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Response of Field Crops to Ameliorative Phosphorus Fertilization

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Abstract

Different types of nutritional unbalances, including also low levels of plant available phosphorus (P), are often limiting factor of soil fertility in Croatia and in countries of the region, particularly in Bosnia and Herzegovina (B&H). Aim of this study was survey our recent investigations (eight stationary field experiments) of maize, soybean, wheat and barley responses to ameliorative P fertilization up to different levels (depending on the trial up to from 825 to 1580 kg P_2O_5 ha^{-1}). Either MAP (monammonium phosphate: 12% N + 52% P_2O_5) or triplephosphate (45% P_2O_5) were used as source of P. Selection of soil was made based on the previous soil test. In spite of low levels of available P (ammonium lactate method: below 10 mg P_2O_5 100 g^{-1} of soil), response of the field crops to applied fertilization in four experiments in Croatia was mainly moderate or without significant differences. However, in B&H by using the rate of 1580 kg P_2O_5 ha^{-1} maize yields were increased depending on year in municipality Kozarska Dubica from 16 to 40%, Gradiska from 8 to 38%, and in Laktasi from 6 to 18% Also, by using 975 kg P_2O_5 ha^{-1} soybean yield in Odzak municipality was increased for 20%. In general, year effect (weather characteristics) was the most influencing factor of yields in our investigations. We presume that ammonium-lactate method is not suitable as criterion of P supplies in all tested soils. From other side, majority of tested soils have additional soil fertility limitations as low pH or unfavorable physical properties.

Key words: phosphorus fertilization, grain yield, maize, wheat, soybean, barley

Introduction

Nutrient uptake is influenced by soil, climate and plant factors. Low natural phosphorus (P) level are main reasons of P deficiency in some soils. Different types of nutritional unbalances, including also low levels of plant available P, are limiting factor of some soils fertility in Croatia and in countries of the region, particularly in Bosnia and Herzegovina (B&H) and soil improvement by correspondingly fertilization could overcome soil fertility limitations and result in field crop yield increase under these conditions (Okiljevic et al., 1997; Petosic et al., 2003; Markovic and Supic, 2003; Markovic et al., 2006).

Phosphorus availability is in different levels limiting factor of soil fertility. P deficiency is oft in close connection with soil acidity. Acid soils occupy nearly 30% (3.95 billion ha) of the arable land area both tropical and template belts of the world (Matsumoto et al., 2004). The Brazilian *Cerrado* or savanna covering approximately 205 million hectares of land. The soils of this area are mostly good physical properties, but highly leached nutrients, acidic with toxic levels of soluble aluminum or manganese and low in phosphorus mainly as affected by fixation (Borlaug and Dowswell, 1997). Fageria and Baligar (2006) recommend management practices in the Brazilian savanna to improve P use efficiency of crops as for example correction of acid soil pH by liming, method and rates of fertilizer application, water management and the use of high yielding or nutrient more efficient cultivars. Omenyo et al. (2010) reported that sub-Saharan Africa region continues to experience with food insecurity due to soil acidity and nutrient depletion including low P supplies and application of P fertilizers had positive effects on crop yield in western Kenya. Kadar et al. (2010) found negative balance of phosphorus in Hungarian agriculture in the period 1991-2000 for

16% partially as result of low rates of fertilizer application.

Aim of this study was survey our recent investigations regarding ameliorative P fertilization effects on field crops yield in Croatia and B&H.

Material and methods

The field experiments and statistical analysis

Eight stationary field trials (the experiments from A to H) of ameliorative fertilization with phosphorus (Tables 2 – 6) and potassium, alone or in their combination, were started in the period 2003-2011 in Croatia and Bosnia and Herzegovina. Monoammonium phosphate (MAP: 12% N +52% P_2O_5) was used as source of phosphorus for ameliorative fertilization with exception of the experiments C, D and E (triplephosphate: 45% P_2O_5). Increasing rates of P fertilizers were added to ordinary fertilization. In the next years subsequent effects were tested and the experiments were fertilized in range of ordinary fertilization only. The experiments were conducted in four replicates. Sizes of basic plots were, depending on the trial, from 32 to 92 m^2.

Data were statistically analysed by ANOVA and treatment means were compared using t-test and at 0.05 probability level (P 0.05).

