Excess of Magnesium Uptake in Maize (Zea mays L.) Plants as promoting Factor of Potassium Deficiency

B. Bertić, V. Vukadinović [1], V. Kovačević [2]

Zusammenfassung

In einem 2jährigen Feldversuch wurde Mais auf einem Boden angebaut, der sehr reich an austauschbarem Magnesium- und sehr arm an austauschbarem Kalium-Gehalt war.
Fünf verschiedene Kaliumanteile wurden angewendet, um eine Konzentration von ca. 1105 K_2O/ha zu erreichen.
Obwohl sehr viel Kalium angewendet wurde, blieb das austauschbare Kalium im gleichen Bereich wie bei normaler Düngung.
Der Magnesiumgehalt im Kolbenblatt (die Blütezeit) jedoch sank von 1,95 % Mg auf 1,23 % Mg, während der Kaliumgehalt von 0,66 % auf 1,47 % Kalium anstieg.
Gleichzeitig stieg der Kornertrag von 4,98 auf 8,96 t/ha.

Summary

Maize was grown two years in field experiment on soil which is high in exchangeable Mg and low in exchangeable K content. Five rates K were applied up to the range of 1105 kg K_2O/ha. Although the very high K rate was applied exchangeable K remained in the equal level as in the case of ordinary fertilization. However ear-leaf Mg decreased from 1.95 % Mg to 1.23 % Mg while ear-leaf K increased from 0.66 % K to 1.47 % K. At the same time grain yield increased from 4.98 to 8.96 t/ha.

Résumé

Au cours d'une expérimentation de deux ans, du maïs a été cultivé sur un terrain riche en ions Mg échangeables et pauvre en ions K échangeables. Cinq taux différents d'apport potassique ont été expérimentés, la concentration la plus élevée étant d'environ 1105 kg de K_2O par hectare. Par rapport aux valeurs enregistrées lors d'une fertilisation normale du sol, les taux de K échangeable sont restés constants même avec la très forte concentration de K_2O. En revanche, la teneur en Mg des feuilles entourant l'épi a diminué de 1,95 à 1,23 %, alors que le taux de K est passé de 0,66 à 1,47 %. Parallèlement, le rendement du maïs a augmenté de 4,98 à 8,96 t/ha.

1) Department of Agricultural Chemistry, Agricultural Faculty Osijek, University of Osijek, Yugoslavia
2) Department of Crop Production, Agricultural Institute Osijek, University of Osijek, Yugoslavia

Introduction

All over the world a common reason for low yield or decreased crop quality is the deficiency one or more of the plant nutrients. Such deficiencies are not always due to a low total content of the actual plant nutrients in the soil. Too slow a transformation from barely soluble compounds to plant available fractions may also cause deficiencies of plant nutrients. Another reason can be antagonism caused by unbalanced supply of plant available nutrient in the soil.
Disorders of plant development — retardation of growth and chlorosis — were observed in maize plants which were grown hydromorfic soil. These disorders were induced by nutritional stress due to extremely high exchangeable Mg content and very low exchangeable K content in the soil. Strongly K fixation was also found by chemical soil test. Debalance of Mg and K in the soil affected correspondingly the Mg and K status in the plants. They developed typical symptoms of K deficiency. The nutritional problems in crop production of Slavonia province were shown by the other studies [1, 6, 7, 8].

Material and Methods

General Characteristics of Soil

The field experiment was performed on gleysol (FAO-Unesco World soil classification) "Jasinje" Agricultural and Industrial Processing Combine. This area was drained recently. In the past, it was pasture ground. The low available P and K status — under 10 mg P_2O_5 and K_2O/100 g of soil — according to AL-method [2] was found. For this reason, field trial with increased K and P fertilization was conducted in the autumn 1984.

Field Experiment

Five levels of K and P fertilizer (Tab. 1) were applied prior and after ploughing (December 7th, 1984 and April 10th, 1985, respectively). Potassium salt (60 % K_2O) and superphosphat (42 % P_2O_5) were used for ameliorative fertilization. The trial was a randomized block design with four replications. Each experimental plot of fertilizer rate measured 294 m^2. Maize hybrid OsSK 407 (selection of Agricultural Institute Osijek) was sown at end of April. Maize was thinned out up to plant density of 64 000 plants/ha when maize was at three to five leaves stage.

Sampling and sample Analysis

The soil samples were taken with the auger to 30 cm of the soil depth from each experimental plot (June 26th, 1985). Mean soil sample consisted of 25 samplings. Ear-leaf from 30 plants was taken from each experimental plot when maize was at the beginning of silkings stage (end of July).

