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MAIZE PRODUCTION AND CATION CONTENT IN BIOMASS DEPENDING ON SOIL ACIDITY NEUTRALIZATION AND MINERAL NUTRITION

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Summary. In a pot experiment with maize the effect of soil acidity neutralization and mineral nutrition on biomass formation and content of H^+, Ca^{2+}, K^+ and Mg^{2+} ions in water soluble and exchange adsorbed state was studied. Maize reacted as an acidic sensitive plant evaluated by the correlation yield–soil pH. The relationship yield–mineral nutrition level showed maximum production at a high concentration of salts in the soil (0.9–1.0 g/100 g). Soil acidity neutralization decreased H^+ ions and increased Ca^{2+} ions in the tissues. The increasing mineral nutrition level strongly increased organic acids and basic cations. The cation exchange capacity of the biomass was enhanced under the influence of both neutralization and mineral nutrition. Cations' distribution in the biomass was traced depending on the applied factors.

Key words**:** soil pH, mineral nutrition level, maize, cation content in the biomass

Introduction

Changes in the nutrient medium conditions lead to certain changes in the plant metabolism. It is of importance to study the influence of different nutrition factors including the interaction between them to achieve a positive effect on plant growth and metabolic reactions (Magalhaes and Huber, 1989; Adetunju and Bamiro, 1994). The influence of soil acidity neutralization and mineral nutrition on some reactions of vegetable and forage plants has been investigated in the author's previous studies (Arsova, 1994). The aim of this work was to proceed an analogous investigation of the combined effect of increasing soil pH and mineral nutrition on maize production and cation content in the biomass as criteria for the evaluation of the plant acidic sensitivity and the acidic and sorption properties of the tissues.

Materials and Methods

A pot experiment with maize (P 3159) was carried out on a light gray forest soil (Dushevo). The soil had the following physico-chemical characteristics determined by the author's method (Ganev and Arsova, 1980): pH 5.1; cation exchange capacity – 24.6 mequ/100 g; total acidity – 8.5 mequ/100 g; exchangeable Al – 2.4 mequ/100 g; exchangeable Ca^{2+} and Mg^{2+} – 16.8 mequ/100 g. Soil acidity was neutralized with $CaCO_3$ in g/100 g soil as follows: Ca_0 – 0.0 g; Ca_1 – 0.25 g calculated according to the optimal liming norm for acid soils (Ganev, 1987); Ca_2 – 0.84 g overliming. Four levels of mineral nutrition were applied (g salts/100 g soil): T_0 – 0.0 g; T_1 – 0.3 g; T_2 – 0.9 g; T_3 – 2.7 g. The salts were in the following combination: $NH_4NO_3 : Ca(H_2PO_4)_2 : KH_2PO_4 : MgSO_4$ = 1 : 0.5 : 0.5 : 0.2. The salt concentrations were specified after previous tests. The experiment (45-day-long) was carried out in pots with 2300 g soil in three replications. The soil moisture was maintained about 60% field capacity. The dry biomass was weighed and the content of H^+, Ca^{2+}, K^+, Mg^{2+} ions in a water soluble and in an exchange adsorbed state was determined by the author's method (Ganev and Arsova, 1982). Soil pH was measured in all variants.

Results and Discussion

The production of maize at different levels of the soil acidity neutralization (pH) and mineral nutrition is presented in Table 1. The differences between the yield values are statistically significant. Fig.1 shows the relationships between the yield and soil pH (A) and the mineral nutrition level (B). The maximum production at the optimal soil acidity neutralization (Ca_1) is confirmed for all levels of the mineral nutrition. The curves (A) according to which plant acidic sensitivity or tolerance are evaluated show that maize reacts to soil acidity neutralization, i.e. it is an acidic sensitive plant. The acidic sensitivity of maize is higher as compared to other cereals (wheat) (Ganev and Kalitchkova, 1992), but in relation to some forage and vegetable plants it is slightly expressed (Arsova, 1994).

