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The Effect of the Acidity-Neutralizing Materials Applied on the Morphological Traits of Maize

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Abstract: A high percentage of agricultural acid-reaction soils is a serious obstacle to the cultivation of a great number of susceptible plant species. Under such conditions, the choice of crops is being limited to tolerant species and, furthermore, their growing without the use of the acidity-neutralizing materials results in lower yields and lower quality. For this reason, amelioration of these soils is essential, not only as a long-term measure for acid soil amendment, but also as a means for a temporary achievement of better performance results.

At the site of Mt. Suvobor (the village of Teocin), a pronounced soil acidity (pH/M KCl 3.55) was determined, coupled with a high mobile aluminium content (over 37 mg/100 g soil). Bentonite, agrozel, crude phosphates, MgO and CaO were used to neutralize soil acidity and an excess of aluminium.

The material used exerted a certain effect on the soil, but also on the maize crop (NS 201) cultivated, having been manifested through variations in the morphological traits examined. The meliorative measures such as the use of bentonite (alone or combined with lime), CaO and MgO combinations and both lime rates, had a positive effect also on increases in the 1000-kernel weight, plant and ear height, as well as on an increase of ear length.

A considerable effect of growing climate-related conditions was registered again. Owing to differing precipitation distribution, differences between the morphological parameters investigated according to the research years, were recorded.

Key words: maize, acidity, 1000-kernel weight, ear, height

Introduction

Over 50 % of agricultural soils in Serbia are of acid reaction (Stevanovic et al., 1995). The same authors record signs of crop (wheat, barley, oil seed rape) poisoning in extremely acid soils with the 4.0 pH value. Based upon these and a number of other results, acid soil liming has been performed for several years now, under the auspices of the Ministry for Agriculture of the Republic of Serbia, via free lime distribution to households where this problem is pronounced.

Acid soils very often contain high concentrations of Al, Mn, Ni, Cr and other unfavourable elements and their compounds endangering crop production. Certain metals (Ni, Co, Zn, Cd) can decrease calcium uptake by the plant (Veltrup, 1981), whereas higher Ca presence can lead to a significant reduction in the uptake of heavy metals thus protecting the plant from being poisoned. Ca incorporation into the soil is therefore of extreme importance for a stable crop production. Although plants do not require high calcium amounts, due to its slow transport through the phloem, the root meristem supply with this nutrient has to be a continuing one (Mengel & Kirkby, 1987).

High mobile Al^{3+} content limits the choice of crops sensible to its presence, which is accompanied by a Ca deficiency and low pH value. This condition has a significant effect on a reduction in product yield and quality unless acidity neutralization takes place (Jovanovic et al., 1995; Bojic et al., 1997; Brocic 1997; Bojic et al., 1998; Bokan et al., 2000; Boskovic-Rakocevic Ljiljana and Bokan 2002), but also on the crop condition during the growing season, being manifested through the effect on the morphological traits of the grown plants.

A number of morphological traits is genetically determined, but growing conditions and technology used produce a pronounced impact on their expression in cultivated crops. Numerous results confirm the effect of soil and meteorological conditions in specific years, as well as of the plant density, fertilizer type and rate, on plant and ear height, ear length and kernel traits (Bagnara, 1985; Bokan et al., 1997; Stevovic et al., 1997; Bokan, 1998; Hugger, 1998).

The aim of this paper was to determine the effect of different acidity-neutralizing materials applied on morphological traits of maize. The cultivated crop habitus is generally highly correlated with the yield, indicating that on the basis of the morphological traits an evaluation of the temporary crop performance and a reliable forecast of final results in crop production on acid soils can be made.

Materials and Method

The experiment was set up in the village of Teocin, Mt. Suvobor, on the pseudogley soil type, using the randomized block design method with three replications. The total trial field surface area was 523.6 m^2 and the plot area was 14 m^2 (5x2.8 m). The trial was set up in 11 variants:

I variant: Control Ø
II variant: Bentonite (45 t/ha)
III variant: Bentonite (45 t/ha) + CaO (3 t/ha)
IV variant: Crude phosphates (1.5 t/ha)
V variant: Crude phosphates (1.2 t/ha)
VI variant: CaO (3 t/ha) + MgO (1 t/ha)
VII variant: CaO (3 t/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, crude phosphates, MgO and CaO were used to neutralize acidity and mobile aluminium excess. The materials were spread manually over the soil surface and, coupled with the NPK fertilizer, introduced by discing into the soil over its preceding seedbed preparation.

Prior to the establishment of the trial, soil samples were taken from the arable layer (0-30 cm deep).

In all the trial variants, including the control, equal fertilizer rates were applied, being as follows: 600 kg/ha NPK 15:15:15 before planting, and 250 kg/ha KAN was added through top-dressing. The early-maturity NS 201 maize hybrid was used in the trial. Wheat was used as a preceding crop in all the variants.

