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The Effects of Amelioration Measures on the Yield of Maize Grown on Acid Soil

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Abstract: Low yields of the plants cultivated on the acid soils seem to be very frequent. There are myriad of reasons for this, such as poor physical properties of the soil, low content of humus, reduced solubility of some bio-genetic elements (P, Ca Mg) and a higher solubility of aluminum and manganese up to the level of toxicity.

In order to eliminate or, at least, reduce these harmful effects on the yield, the trials were set up using an excess of mobile aluminum and a range of the acidity neutralizing materials, such as, bentonite, agrozel, lifos, agromag and calcium oxide. The trials proceeded on the pseudogley type of soil with extremely acid reaction (pH/M KCl around 3.55) and a high content of mobile aluminum (over 37mg/100g soil).

Amelioration measures had a differing effect on the reducing soil acidity and on mobile aluminum content, as well, resulting in maize yield variations, primarily those in acidity itself.

The lowest average maize yield was achieved applying both lifos rates (5.30 and 5.34 t/ha), being somewhat higher in relation to the control (5.16 t/ha) from 2.7 to 3.5 %, but non-significant statistically. However, compared to the control, all the other materials were found to noticeably increase yield. Thus, the increase ranged from 18.6% on the variant with zeolite (the yield of 6.12 t/ha) up to 47.3% on that with several lime rates (the yield of 7.60 t/ha).

Key words: acid soil, amelioration measures, maize yield.

Introduction

Acid soils occupy vast areas in and out of the country. According to some estimations, (Stevanovic et al., 1987) these soils in Serbia account for 50%, of which 30 % fall under extremely acid (mainly in the highlands) soils. If these soils contain a high content of mobile aluminum, most often when pH/MKCl is below 4, crop yields can be extremely low and sometimes even none.

One of these highly spread soils is pseudogley. According to Tanasijevic et al., (1966), this soil occupies 20% of the entire western Serbia. It is characterized with a rather disturbed water-air regime and unsuitable chemical properties. In addition to the natural factors exerting acid soil reaction, their further acidification may also be attributed to an intensive land use without organic and with single mineral Ca-free NPC fertilizer application (Rajkovic et al., 1987, Mineev and Tomanova, 1991, Stevanovic et al., 1994). The studies of acid soils revealed aluminum as the dominant cation in the adsorptive complex of these soils (Kamprath, 1970, Foy, 1984, Hardy et al., 1990, Bojic et al., 1998). Its toxic effect primarily refers to inhibiting of the root growth system, which was corroborated by numerous inland and foreign researchers (Clarkson, 1965, Foy, 1984, 1988, Durman, 1985, Taylor and Foy, 1985, Jakovljevic et al., 1990).

The poorly developed root system further affected the above ground plant growth, hence a noticeably lower yield than the expected one. Certain amelioration measures, decreasing soil acidity and mobile aluminum content, may help increase crop yield. In their research work most researchers (Saric and Novakovic, 1967, Veskovic et al., 1997, Brocic, 1997) found calcification to induce outstanding effects on yield. Its increase was found to directly depend on the changes in the soil chemical properties.

Materials and Method

Over the 3-year period, maize growth was studied on the acid soil containing abundance of mobile aluminum on the slopes of the mountain Suvobor in the western Serbia.

The trial was set up on the pseudogley type of soil using random-split block design with three replications. The trial field amounted to 523.6m^2, and basic plots 14m^2. The trial was set up in eleven variants:

I variant: Control
II variant: Bentonite(45 t/ha)
III variant: Bentonite (45 t/ha) + CaO (3t/ha)
IV variant: Lifos (1.5 t/ha)
V variant: Lifos (1.2 t/ha)
VI variant: CaO (3 t/ha) + MgO (1t/ha)
VII variant: CaO (3t/ha) + MgO (0.6 t/ha)
VIII variant: CaO (2.5 t/ha)
IX variant: CaO (3.5 t/ha)
X variant: Zeolite (2 t/ha)
XI variant: Zeolite (2 t/ha) + CaO (1.5 t/ha) + MgO (0.6 t/ha)

Bentonite, agrozel, lifos and calcium oxide were used to neutralize acidity. These materials were manually spread over the soil surface, and, coupled with NPC (600 kg/ha, 15: 15 : 15) entered into the soil over its pre-seeding preparation.

