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EFFECT OF FERTILIZER APPLICATION AND SOIL pH ON THE ACIDIC AND SORPTION PROPERTIES OF MAIZE LEAVES AND STEMS

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Summary. The capacity values of strongly acidic and weakly acidic ionexchangers of biopolymers and the total cation exchange capacity of leaves and stems of maize are determined in dependence of fertilizer application level, soil pH and growth stage under field experiment conditions.

Acidification of leached cinnamonic forest soil at high fertilizer application levels leads to an increased share of strongly acidic ionexchangers, mainly in the leaves. This provides additional cation exchange and shows the adaptability of maize to high soil acidity. The cation exchange capacities of leaves and stems increase with the rise in fertilizer application level and plant age. The capacity of stems is higher than that of the leaves, but the difference between them decreases in the same direction. In milk ripenness stage and highest fertilizer application level the capacities of leaves and stems are almost equal.

Key words**:** soil pH; fertilizer application; maize; leaves and stems; acidic and sorption properties of plant tissues

Abbreviation: CEC_{SA} – capacity value of strongly acidic ionexchangers of biopolymers; CEC_{A} – capacity value of weakly acidic ionexchangers of biopolymers; $CEC_{(SA+A)}$ – total cation exchange capacity of plant tissues

Introduction

Physicochemical factors of the nutrient substratum, including soil (pH, salt concentration, relationship between elements, etc.), influence the ionexchange capability of plants, which depends on the acidic ionization of biopolymers (Osmolovskaja and

Ivanova, 1985; Findenegg et al., 1989; Magalhaes and Huber, 1989; Rengel and Robinson, 1989; Arsova, 1990; Ganev and Kalichkova, 1992). It is experimentally established that bioadsorption structures react in cation exchange according to the degree of ionization of their H^+ ions as strongly acidic and weakly acidic ionexchangers, which form the total cation exchange capacity of plant tissues (Ganev and Arsova, 1989). Recently moderately acidic groups of the biopolymers have been found (Ganev and Kalichkova, 1991). The aim of this paper was to study the acidic and sorption properties of leaves and stems of maize during vegetation depending on fertilizer application and soil pH under field experiment conditions.

Materials and Methods

Plant and soil material was taken from a field experiment, carried out on leached cinnamonic forest soil (Lozen, 1991) with maize (Volga, P 3475) at four levels of fertilizer application under natural soil moisture conditions, which were optimal for maize during the year (the samples were kindly given by Dr Rafailov, N.Poushkarov Institute). The applied fertilizer were ammonium nitrate, superphosphate and potassium chloride per kg/dka as follows: $N_0P_0K_0$, $N_{10}P_8K_6$, $N_{20}P_{16}K_{12}$, $N_{30}P_{24}K_{18}$. Plant samples were taken according to the fertilizer levels three times during the vegetation – 31.07.1991 (beginning of tasseling stage), 14.08.1991 (tasseling stage) and 28.08.1991 (milk ripenness stage). In dry biomass of leaves and stems the capacity values of strongly acidic and weakly acidic ionexchangers in biopolymers and the total cation exchange capacity were determined by the author's methods (Ganev and Arsova, 1989). $pH_{(H_2O)}$ and exchangeable acidity (exch. Al) of the soil samples (0–20 cm) at different fertilizer levels were measured (Ganev and Arsova, 1980).

Results and Discussion

Fig.1 shows a decrease in soil pH with the increase of the fertilizer level from pH 5.9 at level $N_0P_0K_0$ to pH 5.2 at level $N_{30}P_{24}K_{18}$. An exchangeable soil acidity (exch. Al), which is toxic for plants appears under these conditions (pH<6.0) and increases respectively from 0.0 mequ/100 g to 1.5 mequ/100 g. The effect of soil acidification due to high fertilizer levels, established in the practice is confirmed. It proves that the influence of fertilizers on the acidic and sorption properties of plant tissues should be studied in connection with the changes of the soil's acidic state which are decisive for the acidic ionization of plant biopolymers.