Exchangeable cations were extracted with in ammonium acetate [11]. Plant samples were wet-ashed with selen contained in the sulphuric acid [3]. Ca and Mg concentrations were determined with atomic absorption, while K was determined plamenphotometrically.

Grain yields were calculated on 14 % moisture basis, while the results of soil and plant analysis were calculated on air-dry weight basis.

Tab. 1: Chemical characteristics of soil

Fertilization in autumn, 1984 (kg/ha)			pH		Exchangeable cations (mg/100 g of soil)		
N	P_2O_5	K_2O	H_2O	KCl	Ca	Mg	K
Soil status during maize growth (June 26th, 1985)							
240	120	160	7.93	7.15	1054	157	11.2
240	120	430	7.82	7.18	1058	137	10.0
240	120	655	7.66	7.05	933	144	10.7
240	120	880	7.89	7.33	1117	134	10.5
240	120	1105	8.01	7.40	1238	150	10.5
240	390	160	8.01	7.08	1055	152	11.8
240	615	160	7.95	7.00	1145	185	11.8
240	840	160	7.81	6.98	1065	138	10.7
240	1065	160	7.85	7.23	1065	157	10.8
	LSD	5 %	0.29	0.35	247	29	1.0
	LSD	1 %	0.39	0.46	331	39	1.4

Tab. 2: Ear-leaf composition (maize hybrid OsSK 407)

Fertilization in autumn, 1984 (kg/ha)*			Ear-leaf at silking stage (% on dry matter basis)						Grain yield (t/ha)	
			July 25, 1985			July 24, 1987				
N	P_2O_5	K_2O	Mg	K	Ca	Mg	K	Ca	1985	1987
240	120	160	1.95	0.66	0.97	1.49	0.63	0.93	4.98	5.30
240	120	430	1.84	0.79	1.12	1.54	0.66	1.08	7.61	5.53
240	120	655	1.37	1.25	1.00	1.47	0.72	1.08	8.03	6.43
240	120	880	1.51	1.20	1.00	1.46	0.72	1.10	8.17	6.46
240	120	1105	1.23	1.47	0.91	1.37	0.70	1.06	8.96	6.71
240	390	160	1.80	0.87	1.09	1.53	0.64	0.97	5.45	5.14
240	615	160	1.97	0.69	0.94	1.50	0.66	0.99	4.82	5.59
240	840	160	1.95	0.70	1.02	1.53	0.63	1.05	4.70	5.95
240	1065	160	1.84	0.90	1.03	1.56	0.65	1.08	5.13	5.34
	LSD	5 %	0.23	0.13	0.10	0.13	0.11	0.09	0.98	0.88
	LSD	1 %	0.31	0.18	0.13	0.18	0.15	0.12	1.30	1.17

* fertilization in the following years: in level of the ordinary fertilization

Results and Discussion

Slightly alkaline soil reaction, low exchangeable K and high exchangeable Mg content (Mg and K antagonism) are the main chemical characteristics of experimental plot. However, levels of exchangeable K remained nearly equal in the plot of ordinary and ameliorative K treatment. Also, the level of exchangeable Mg was in the similar range (Tab. 1). By the recent investigations, a strong K fixation was found. By adding of 100 mg K/100 g of soil it was found only 30 % of this amount in the soil solution by wet fixation method [10].

Johansson and *Hahlin* [4] found that a positive response to potassium fertilization appears only on soil with a relatively low ratio between exchangeable potassium and magnesium. At K:Mg ratio less than 1, the yield response to potassium fertilization is likely to be positive, even on soil with a rather high potassium level. In our case extremelly low K:Mg ratio was found (in mean 0.07 only). For this reason, response to K fertilization was very expressed, especially in the first year of testing.

Ear-leaf composition and grain yield of maize plants was different, depending on fertilizer rate (Tab. 2). According to the literature data [9], ear-leaf Mg was extremely high, especially when maize plants were grown under conditions of ordinary K fertilization. By addition of the highest K level, ear-leaf Mg concentration was decreased 37 % compared with the ordinary fertilization. At the same time, ear-leaf K concentration increased 123 %. However, by the ameliorative K fertilization ear-leaf K and Mg concentrations were only in the first year of testing increased and decreased, respectively. In the third year of testing, ear-leaf composition was independent on fertilizer treatments three years ago.