The experiments have been situated in Bjelovar-Bilogora County (A and C: localities Maslenjaca and Pavlovac, respectively), Pozega-Slavonia County (B: locality Badljevina) in Croatia, municipalities Kozarska Dubica (D: locality Brekinja), Gradiska (E: locality Catrnja) and Laktasi (F: locality Mahovljani) in Republic of Srpska entity (B&H) and municipality Odzak in Posavina Canton, (G and H: Trnjak andVojskova, respecively) in Federation entity (B&H). Five experiments situating in B&H (from D to H) are result of international colaboration of Faculty of Agriculture, Universty J. J. Strossmayer in Osijek (Croatia) with Faculty of Agriculture,University of Banja Luka (RS, B&H) and Faculty of Tecnology, University of Tuzla (FB&H, B&H). In this study, P fertilization treatments were selected for review of field crops response (grain yield) to phosphorus fertilization, while the other results of individual experiments, soil nad weather characteristics and methods of experimentations, were in detail elaborated in the original studies (Antunovic et al., 2012; Jovic et al., 2013; Komljenovic et al., 2005, 2006, 2008, 2010, 2013; Kovacevic et al., 2007, 2008, 2009a, 2009b, 2010, 2011; Loncaric et al., 2005; Rastija et al., 2014; Seput et al 2008; Stojic et al., 2012).

Soil pH and plant available phosphorus status at starting of the experiments: Selection of soils for the field experiments wre made based on the previous soil test and main criterion was level of plant available phosphorus determnied by AL-method (Egner et al., 1960). The levels below 10 mg P_2O_5 100 g^{-1} of soils characaterizing low supplies

Table 1. General data for the field experiments

	Designation of the experiment							
	A	B	C	D	E	F	G	H
	Starting of the experiment							
Country	Croatia				Bosnia & Herzegovina			
Spring of year	2003	2003	2004	2004	2005	2009	2011	2011
	Soil characteristics (0-30 cm depth) before starting of the trials							
pH(1n KCl)	6.48	4.30	3.67	6.84	4.41	4.28	7.06	7.95
Phosphorus*	7.60	4.50	8.40	2.20	2.00	2.91	5.40	5.90

* mg P_2O_5 100 g^{-1} of soil (AL-method: Egner et al., 1960)

Results and discussion

In general, year effect (mainly weather characteristics) was the most influencing factor of maize and other field crops yield in our investigations. In spite of low levels of plant available phosphorus (below 10 mg P_2O_5 100 g^{-1} of soil) determined by the AL-method (Table 1), response of field crops to ameliorative P fertilization was mainly moderate or without significant response. We presume that AL-method is not suitable as reliable criterion of P supplies for all tested soils. From other side, majority of these soils have soil fertility limitations as low pH or unfavorable physical properties which is not eliminated by phosphorus fertilization.

By using the highest rate of P in the experiment A grain yield of maize was increased for 10% (4-year mean). However, in the experiment B non-significant differences of yield were found in three years, while in one year yield were increased for 9% by using the highest P rate (Table 2).

Table 2. Response of maize to ameliorative fertilization (the experiments A and B)

Impact of P fertilization (MAP: 12% N + 52% P_2O_5) in spring 2003 (the experiment A and B) on the field crops (M = maize, W = winter wheat, B = winter barley) yield

The experiment A (Kovacevic et al., 2008)					The experiment B (Loncaric et al., 2005; Kovacevic et al., 2008)						
P_2O_5	Year				P_2O_5	Year					
kg ha^{-1}	2003	2004	2005	2006	kg ha^{-1}	2003	2004	2005	2006	2007	2008
	M	M	M	M		M	M	W	M	B	M
	Grain yield (t ha^{-1})					Grain yield (t ha^{-1})					
125	7.37	13.33	10.71	8.70	150	9.77	11.95	6.14	9.47	6.19	12.24
375	7.44	13.33	11.11	9.66	650	10.12	11.85	6.58	10.09	6.47	12.46
625	7.57	13.70	11.09	9.64	1150	9.92	11.91	6.41	10.36	6.59	12.61
825	8.07	13.76	12.23	10.10							
P 0.05	0.46	ns	0.82	0.77	P 0.05	ns	ns	ns	0.64	ns	ns

Table 3. Response of field crops to phosphorus fertilization (the experiment C)

Impact of P fertilization (triplephosphate: 45% P_2O_5) in spring 2004 on grain yield of maize, soybean and winter wheat (Kovacevic et al., 2011; Stojic et al., 2012)

