

INFLUENCES OF SOIL AND FERTILIZATION WITH PHOSPHORUS AND POTASSIUM ON ZINC, MANGANESE, COPPER AND IRON STATUS IN MAIZE

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Abstract

Increased rates of P and K (monoammonium phosphate and potassium chloride) were applied in four replicates on two soils in spring 2001 as follows: a) standard fertilization (kg ha^{-1} : 177 N + 100 P_2O_5 + 150 K_2O); b) a + 1500 $\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$; c) a + 1500 $\text{kg K}_2\text{O ha}^{-1}$; d) = b + c. Residual effects of the fertilization were tested in the next year. Maize (OsSK552 hybrid) growing on Luzani soil resulted in 15% lower yield compared to the Kobas soil (7.75 and 9.06 t ha^{-1} , respectively). Mean the leaf (the ear-leaf at silking) concentrations (mg kg^{-1}) were 41.8 (Zn), 14.1 (Cu) and 131 (Fe), respectively. The leaf Mn was by 60% lower and the leaf Zn by 16% higher in 2002 compared to 2001. Maize grown in the Luzani trial had by 9% lower the leaf Zn, 10% lower the leaf Cu and by 37% higher the leaf Mn compared to the Kobas soil. Under the influence of P fertilization, the leaf Zn decreased by 37% compared to the control. Application of both P and K resulted in decreases of leaf Zn by 30%. However, P fertilization, alone or in combination with K, increased the leaf Mn for 111% and 72% respectively. Significant difference the leaf Cu (by 9% lower) was found under influences K fertilization only. The leaf Fe was independent on these factors.

Key words: maize, grain yield, phosphorus and potassium fertilization, ear-leaf at silking, zinc, manganese, copper, iron

Introduction

Nutritional unbalances, mainly low phosphorus (P) and potassium (K) supplies were found on some soils in Croatia (Kovacevic and Vukadinovic 1992; Kovacevic et al. 2002). The aim of this study was to test the response of maize to ameliorative fertilization with P and K fertilizers on two hydromorphic soils with emphasis on yield, zinc (Zn), manganese (Mn), copper (Cu) and iron (Fe) in plants. Status of P, K, calcium (Ca) and magnesium (Mg) were elaborated in the previous study (Kovacevic et al. 2004).

Material and methods

The field experiments

Two identical field experiments were set up on two soils at the beginning of April 2001. Yields and nutritional status as affected by soil and fertilization were tested on maize (OsSK552 hybrid). Increased rates of P and K were applied in the experiments: a) control, b) a + 1500 $\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$; c) a + 1500 $\text{kg K}_2\text{O ha}^{-1}$; d) = b + c. P was applied as monoammonium phosphate (MAP: 12% N + 52% P_2O_5) and K as KCl. Urea (46% N) was used to equalize N levels added by MAP. Residual effects of ameliorative fertilization were tested in the following growing season (2002) and standard fertilizer rates were applied (kg ha^{-1} : 500 NPK 7:20:30, 200 urea and 150 calcium ammonium nitrate = 177 N + 100 P_2O_5 + 150 K_2O).

Field trials were performed in four replications. The size of the experimental fertilization plot was 64.3 m². Maize was sown at the end of April/beginning of May (planned plant density or PPD = 58310/ha; within-row spacing 24.5 cm) and harvested at the beginning of October.

Soil characteristics

Two experiments were conducted on two hydromorphic soils in the western part of Brod-Posavina County, on the left side of the Sava valley, in Eastern Croatia (Luzani silt loam and Kobas silt clay loam). The air-distance between these soils is about 5 km in NS direction. According to the soil test (Table 1), Luzani soil is less fertile than Kobas soil. The lower levels of plan-available Zn and Cu in soil as well as more acid reaction are the main characteristics of the Luzani soil.

Table 1. Soil characteristics (0-30 cm) of experimental fields

Soil	Soil characteristics before start of experiments (0-30 cm depth)								
	pH		%	Soil texture (%) [*]			mg kg ⁻¹ soil ^{**}		
	H ₂ O	KCl		Sand	Silt	Clay	Zn	Mn	Cu
Luzani	5.06	4.82	1.72	17.9	62.6	19.6	0.70	133	1.30
Kobas	6.61	5.34	1.74	8.2	60.5	31.3	2.77	146	2.63

^{*} texture designation: silt loam and silt clay loam, for Luzani and Kobas soils, respectively

^{**} extraction by Lakanen-Ervio (1971) method with NH₄-Acetate+EDTA (pH 4.6)

