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RESPONSE OF MAIZE GENOTYPES TO FERTILIZATION ON HYDROMORPHIC SOIL OF SAVA VALLEY

B. Šimić [(1)], V. Kovačević [(2)], Zorica Jurković [(1)]

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ABSTRACT

Growing seed-maize is more profitable than mercantile maize, but also riskier, especially under less favourable soil conditions because parents of maize hybrids are less tolerant than their progeny to environmental stress, including plant nutrition problems. For this reason, we conducted the field experiment with P and K fertilization and a range of maize genotypes (parents of seed-maize) on soil with moderate P and K supplies. Following application of 382 kg P and 726 kg K ha^{-1}, maize grain yields increased from 1.93 t ha^{-1} to 2.86 t ha^{-1} (3-year means). High correlations were found between grain yields of maize genotypes and nutrient concentrations in ear-leaf at silking stage (r = 0.82** for P and r = 0.90** for K). Based on these results, we could recommend the higher P and K fertilization of seed-maize crops on soils of similar chemical properties.

Key-words:* *fertilization, maize, nutritional status, phosphorus, potassium, yield

INTRODUCTION

Environmental conditions for maize growing in Croatia, especially in the Eastern Croatia, are generally favourable. Possible problems in some growing seasons are connected with water shortage (Kovačević and Josipović, 1998). In addition, low phosphorus and potassium supplies are limiting maize growth on some gleysols of Sava valley area (Kovačević and Vukadinović, 1992; Kovačević et al., 1996). In general, it is more profitable to grow seed-maize than mercantile maize. However, growing seed-maize is accompanied by more risks in comparison with growing mercantile maize (hybrids) since parents of maize hybrids compared to their progenies are less tolerant to environmental stresses, including drought and unfavourable soil properties, mainly low pH and nutritional disorders. For this reason, we conducted the field experiment with increased rates of P and K fertilization and different maize genotypes (parents of seed-maize) on soil characterized by moderate K and P supplies. Country needs for maize seed stock has been covered by own seed-maize production. For example, seed-maize production in Croatia (Pucarić, 1992) for the 10-year period (1981-1990) was 14 894 t annually (domestic consumption 8503 t and export 6391 t).

MATERIAL AND METHODS

The field experiment

Seven maize (*Zea mays* L.) parents of hybrids (inbred lines: Os36-16, Os2-48, Os84-44, Os138-9, Os89-9 Os84-49 i Os86-39) were grown under field conditions for three growing seasons (1993, 1994 and 1995) on Orubica eutric gleysol. Fertilization treatments were as follows: *a*) control (standard fertilization: 180 kg N + 52 kg P and 133 kg K ha^{-1}), *b*) a + 382 kg P ha^{-1} as monoammonium phosphate (MAP: 23% P and 12% N), *c*) a + 726 kg K ha^{-1} as KCl (50% K), *d*) a + 382 kg P ha^{-1} + 726 kg K ha^{-1}. Ameliorative fertilization with phosphorus and potassium was made before maize was sown

(1) Ph.D Branimir Šimić and Ph.D Zorica Jurković - Agricultural Institute, Južno predgrađe 17, 31000 Osijek, Croatia, (2) Ph.D Vlado Kovačević, Full Professor - J.J. Strossmayer University of Osijek, Faculty of Agriculture, Trg sv. Trojstva 3, 31000 Osijek, Croatia

in the first trial year (March 22, 1993), while for the second and third year at the field trial the standard fertilization was applied (kg ha^{-1}): 180 kg N + 52 P + 133 K ha^{-1} (before sowing 200 kg ha^{-1} urea and 400 kg ha^{-1} NPK 10:20:30; top dressing with 200 kg ha^{-1} calcium ammonium nitrate).
Additional quantities of urea (192 kg N ha^{-1}) were used during ameliorative fertilization for the *a* and *c* treatments for equalization of nitrogen application. For this reason, total N quantity for ordinary fertilization in the first year of testing was 372 kg N ha^{-1}. The field experiment was set up in the split-plot design with four replicates then main plot (fertilization treatment) 300 m^2 and subplot (genotypes) 40 m^2. Maize was sown at the end of April/beginning of May. Grain yields were calculated on theoretical plant density (66,027 plant ha^{-1}) reduced by 25% (49,520 plants ha^{-1} = share of mother parent in the seed-maize crop) and 14% grain moisture basis.

