus fertilization resulted mainly in considerable yield increase being 17% (4-year means: 4.30 and 5.02 t ha^{-1}, for control and ameliorative P-fertilized treatments, respectively). Yield increases were achieved mainly by application of the P at the level of 750 kg P_2O_5 ha^{-1}, while differences among P treatments were significant only in the second year of testing (Table 3). Also, significant P fertilization impact on grain moisture was found only in the 2006 growing season because the highest P rate resulted in 4.6% reduction of grain moisture (26.9 and 22.3 %, for the control and 1750 kg kg P_2O_5 ha^{-1}, respectively). Weather characteristics are important factors of maize yields. In general, water shortage, especially in July, is in connection with low maize yields (Josipovic et al., 2005; Kovačević et al., 2005). Our results are in agreements with these observations.

Protein, starch and oil contents in maize grain (2-year means: 8.83%, 72.04% and 3.78%, respectively) were independent on applied P fertilization (Table 4).

Appraisal of the nutrient status of the ear-leaf of maize at the silking stage was used (cit. Mengel and Kirkby, 2001) for the data interpretation according to Christensen. It is as follows (on dry matter basis): from 0.2 to 0.5 % P, from 0.2 to 1.0% Ca and Mg, from 1.5 to 3.0% K; from 20 to 200 mg Mn kg^{-1}, from 6 to 50 mg Cu kg^{-1}; from 10 to 300 mg Fe kg^{-1} and from 20 to 70 mg Zn kg^{-1}. Similar ranges were reported by Bergmann (1992). According these criteria, low leaf-K was found (in range close to acute K-deficiency: less than 1.0%), while the other tested elements were in adequate ranges.

P fertilization had significant influence on P, Mg, Mn and Zn status in maize leaves, while differences in leaf K, Ca, S Fe and Cu were in ranges of statistical errors. Affected by P fertilization nutrient concentrations in leaves increased compared to the control by 56% (phosphorus), 27% (magnesium) and 30% (manganese), respectively. At the same time, leaf zinc decreased to the level of 40% (Table 5). Considerable influence of P fertilization on Zn status in maize plants was found by Kovačević et al. (2007).

Table 3. Response of maize to ameliorative phosphorus fertilization on Gradiska hydromorphic soil (RS, Bosnia and Herzegovina)

Tablica 3. Reakcija kukuruza na melioracijsku gnojidbu fosoforom na hidromorfnom tlu kod Gradiške (RS, BiH)

Fertilization* *Gnojidba** (April 8, 2005) *(Travanj 8, 2005.)*		Maize properties (NSSK444 hybrid): plant density or PD (TD=theoretical PD = 100% PD = 51102 plants ha^{-1}), grain moisture at harvest (GM) and grain yield (GY) on 14% GM and realized PD) *Svojstva kukuruza (hibrid NSSK444): sklop ili PD (TD=teoretski sklop =100% PD = 51102 biljaka ha^{-1}), vlaga zrna u berbi (GM) i prinos zrna (na bazi 14% vlage i ostvareni sklop)*							
	P_2O_5 (kg/ha)	PD		GM (%)	GY (t ha^{-1})	PD		GM	GY
		plants ha^{-1} *biljaka ha^{-1}*	% TD			plants ha^{-1} *biljaka ha^{-1}*	% TD	(%)	(t ha^{-1})
		The 2005 growing season *Vegetacija 2005.*				The 2006 growing season (residual effects) *Vegetacija 2006.(naknadni učinci)*			
a	0	43776	85.8	30.1	4.57	31442	61.6	26.9	4.62
b	750	45850	89.9	29.4	5.02	32130	63.0	26.1	5.46
c	1250	44001	86.2	30.5	5.05	31671	62.1	22.6	6.34
d	1750	42237	82.8	30.6	5.12	33048	64.8	22.3	5.47
			LSD 5%	ns	0.43		LSD 5%	2.0	0.41
			LSD 1%		ns		LSD 1%	2.6	0.60
Average / *prosjek*		43966	86.2	30.2	4.94	32073	62.9	24.5	5.47
		The 2007 growing season (residual effects) *Vegetacija 2007.(naknadni učinci)*				The 2008 growing season (residual effects) *Vegetacija 2008.(naknadni učinci)*			
a	0	38331	75.1	21.8	3.18	36990	72.5	24.8	4.84
b	750	39898	78.2	21.8	4.02	36060	70.7	24.3	4.98
c	1250	40205	78.8	20.6	4.12	36519	71.6	24.4	5.04
d	1750	41315	80.1	21.1	4.38	36749	72.0	24.3	5.22
			LSD 5%	ns	0.55		LSD 5%	ns	0.35
			LSD 1%		0.79		LSD 1%		ns
Average / *prosjek*		39937	78.0	21.3	3.93	36580	71.7	24.4	5.02

* treatments from *a* to *d* on ordinary fertilization (160 N + 60 P_2O_5 + 60 K_2O kg ha^{-1})

* *tretmani od a do d na standardnu gnojidbu (160 N + 60 P_2O_5 + 60 K_2O* kg ha^{-1}*)*

