

## RESPONSE OF MAIZE GENOTYPES TO SOIL STRESS ON STRONG K-FIXING SOILS

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*Maize hybrids were grown under field condition of river Sava valley area on drained soils characterizing nutritional unbalances (K-deficiency/Mg-oversupply alone or in combination with P-deficiency). Growing 14 hybrids on Mikanovci K-deficient gleysol resulted by yield differences among the hybrids from 2.83 to 7.20 t/ha, as well as stalk lodging at maturity (SL) from 0.7% to 95.6%. Seven maize hybrids of Os1-48 inbred line were more tolerant because their mean yield (5.64 t/ha) was for 36% higher in comparison with seven hybrids of the Os87-24 inbred line. Also, the Os1-48 could be used as source of property characterizing resistance to SL under conditions of K deficiency (means 4.9% and 59.1% SL for the hybrids of Os1-48 and Os87-24, respectively). Growing these hybrids under conditions low both K and P supplies (Crnac polje gleysol) resulted by yield differences among the hybrids from 2.49 to 4.99 t/ha (means 4.02 and 3.61 t/ha, as well 4.7% and 15.1% SL, for the hybrids of the Os1-48 and the Os87-24 inbred line, respectively). Under conditions of Babina Greda K-deficient soil, four of ten hybrids (OsSK568exp, OsSK602, OsSK444 and OsSK458exp.) could be designated as a more tolerant (yield 8.01 t/ha and 15.3% SL) and four hybrids (OsSK552, OsSK554, OsSK558 and OsSK497exp.) less tolerant (mean yield 4.55 t/ha and 43% SL). Under normal conditions of the Stitar soil (4 km air-distance from K-deficient soil), growing of these ten maize hybrids resulted by 62% higher yield in comparison with Babina Greda K-deficient soil. Low and high yielding group of the hybrids on the K-deficient soil had on Stitar soil similar yields and absence of SL.*

**Keywords:** maize hybrids, K-deficient soils, grain yield, nutritional status.

Nutritional disorders closely connected with potassium (K) deficiency alone or in combination with low phosphorus (P) supplies were found on some clay soils of the Posavina area (Vukovar-Srijem and Brod-Posavina counties) in Croatia. Soil improvement is possible by adequate fertilization, but choice of more tolerant genotypes could be also useful solution. Details of this problem elaborated in the previous studies (Bertic et al. 1989; Katusic 1992; Kovacevic 2001; Kovacevic and Basic, 1997; Kovacevic and Vukadinovic 1992; Richter et al. 1990;

Vukadinović et al. 1988 etc.). Aim of this study was to give survey of some our earlier investigations focusing the problem with aspects of genetics and breeding.

## MATERIAL AND METHODS

Testing of maize (*Zea mays* L.) genotypes under less favorable soil conditions was performed on three soils characterizing different degrees of plant available K and Mg unbalances (K deficiencies and oversupplies of Mg) situating on the localities of river Sava valley area as follows: Mikanovci, Babina Greda and Crnac Polje, respectively. The field experiments were conducted in four replicates. Experimental plots of each maize genotype measured, depending on the trial, from 7.2 to 18.2 m<sup>2</sup>. The ear-leaf was taken from each experimental plot at beginning of silking stage (Tables 2, 3 and 4). Stalk base was taken at maturity stage (Table 1). In average sample were taken about 25 individual sampling from each experimental plot.

### ***The experimental field Mikanovci (Vukovar-Sirmium County)***

Maize genotypes differing in origin were grown under field conditions on drained gleysoil during the growing seasons 1990 (Table 1) and 1993 (Tables 3 and 4). The initial pH was 7.3 / (KCl), exchangeable K was less than 100 mg/kg, exchangeable Mg was 1500 mg/kg and the CaCO<sub>3</sub> content was 14.9%. The organic matter content was 2.4% and the clay, silt and sand contents were 35.2%, 62.0% and 2.7%, respectively. The clay fraction consists of vermiculite/chlorite (30%), smectite (30%), mixed layer minerals (20%), illite (15%) and kaolinite (5%). Strong K-fixation and oversupply of plant available Mg are main limiting factors in this soil (Kovacevic and Vukadinovic, 1992; Richter et al., 1990). The results were elaborated by previous studies (Kovacevic and Vujevic, 1994; Brkic et al., 1996; Kovacevic et al., 1996).

