ACTA SOCIETATIS
BOTANICORUM POLONIAE
Vol. XLIV, nr 4
1975

# Effectiveness of humic compounds in dependence on calcium content in water tomato cultures

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(Received: July 5, 1975)

Abstract

The influence of Na-humate and its fractions on dry weight increment of tomato seedlings in water culture and their calcium uptake in conditions of its deficit in the medium were investigated.
Only fraction II of Na-humate was found to exert a significant effect; unfractionated Na-humate and fraction I had no noticeable influence.

## INTRODUCTION

Humic compounds (Wilk, 1964) are a complex of high molecular weight compounds of aromatic nature and containing nitrogen. To the aromatic nucleus carboxyl, hydroxyl, carbonyl and methoxyl groups are attached as main functional groups.

These compounds form in the soil, in peat and compost, that is everywhere where organic matter is accumulated and undergoes decomposition. A characteristic feature of humic compounds is their heterogeneity, that is the presence in them of humic compounds with different degrees of humification, this giving differences in a number of their properties, so that fractions with a homogeneous type of structure (aromatic nucleus) can be isolated. They differ, however, from one another by their elementary composition, the size of their molecules, percentual content of the particular functional groups, degree of mobility, their role in soil-forming processes etc.

The action of sodium humate is most clearly visible in conditions unfavourable to plant growth (Badurowa, Gumiński and Suder-Moraw, 1967; Badura, 1965; Tatkowska, 1970; Kyć, 1970; Jurajda, 1974). Czerwiński (1967) as well as Gumiński, Gumińska and Sulej (1965) demonstrated that sodium humate forms complexes with iron, thus preventing precipitation of iron from the culture medium, and in unaerated water cultures supplies iron in an easily available form.

Comparison of the activity of natural humates, their ash and synthetically prepared similar model compounds, and comparison of the effectiveness of humates with versenate (Badura, 1965; Gumiński, Gumińska and Sulej, 1965; Kyć, 1970; Tatkowska, 1970) showed that it is actually the humic compounds themselves and not the organic or inorganic substances accompanying them that act on the plants.

When iron is deficient, humates favourably affect plant development, but the presence of large quantities of calcium ions reduces their effectiveness (Gumiński, Gumińska and Sulej, 1965). It is known, moreover, that humic acids form complexes with calcium.

The present study was undertaken in order to establish whether and in what way humic compounds affect the growth of tomato seedlings in water cultures and their calcium uptake in conditions of deficiency of this action in the medium.

## MATERIAL AND METHODS

### Methods of preparation of Na-humate and its fractions

Sodium humate was obtained from one-year leaf compost by the method of Gumiński (1950) and Gumiński et al. (1955).

This compost was extracted for 74 h with hydrochloric acid 1 per cent solution to remove the mineral parts (pH of the mixture ca. 2). Then the washings were filtered and the sediment was washed with distilled water until disappearance of the reaction for chlorine, and extracted with a 1 per cent NaOH solution and left to stand for 24 h. Then the "crude humate" was filtered off from the earthy parts and the filtrate was coagulated with 15 per cent hydrochloric acid. Fulvoacids were filtered off and sodium humate gel after washing with distilled water was dried at room temperature and stored as dry powder. Thus prepared sodium humate will be referred to further as "the whole" (h.c.).

Sodium humate was fractionated by column chromatography after Unger (1965) with certain modifications. As adsorbent aluminium oxide with activity II according to Brockman (and not I as given by Unger) was used. As solvent and eluate served acetone with water in a 2 : 1 ratio.

A glass column 4 cm in diameter and 60 cm long was filled with aluminium oxide (200 g per column) mixed with the solvent (240 ml per column).

The solution prepared as follows was placed on the column: 1 g of sodium humate was infused with 100 ml of solvent and left to stand for 24 h with stirring from time to time. The solution was decanted through a filter and the residue was once more infused with solvent (15 + 25 ml). The sediment remaining after 3 h was filtered off, and the dark brown sediment was combined and placed on the column.