The reaction of maize to the factor mineral nutrition (Fig. 1B) is essential and a very specific one. It is connected with the characteristics of maize – C_4 photosynthetic cycle and active metabolism. The maximums in the correlation yield/g salts are clearly expressed and correspond to 0.9–1.0 g salts per 100 g soil that is about three times higher than the optimal concentration established for other plants (Arsova,

Table 1. Yield of maize depending on soil pH and mineral nutrition level

Treatments	Salts, g/100g soil	Soil pH	Yield, g/5 plants
T_0Ca_0	0.0	5.1	2.79
T_0Ca_1	0.0	6.2	3.75
T_0Ca_2	0.0	7.5	3.20
T_1Ca_0	0.3	5.0	20.80
T_1Ca_1	0.3	6.1	24.70
T_1Ca_2	0.3	7.1	22.50
T_2Ca_0	0.9	4.9	21.60
T_2Ca_1	0.9	5.9	26.90
T_2Ca_2	0.9	6.7	25.70
T_3Ca_0	2.7	4.7	3.52
T_3Ca_1	2.7	5.7	4.23
T_3Ca_2	2.7	6.3	3.03

Factor A (neutralization)	GD	1%	0.53 ***
	GD	0.1%	0.75 ***
Factor B (mineral nutrition)	GD	1%	0.63 ***
	GD	0.1%	0.88 ***
A × B	GD	1%	1.07 ***
	GD	0.1%	1.51 ***

1994). It is confirmed that the effectiveness of mineral nutrition on yield is maximal at the optimal soil acidity neutralization.

The influence of neutralization and mineral nutrition level on the content of cations in a water soluble and in an exchange adsorbed state in maize biomass could be seen in Table 2. Increased neutralization level decreases H^+ ions in a water soluble state (organic acids) and H^+ ions in an exchange adsorbed state on the biopolymers for all levels of a mineral nutrition. K^+ ions also decrease in the two phases, while Ca^{2+} ions increase (Ca salts of organic acids and exchange adsorbed Ca^{2+}). The decrease of the acidity (H^+ ions) in the tissues is not very significant and it is a reflection of the degree of maize acidic sensitivity. For example, H^+ ions in a water soluble state decrease from Ca_0 to Ca_2 variants with 1.6 mequ at T_0 and with 5.6 mequ at T_3 level. The decrease of the acidity under the influence of the neutralization is weakly expressed as compared to other more acidic sensitive plants (Arsova, 1994).

However, the increase of Ca^{2+} ions in a water soluble state in maize biomass is significant. Ca^{2+} ions between the variants Ca_0 and Ca_2 rise with 20.0 mequ at T_0 and with 25.1 mequ at T_3 level. This is connected again with the degree of a plant acidic sensitivity since the increasing soil pH enchances the organic acid neutralization in the tissues of the weakly sensitive plants and leads to an excess of Ca salts (Ganev