Katušić et al. [5] found excess in Mg uptake by soybean plants growing on gleysol of Posavina area. In the first year of testing, due to the increased K fertilization from 0 to 990 kg K_2O/ha, Mg concentration (the upperest full-developed leaf at beginning of flowering stage) decreased from 1.49 % to 0.74 % Mg on dry matter basis. At the other hand, K concentration increased from 0.87 % to 1.28 % K, while grain yield of soybean increased from 2.40 to 2.83 t/ha. The analogous values in the second year of testing (uniform fertilization of the all treatments in range of ordinary fertilization) were as follows: 1.35 % and 0.77 % Mg; 0.91 and 1.29 % K; 1.45 and 1.85 t/ha. Also, in these investigations was found the antagonism in Mg and K uptake by plants.

For practical purposes, we recommend the increased K fertilization to 500 kg K_2O/ha every third year. The part of K need should be added in the form of band fertilization simultaneously with the sowing.

Conclusion

Maize plants were grown in the field experiment during two growing seasons. Five rates of K and P were added (to 1065 kg P_2O_5/ha and 1105 kg K_2O/ha, respectively). Extremely high exchangeable form of Mg and low K contents, as well as strongly K fixation were found by soil test.

Although the very high K rate was applied (1105 kg K_2O/ha) exchangeable K amount remained in the equal level as in the case of ordinary fertilization. The exchangeable Mg remained very high, too. At the same time, however, ear-leaf Mg decreased from 1.95 % (ordinary fertilization) to 1.23 % Mg, while ear-leaf K increased from 0.66 % to 1.47 % K. These concentrations were still out of the optimal range. Due to the increased K fertilization, grain yield of maize increased from 4.98 t/ha (ordinary treatment) to 8.96 t/ha (the first year of testing) and from 5.30 t/ha to 6.71 t/ha (the third year of testing). In the third year of testing, ear-leaf K was extremely high, while ear-leaf K was extremely low, regardless the fertilizer treatment three years ago.

References

[1] *Bertić, B., V. Vukadinović, V. Kovačević, I. Jurić:* Influence of liming on soil acidity and iron availability. Journal of Plant Nutrition **11** (1988) 1361–1367.

[2] *Egner, H., H. Riehm, W. R. Domingo:* Untersuchungen über die chemische Bodenanalyse als Grundlage für die Beurteilung des Nährstoffzustandes der Böden. II. Chemische Extractions-Methoden zur Phosphor- und Kaliumbestimmung. K. Lantbr. Högsk. Annaler **26** (1960) 199–215.

[3] *Holz., F.:* Die automatische Bestimmung des Stickstoffs als Indophenolgrün in Böden und Pflanzen. Landw. Forsch. **26**, Sonderheft (1973) 177–192.

[4] *Johansson, O. A. H., J. M. Hahlin:* Potassium/magnesium balance in soil for maximal yield. Proceedings, International Seminar on Soil Environment and Fertilizer Management in Intensive Agriculture (SEFMIA) Tokyo. Society of the Science of Soil and Manure (1977) 487–494.

[5] *Katušić, V., V. Kovačević, I. Žugec:* Response of soybean to potassium and phosphorus fertilization on hypogley of East Croatia. Proceedings, 7th Colloquium of International Association for Optimization of Plant Nutrition, Nyborg, Denmark 1988 (in press)

[6] *Kovačević, V., B. Bertić, V. Vukadinović:* The disorders of potassium uptake by maize plants on hypogley soil. Proceedings, 7th International Colloquium of International Association for Optimization of Plant Nutrition, Nyborg, Denmark (in press)

[7] *Kovačević, V., V. Vukadinović, B. Bertić:* Excess in iron and aluminium uptake and nutritional stress in corn (Zea mays L.) plants. Journal of Plant Nutrition **11** (1988) 1263–1272.

[8] *Kovačević, V., I. Žugec, B. Bertić:* Poremećaji mineralne ishrane biljaka na tlima Slavonije. Savremena poljoprivreda **34** (1986) 133–150.

[9] *Melsted, S. W., H. L. Motto, T. R. Peck:* Critical plant nutrient composition values useful in interpreting plant analysis data. Agronomy Journal **61** (1969) 17–20.

[10] *Vukadinović, V., B. Bertić, V. Kovačević:* Kalium- und Phosphorverfügbarkeit auf den Böden im Gebiet von Posavina. Symposium, Characterisierung pflanzenverfügbarer Nährstoffe im Boden, Jena, DDR 1987 (in press)

[11] *Whiteside, P. J.:* An introduction to atomic absorption spectrophotometry. Pye Unicam Ltd., Cambridge 1979, p. 63–67.

For the authors: Prof. Dr. *Vlado Kovacevic,* Biotehnicki znanstveno nastavni centar, OOUR Poljoprivredni Institut, YU-54000 Osijek, Yugoslavia