The residue on the filter, that is the remaining unsoluble substance was dried and used for further investigations as fraction I.

The part of the solution which passed through the column constituted fraction II. It was collected together with the eluate used for washing the column, used in an amount sufficient to make up the fraction volume to 500 ml. After evaporation of the solvent on a water bath and drying a dark brown powder was obtained.

In studies concerning the influence of humic compounds on calcium uptake it is important to characterize these compounds in respect to their content of the latter element.

The analyses demonstrated that:

1 g h.c. contains 0.44 mg calcium

1 g of fraction I contains 0.66 mg calcium

1 g of fraction II contains 29.60 mg calcium.

The particular humic compounds were introduced into the culture medium in the amount of 50 mg/l. (fraction II introduces into the medium 1.480 mg calcium per liter).

Before adding to the medium, a weighed amount of the humic compounds was dissolved in a known amount of 0.1 N NaOH and sterilized in an autoclave for 20 min. The solutions thus obtained were introduced into the medium in such amounts as to give 50 mg of dry weight of the humic compounds per 1 l. of culture medium.

## Method of vegetative experiments

In the vegetative experiments the water culture method was applied in a nonairconditioned glasshouse. During the vegetation of the plants temperature and the general course of weather were recorded. As test plant in the experiments served tomatoes of the variety Stenora. Tomatoes are very sensitive to humus (Gumiński, 1950; Christeva, 1953; Gumiński et al., 1959), and they are frequently used for experiments with humates.

The plants were germinated in sand and watered with a solution of the basic medium diluted with distilled water in a 1 : 1 ratio. Plants cultured in this way from the beginning take up intensively mineral salts in the course of the experiment proper (Hoagland and Broyer, 1936). The experiments were started when the seedlings reached the 2-leaf stage (8—10 days). Chosen seedlings of dimensions not deviating from the average were fixed by means of cotton wool in the openings of cardboard paraffin-coated lids and placed in glass jars (Weck) of 1200 ml capacity filled with special culture medium for tomatoes (Versailles medium acc. to Hampe, 1938 in the modification of Gumińska, 1964) of the following composition:

| | | |
|---|---|---|
| $Ca(NO_3)_2 \cdot 4H_2O$ | — | 0.710 g/l. |
| $KNO_3$ | — | 0.568 g/l. |
| $MgSO_4 \cdot 7H_2O$ | — | 0.284 g/l. |
| $(NH_4)_2 \cdot HPO_4$ | — | 0.142 g/l. |
| $Fe(SO_4)_3 \cdot nH_2O$ | — | 0.116 g/l. |

supplemented with microelements (Delwich, Johnson, Reisenauer, 1961):

| | | | |
|---|---|---|---|
| B | $H_3BO_3$ | — | 0.27 p.p.m. |
| Mn | $MnCl_2$ | — | 0.27 p.p.m. |
| Zn | $ZnSO_4 \cdot 7H_2O$ | — | 0.13 p.p.m. |
| Cu | $CuSO_4 \cdot 5H_2O$ | — | 0.03 p.p.m. |
| Mo | $Na_2MoO_4$ | — | 0.05 p.p.m. |

The culture medium was prepared 48 h before starting the experiment. The pH of the medium was adjusted to 6.6 (0.1 N NaOH).

During the experiment the medium was aerated every day by pouring it from one jar into another (Gumiński and Gumińska, 1953).

The vegetative experiment lasted 3 weeks. After its end the plants were first exposed to 90°C, dried at 105°C and then weighed on an analytical balance with an accuracy to decimal digits.

## Method of chemical analyses

Calcium, potassium and sodium were quantitatively determined by flame photometry (Nowosielski, 1968).

A Zeiss photometer with suitable filters and an acetylene burner were used. The plant material comminuted in an electric mill was incinerated wet. The solutions were diluted adequately, by adjusting the concentration to the range of highest sensitivity of the apparatus.

Magnesium was quantitatively determined by the method of English-Peech in the modification of Hands-Johnson (Nowosielski, 1968).