### ***The experimental fields (2) Babina Greda and Stitar (Vukovar-Sirmium County)***

Ten maize hybrids (Table 5) were grown on two soils (K-deficient Babina Greda calcaric fluvisol and normal Stitar eutric cambisol) during 1998. These experiments were mutually distanced about 4 kilometers by air-line. By initial testing there were found chemical properties as follows (K-deficient and normal soil, respectively): pH in KCl 7.12 and 5.89; organic matter contents 3.14% and 2.65%; plant available K (AL-method) 9.86 and 19.3 mg K<sub>2</sub>O/100 g; EUF-extraction (20°C: mg/100g) 2.93 K and 5.76 K, 24.2 and 8.42 Mg, respectively. The results were partially published in the previous study (Kovacevic et al., 2001).

### ***The experimental field Crnac Polje (Brod-Posavina County)***

The field trials were conducted on drained Crnac polje area in 1990. The soil was gleysoil with the following properties: pH in KCl 6.92; plant-available P and K (extracted by AL-method) 8.9 mg P<sub>2</sub>O<sub>5</sub> and 16.9 mg K<sub>2</sub>O /100 g. Particle-size fractionation showed 19.5%, 22.2% and 58.3% for sand, silt and clay fractions, respectively. Upon addition of 100 mg of either P or K to 100 g of soil, 71% of added P and 88% of added K were fixed as shown by the wet fixation method. For this reason, as affected by applied P and K fertilizations yields of soybeans (Kovacevic, 1993) and maize (Kovacevic et al. 1997) were considerably increased.

## RESULTS AND DISCUSSION

In our investigations considerable role of maize genotype on grain yields, stalk lodging and nutritional status of maize were found (Tables 1-5).

Growing fourteen maize hybrids on K-deficient Mikanovci gleysol resulted by mean yield 4.90 t/ha and yield differences among the hybrids from 2.83 to 7.20 t/ha, as well as stalk lodging incidences from 0.7% to 95.6%. Maize hybrids of Os1-48 inbred line were more tolerant to this type of soil stress because their mean yield (5.64 t/ha) was for 36% higher in comparison with the hybrids of the Os87-24 inbred line. Also, the Os1-48 inbred line could be used as source of property characterizing resistance to stalk lodging at maturity stage under conditions of K deficiency (means 4.9% and 59.1% stalk lodging for the hybrids of Os1-48 and Os87-24, respectively). Liebhardt and Murdock (1965) found 78% stalk lodging of maize on the fertilization treatment (kg/ha) 176 N + 77 P + 0 K in comparison with only 3% on the treatment 176 N + 0 P + 146 K. For this reason, the higher concentrations of P in stalk base could be in connection with inclination maize to lodging at maturity stage. Also, nutritional balance (relation between K and Mg) was more favorable in the hybrids of the Os1-48 line (Table 1). Growing of the same groups of the hybrids under conditions low both K and P supplies (Table 2) resulted by mean yield 3.82 t/ha and yield differences among the hybrids from 2.49 to 4.99 t/ha (means 4.02 and 3.61 t/ha, for the hybrids of the Os1-48 and the Os87-24 inbred line, respectively). Also, the lower incidences of stalk lodging for the hybrids of Os 1-48 inbred line were found (means 4.7% in comparison with 15.1 %). These investigations were in detail elaborated by the previous studies (Kovacevic and Vujevic, 1994; Kovacevic et al. 1997).

Table 1

**Response of maize hybrids to Mikanovci strong K-fixing soil for the growing season 1990 (Kovacevic and Vujevic, 1994)**

Father parent of maize hybrids: A = Os1-48 and B = Os87-24					
Pedigree of maize hybrids (Mother x Father)	Grain yield (t/ha)	Stalk lodging (%)	Stalk (three full-developed the lowest nodes) at maturity (% in dry matter )		
			K	Mg	P
Os87-44 x A	5.23	8.8	0.30	0.48	0.11
Os84-15 x A	6.30	4.8	0.30	0.55	0.07
Os84-25 x A	5.56	4.1	0.18	0.52	0.14
Os84-24 x A	5.89	4.6	0.17	0.48	0.08
Os86-39 x A	4.45	7.5	0.18	0.71	0.16
Os89-24 x A	7.20	4.1	0.30	0.45	0.07
B x A	4.83	0.7	0.21	0.52	0.27
Os87-61 x B	2.83	79.0	0.18	0.64	0.18
Os88-15 x B	4.71	83.3	0.21	0.88	0.29
Os86-92 x B	2.90	23.7	0.17	0.74	0.22
Os87-56 x B	3.52	52.1	0.21	0.74	0.21
Os84-24 x B	5.45	95.6	0.18	0.68	0.24
Os87-57 x B	4.28	74.1	0.19	0.68	0.22
A x B	5.40	5.3	0.18	0.69	0.19
LSD 5%	0.53		0.04	0.09	0.03
LSD 1%	0.72		0.05	0.12	0.04
Mean A	5.64	4.9	0.24	0.53	0.13
Mean B	4.16	59.1	0.19	0.72	0.22