Table 4. Protein, starch and oil contents in maize grain

Tablica 4. Sadržaj bjelančevina, škroba i ulja u zrnu kukuruza

Fertilization / *Gnojidba* April 2005 / *Travanj 2005.*		Parameters of maize grain quality: protein, starch and oil contents *Parametri kvalitete zrna kukuruza: sadržaj bjelančevina, škroba i ulja*					
	P_2O_5 (kg/ha)	Protein *Bjelančevine* (%)	Starch *Škrob* (%)	Oil *Ulje* (%)	Protein *Bjelančevine* (%)	Starch *Škrob* (%)	Oil *Ulje* (%)
		The 2005 growing season *Vegetacija 2005.*			The 2006 growing season *Vegetacija 2006.*		
a	0	8.53	72.43	3.60	8.93	71.83	3.77
b	750	8.93	71.90	3.83	8.93	72.07	3.63
c	1250	8.73	71.93	3.83	8.93	72.03	3.73
d	1750	8.33	72.50	3.87	9.30	71.57	3.93
	LSD 5%	ns	ns	ns	ns	ns	ns
Average / *Prosjek*		8.63	72.19	3.78	9.02	71.89	3.77

Very low level of plant available P was found (less than 5.0 mg P_2O_5 $100g^{-1}$) by soil test and it was the main reason for conducting of P fertilization experiment on the soil. However, leaf P in maize was in normal range (from 0.2 to 0.5 %). For this reason AL-method suitability for estimation of P nutritional status for this soil type is questionable. Regarding this, results of our study are in agreement with the earlier experiences under similar agroecological conditions in Croatia (Banaj et al., 2006; Kovačević et al., 2008; Rastija et al., 2006).

Komljenović et al. (2006, 2008) applied ameliorative P fertilization up to 1500 kg P_2O_5 ha^{-1} on Knespolje soil in the northern Bosnia. The yield increased compared to the control was up to 32% (2004), 17% (2005) and 20% (2006). However, under drought stress conditions in 2007 effects of P fertilization were not found. Also, under drougth conditions of 2007 maize yield was even 60% lower than in 2006 (means 3.41 and 7.63 t ha^{-1}, respectively).

Rastija et al. (2006) applied four rates of NPK 10:30:20 up to 3748 kg ha^{-1} for maize –soybean rotation. Yield increases were up to 14% and up to 32%, for maize and soybean, respectively. However, Banaj et al. (2006) and Loncaric et al. (2005) reported low effects of ameliorative P rates on maize yields, although moderate levels of available P were found by previous soil test (AL-method).

Table 5. Influences of P fertilization on nutritional status of maize

Tablica 5. Utjecaj gnojidbe fosforom na stanje mineralne ishrane kukuruza

Fertilization* / *Gnojidba** P_2O_5 kg ha^{-1}	The ear-leaf of maize at silking stage of the 2005 growing season (on dry matter basis) *List ispod klipa kukuruza u svilanju vegetacije 2005. (na bazi suhe tvari).*								
	Percent / *Postotak*					mg kg^{-1}			
	P	K	Ca	Mg	S	Mn	Zn	Fe	Cu
0	0.359	1.09	0.77	0.606	0.22	53.3	68.0	143	12.2
750	0.458	1.04	0.83	0.708	0.22	52.4	49.8	154	11.9
1250	0.553	1.05	0.93	0.783	0.23	59.3	51.9	155	10.7
1750	0.559	1.00	0.80	0.771	0.23	69.2	41.1	142	9.7
Average / *Prosjek*	0.483	1.05	0.83	0.717	0.23	58.6	52.7	148	11.1
LSD 5%	0.09	n.s.	n.s.	0.013	n.s.	13.0	15.0	n.s.	n.s.

CONCLUSION

Under conditions of hydromorfic soil in Bosnian Posavina area, low yields of maize were found. P fertilization had mainly considerable influences on maize yields because they increased average by 17% for four year of testing. Depending on the growing season, yield increases due to P application, were from 8 to 38%. AL-method is not suitable for prediction of soil P status from plant nutrition aspect because leaf P was in normal range under very low soil P conditions. P fertilization also affected Mg, Mn and Zn leaf status. However, protein, starch oil in maize grain were independent on P fertilization.

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REAKCIJA KUKURUZA NA GNOJIDBU FOSFOROM NA HIDROMORFNOME TLU BOSANSKE POSAVINE

SAŽETAK

Istraživan je utjecaj melioracijske gnojidbe fosforom (0, 750, 1250 i 1750 P_2O_5 kg ha^{-1} u obliku trostrukoga superfosfata 45% P_2O_5) na prinose i stanje ishrane kukuruza (list ispod klipa u svilanju). Gnojidba fosforom povećala je prinose kukuruza u prosjeku za 17% (4-g prosjek 2005.-2008.: 4.30 i 5.02 t ha^{-1}, na kontroli i na tretmanima gnojidbe fosforom). Povećanje prinosa uslijedilo je već primjenom 750 kg P_2O_5 ha^{-1}, a statistički značajne razlike između pojedinih stepenica dodanoga P bile su evidentne samo u 2006. godini. Melioracijska gnojidba fosforom značajno je utjecala na koncentracije P, Mg, Mn i Zn u listu (0,36 i 0,56% P; 0,61 i 0,77% Mg; 53,3 i 69,2 mg Mn kg^{-1}; 68,0 i 41,1 mg Zn kg^{-1} za kontrolu, odnosno 1750 kg P_2O_5 kg ha^{-1}), dok su koncentracije K, Ca, S, Fe i Cu bile slične (prosjeci 1,05% K, 0,83% Ca, 0,23% S, 148 mg Fe kg^{-1} i 11.1 mg Cu kg^{-1}). Sadržaj bjelančevina, škroba i ulja u zrnu (2-god. prosjeci: 8,83%, 72,04%, odnosno 3,78%) bili su neovisni o gnojidbi fosforom.

Ključne riječi: gnojidba fosforom, kukuruz, prinos zrna, bjelančevine, škrob, ulje, hraniva u listu

(Received on 15 October 2010; accepted on 13 November 2010 - *Primljeno 15. listopada 2010.; prihvaćeno 13. studenoga 2010.*)