Table 1. Chemical and physical properties of the Orubica soil
Tablica 1. Kemijska i fizikalna svojstva tla kod Orubice

Chemical properties - *Kemijska svojstva*								
pH		Humus (%)	EUF - fraction 20°C and 80° C (mg kg^{-1}) *EUF frakcija 20°C and 80° C (mg kg^{-1})*					
H_2O	KCl			P	K	Mn	Zn	Fe
6.60	5.30	1.75	20°C 80°C	5.28 4.18	40.4 50.6	13.8	13.4	7.6

Physical properties - *Fizikalna svojstva*					
Horizons *Horizont*	Depth *Dubina* (cm)	Texture (share of soil particles size in %) *Tekstura (udjel čestica tla po veličini u %)*			
		2-0.2 mm	0.2-0.02 mm	0.02-0.002 mm	<0.002 mm
P	0-30	0.82	21.98	25.90	51.30
Gso	30-50	1.53	30.37	24.10	44.00
Gso	50-115	2.97	31.34	28.10	37.50
Gr	115-135	4.39	34.91	30.10	30.60

Comment: very compacted clay soil - *Komentar: jako zbijeno glinasto tlo*

Sampling and sample analysis

Maize ear-leaf samples were collected at the start of silking (the middle of July) from each plot (25 leaves per sample). They were prepared for chemical analysis by drying (70°C) and grinding. Plant material was digested using the wet-ashing procedure by concentrated sulfuric acid and catalyst Se (Holz, 1973). Potassium was determined by flame emission spectrometry, and P spectrophotometricaly by molybdenum-vanadium complex. For soil analysis we used the surface soil layer (30 cm deep) (soil sampling before ameliorative fertilization - March 10, 1993). Soil test was done by the EUF-method (Nemeth, 1982).

Soil properties

Orubica eutric gleysol (before the trial: pH 1 N KCl = 5.30; humus 1.75% g) is located near Nova Gradiška, Eastern Croatia. Soil test (EUF method) showed low plant available phosphorus and potassium (mg kg $^{-1}$) as follows: 5.28 and 4.18 P content; and 40.4 and 50.6 K content for extraction at 20 and 80°C, respectively (Table 1). The soil contain in the large proportion of clay (51.3%) is highly compacted. Lowland position in the landscape was disadvantageous during the period of water excess.

Weather conditions

In general, weather conditions during the three growing seasons were favourable for maize, with exception of 1995 when excess of water occurred at the early growth stage (194 mm in the May/June period). Rainfall in the 7-month period April-October (Nova Gradiška Weather Bureau) was 490 mm, 752 mm and 486 mm, for the growing seasons 1993, 1994 and 1995, respectively. Rainfall and mean air-temperatures in the critical period for maize (July + August) were adequate (total 190 mm, 282 mm and 143 mm, as well as 22.7°C, 22.6°C and 22.5°C, for the 1993, 1994 and 1995, respectively). Excess rainfall in June and July 1994 (total 390 mm) was useful for maize because of its increased needs for water in this period.

RESULTS AND DISCUSSION

Our results confirmed considerable influences of the growing season, fertilization and genotype on maize yields and its nutritional status (Table 2). For example, depending on the growing season mean grain yields ranged from 1.33 t ha^{-1} to 3.40 t ha^{-1}. Especially low yields in the 1995 growing season could be in connection with lowland position of the soil and excess of rainfall the beginning of maize growth (May and June rainfall 194 mm). In the previous years of testing, grain yields were similar and considerably higher (2-year mean 3.29 t ha^{-1}).

In general, ear-leaf P and K status were considerably different among the growing seasons, applied fertilization and genotype (Table 2)

As affected by ameliorative fertilization, maize grain yields were almost increased by 50% (3-year means: 1.93 t ha^{-1} and 2.86 t ha^{-1}, for the control and ameliorative fertilization, respectively). Analogous values for maize nutritional status (ear-leaf P and K concentrations at beginning of silking stage) were as follows: 0.29% P and .43% P, 0.86% K and 2.04% K, respectively. Application of both elements in ameliorative quantities resulted by 56% increase of maize yield, while by individual addition of these elements yield increases were similar (for 45%).