	The growing season							
P_2O_5	2004	2005	2006	2007	2008	2009	2010	2011
kg ha^{-1}	Maize	Soyb.	Maize	Wheat	Maize	Maize	Soyb.	Maize
	Grain yield (t ha^{-1})							
60	12.28	3.66	10.37	5.08	10.93	9.00	3.40	7.58
560	12.67	3.58	10.55	5.59	11.11	9.20	3.50	8.00
1060	12.62	3.47	10.84	5.60	11.30	9.74	3.55	8.42
1560	12.65	4.36	10.45	5.73	11.91	10.15	3.75	8.62
P 0.05	ns	0.37	ns	0.44	0.50	0.49	ns	1.02

Table 4. Response of maize to phosphorus fertilization the experiments D and E)

Response of maize to P fertilization (the experiments D and E)

The experiment D (Komljenovic et al., 2005, 2006, 2008)					The experiment E (Komljenovic et al., 2010)				
P_2O_5	The growing season				P_2O_5	The growing season			
kg ha^{-1}	2004	2005	2006	2007	kg ha^{-1}	2005	2006	2007	2008
	Grain yield of maize (t ha^{-1})					Grain yield of maize (t ha^{-1})			
80	7.90	7.27	7.34	3.33	60	4.57	4.62	3.18	4.82
580	9.18	8.53	9.73	3.33	810	5.02	5.46	4.02	4.98
1080	9.85	8.38	10.26	3.44	1310	5.05	6.32	4.12	5.04
1580	10.40	8.42	9.81	3.55	1810	5.12	5.47	4.38	5.22
P 0.05	0.37	0.29	0.70	ns	P 0.05	0.43	0.41	0.55	0.35

Table 5 . Response of field crops (M = maize, W = winter wheat, S = soybean) to phosphorus fertilization: the experiments F (Komljenovic et al., 2013), G (Antunovic et al. 2012; Rastija et al., 2014) and H (Jovic et al., 2013)

The experiment F				The experiment G			The experiment H	
	Year				Year			Year
P_2O_5	2009	2010	2011	P_2O_5	2011	2012	P_2O_5	2011
kg ha^{-1}	M	M	M	kg ha^{-1}	S	W	kg ha^{-1}	M
	Grain yield (t ha^{-1})				Grain yield (t ha^{-1})			(t ha^{-1})
75	8.68	8.44	4.97	75	2.11	6.21	0	7.34
575	9.01	9.47	5.89	225	2.45	6.90	75	10.76
1075	9.13	9.73	5.85	375	2.53	6.81	275	11.25
1575	9.21	9.36	5.87	525	2.36	6.94	475	10.94
				975	975	7.04	875	11.61
							1275	10.58
P 0.05	0.43	0.33	0.49	P 0.05	0.24	0.54	P 0.05	1.00

Winter wheat and winter barley were grown each crop in one growing season and the yield differences were in range of statistical error (Table 2).

Maize in the experiment C was grown five years and significant differences of yields were found in three years: by using the highest P rate yield was increased for 12 % (3-year mean). Soybean was grown two years on the experiment C and significant differences of yield (increases up to 19%) were found, while yield of wheat was increased up to 12% as affected by P fertilization (Table 3).

In general, response of maize to P fertilization in the experiments situating in B&H (D, E and F) were the better (Tables 4 and 5) compared to those in Croatia (A, B and C) probably because of very low supplies of plant available P in the soil (Table 1). For example, as affected by P fertilization grain yield of maize was significantly increased for 27% in the experiment D (3-year average), while under drought stress of 2007 yields of maize were considerably lower and non-significant differences were found. Increases of maize yields in the experiment E (4-year means) were up to 19% (Table 4).

Maize was grown three growing season in the experiment F (Table 5) and responded to P fertilization by yield increases up to 12% (3-year mean). In the experiment G, grain yield of soybean and wheat were increased for 20% and 12%, respectively (Table 5).
Non-significant differences of maize yields among P fertilized treatments (mean 11.03 t/ha) were found in the experiment H, but yield under non-fertilized conditions were for 33% lower (Table 5).

Conclusions

Low levels of plant available phosphorus, are often limiting factor of soil fertility in Croatia and in countries of the region, particularly in Bosnia and Herzegovina. However, applications of the ameliorative rates of phosphorus fertilizers (monoammonium phosphate and triplephosphate) mainly resulted by moderate increases of field crops yield. In the future investigations could be made testing of different types of soil extractions for prediction of plant available soil P status because of ammonium-lactate method is not suitable as criterion of P supplies in all tested soils. Also, improvement of acid soils by liming is needed for more efficiency of applied P fertilizers.

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