Sampling, chemical and statistical analysis

Ear leaves from each experimental plot were taken for chemical analysis at the beginning of the silking stage (sampling in the second decade of July from three trial replicates; 25 leaves in mean sample). The total amount of Zn, Mn, Cu and Fe in maize leaves and soil sample (mean sample 0-30 cm depth; sampling before ameliorative fertilization) was measured by the ICP-AES technique after their microwave digestion using concentrated HNO₃+H₂O₂. Mobile fractions of these elements in soils were also determined by ICP-AES after their extraction with ammonium acetate-EDTA (pH 4.65) by the Lakanen and Ervio method (1971). Plant and soil analyses were done in the laboratory of the Research Institute for Soil Science and Agricultural Chemistry (RISSAC), Budapest, Hungary. Statistical analyses of the data (grain yield, leaf Zn, Mn, Cu and Fe status at flowering) were performed according to Mead et al. (1996). The results were calculated as a three-factorial experiment (A = growing season; B = soil characteristics, and C = fertilization).

Weather characteristics

Excess precipitation in June and September, their shortage in July and August, as well high temperatures in August, are the main characteristics of the weather during the maize growing season in 2001. In general, the precipitation distribution in 2002 was more favorable for maize requirements (Table 2).

Table 2. Weather data for Slavonski Brod

Rainfall (mm) and mean air temp. (°C) - Slavonski Brod Weather Bureau [†]		May	June	July	August	Sept.	Total mm	Mean °C
Growing season	mm	32	188	25	32	224	501	
2001	°C	17.9	17.8	21.9	22.2	14.5		18.9
Growing season	mm	80	55	78	122	136	471	
2002	°C	18.1	21.0	22.4	20.7	15.2		19.5
Long-term means	mm	74	82	87	71	54	368	
1971-1990	°C	15.9	18.8	20.6	19.9	15.9		18.2

[†] approx. westward air-distance between the exp. field and Slavonski Brod ca. 25 km

Results and discussion

The mean grain yield of maize in the experiment was 8.41 t ha⁻¹. The mean maize yield achieved in our experiment was by 6% higher in 2001 than in 2002. However, this difference is in the area of statistical error. Maize growing on Luzani resulted in 15% lower yield compared to the Kobas experiment. Fertilization with P and P in combination with K resulted in yield increases of 5% and 9%, respectively (Table 3).

Table 3. Influences of year, soil and fertilization on zinc, manganese, copper and iron concentrations in maize leaves (the hybrid OsSK552)

Influences of year (factor A: 2001, 2002), soil (factor B: Luzani and Kobas) and ameliorative fertilization* (factor C) on the ear-leaf composition** (in dry matter) of maize at silking												
Year	Soil	Fertilization (factor C)					Fertilization (factor C)					
(A)	(B)	STD	P	K	PK	Mean	STD	P	K	PK	Mean	
Grain yield (t ha ⁻¹)						Ear-leaf zinc (mg Zn kg ⁻¹)						
Interaction AC						A	Interaction AC				A	
2001		8.63	9.01	7.87	9.16	8.67	48.0	26.9	46.4	33.6	38.7	
2002		7.68	8.19	8.11	8.61	8.15	54.3	37.9	49.2	38.5	45.0	
Mean C		8.16	8.60	7.99	8.89		51.2	32.4	47.8	36.0		
Interaction BC						B	Interaction BC				B	
	Luzani	7.45	8.10	6.99	8.49	7.75	44.5	35.7	41.5	38.0	39.9	
	Kobas	8.87	9.11	8.99	9.28	9.06	57.9	29.1	54.1	34.1	43.8	
Interaction AB						Interaction AB						
	Luzani	2001: 8.68	2002: 6.83				2001: 35.0	2002: 44.8				
	Kobas	8.66	9.47				42.5	45.2				
Ear-leaf manganese (mg Mn kg ⁻¹)						Ear-leaf copper (mg Cu kg ⁻¹)						
Interaction AC						A	Interaction AC				A	
2001		116	278	121	230	186	15.0	14.9	14.2	14.7	14.7	
2002		62	99	67	77	76	14.3	13.7	12.6	13.2	13.5	
Mean C		89	188	93	153		14.7	14.3	13.4	13.9		
Interaction BC						B	Interaction BC				B	
	Luzani	93	220	92	201	152	14.2	13.1	12.3	13.9	13.3	
	Kobas	85	157	95	106	111	15.2	15.6	14.5	13.9	14.8	
Interaction AB						Interaction AB						
	Luzani	2001: 228	2002: 75				2001: 14.2	2002: 12.5				
	Kobas	145	77				15.2	14.4				
Ear-leaf iron: mean 132 mg Fe kg ⁻¹ and non-significant (n.s.) differences among tested factors and their interactions												
Analysis of variance												
	A	B	C	AB	AC	BC	A	B	C	AB	AC	BC
Grain yield						Ear-leaf zinc						
LSD 5%	n.s.	0.7	0.4	1.13	0.6	0.6	3.7	2.1	3.1	3.1	4.7	4.7
LSD 1%		4	1	n.s.	3	3	n.s.	n.s.	4.2	4.3	6.8	6.8
		n.s.	0.5		n.s.	n.s.						
			7									
Ear-leaf manganese						Ear-leaf copper						
LSD 5%	9	16	19	25	29	29	n.s.	1.0	1.1	n.s.	n.s.	1.6
LSD 1%	11	22	26	35	42	42		n.s.	n.s.			n.s.