The seeding of the maize hybrid NSSC 201 was performed in the third decade of April with wheat as a preceding crop. Over the vegetation, cultivation measures for maize were as usual.

After usual harvesting at the end of October every year, crop yield was determined measuring two middle rows.

The data were processed, using variance analysis of the two-factorial experiment, with statistical significance of the differences made through LSD test.

Environmental conditions

Meteorological conditions. As an element of the climate, heat is considered one of the most important vegetation factors determining plant production, meteorological conditions so affecting the areal crop distribution to a great extent. Being so, on the area of the mountain Suvobor - the locality of Teocin, the heat was decisive in reducing the choice of hybrids to those of a shorter vegetation period from the FAO maturity groups 100 and 200. The temperatures and precipitations outlined in the paper refer to Čačak and serve as the orientation in case of failing to ascertain the exact ones for the area under way.

Tab.1. The Outline of Temperatures and Precipitations

Month	Characteristic							
	Mean monthly air temperatures (°C)				Precipitation levels (mm)			
	1996	1997	1998	1965-1994	1996	1997	1998	1965-1994
January	0,0	0,7	0,2	-0,3	14,2	20,5	61,5	50,2
February	-0,9	4,0	4,7	2,4	63,5	35,1	38,5	44,8
March	1,9	5,6	4,3	6,4	50,5	54,7	28,6	53,8
April	11,2	6,7	13,6	11,5	61,4	64,8	34,0	57,8
May	17,5	17,0	15,5	16,2	138,3	45,8	68,8	88,6
June	20,4	21,2	21,4	19,5	46,5	22,9	58,8	98,2
July	21,4	20,9	23,0	20,9	10,2	129,9	44,6	76,0
August	21,7	19,6	22,6	20,5	38,8	116,3	45,4	59,5
September	13,9	15,6	16,5	16,9	141,4	32,9	85,7	56,5
October	11,5	8,4	12,7	11,8	54,2	111,7	112,9	47,8
November	8,2	7,4	3,9	5,8	42,1	13,2	84,8	58,6
December	0,8	2,8	-3,0	1,5	99,7	80,3	42,7	57,6
IV - IX	17,7	16,8	18,8	17,6	436,6	412,6	337,3	436,6

In the first research year, the mean temperature of the vegetation period was at the level of the long-term average. Over the second year, it was colder by 0.8°C, but warmer by 1.1°C over the third one mostly due to considerably warmer months, i.e. April (13.6°C), July (23.0°C) and August (22.6°C), than being the long-term average. So high temperatures, coupled with the lack of precipitations in 1998 (by 99.3 mm less than the average for the vegetation period concerned), largely reduced yield due to acidity neutralizing materials poorer effects and mobile aluminum excess, as well. Precipitation sums over maize vegetation periods of 1996 (436.6 mm) and those of 1997 (412.6mm) are very much the same to the long-term average (436.6 mm). Taken by months for both research years, the most abundant rainfalls fell in May (138.3 mm) and in September (141.4 mm) of 1996 as well as in July (129.9 mm) and in August (116.3 mm) of 1997. As regards rainfall distribution, 1997 appeared to be the most suitable year for maize cultivation.

Results and Discussion

When analyzing maize yields, two facts must be taken into account. First, maize was seeded on a different locality every year and the material to neutralize acidity had been added immediately before seeding so that maize growth and development went on simultaneously with the material being dissolved in the soil. Second, taken by years, the environmental conditions, particularly precipitation distribution, considerably varied, which accelerated the dissolution of the neutralizing materials. Therefore, on a year basis, these were major reasons for the statistically highly significant differences in maize yield.