## Statistical method

For establishing whether the differences in dry weight of the shoots and roots of the experimental plants in the particular combinations are significant, the results were subjected to mathematical-statistical analysis by Snedecor's test (Perkal, 1963 and Barbacki, 1951). This test allowed to find an answer to the following questions:

(a) whether reduced calcium doses cause significant differences in plant growth,

(b) whether humic compounds significantly affect the changes in growth due to the reduced calcium supply,

(c) whether there are significant differences in the effectiveness of the particular humic fractions.

## Course and results of experiments

The first experiments were preliminary, aiming at establishment of the conditions for the experiments proper with humic compounds.

On the basis of the results and observations it was found that the plants show marked differences when receiving the following calcium doses in the medium:

(a) Ca = 1, i.e. 0.1204 g Ca/l. control: normal calcium, dose in Versailles medium,

(b) Ca = 1/10, i.e. 0.01204 g Ca/l. enfold reduced calcium dose in relation to control,

(c) Ca = 1/50, i.e. 0.00240 g Ca/l. fifty times lower dose than in control.

In all the subsequent experiments the same doses were applied. Further reduction of the amount of calcium in the medium is purposeless, since the tomato seedlings soon die. The differences between the plants in the particular combinations with different calcium doses are significant after 3 weeks when the experiment should be ended.

The experiments in which with reduced calcium doses — (less $Ca(NO_3)_2$ — nitrogen was supplied in the form of $NaNO_3$; $Mg(NO_3)_2$ and $KNO_3$ demonstrated that disturbance of the equilibrium caused by higher doses of such cations as $Na^+$, $Mg^{++}$ and $K^+$ has a significant influence on the dry weight increment of the plants.

Figure 1 taken on the day of liquidation of the experiment shows the differences between the plants of various combinations.

The tomatoes of the Ca = 1/50 + $Mg(NO_3)_2$ combination (50 times reduced calcium dose in relation to control), nitrogen supplemented in the form of $Mg(NO_3)_2$ almost died. In the remaining combinations in which calcium was also reduced to 1/50 were retarded in growth as compared with the control (Ca = 1), the upper leaves were rolled (leafroll), their colour was paler, the roots were slimy and brown.

The results in dry weight of shoots and roots are shown graphically in Fig. 2. Mathematical-statistical analysis of the data showed unequivocally that:

1 — different calcium doses change significantly the dry weight of shoots and roots;

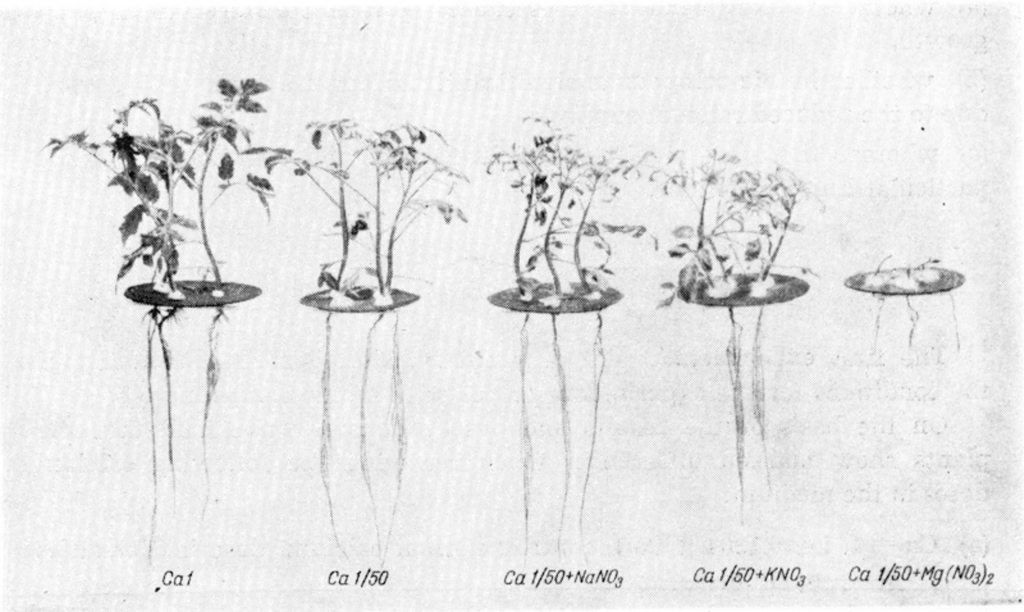


Fig. 1. Tomato seedlings cultured with various calcium doses in the culture medium