Each study year, following the harvesting period, maize kernels in the maturity stage were sampled for analyses from each variant and replication. 10 average ears were selected for measurements.

Environmental conditions

<u>Soil conditions.</u>

Table 1.- Soil chemical properties prior to the trial establishment

Site	pH		V(%)	Al (mg/100g)	Humus (%)	Total N (%)	P_2O_5 (mg/100g soil)	K_2O
	H_2O	KCl						
1.	4.46	3.55	17.55	41.7	2.39	0.178	14.8	23.8
2.	4.61	3.58	19.94	37.9	2.67	0.211	15.0	30.1
3.	4.52	3.52	18.83	38.2	2.30	0.174	13.2	24.0

The pseudogley, where the investigations proceeded, was characterized by extremely acid soil reaction which, depending on the study year, ranged from pH/H_2O = 4.46 – 4.61 and pH/KCl – 3.52 – 3.58 (tab.1). This highly active and substitutional soil acidity was accompanied by a high level of alkaline saturation (V = 17.55 – 19.94%).

The extremely acid soil reaction brought about a higher mobility of Al^{3+} ions the content of which ranged from 37.9 – 41.7 mg/100 g soil. Such a high mobile aluminium content is considered toxic not only to the plants cultivated but also to the weeds potentially resulting in a complete crop decay on the soil.

As regards the content of basic plant nutrients the pseudogley examined was characterized by medium humus, total nitrogen and available phosphorus supplies and a high available potassium supply. Higher contents of available phosphorus and potassium in the soil compared to average pseudogley values indicate that the introduction of higher NPK rates tended to overcome the low-yield problems resulting from very acid soil reaction and a high mobile aluminium content and not from a deficiency of the NPK nutrient.

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 Cacak and serve as the orientation in case of failing to ascertain the exact ones for the area under way.

Tab. 2. 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 (tab. 2). 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 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 aluminium excess, as well (Bokan et al. 2000). 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

1000-kernel weight as many other maize yield structure indicators is a genetically determined trait much affected by the growing conditions (Hugger, 1989). Certain acidity-neutralizing materials applied had a specific effect on this kernel trait (Tab. 3).

Tab. 3. - 1000-kernel weight (g)

Trial variant (A)	Research year (B)			Average	
	1996	1997	1998	g	%
Control	234.8	244.4	234.5	**237.9**	**100.0**
Bentonite	285.6	267.6	259.1	**270.8**	**113.8**
Bentonite + CaO	277.3	261.9	255.6	**264.9**	**111.3**
Crude phosphates I	231.1	241.8	226.1	**233.0**	**97.9**
Crude phosphates II	231.2	242.4	211.1	**228.2**	**95.9**
CaO+MgO (3:1)	261.1	270.4	264.8	**265.4**	**111.6**
CaO+MgO (5:1)	261.5	275.2	281.3	**272.7**	**114.6**
CaO I	253.3	284.2	268.5	**268.7**	**112.9**
CaO II	249.1	282.1	278.2	**269.8**	**113.4**
Zeolite	227.5	276.0	242.9	**248.8**	**104.6**
Zeolite + CaO+MgO	235.5	269.7	263.4	**256.2**	**107.7**
Average	**249.8**	**265.1**	**253.2**	**256.0**	

Average values for the 1000-kernel weight ranged from 228.2 g (crude phosphates, lower rate) to 272.7 g (CaO+MgO at the 5:1 ratio). Compared to the control, in both variants where crude phosphates were applied there was a minor reduction of the 1000-kernel weight value (by 4.1 %, lower crude phosphates rate, i.e. 2.1 %, higher crude phosphates rate). In all the other variants the 1000-kernel weight value increased, as determined, by 4.6% (zeolite) to 14.6 % (Cao+MgO; 5:1).

If the 1000-kernel weight values are compared to the maize yields obtained (Bokan et al., 2000), a positive dependence between the two parameters can be established. Namely, the maize yield increase was least when both crude phosphate rates were applied, resulting in the lowest 1000-kernel weight values. The use of bentonite (alone or combined with lime), the CaO and MgO combination and both lime rates resulted in high yields coupled with high 1000-kernel weight values.

The plant height is also a genetically determined trait changing depending on the nutrient soil supply and climatic conditions. A positive impact of favourable climatic conditions was recorded in 1997, when the average plant height was 242.0 cm (tab. 4), being quite uncommon for the NS 201 hybrid. In the other two research years, the average plant height values were considerably lower (165.4 and 142.2 cm, respectively).