Tab.2. Maize Grain Yield (t/ha)

Variant (A)	Research Year (B)			Average	
	1996.	1997.	1998.	T/ha	%
Control	7,28	6,58	1,62	5,16	100,0
Bentonite	8,61	8,54	3,96	7,04	136,4
Bentonite + CaO	8,51	8,33	3,48	6,78	131,4
Lifos I	6,84	7,70	1,36	5,30	102,7
Lifos II	6,75	7,83	1,43	5,34	103,5
CaO+MgO (3:1)	8,10	9,67	3,20	6,98	135,3
CaO+MgO (5:1)	8,02	9,08	4,17	7,09	137,4
CaO I	7,63	9,91	4,17	7,24	140,3
CaO II	7,86	10,14	4,79	7,60	147,3
Zeolite	7,01	8,87	2,46	6,12	118,6
Zeolite + CaO+MgO	7,38	9,09	2,10	6,19	120,0
Average	7,64	8,71	2,98	6,44	

		A	B	AB
	0,05	0,38	0,20	0,66
LSD	0,01	0,50	0,26	0,87

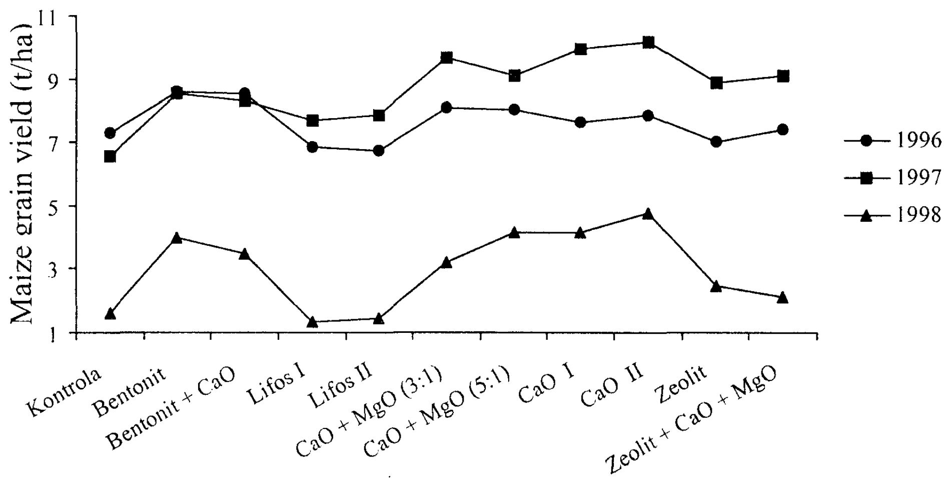
In 1996, which was by rainfall amounts identical to the long-term average, the average maize yield of 7.64 t/ha was achieved. The highest yield (8.61 t/ha) was achieved on the variant with bentonite, and the lowest one (6.75 t/ha) on that with lifos in the amount of 1.2 t/ha.

In 1997, the highest maize yield averaged 8.71 t/ha benefiting from good water distribution in the soil, with 412.6 mm of the rainfall amounts recorded, being lower than the long-term average by 24mm, but better distributed in relation to the preceding year. All the amelioration measures used brought about a higher yield compared to the control. The highest yield was achieved with 3.5 t/ha lime (10.14 t/ha), and the lowest one (7.70 t/ha) with 1.5 t/ha lifos.

The lowest maize yield (2.98 t/ha) was recorded in 1998, as an extremely dry year. Over maize vegetation, 337.3mm rainfalls were recorded being around 100 mm lower than the long-term average. The highest water deficit was recorded soon after seeding, which, together with lacking soil moisture before seeding slowed down dissolution of the lime material in the soil. Still, the increase in maize yield was recorded on all the variants with amelioration measures applied, excepting both lifos rates with an even lower yield than that on the control (just as being in the first research year). The highest yield in 1998 (4.79 t/ha) was recorded with 3.5 t/ha lime, and the lowest one (1.36 t/ha) with 1.5 t/ha lifos.