Maize hybrids OsSK377 and OsSK382 could be designated as something more tolerant to K-deficiency/Mg-oversupply because their yield (in mean 2.31 t/ha) was in mean 44% higher compared to the other four tested hybrids (in mean 1.60 t/ha). However, by these two hybrids more inclination to stalk lodging (mean 50%) in comparison with remaining four hybrids (mean 16%) was found (Table 3). Also, low connection was found between the ear-leaf P, K, Mg and Ca status and these two properties.

Table 2

**Response of maize hybrids to Crnac Polje K-fixing and P-fixing soil for the growing season 1990 (Kovacevic et al. 1997)**

Father parent of maize hybrids: A = Os1-48 and B = Os87-24					
Pedigree of maize hybrids (Mother x Father)	Grain yield (t/ha)	Stalk lodging (%)	The ear-leaf at silking stage (% in dry matter)		
			K	Mg	P
Os87-44 x A	3.23	5.8	0.77	1.21	0.35
Os84-15 x A	4.25	5.5	0.81	1.36	0.34
Os84-25 x A	3.86	4.6	0.84	1.39	0.38
Os84-24 x A	4.31	4.0	0.82	1.49	0.41
Os86-39 x A	3.86	6.8	0.67	1.33	0.34
Os89-24 x A	4.99	5.0	0.82	1.39	0.32
B x A	3.65	1.2	0.76	1.30	0.31
Os87-61 x B	3.28	18.5	0.80	1.45	0.35
Os88-15 x B	2.49	19.0	0.81	1.49	0.37
Os86-92 x B	3.41	12.6	0.78	1.32	0.32
Os87-56 x B	3.54	16.3	0.81	1.48	0.37
Os84-24 x B	4.50	20.2	0.80	1.32	0.34
Os87-57 x B	4.15	16.5	0.78	1.53	0.35
B x A	3.92	2.6	0.79	1.31	0.29
LSD 5%	0.45		0.08	0.12	0.02
LSD 1%	0.61		0.11	0.16	0.03
Mean A	4.02	4.7	0.78	1.35	0.31
Mean B	3.61	15.1	0.80	1.41	0.30
Normal ranges (Bergmann, 1992)			2.0-3.0	0.2-0.5	0.2-0.5

Table 3

**Response of maize hybrids to Mikanovci strong K-fixing soil for the growing season 1993 (Kovacevic et al. 1996)**

Yield, stalk lodging (SL), plant density realization (PDR in % of planned), grain moisture (GM) at harvesting and the ear-leaf composition of maize hybrids								
Maize hybrid	Yield (t/ha)	SL (%)	PDR (%)	GM (%)	The ear-leaf (% in dry matter)			
					K	Mg	Ca	P
OsSK377	2.47	47	68.4	30.7	0.37	1.16	0.99	0.80
OsSK382	2.14	54	67.2	23.3	0.33	0.92	0.83	0.56
OsSK407	1.78	21	75.3	36.9	0.30	1.07	0.98	0.62
OsSK552	1.46	17	66.2	33.6	0.31	1.08	0.92	0.55
OsSK644	1.60	11	59.1	41.7	0.30	1.10	0.86	0.59
Bc 66-61	1.54	14	71.1	38.5	0.26	1.15	1.06	0.72
LSD 0.05	0.48				0.07	0.05	0.05	0.04
LSD 0.01	0.63				0.09	0.07	0.07	0.05
Normal ranges (Bergmann, 1992)					2.0-3.0	0.2-0.5	0.2-1.0	0.2-0.5

Response of maize inbred lines (parents of maize hybrids) to soil stress induced by K deficiency and Mg oversupply was under considerable influence of inheritance factors (Table 4). Os30-8 inbred line is more tolerant to K deficiency because its grain yield (1.85 t/ha) was near 50% higher compared to mean yield of remaining five tested inbred lines. Also, three tolerant inbred line to lodging (the group B: in mean 5% lodging) under soil stress conditions had considerably higher grain yields (in mean 1.35 t/ha) compared to susceptible inbred lines of the group A (in mean 0.88 t/ha and 43% lodging). Although significant differences of the ear-leaf composition (K, Mg and P concentrations) were found among maize inbred lines, they are low connection of these properties with grain yield and lodging, probably due to fact that it was found acute K deficiency (less than 1% according to Bergmann 1992) in plants. However, inbred lines of the group B had in mean the higher ear-leaf K, Mg and P concentrations, compared to group A (Table 4).