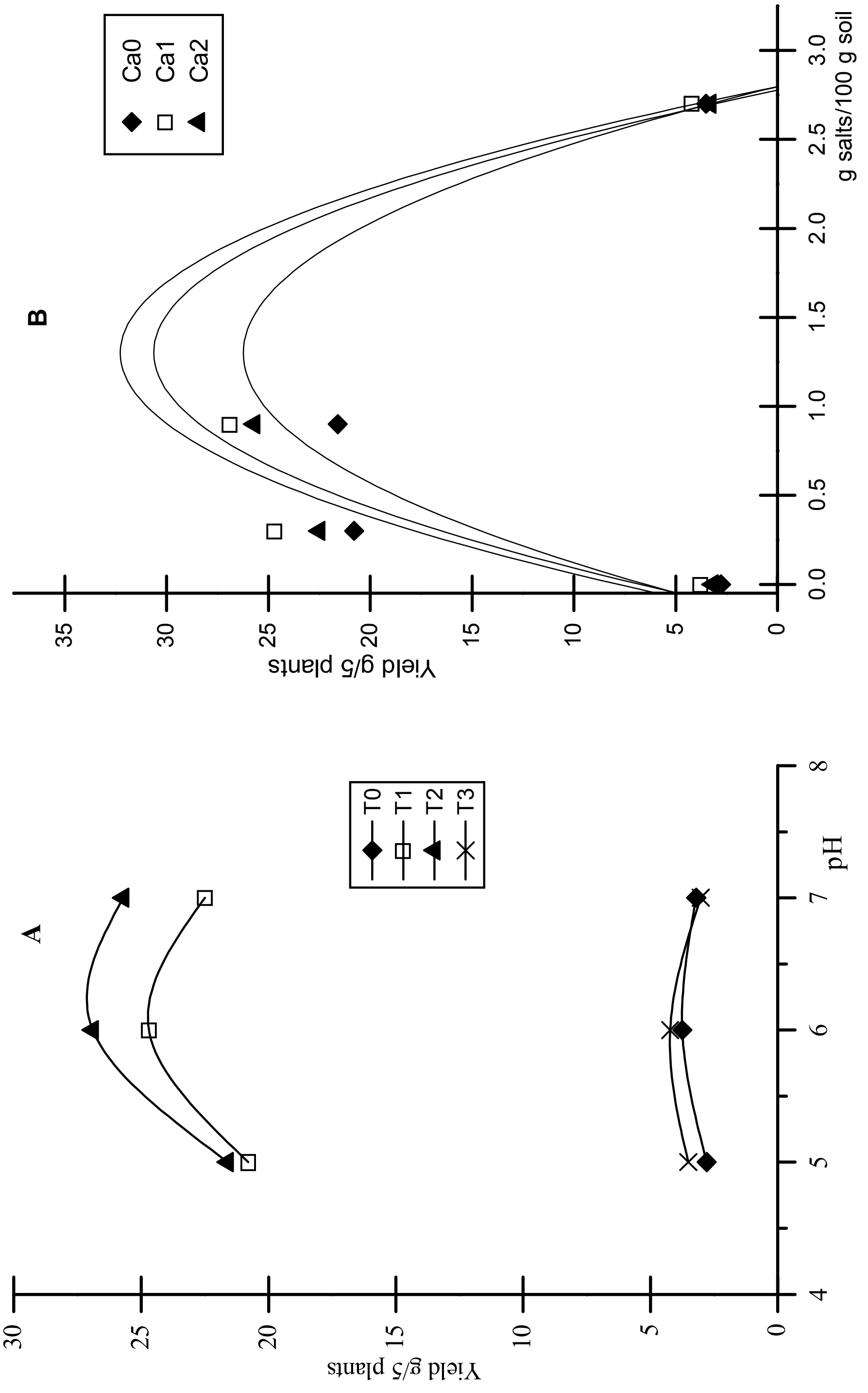

Fig. 1. Yield of maize depending on soil pH (A) and mineral nutrition (B)

Table 2. Cation content in the biomass of maize in mequ/100 g dry matter

Treat-ments	H^+	Ca^{2+}	Mg^{2+}	K^+	Σ	H^+	Ca^{2+}	Mg^{2+}	K^+	Σ
	water soluble cations					exchange adsorbed cations				
T_0Ca_0	38.0	30.5	2.5	59.8	130.8	5.2	13.8	1.2	0.7	20.9
T_0Ca_1	37.2	42.5	2.7	48.0	130.4	3.2	15.3	1.2	0.6	20.3
T_0Ca_2	36.4	50.5	2.7	40.4	130.0	2.8	17.5	1.3	0.5	22.1
T_1Ca_0	39.6	33.0	2.8	59.4	134.8	5.6	14.3	1.2	1.0	22.1
T_1Ca_1	38.4	43.0	2.9	49.4	133.7	4.8	16.0	1.2	0.8	22.8
T_1Ca_2	37.6	52.5	2.9	41.6	134.6	3.2	18.3	1.3	0.6	23.4
T_2Ca_0	55.2	36.5	3.0	68.5	136.2	6.0	15.0	1.2	1.2	23.4
T_2Ca_1	53.6	47.0	3.0	53.1	156.2	5.2	16.8	1.2	0.9	24.1
T_2Ca_2	51.2	57.5	3.1	44.8	156.6	3.6	21.0	1.3	0.7	26.6
T_3Ca_0	60.8	45.4	3.1	80.5	189.8	7.2	15.8	1.2	1.2	25.4
T_3Ca_1	57.2	59.0	3.1	60.8	180.1	5.6	18.8	1.2	1.0	26.6
T_3Ca_2	55.2	70.5	3.1	48.0	177.0	4.0	23.0	1.3	0.9	29.2

and Kalitchkova, 1992; Arsova, 1994). This way the presence of a high concentration of Ca salts in the liquid phase of the maize biomass could be explained.