For estimation of nutritional status of maize plants, as reliable criterion is nutrient concentrations in ear-leaf at the beginning of silking stage. For example, critical concentrations (on dry matter basis) for high yields of maize are 0.25% P and 1.90% K (Melsted et al., 1969), while adequate ranges are from 0.25% to 0.35% P and from 1.75% to 2.25% K (Barber and Olson, 1968). By the other study, adequate ranges (leaf situated opposite the cob at the beginning of silking stage) are as follows: from 0.25% to 0.50% P and from 3.00 % to 4.50% K (Bergmann, 1992). In general, according to these criteria, potassium status of maize in our testing could be designated as moderate and phosphorus as adequate for maize growth. Also, acute K deficiency (less than 1.0% K) and low P contents (less than 0.30% P) were found by maize growing on the control treatment, while ameliorative fertilization considerably improved both P and K status to normal levels.

Nutritional status of maize is also under considerable influences of heredity because under identical environmental conditions differences were found among cultivars and hybrids (3, 7, 8). By our testing differences were found concerning genotype influences (3-year means) from 0.38 to 0.42% P and from 1.72 to 1.80% K and being highly significant. The highest concentrations of tested elements were found in the genotypes as follows: Os86-39 (phosphorus), Os84-44 and Os89-9 (potassium).

Considerably higher yields (mean 2.86 t ha^{-1}) were found by the Os84-44 and Os138-9 genotypes compared to Os2-48 and Os84-49 (mean 2.42 t ha^{-1}).

Three year means of maize properties (genotype x fertilization) were tested by correlations (total 28 pairs) whereas very high connections between grain yields and ear-leaf composition were found as follows: r = 0.82** (phosphorus) and r = 0.90** (potassium).

Residual effects of application of high levels of fertilizer were also found by other investigations. For example, application of 130 kg P ha^{-1} in form of calcium superphosphate on calcareous soils resulted in wheat yield increase for 16% in the fourth testing year (Shaoling, 2000).

CONCLUSION

Although environmental conditions in the eastern Croatia are mainly favourable for seed-maize growing, phosphorus and potassium nutritional problems could be a limiting factor of profitable yields. Considerable differences of maize yields depending on the growing season, applied fertilization and tested genotypes were found by our testing. As nutritional status of maize (ear-leaf P and K status) were in close connection with grain yields, based on our investigations, we could recommend application of more P and K fertilizers for seed-maize growing, especially on less favourable soils. Increased inputs as affected by recommend fertilization are covered by the higher yields of seed.

Table 2. Influences of the growing seasons, fertilization and genotype on maize properties
Tablica 2. Utjecaj godine, gnojidbe i genotipa na svojstva kukuruza