Table 4

**Response of maize inbred lines to Mikanovci strong K-fixing soil for the growing season 1993 (Brkic et al. 1996)**

Corn	Grain yield (t/ha)	Percent			The ear leaf at silking (% in dry matter)		
		Stalk lodging	Sterile plants	Grain moisture	K	Mg	P
The group A							
Os86-39	0.73	37	18	31.3	0.42	1.08	0.50
Os84-44	0.86	41	2	17.0	0.56	1.08	0.44
Os84-49	1.06	51	20	22.9	0.41	1.15	0.55
The group B							
Os89-9	1.16	7	11	30.9	0.55	1.46	0.69
Os1-44	1.04	6	20	35.2	0.62	1.36	0.61
Os30-8	1.85	3	10	37.2	0.48	0.95	0.57
Mean A+B	1.12	24	14	29.2	0.51	1.18	0.56
Normal ranges (Bergmann, 1992)					2.0-3.0	0.2-0.5	0.2-0.5
LSD 5%	0.31				0.12	0.05	0.04
LSD 1%	0.42				0.17	0.08	0.06
Group A	0.88	43	14	23.7	0.46	1.10	0.50
Group B	1.35	5	14	34.4	0.55	1.26	0.62

Under conditions of K-deficient soil, considerable differences of maize yields were found among the hybrids from 3.61 to 9.59 t/ha. Four hybrids (OsSK568exp, OsSK602, OsSK444 and OsSK458exp.) could be designated as a more tolerant (mean yield 8.01 t/ha), four hybrids (OsSK552, OsSK554, OsSK558 and OsSK497exp.) less tolerant (mean yield 4.55 t/ha) to soil stress induced by K deficiency, while remaining two hybrids (OsSK382 and OsSK617exp.) are in mean range (6.45 t/ha). Stalk lodging incidences of individual hybrids were from 3.4% (OsSK444) to 65.9% (OsSK497exp.). Stalk lodging of two groups hybrids were as follows: 15.7% (the high yielding group) and 43% (the low yielding group), respectively. (Table 5). Under normal conditions of the Stitar soil, growing of these ten maize hybrids resulted by 62% higher yield in comparison with Babina Greda K-deficient soil (means 10.25 t/ha and 6.31 t/ha, respectively) and lower yield

differences among the hybrids (from 8.56 to 11.79 t/ha). The low and high yielding group on the K-deficient soil had similar yields and absence of stalk lodging under normal soil conditions (Table 5).

Table 5

**Response maize hybrids on Babina Greda K-deficient soil (Kovacevic et al., 2001) and normal Stitar soil**

Hybrid		K-deficient soil				Normal soil			
		Yield t/ha	Percent			Yield t/ha	Percent		
			RPD	SL	FSP		RPD	SL	FSP
1	OsSK382	6.91	85.9	38.7	0	8.56	103.6	0	5.5
2	OsSK444	7.31	82.0	3.4	0	9.41	103.0	0	1.6
3	OsSK458exp	7.14	87.0	22.9	0	10.09	102.9	0	0
4	OsSK497exp	5.27	95.8	65.9	8.6	10.48	100.2	0	4.7
5	OsSK552	3.61	75.5	40.5	0	8.90	103.7	0	3.3
6	OsSK554	4.24	85.7	23.1	2.1	9.69	100.9	0	1.6
7	OsSK558	5.08	83.3	42.4	0	11.79	103.9	0	0.4
8	OsSK568exp	9.59	68.4	23.1	2.9	11.73	99.4	0	1.2
9	OsSK602	8.01	72.3	13.2	4.4	10.73	100.2	0	3.3
10	OsSK617exp	5.98	81.9	10.9	7.8	11.13	97.8	0	1.3
Mean		6.31	82.0	28.4	2.6	10.25	101.6	0	2.3
LSD 5%		1.42				1.46			
LSD 1%		2.02				2.01			

\* realized plant densities (RPD: in % compared to theoretical plant densities (TPD); TPD (100%) plants/ha = 62964 (hybrids 1+2+3+4), 58201 (hybrids 5+6+7+8), 54945 (hybrids 9+10); TPD (mean of trial) = 59455; grain yields calculated on 14% moisture and 90% TPD basis.