2 — the cation additionally introduced with the nitrogen supplied has a significant influence on the dry weight of shoots and roots. This is particularly true of $Mg^{++}$ and $K^{+}$ ions;

3 — there is a correlation between the calcium dose and the additionally introduced cation.

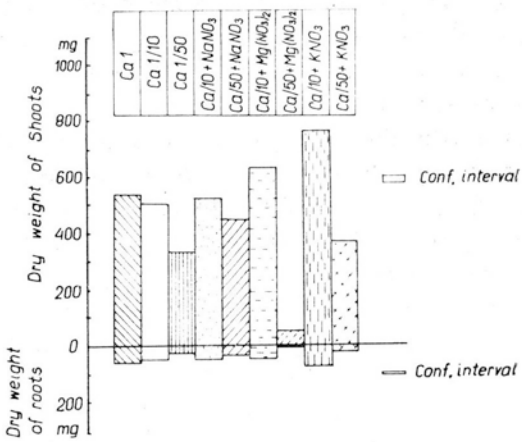


Fig. 2. Influence of various calcium doses and cations introduced with nitrogen supplementation on the dry weight of shoots and roots

For instance potassium nitrate significantly increases the dry weight of shoots and roots at a calcium dose of Ca = 1/10 (as compared with the control Ca = 1/10 without nitrogen supplemented), but it has no effect at Ca = 1/50.

Magnesium nitrate has a weaker influence than the potassium cation on the increase in dry weight at a dose of Ca = 1/10, but its effect is distinctly negative at Ca = 1/50.

Chemical analyses of the content of such elements, as calcium, magnesium, potassium and sodium in the shoots of the experimental plants demonstrated that (Table 1):

1. with the reduction of the calcium dose in the medium, the content of this element (converted to dry weight) decreases in the plant more when its doses are reduced to 1/10 (cf. combination Ca = 1 and Ca = 1/10) than when Ca content is further diminished to 1/50 (cf. combination Ca = 1/10 and Ca = 1/50);

2. with reduction of the calcium content in the medium accumulation of $K^{+}$, $Na^{+}$ and $Mg^{++}$ increases;

3 introduction of sodium into the medium at a Ca = 1/10 and 1/50 content enhances sodium uptake. The same is observed when potassium is additionally introduced into the medium. On the other hand, magnesium is accumulated in larger amounts only at a calcium dose of 1/10;

4. the presence of one cation in excess in the medium causes changes in the uptake of other cations by the plant.

Table 1 shows also, against the bacground of relations between the particular elements in the medium, the interrelations between these cations in the plant. The K/Ca, Na/Ca and Na/Mg and K/Mg ratios are shown as a picture of the relations between uni- and bivalent cations and the relation between two antagonistically acting bivalent ions Ca and Mg. These relations play a role in the growth and development of plants (Nowotny-Mieczyńska, 1965).

As seen from the table the quantitative relations prevailing in the medium between the particular cations are reflected in the same relations in the plant, but there is no simple dependence. For instance when the $Ca^{++}$ dose is tenfold diminished in the medium the K/Ca ratio in it is 10 times higher, while in the plant it is only two times higher. The Ca/Mg ratio reduced 10-fold in the medium (as compared with the control Ca = 1) is only 3 times smaller in the plant:

— at a dose of Ca = 1/50:

— — in the medium the K/Ca ratio is 10 times increased
and the Ca/Mg ratio 30 times reduced:

— — in the plant the K/Ca ratio is 6 times increased
and the Ca/Mg ratio 7 times lower

as compared with the case when a normal dose Ca = 1 is given in the medium.