Genotype (C) *Genotip (C)*	Growing season (A) *Godina (A)*			Fertilization (B)* *Gnojidba (B)**				Mean (C) *Prosjek*
	1993	1994	1995	a	b	c	d	
Grain yield - *Prinos zrna* (t ha^{-1})								
Os 36-16	3.19	3.11	1.24	1.83	2.69	2.57	2.96	*2.51*
Os 2-48	3.06	2.90	1.28	1.76	2.50	2.43	2.92	*2.41*
Os 84-44	3.67	3.48	1.50	2.21	2.99	3.18	3.17	*2.88*
Os 138-9	3.70	3.44	1.42	2.18	3.01	3.17	3.09	*2.85*
Os 84-49	3.15	2.89	1.22	1.79	2.60	2.38	2.90	*2.42*
Os 89-9	3.44	3.14	1.28	1.99	2.58	3.00	3.05	*2.62*
Os 86-39	3.58	3.26	1.37	1.91	2.86	2.95	3.07	*2.74*
Mean A (B) *Prosjek*	*3.40*	*3.17*	*1.33*	*1.93*	*2.77*	*2.81*	*3.02*	2.63
LSD 5%	A: 0.10	AC: 0.03		B: 0.011	BC: 0.03			C: 0.01
Ear-leaf phosphorus at silking - *Fosfor u listu ispod klipa* u svilanju (% P)								
Os 36-16	0.36	0.37	0.42	0.27	0.42	0.37	0.45	*0.38*
Os 2-48	0.35	0.39	0.45	0.26	0.44	0.37	0.46	*0.40*
Os 84-44	0.34	0.40	0.48	0.29	0.46	0.40	0.47	*0.41*
Os 138-9	0.32	0.39	0.46	0.29	0.43	0.38	0.43	*0.39*
Os 84-49	0.34	0.37	0.49	0.29	0.45	0.41	0.44	*0.40*
Os 89-9	0.39	0.38	0.43	0.31	0.46	0.39	0.46	*0.40*
Os 86-39	0.40	0.39	0.47	0.29	0.50	0.40	0.49	*0.42*
Mean A (B) *Prosjek*	*0.36*	*0.38*	*0.46*	*0.29*	*0.45*	*0.39*	*0.46*	0.40
LSD 5%	A: 0.05	AC: 0.02		B: 0.011	BC: 0.02			C: 0.011
Ear-leaf potassium at silking - *Kalij u listu ispod klipa u svilanju* (% K)								
Os 36-16	1.67	1.74	1.74	0.83	1.90	2.05	2.10	*1.72*
Os 2-48	1.68	1.73	1.75	0.85	1.89	2.06	2.08	*1.72*
Os 84-44	1.74	1.91	1.76	0.93	1.92	2.20	2.16	*1.80*
Os 138-9	1.60	1.92	1.80	0.91	1.94	2.17	2.24	*1.77*
Os 84-49	1.70	1.76	1.71	0.86	1.87	2.07	2.10	*1.72*
Os 89-9	1.71	1.88	1.81	0.86	1.92	2.22	2.21	*1.80*
Os 86-39	1.72	1.73	1.72	0.81	1.86	2.13	2.11	*1.72*
Mean A (B) *Prosjek*	*1.70*	*1.82*	*1.76*	*0.86*	*1.90*	*2.10*	*2.11*	1.74
LSD 5%	A: 0.02	AC: 0.09		B: 0.03	BC: 0.11			C: 0.05

*for the 1993 growing season: a = control (372 kg N + 52 kg P and 133 kg K ha^{-1}), b = a + 382 kg P ha^{-1}, c = a + 726 kg K ha^{-1}, d = a + 382 kg P ha^{-1} + 726 kg K ha^{-1}. For the 1994 and 1995 growing seasons all treatments were fertilized uniformly in range of the control (nitrogen 180 kg N ha^{-1}).

*** za 1993. godinu: a = kontrola (372 kg N + 52 kg P i 133 kg K ha^{-1}), b = a + 382 kg P ha^{-1}, c = a + 726 kg K ha^{-1}, d = a + 382 kg P ha^{-1} + 726 kg K ha^{-1}. Za 1994. i 1995. godinu svi tretmani gnojeni su jednako na razini kontrole (dušik 180 kg N ha^{-1}).*

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REAKCIJA GENOTIPOVA KUKURUZA NA GNOJIDBU NA HIDROMORFNOM TLU POSAVINE

SAŽETAK

Uzgoj sjemenskog kukuruza profitabilniji je od uzgoja merkantilnoga kukuruza, ali i više riskantan, osobito na tlima slabije plodnosti. Razlog tome je u činjenici da su roditelji hibrida kukuruza manje tolerantni od svoga potomstva prema stresu izazvanog okolišem, uključujući i probleme s ishranom. Zato smo postavili poljski pokus gnojidbe fosforom (P) i kalijem (K) i genotipovima kukuruza (roditelji sjemenskog kukuruza) na tlu umjereno opskrbljenom s P i K. Primjenom 382 kg P i 726 kg K ha^{-1}, prinos kukuruza je povećan od 1,93 t ha^{-1} do 2,86 t ha^{-1} (3-god. prosjeci). Visoke su korelacije ustanovljene između prinosa zrna genotipova kukuruza i koncentracija P i K u listu ispod klipa u fazi svilanja (r = 0,82** za P and r = 0,90** za K). Na osnovu takvih rezultat, mogli bismo predložiti jače naglašenu gnojidbu fosforom i kalijem od uobičajene za sjemenski kukuruz na tlima sličnih kemijskih svojstava.

Ključne riječi: gnojidba, kukuruz, stanje hraniva, fosfor, kalij, prinos

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