

INFLUENCES OF FERTILIZATION BY PHOSPHORUS ON YIELD AND NUTRITIONAL STATUS OF MAIZE IN POTKOZARJE AREA

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Abstract

The field experiment with four rates of phosphorus (P) fertilization was conducted in spring of 2004 with treatments as follows: a) ordinary fertilization (kg/ha: 200 N + 80 P₂O₅ + 120 K₂O); b) a + 500 kg P₂O₅; c) a + 1000 kg P₂O₅; and d) a + 1500 kg P₂O₅. The triplephosphate enriched with sulphur and zinc (45% P₂O₅ + 1,2% S + 0,06% Zn) was used as a source of P. Maize (Bc5984 and OsSK494 hybrids, for the growing season 2004 and 2005, respectively) was grown on the experimental plot. P fertilization significantly influenced on decreases of the leaf Mg by 38%, Mn by 30%, Zn by 48% and Mo by 53% compared to the control (mg kg⁻¹ on the control: 1526 Mg, 44.3 Mn, 45.2 Zn, 2.62 Mo) and increases of the leaf Sr by 31% and Cd by 84% (mg kg⁻¹ on the control: 62.3 Sr and 0.25 Cd), while differences of the remaining measurable elements (P, K, S, Fe, Cu, Ni, Cr, B, Ba, Na, and Al) were non-significant. Also, the leaf As, Hg and Se concentrations were under detectable levels of the method. In general, grain composition was less dependent on the fertilization in comparison with the leaf composition. For the 2005 growing season, only ordinary fertilization was applied. As affected by applied fertilization maize grain yields increased up to 32% and 17% compared to the control, for 2004 and 2005, respectively.

Key words: maize, phosphorus fertilization, yield, leaf, grain, nutritional status

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 under conditions of northern Bosnia (Okiljević et al. 1997, Todorovic et al. 2003). Liming and increased fertilization (mainly with P) are usually recommendations for improvement of pseudogley soils (Kovacevic et al. 1993, 2004a, Petosic 2003). Aim of this study was testing of maize response to P fertilization on soil of moderate fertility in the northern Bosnia.

Material and methods

The field experiment

The experimental field is situated in Potkozarje area (Knespolje, Brekinja village near Medjuvodje in the municipality Kozarska Dubica, Republic of Srpska, Bosnia and Herzegovina). The field experiment with four rates of P fertilizers was conducted in term of May 7, 2004 with treatments as follows: a) ordinary fertilization (kg/ha: 200 N + 80 P₂O₅ + 120 K₂O); b) a + 500 kg P₂O₅; c) a + 1000 kg P₂O₅; and d) a + 1500 kg P₂O₅. For ordinary fertilization, KAN (calcium ammonium nitrate enriched with Mg: 27% N + 4.8% Mg) and NPK 7:20:30 were applied. These fertilizers were produced in Petrokemija Fertilizer Factory Kutina, Croatia. The triplephosphate enriched with sulphur and zinc (45% P₂O₅ + 1,2% S + 0,06% Zn) was used for increased P fertilization. It is produced as DC-Triplephoshat (original protected name) in Donau Chemie AG Werk Pischelsdorf 3435 Zwentendorf, Austria.

The experiment contains four plots, each of 31.5 m² area (9.0 m x 3.5 m) with five rows of maize. Maize (hybrid Bc5984 of Bc-Plant Breeding Institute in Zagreb, Croatia) was sown

manually in term May 8, 2004 (theoretical plant density 63493 plants/ha). In the second year (2005), residual effects of P fertilization were tested and the experiment fertilized uniformly (kg ha^{-1} : 200 N + 80 P_2O_5 + 120 K_2O). Maize hybrid OsSK494 (developed in Osijek Agricultural Institute, Croatia) was sown in term April 20, 2005 by pneumatic sowing machine on the theoretical plant density (TPD) 54945 plants ha^{-1} . Under influences of bird damages, realized plant density was considerably reduced. Yields were calculated on 85% and 65% TPD (for 2004 and 2005, respectively) and 14% grain moisture basis.