Table 1 presents the capacity values of strongly acidic (CEC_{SA}) and weakly acidic (CEC_A) ionexchangers in biopolymers of leaves and stems and total cation exchange capacities ($CEC_{(SA+A)}$) depending on fertilizer levels and vegetation stage. Total capacities are formed by the sum of CEC_{SA} and CEC_{A}. Strongly acidic positions of the biopolymers in plant organs increase with the fertilizer levels and the part of CEC_{SA} in the stems is larger than in the leaves. Weakly acidic reaction of the biopolymers shows the same but not so well expressed tendency. The dynamics of CEC_{SA} and CEC_{A} values indicates that the plant reacts to the changing acidic conditions of the soil. The H^+ ion adsorption on the biopolymers increases with the increase of fertilizers (resp. of soil acidity). Soil acidification causes a more significant increase of the capacity of strongly acidic ionexchangers, mainly in the leaves, which enhances during vegetation. In leaves, for example, the differences between the capacity values of strongly acidic ionexchangers (Δ CEC_{SA}) at level $N_0P_0K_0$ and $N_{30}P_{24}K_{18}$ increase from 2.4 to 5.0 mequ/100 g and in stems – from 2.0 to 2.3 mequ/100 g. These differences between the capacity values of strongly acidic ionexchangers (Δ CEC_{A}) are smaller – from 1.2 to 1.8 mequ/100 g in leaves and from 0.5 to 1.2 mequ/100 g in stems. The fact could be explained in the following way: in case exchangeable acidity exists in the soil (i.e. in the presence of a strongly acidic system of soil adsorbent) biopolymers with the same strongly acidic character take part in H^+ ion adsorption (phospholipides, polyuronic acids, nucleis acids, etc.). The adsorption of H^+ ions on strongly acidic ionexchangers increases with soil acidification and respectively their share in the total capacity rises. As a result, more H^+ ions can take part in the cation exchange. This means that maize opposes high soil acidity by increasing the share of strongly acidic ionexchangers in the total cation exchange capacity, which provides the possibility for additional cation adsorption and improves plant nutrition with basic cations. For example, in leaves, at the beginning of the tasseling stage, $CEC_{SA}\%CEC_{(SA+A)}$ increases from 33.1% ($N_0P_0K_0$) to 38.9% ($N_{30}P_{24}K_{18}$) and in the milk ripenness stage $CEC_{SA}\%CEC_{(SA+A)}$ varies from 40.8% to 48.1% respectively.

Fig. 1. pH of leached cinnamonic soil (Lozen, 0–20 cm) depending on increased fertilizer application levels

It can be noticed that the capability of maize for additional cation exchange increases also with plant age – $CEC_{SA}\%CEC_{(SA+A)}$ in milk ripenness stage at levels

Table 1. Capacity of strongly acidic (CEC_{SA}) and weakly acidic (CEC_A) ionexchangers and total cation exchange capacity ($CEC_{(SA+A)}$) of maize leaves and stems depending on fertilizers application and vegetation stage