Analysis of the average 3-year old maize yield indicated that, excepting lifos having elevated yield only by 2.7 and 3.5% compared to the control, all the acidity neutralizing materials and mobile aluminum excess were found to statistically significantly raise yield compared to the control (Fig.1.). As the soil was acid, a positive effect of lifos was expected.

Fig.1. Effects of Amelioration Measures on Maize Yield Increase



However, phosphorus contained in the pseudogley seemed to be high for such an acid soil so that the addition of lifos did not increase Al-phosphates sedimentation and thus helped the content of mobile aluminum in the soil be kept up to the level of toxicity. As a result, a sparsely developed root system was not able to take up water and plant nutrients so that plants grown in these conditions were legging behind in their vegetative growth, hence, a poor yield. The other amelioration measures led to higher yields, ranging from 18.6% on the variant with zeolite (the yield of 6.12 t/ha) to 47.3% on that with a more abundant lime rate (the yield of 7.60 t/ha). No statistically significant differences were revealed, comparing the yields imparted by these materials used in two different rates or in combination with lime. All this suggests that of all the amelioration measures, those with lime alone or combined with some other material displayed the best effect. That calcification favoured maize yield increase on pseudogley has been confirmed by numerous research works bearing in mind its being highly dependent on the calcification material rate and soil acidity, as well. Thus, Stevanovic et al., (1992) recorded maize yield increase by 35%, Radanovic (1995) by 48%, Broćić (1997) by 38.43%, Veskovic et al., (1997) by 38% and finally Bojic et al., (1998) found by 42.3% greater one.

Conclusions

Based on the research goals, the following conclusions may be drawn:

- The NSSC 201 maize hybrid, under conditions of good water availability to soil (over the first two study years), displayed somewhat tolerance to low pH and to the high content of mobile aluminum,
- Maize grain yield was on average increased by 2.7 to 47.3% with application of remedial measures.
- Of all the amelioration measures, calcification displayed the best effect meaning its being unavoidable in plant production regulation on acid soil.

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UTICAJ MELIORATIVNIH MERA NA PRINOS KUKURUZA GAJENOG NA KISELOM ZEMLJIŠTU

-originalni naučni rad-

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Rezime

Niski prinosi gajenih biljaka na kiselim zemljištima su česta pojava, koju prouzrokuju brojni činioci (loše fizičke osobine zemljišta, nizak sadržaj humusa, smanjena rastvorljivost nekih biogenih elemenata (P, Ca, Mg), a povećana rastvorljivost aluminijuma i mangana do granice toksičnosti).

U cilju eliiminisanja ili smanjenja ovih štetnih uticaja na prinos, postavljeni su ogledi gde su korišćeni različiti materijali za neutralizaciju kiselosti i viška mobilnog aluminijuma: bentonit, agrozel, lifos, agromag i kalcijum oksid. Ogled je postavljen na zemljištu tipa pseudoglej, ekstremno kisele reakcije (pH/MKCl oko 3,55) sa visokim sadržajem mobilnog aluminijuma (preko 37 mg/100 g zemljišta).

Izvedene meliorativne mere ispoljile su različit uticaj na smanjenje kiselosti zemljišta i sadržaja mobilnog aluminijuma, pa je i prinos kukuruza varirao zavisno od ovih promena i pokazivao je direktnu zavisnost od postignutih promena kiselosti.

Najniži prosečni prinos kukuruza ostvaren je primenom obe doze lifosa (5,30 i 5,34 t/ha), što je povećanje u odnosu na kontrolnu varijantu (5,16 t/ha) od 2,7, odnosno 3,5% i statistički nije značajno. Svi ostali materijali značajno su povećali prinos kukuruza u odnosu na kontrolnu varijantu. To povećanje se kretalo od 18,6% na varijanti gde je primenjen zeolit (prinos 6,12 t/ha), do 47,3% na varijanti gde je primenjena viša doza kreča (prinos 7,60 t/ha).