Tab. 4.- Plant and ear height (cm)

Trial variant (A)	Plant height					Ear height				
	Research year (B)			Average		Research year (B)			Average	
	1996	1997	1998	cm	%	1996	1997	1998	cm	%
Control	154.8	211.2	120.2	**162.1**	**100.0**	42.0	70.6	30.0	**47.5**	**100.0**
Bentonite	203.8	240.3	155.0	**199.7**	**123.2**	70.3	87.5	44.5	**67.4**	**141.9**
Bent.+CaO	194.6	246.0	142.4	**194.3**	**119.9**	59.2	91.8	38.3	**63.1**	**132.8**
Crude phosphates I	158.0	238.2	124.2	**173.5**	**107.0**	44.5	86.5	26.6	**52.5**	**110.5**
Crude phosphates II	152.3	249.2	120.3	**173.9**	**107.3**	40.1	92.3	24.5	**52.3**	**110.1**
CaO+MgO (3:1)	160.7	242.9	147.5	**183.7**	**113.3**	45.7	87.1	38.0	**56.3**	**119.8**
CaO+MgO (5:1)	161.9	253.2	153.9	**189.7**	**117.0**	45.0	101.5	40.7	**62.4**	**131.4**
CaO I	161.6	244.4	151.5	**185.8**	**114.6**	45.9	93.3	37.7	**59.0**	**124.2**
CaO II	163.8	246.8	153.3	**188.0**	**116.0**	46.7	98.8	41.1	**62.2**	**130.9**
Zeolite	151.4	248.9	138.9	**179.4**	**110.7**	38.5	94.4	29.3	**54.1**	**113.9**
Zeolite+CaO+ MgO	156.2	241.5	157.0	**184.9**	**114.1**	41.7	93.6	46.4	**60.6**	**127.6**
Average	**165.4**	**242.0**	**142.2**	**183.2**		**47.2**	**90.7**	**36.1**	**58.0**	

Average plant height in all the meliorated variants was higher than in the control (162.1 cm), ranging from 11.4 and 11.8 cm (crude phosphates, both rates) to 37.6 cm (bentonite). The increase varied from 7.0-23.2 %, depending on the soil acidity change level after the neutralization performed.

All the meliorative measures, as in the yield and 1000-kernel weight, can be divided into two groups. One group includes crude phosphate and zeolite application with the lowest values determined for plant height, 1000-kernel weight and maize yield. The second one consists of the rest of the meliorative measures the effect of which brought about an increase in available calcium content (Boskovic-Rakocevic, Ljiljana et al., 2004), a decrease in acidity and mobile aluminium content, a higher nutrient content in the soil and nutrient uptake by the plant, resulting in the yield, 1000-kernel weight and plant height increases.

The highest variation was determined with the ear height trait, depending on the meliorative measure used and the research year. Namely, the lowest average ear height (47.5 cm) was registered with the control variant. In the variant with crude phosphates (both rates) the heights of 52.3 and 52.5 cm were recorded, and in the one with the use of bentonite, the ear height was 67.4 cm. Other values for ear height ranged within the variation interval and were similar to the maize yield, 1000-kernel weight and plant height previously analyzed. The effect of favourable climatic conditions was clearly evident here, too, considering that the ear height recorded in 1997 was 90.7 cm, or by 43.5 cm and 54.6 cm greater than in 1996 and 1998, respectively.

The ear length and thickness are genetically-determined traits, as well, which can change to a lesser or greater degree depending on the soil conditions altered and on climatic characteristics (tab. 5).

Tab. 5. – Ear length and thickness (cm)

Trial variant (A)	Ear length					Ear thickness				
	Research year (B)			Average		Research year (B)			Average	
	1996	1997	1998			1996	1997	1998		
Control	16.3	17.3	11.3	**15.0**	**100.0**	4.4	4.4	4.2	**4.3**	**100.0**
Bentonite	18.2	17.4	14.4	**16.7**	**111.3**	4.5	4.4	4.2	**4.4**	**102.3**
Bent.+CaO	17.2	19.4	13.8	**16.8**	**112.0**	4.5	4.7	4.1	**4.4**	**102.3**
Crude phosphates I	16.3	19.1	10.0	**15.1**	**100.7**	4.4	4.6	3.7	**4.3**	**100.0**
Crude phosphates II	16.5	18.5	9.9	**15.0**	**100.0**	4.4	4.5	3.6	**4.2**	**97.7**
CaO+MgO (3:1)	17.2	19.1	13.5	**16.6**	**110.7**	4.4	4.6	4.1	**4.4**	**102.3**
CaO+MgO (5:1)	17.3	18.6	14.8	**16.9**	**112.3**	4.4	4.5	4.5	**4.5**	**104.6**
CaO I	17.2	18.7	14.8	**16.9**	**112.3**	4.4	4.5	4.2	**4.4**	**102.3**
CaO II	17.3	19.1	15.9	**17.4**	**116.0**	4.4	4.5	4.3	**4.4**	**102.3**
Zeolite	16.3	19.6	13.2	**16.4**	**109.3**	4.4	4.5	4.4	**4.4**	**102.3**
Zeolite+CaO +MgO	16.7	19.6	15.2	**17.2**	**114.7**	4.4	4.6	4.5	**4.5**	**104.6**
Average	**17.0**	**18.8**	**13.3**	**16.4**		**4.4**	**4.5**	**4.2**	**4.4**	