Soil acidity neutralization does not influence the total electrolytic content (sum of cations in a water soluble state) and it is relatively constant for each variant of the mineral nutrition. The cation exchange capacity (sum of exchange adsorbed cations), however, shows a tendency to increase.

The effect of increasing mineral nutrition on cation content in the biomass differs from the neutralization effect and causes an increase of H^+, Ca^{2+} and K^+ ions in the two phases, respectively of the electrolytic content and the cation exchange capacity. The influence of the mineral nutrition should be discussed connected with the changes in the soil acidic state induced by this factor. The known effect of a soil acidification with an increase of the mineral fertilization has been manifested. The application of high salt concentrations in the experiment with maize additionally decreases pH of the acid soil (Table 1). The increasing soil acidity rises the organic acids (H^+ ions in the liquid phase) and enhances the adsorption of H^+ ions on the biopolymers (Ganev and Kalitchkova, 1992). The increase of acidity in maize tissues is high in comparison to the other plants (Arsova, 1994) because of the increased soil acidity. For example, H^+ ions in the liquid phase increase twice from T_0 to T_3 level in the acid control (Ca_0). The lowest soil pH is measured in Ca_0T_3 variant and the content of H^+ ions in a water soluble and in an exchange adsorbed state is highest – 60.0 and 7.2 mequ/100 g respectively.

The basic content in the two phases of the biomass also rises under the influence of the mineral nutrition and manifests the neutralizing capability of maize to