Treatment	Organ	CEC_{SA}	CEC_A	$CEC_{(SA+A)}$	CEC_{SA}	CEC_A
		in mequ/100 g dry matter			in % of $CEC_{(SA+A)}$	
31.07.91 Beginning of tasseling						
$N_0P_0K_0$	leaves	7.8	14.8	22.6	33.1	65.4
	stems	11.5	15.8	27.3	42.1	57.8
$N_{10}P_8K_6$	leaves	8.4	14.8	23.2	36.2	63.7
	stems	12.2	15.8	28.0	43.5	56.4
$N_{20}P_{16}K_{12}$	leaves	9.2	15.6	24.8	37.1	62.9
	stems	12.8	16.0	28.8	44.4	55.5
$N_{30}P_{24}K_{18}$	leaves	10.2	16.0	26.2	38.9	61.0
	stems	13.5	16.3	29.8	45.3	54.6
14.08.91 Tasseling						
$N_0P_0K_0$	leaves	8.6	14.6	23.2	37.1	62.9
	stems	12.1	15.5	27.6	43.8	56.1
$N_{10}P_8K_6$	leaves	9.8	14.6	24.4	40.1	59.8
	stems	12.8	15.5	28.3	45.2	54.7
$N_{20}P_{16}K_{12}$	leaves	11.0	15.4	26.4	41.6	58.3
	stems	13.1	16.0	29.1	45.0	54.9
$N_{30}P_{24}K_{18}$	leaves	11.4	15.6	27.0	42.2	57.7
	stems	14.0	16.3	30.3	46.2	53.8
28. 08. 91 Milk ripenness						
$N_0P_0K_0$	leaves	9.8	14.2	24.0	40.8	59.2
	stems	12.5	15.8	28.3	44.2	55.8
$N_{10}P_8K_6$	leaves	12.2	14.4	26.6	45.8	58.2
	stems	13.7	16.3	30.0	45.6	54.3
$N_{20}P_{16}K_{12}$	leaves	15.0	15.0	30.0	50.0	50.0
	stems	14.7	16.3	31.0	47.4	52.2
$N_{30}P_{24}K_{18}$	leaves	14.8	16.0	30.8	48.8	51.9
	stems	14.8	17.0	31.8	46.5	53.4

and $N_{30}P_{24}K_{18}$ are 7.7% and 9.2% higher than in the beginning of the tasseling stage. In the stems the increase of $CEC_{SA}\%CEC_{(SA+A)}$ is smaller – about 2–3%. The share of weakly acidic ionexchangers (pectin, proteins, etc.) in the total capacities of leaves and stems ($CEC_A\%CEC_{(SA+A)}$) decreases slightly with the increase of fertilizers and plant age. As the participation of weakly acidic groups of the biopolymers in cation exchange is of importance at low soil acidity, the strongly acidic ionexchangers in plant tissues are decisive under definite acidic conditions in leached cinnamonic forest soil, despite the smaller absolute values of their capacities.

Table 1 shows that the total cation exchange capacities of plant organs, representing the sum of capacities of strongly acidic and weakly acidic ionexchangers, are also dynamic values and increase depending on the increased adsorption of H^+ ions on the biopolymers. The fact confirms the hypothesis that new adsorption centres arise with the nutrient medium's acidification, mainly on account of the increased share of strongly acidic ionexchangers in plant tissues. Participation of metabolically produced H^+ ions in this process should not be excluded (Ganev and Kalichkova, 1992).

The dynamics of the total capacities of maize leaves and stems depending on fertilizer levels and vegetation stage is presented in Fig.2. It is obvious that stem capacity is higher than that of the leaves, but the difference between them diminishes with the increase of fertilizer application and plant age. At the highest level ($N_{30}P_{24}K_{18}$) and in the stage of milk ripenness the two capacities are almost equal – the difference Δ CEC$(_{SA+A})$ is about 1 mequ/100 g.

Fig. 2. Dinamics of cation exchange capacity of maize leaves and stems at increasing fertilizer levels

Conclusions

1. The acidification of leached cinnamonic forest soil caused by high fertilizer level, influences the acidic state of maize tissues. Acidic ionization of biopolymers in leaves and stems increases and leads to a larger share of strongly acidic ionexchangers, mainly in the leaves.

2. The total cation exchange capacities of leaves and stems increase with the soil's acidification, due to the higher degree of H^+ ions adsorption on the biopolymers. The capacity of stems is greater than that of the leaves, but the difference between

them diminishes with the increase in fertilizer application and plant age. At the stage of milk ripenness and the highest fertilizer level the capacities of leaves and stems are almost equal.

3. The increase of leaf and stem capacities provides additional cation exchange and expresses maize ability of adsorption at high soil acidity conditions.

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