The meliorative measures applied had a small effect on the variation of average ear length values (from 0.0 – 16.0 %), but the smallest effect of both crude phosphate rates was registered with this trait as well. The ear length in the variants (15.0 and 15.1 cm, respectively) was almost equal to the values registered in the control variant (15.0 cm), whereas other meliorative measures brought about an increase in the ear length ranging from 1.4 to 2.4 cm. Similarly, Dugalic (1993) recorded a significant increase in the ear length compared to the control (11.93%), due to the lime material used. With respect to the research years, the highest ear length (18.8 cm) was recorded in 1997, followed by a somewhat smaller length (17.0 cm) in 1996 and the smallest one (13.3 cm) in 1998, being identical to the effect of the research year and different climatic factors on the plant and ear heights and in accordance with the results obtained by a number of authors (Bagnara, 1985; Bokan et al. 1997; Stevovic et al., 1997; Bokan, 1998; Hugger, 1998).

Of all the maize morphological traits examined, the lowest effect of the meliorative measures was registered with the ear thickness. Average ear thickness values ranged from 4.2 cm (lower crude phosphate rate) to 4.5 cm (CaO+MgO; 5:1 and zeolite + CaO + MgO), or from 0.0 – 4.6 %. Such a narrow variation interval was expected, since the meliorative measures brought about certain changes in the soil that could not considerably alter this ear trait.

Conclusions

Based upon the three-year investigations of the maize morphological traits, depending on the acidity-neutralizing materials applied on extremely acid soils with a high mobile aluminium content, the following conclusions may be drawn:

All the traits examined were highly affected by different meteorological conditions over the vegetation period of the maize cultivated under the conditions of mountainous climate of the Suvobor region, more precisely, the village of Teocin. The plant habitus showed typical characteristics of the NS 201 hybrid cultivated only in the second research year, when the precipitation distribution favoured the maize needs. The average plant and ear heights registered then were 242 cm and 90.7 cm, respectively.

The meliorative measures that contributed to the decrease in acidity and mobile aluminium content, as well as to improved nutrient contents in the soil and their uptake by the crop, such as the use of bentonite (alone or coupled with lime), of the CaO and MgO combination and both lime rates, had a positive effect on both the 1000-kernel weight, plant and ear height increase and the ear length increase.

The lowest variation was registered with the ear thickness trait, so that neither the climatic conditions over the research years, nor the meliorative measures used, had exerted any visible effect on its expression.

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UTICAJ PRIMENJENIH MATERIJALA ZA NEUTRALIZACIJU KISELOSTI NA MORFOLOŠKE OSOBINE KUKURUZA

- originalni naučni rad -

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Rezime

Visok procenat poljoprivrednog zemljišta kisele reakcije otežava gajenje velikog broja osetljivih biljnih vrsta. Osim što se u takvim uslovima sužava izbor useva na tolerantne vrste, i njihovim gajenjem bez primene materijala za neutralizaciju kiselosti, dobijaju se niži prinosi i slabiji kvalitet. Zato su melioracije ovakvih zemljišta neophodne, ne samo kao dugoročna mera popravke kiselih zemljišta, već i za trenutno ostvarivanje boljih proizvodnih rezultata.

Na lokaciji planine Suvobor (selo Teočin), utvrdili smo izraženu kiselost zemljišta (pH/M KCl 3.55), praćenu visokim sadržajem mobilnog aluminijuma (preko 37 mg/100g zemljišta). U cilju neutralizacije kiselosti i viška aluminijuma, korišćeni su bentonit, agrozel, sirovi fosfati, MgO i CaO.

Primenjeni materijali su izvršili određeni uticaj na zemljište, ali i na gajenu biljku kukuruza (NS 201), što se manifestovalo variranjem posmatranih morfoloških osobina. Meliorativne mere kao što su primena bentonita (samog ili u kombinaciji sa krečom), zatim kombinacije CaO i MgO i obe doze kreča, pozitivno su uticale i na povećanje mase 1000 zrna, visine biljke i klipa, kao i povećanje dužine klipa.

I ovaj put se pojavio značajan uticaj uslova uspevanja, sa aspekta klimatskih prilika. Tako su, zbog različitog rasporeda padavina, zabeležene razlike između posmatranih morfoloških pokazatelja, po godinama proučavanja.