Sampling, chemical and statistical analyses

The ear-leaf of maize was taken at beginning of silking (August 2, 2004; 25 leaves in the mean sample) from each experimental plot. The soil samples were taken after maize harvesting (October, 2004). At the same time soil sample was taken from the control by auger to 30 cm of depth (15 individual sampling in the mean sample). The total amount of the elements in the leaf samples was measured by the ICP-AES technique after their microwave digestion using concentrated $\text{HNO}_3 + \text{H}_2\text{O}_2$. Mobile fraction of the elements in soil was also determined by ICP-AES after their extraction by ammonium acetate-EDTA (pH 4.65) solution by Lakanen and Ervio method (1971). Oil content in the grain was determined by nuclear magnetic resonance (NMR) spectroscopy method, while protein and starch contents were determined by Near Infrared spectroscopic method on Foss Tecator ("Infratec 1241 Grain Analyzer"). Statistical analyses were made according Mead et al. (1996).

Weather characteristics

Precipitation quantities and air-temperatures in the 6-month period April-September were higher in comparison with the long-term mean (Table 1). In general, the low yields of maize are in close connection with water deficit and the higher air-temperatures, especially during July and August (Kovacevic et al., 2005; Josipovic et al., 2005).

Table 1. Meteorological data (Sisak Weather Bureau) for 2005 and long-term means (LTM)

The period	Precipitation and mean air-temperatures in Sisak*							Total	Mean
		April	May	June	July	Aug.	Sept.		
2004	mm	152	65	120	45	61	115	558	17.4
	°C	11.8	15.0	19.3	21.3	21.1	15.7		
2005	mm	65	76	32	104	182	84	543	17.7
	°C	11.7	16.7	20.1	21.7	19.0	16.9		
LTM (1961-1990)	mm	73	91	91	77	85	76	484	17.1
	°C	11.2	19.1	19.1	20.8	19.8	16.0		

* Sisak (Croatia) is air-distanced about 40 km from Medjugorje in the NW- direction

Results and discussion

P fertilization significantly influenced on decreases of the leaf Mg by 38%, Mn by 30%, Zn by 48% and Mo by 53% compared to the control (mg kg^{-1} on the control: 1526 Mg, 44.3 Mn, 45.2 Zn, 2.62 Mo) and increases of the leaf Sr by 31% and Cd by 84% (mg kg^{-1} on the control: 62.3 Sr and 0.25 Cd), while differences of the remaining measurable elements (P, K, S, Fe, Cu, Ni, Cr, B, Ba, Na, and Al) were non-significant. Also, the leaf As, Hg and Se concentrations were under detectable levels of the method. The leaf nutritional status was mainly in accordance with supplies of the soil by individual elements. In general, grain composition is under less influences of the fertilization because significant differences of P, Cu, B and Mo were found (Table 2).

The harmful elements monitoring, particularly Cd, Hg and Pb, have become important for environmental protection. Their critical concentrations in plants and diet of animals (in the brackets) are as follows: 5-10 (0.5-1) ppm Cd, 2-5 (1) ppm Hg and 10-20 (10-30) ppm Pb. Concentrations of these elements in the higher plants normally vary between 0.2 and 3.00 ppm Cd, 0.01 and 0.02 ppm Hg, 2 and 7 ppm Pb (Bergmann 1992; Mengel and Kirkby, 2001). High Sr contents in plants and diet is also toxic. Their toxicity is mainly induced by mimicking of lighter essential elements in uptake and metabolism (for example, Cd by Zn, Pb and Sr by Ca). In our study, low levels of harmful elements in maize and soil were found.

Table 2. The ear-leaf (the silking stage: August 2, 2004), grain composition at maturity of maize (the hybrid Bc 5984) and soil properties (August 2, 2004)– the experiment Brekinja