Response of plants to soil stress induced by K-deficiency/Mg-oversupply in level of field crop is also different. With that regard, maize and soybean are more susceptible (Kovacevic and Vukadinovic, 1992) in comparison with winter wheat (Kovacevic et al., 1990) and sugar beet (Kristek et al., 1996).

**BIBLIOGRAPHY**

1. Bergmann W., 1992 - Nutritional disorders of plants – development- visual and analytical diagnosis. Gustav Fischer Verlag Jena. Stuttgart. New York.
2. Bertic Blazenka. Vukadinovic V., Kovacevic V., 1989 - Excess of magnesium uptake in maize plants as promoting factor of potassium deficiency. Magnesium-Bulletin, vol. 11 , No 1, p. 25-27.
3. Brkic I., Kovacevic V., Josipovic M., 1996 - Inheritance as factor influencing phosphorus status of corn (Zea mays L.) plants. IXth International Colloquium for the Optimization of Plant Nutrition , 8-15. September 1996, Prague, Czech Republic, p. 360-362.
4. Katusic V. ,1992 - Gnojidba kalijem na hipogleju naglasene fiksacije kalija (MS thesis). Univerza v Ljubljani. Agronomija.
5. Kovacevic V., 1993 - Phosphorus and potassium deficiency in soybeans on gleysol of Croatia. Rostlinna Vyroba, vol. 39, no 4, p. 345-352.
6. Kovacevic V., 2001 - Nutritional disorders of corn growing in the eastern Croatia. Bulletin of the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca (Agriculture) Volume 55-56 p. 36-41.

7. Kovacevic, V., Basic, F., 1997 - The soil potassium resources and the efficiency of potassium fertilizers in Croatia (Country Report 10). International Potash Institute, Coordinator Central/Eastern Europe, CH-4001 Basel/Switzerland.
8. Kovacevic V., Banaj D., Antunovic Manda, Bukvic Gordana, 2001 - Influences of genotype and soil properties on corn Potassium and magnesium status. In: Plant nutrition - food security and sustainability of agro-ecosystems (Developments in Plant and Soil Sciences, Volume 92; W. J. Horst et al. eds). Kluwer Academic Publishers Dordrecht/Boston/London. p.90-91.
9. Kovačević V., Jurić I. , Žugec I. , 1990 - Agromeliorativne mjere kao faktor prinosa pšenice u uvjetima Slavonije. Savremena poljoprivreda, vol. 38, No. 5-6, p. 469-474.
10. Kovačević V., Kadar I., Brkic I., 1996. Response of corn (*Zea mays* L.) hybrids to potassium fertilization on strong K-fixing soil. In «Optimization of Plant Nutrition» (Editors P. Martin-Prevel and J. Bayer). IXth Intern. Coll. for the Optimization of Plant Nutrition. Sept. 8-15. 1996. Prague. Czech Republic. p.458-461.
11. Kovacevic V., V. Vukadinovic, 1992 - The potassium requirements of maize and soyabean on a high K-fixing soil. South African Journal of Plant and Soil 9. p. 10-13.
12. Kovacevic V., Vukadinovic V., Bertic B.. 1997 - Response of maize (*Zea mays* L.) to soil stress and fertilization on strong K-fixing soil. In: Developments in Plant and Soil Sciences, Volume 78: Plant Nutrition for Sustainable Food Production and Environment (Edited by Ando T., Fujita K., Mae T., Matsumoto H., Mori S. and Sekiya J.), Proceedings of the XIII International Plant Nutrition Colloquium, 13-19 September 1997, Tokyo, , Kluwer Academic Publishers, Printed in Japan, p. 315-316.
13. Kristek A., Rastija Manda, Kovacevic V., Liovic I., 1996 - Response of sugar beet to potassium fertilization on high K-fixing soil. Rostlinna vyroba. vol. 42, No 11, p. 523-528.
14. Liebhardt W. C., Murdock J. T., 1965 – Effect of potassium on morphology and lodging of corn. Agronomy Journal, vol. 57, p. 325-328.
15. Richter D., Kovacevic V., Flossmann Renata, 1990 - Ergebnisse and Untersuchung von K-fixierenden Boden Jugoslawiens. In: Richtig dungen - mehr ernten. Kali-Begbau Handelsgesellsch. mbH Berlin. vol. 14, No 2), p.1-6.
16. Vukadinovic V., Bertic Blazenka, Kovacevic V., 1988 - Kalium- und Phosphorverfugbarkeit auf den Boden im Gebiet von Posavina. Tagung Bericht Akademie der Landwirtsch. Wissenschaft der DDR. Berlin. No 267. p. 73-80.