* spring 2001 (kg/ha on standard fertilization): 0 (STD), 1500 P₂O₅ (P), 1500 K₂O (K), P+K; standard fertilization of four treatments for 2002.

Growing season had significant influences on the leaf Mn (60% lower in 2002 compared to 2001) and the leaf Zn (14% lower in 2001 compared to 2002), while the leaf Cu was similar in both years. As regards the influence of soil, maize grown in the Luzani trial had by 9% lower the leaf Zn, 10% lower the leaf Cu and by 37% higher the leaf Mn compared to the Kobas trial. Fertilization had considerable and mainly significant influence on nutritional status of maize. For example, under the influence of P fertilization, the leaf Zn decreased by 37% compared to the control. K fertilization decreased the leaf Zn by 7% only. Application of both P and K resulted in decreases of leaf Zn by 30%. However, P fertilization, alone or in combination with K, increased the leaf Mn for 111% and 72% respectively, while as affected by K fertilization Mn concentrations were in level of the control. In general, influence of applied fertilization on the leaf Cu was low. Significant difference (by 9% lower Cu concentration compared to the control) was found under influences K fertilization only. The mean leaf Fe was 131 mg Fe kg⁻¹ and the leaf Fe status was independent on tested factors because non-significant differences of Fe concentrations were found (Table 3).

For the data interpretation appraisal of the nutrient status of the ear-leaf of maize at the flowering stage according to Christensen was used (cit. Mengel and Kirkby, 2001) as follows (adequate amounts in mg kg⁻¹ on dry matter basis): 20-70 Zn, 20-200 Mn, 6-50 Cu and 10-300 Fe. Normal nutritional status of maize regarding the leaf Zn, Mn, Cu and Fe concentrations under conditions of standard fertilizations were found. Although applied fertilization mainly considerable and significantly influenced on these nutrients status, they were all cases in normal levels (Table 3).

In our previous study were reported influences the soil and the fertilization on the leaf P, K, Ca and Mg status (Kovacevic et al. 2004). Maize grown in the Luzani trial had a three times lower Mg concentration than that in the Kobas trial (0.20 and 0.30% Mg, respectively), which is within the limits of normal Mg supply. For example, under the influence of P fertilization the leaf P, Ca and Mg increased by 25%, 20% and 22%, respectively, compared to the control while leaf Mg decreased by 10%. K fertilization decreased the leaf Mg, Ca and P by 30%, 13% and 7%, respectively, while leaf K increased by 16%, respectively

References

- Kovacevic V., Brkic I., Stojic B., Buzasi I. (2002): Phosphorus as a limiting factor of rural development in Lika region. International Scientific Conference "Energy efficiency and agricultural engineering" 4-6 April 2002, Rousse, Bulgaria (Conference Proceedings, Volume 1). p. 80-83.
- Kovacevic V., Banaj D., Brkic I., Antunovic M., Petosic D. (2004): Fertilization impacts on the yield and nutritional status of maize (*Zea mays* L.). Cereal Res. Comm. 32 (3) 403-410.
- Lakanen E., Ervio R. (1971): A comparison of eight extractants for the determination of plant available micronutrients in soils. Acta Agr. Fenn. 123, 223-232.
- Kovačević V., Vukadinović V. (1992): The potassium requirements of maize and soybean on a high K-fixing soil. South African Journal of Plant and Soil 9, pp.10-13.
- Mead R., Curnow R. N., Hasted A.M. (1996): Statistical methods in agriculture and experimental biology. Chapman & Hall, London.
- Mengel K., and E. A. Kirkby. (2001): Principles of plant nutrition. Kluwer Academic Publishers Dordrecht/Boston/London.