P ₂ O ₅ kg/ha	The ear-leaf of maize (mg kg⁻¹ on dry matter basis) at silking stage*								
	P	K	Ca	Mg	S	Mn	Zn	Fe	Cu
80	3329	23532	8026	1526	1866	44.3	45.2	141	10.0
580	3033	21697	7695	950	1628	36.7	37.3	154	6.9
1080	3212	23697	10333	952	1928	31.2	28.2	135	8.7
1580	3110	26262	10036	996	1944	37.0	23.7	120	8.4
LSD 5%	n.s.	n.s.	1285	279	n.s.	7.1	9.4	n.s.	n.s.
LSD 1%			1946	423		n.s.	14.3		
	Mo	Ni	Cr	Sr	Cd	B	Ba	Na	Al
80	2.62	0.55	1.61	62.3	0.25	2.15	0.98	14.5	35.5
580	2.27	0.84	2.28	62.9	0.22	2.09	1.18	18.2	51.9
1080	1.73	1.08	2.54	76.3	0.39	1.95	1.18	12.7	42.4
1580	1.22	1.17	1.84	81.9	0.46	1.98	1.74	21.3	40.3
LSD 5%	0.49	n.s.	n.s.	12.6	0.11	n.s.	n.s.	n.s.	n.s.
LSD 1%	0.75			n.s.	0.16				
P ₂ O ₅ kg/ha	Grain of maize (mg kg⁻¹ on dry matter basis)*								
	P	K	Ca	Mg	S	Mn	Zn	Fe	Cu
80	2736	3749	30.7	932	891	3.31	21.8	18.7	2.00
580	2966	3621	27.9	932	900	3.31	21.3	17.8	2.30
1080	2992	3653	40.2	919	923	3.67	19.9	18.7	1.97
1580	3191	3694	30.7	969	936	3.75	19.0	18.8	1.77
LSD 5%	203	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.31
LSD 1%	n.s.								n.s.
	Mo	Ni	Cr	Sr	Cd	B	Ba	Na	Al
80	0.25	<0.20	<0.10	0.53	<0.02	1.17	0.78	4.91	<1.30
580	0.28	<0.20	<0.10	0.48	<0.02	0.88	0.75	5.79	<1.30
1080	0.20	<0.20	<0.10	0.49	<0.02	0.97	0.71	5.06	<1.30
1580	0.16	<0.20	<0.10	0.44	<0.02	0.91	0.68	4.32	<1.30
LSD 5%	0.04			n.s.		0.17	n.s.	n.s.	
LSD 1%	0.07					n.s.			
P ₂ O ₅ kg/ha	Mobile fraction in the soil (mg kg⁻¹: NH₄-Acetate + EDTA extraction)**								
	P	K	Ca	Mg	S	Mn	Zn	Fe	Cu
80	15.2	192	28880	176	89.3	206	0.96	166	6.6
	Mo	Ni	Cr	Sr	Cd	B	Ba	Na	Al
80	0.014	5.14	0.09	374	0.70	1.51	62.4	201	87.3

* under detection limit also As (<0.40), Hg (<0.12), Se (<0.004), Pb (<0.30), Co (<0.04)

** Co = 2.14 and Pb = 4.7

Under influences of P fertilization maize yields were increased up to 32% and 17% compared to the control, for 2004 and 2005, respectively. Also, there were tendency for increases protein and oil contents (Table 3).

Table 3 . Influences of P fertilization on yield and quality of maize grain

Influences of P fertilization (kg P ₂ O ₅ ha ⁻¹) on yield (t ha ⁻¹) and quality of maize grain: protein, starch and oil contents (% in dry matter)									
The growing season 2004					The growing season 2005*				
P ₂ O ₅ kg ha ⁻¹	t ha ⁻¹ Yield	% in maize grain			P ₂ O ₅ kg ha ⁻¹	t ha ⁻¹ Yield	% in maize grain		
		Prot.	Starch	Oil			Prot.	Starch	Oil
80	7.90	9.65	69.6	4.38	80	7.27	7.78	71.3	3.54
580	9.18	9.60	70.0	4.56	80	8.53	8.29	71.3	3.45
1080	9.85	9.80	69.9	4.66	80	8.38	8.89	71.2	3.51
1580	10.40	9.95	69.6	4.70	80	8.42	7.85	71.4	3.55
Analyses of variance (LSD-values)					Analyses of variance (LSD-values)				
5%	0.37	n.s.	n.s.	n.s.	0.29	n.s.	n.s.	n.s.	n.s.
1%	0.53				0.42				

* residual effects of the ameliorative P fertilization

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