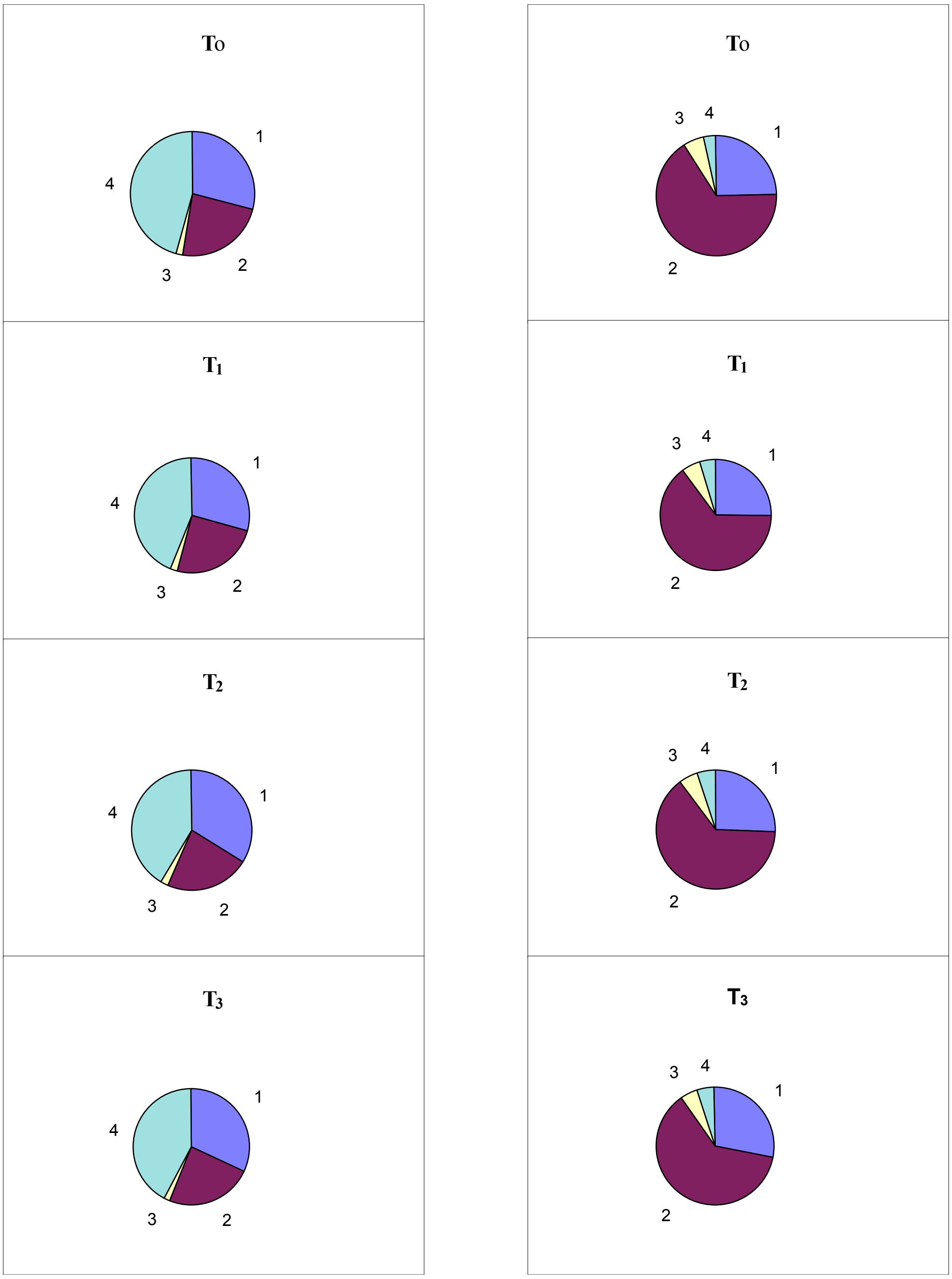

Fig. 2. Cations in water soluble state (A) and in exchange adsorbed state (B) in % of their sums at different nutrition levels

increased tissue acidity. Among the bases in the liquid phase K^+ ions (K salts of organic acids) increase more significantly. For example, K^+ ions in Ca_0T_3 are 20.0 mequ more than in the Ca_0T_0 variant. The increase of the exchange adsorbed bases could be explained as a result of an enhanced adsorption of H^+ ions at a lower soil pH. An additional cation exchange occurs and the amount of exchange adsorbed bases on the biopolymers (mainly Ca^{2+}) rises. As a result the cation exchange capacity increases from 20.9 mequ/100 g (Ca_0T_0) to 29.2 mequ/100 g (Ca_2T_3). The capacity of maize biomass is smaller than that of some vegetable and forage plants and it is similar to other cereals.

The percentage composition of cations in a water soluble and in an exchange adsorbed state in the biomass is presented in Fig. 2. Cation distribution in a water soluble state (Fig. 2A) follows the row: $K^+ \geq H^+ > Ca^{2+} >> Mg^{2+}$, while the cations forming the capacity (Fig. 2B) are in the row: $Ca^{2+} >> H^+ >> Mg^{2+} \geq K^+$. The relative share of cations in the liquid and in the adsorption phase in the biomass is specific for the different plants but as a general characteristic dominant K^+ ions in a water soluble state and Ca^{2+} ions in an exchange adsorbed state have been observed. Variation of neutralization and mineral nutrition level does not influence the character of the cation distribution in both phases. This manifests the adaptability of maize to changes of the nutrient medium conditions.

Conclusions

1. Maize reacts like an acidic sensitive plant according to the biomass formation in dependence of soil acidity neutralization.

Depending on the mineral nutrition level a maximal production of maize is obtained at a high salt concentration in the soil – 0.9–1.0g/100g.

2. Soil acidity neutralization decreases H^+ ions and increases Ca^{2+} ions in a water soluble state in the biomass without changing the electrolytic content.

Increasing mineral nutrition enhanced the bases (Ca^{2+} and K^+), the acidity (H^+ ions) and the electrolytic content in the liquid phase of the biomass.

Maize is characterized by a significant excess in Ca salts of organic acids under the influence of neutralization and with a strong acidification (organic acids) under the influence of mineral nutrition.

3. Cation exchange capacity of maize biomass increases depending on the soil acidity neutralization and mineral nutrition from 20.9 to 29.0 mequ/100 g.

4. The character of cation distribution in the biomass of maize is not influenced by the variation of soil acidity neutralization and mineral nutrition and manifests the adaptability of maize to changes of the nutrient medium.

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