Table 1

$Ca^{++}$, $K^{+}$, $Na^{++}$ and $Mg^{++}$ content in shoots and relation between the eumerated cations in the medium and in the plant

| Combinations | Content in mg/g d.wt. | | | | Ratios in plant | | | | | | Ratios in medium | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Ca^{++}$ | $K^{+}$ | $Na^{+}$ | $Mg^{++}$ | K/Ca | Na/Ca | Mg/Ca | Ca/Mg | K/Mg | Na/Mg | K/Ca | Mg/Ca | Ca/Mg | K/Mg |
| Ca=1 | 20.0 | 42.0 | 35.0 | 7.0 | 2.1 | 1.7 | 0.35 | 2.8 | 6.0 | 5.0 | 1.8 | 0.2 | 4.3 | 7.84 |
| Ca/10 | 8.9 | 45.0 | 39.0 | 10.0 | 5.0 | 4.0 | 1.13 | 0.9 | 4.5 | 3.9 | 18.2 | 2.3 | 0.4 | 7.84 |
| Ca/50 | 5.0 | 60.0 | 48.0 | 12.0 | 12.0 | 9.6 | 2.40 | 0.4 | 5.0 | 4.0 | 91.0 | 11.6 | 0.1 | 7.84 |
| Ca/10+$NaNO_3$ | 8.0 | 40.0 | 55.0 | 10.0 | 5.0 | 6.9 | 1.25 | 0.8 | 4.0 | 5.5 | 18.2 | 2.3 | 0.4 | 7.84 |
| Ca/50+$NaNO_3$ | 5.2 | 41.0 | 60.0 | 10.9 | 7.9 | 11.6 | 2.1 | 0.5 | 3.7 | 5.3 | 91.0 | 11.6 | 0.1 | 7.84 |
| Ca/10+$Mg(NO_3)_2$ | 7.9 | 43.0 | 41.0 | 14.6 | 5.4 | 5.2 | 1.86 | 0.5 | 2.9 | 2.8 | 18.2 | 7.7 | 0.1 | 2.3 |
| Ca/50+$Mg(NO_3)_2$ | 4.9 | 6.54 | 51.1 | 2.9 | 1.34 | 10.4 | 0.59 | 1.6 | 2.2 | 17.6 | 91.0 | 41.1 | 0.02 | 2.2 |
| Ca/10+$KNO_3$ | 6.8 | 60.0 | 30.6 | 9.0 | 8.8 | 4.5 | 1.32 | 0.8 | 6.6 | 3.4 | 35.8 | 2.3 | 0.4 | 15.4 |
| Ca/50+$KNO_3$ | 5.5 | 71.0 | 32.0 | 11.0 | 12.9 | 5.8 | 2.20 | 0.5 | 6.4 | 2.7 | 186.0 | 11.6 | 0.1 | 16.0 |

Additional introduction into the medium (with nitrogen supplementation) of such cations as sodium, potassium and magnesium interferes also with the relations between the particular cations not only in the medium, but also in the plants. At Ca dose of 1/50, the introduction of sodium ($NaNO_3$) into the medium reduces as compared with the control (1/50 Ca without nitrogen supplementation) the K/Mg and K/Ca ratios and increases the Na/Ca ratio in the plants. Introduction of magnesium $Mg(NO_3)_2$ with a Ca = 1/10 dose markedly changes the above mentioned ratios.

At a dose of Ca = 1/50 + $Mg(NO_3)_2$ the plants die, thus the picture of the relations between the particular cations is a pathological symptom. With an excess of magnesium ions in the medium, above all a decreased potassium accumulation is found in the plants.

The most severe disturbances in cation uptake by the plants appear when large magnesium amounts are introduced into the medium.

The above described results served as basis for further investigations on the effectiveness of humic compounds. The influence of the humic compounds studied, in relation to the calcium content in the medium, on the dry weight of the shoots and roots is shown in Figs. 2, 3 and 4.

It may be concluded from the results obtained in the successive experiments, after mathematical-statistical analysis that:

1. there exists an interaction between various calcium doses and the particular humic compounds, and also the cation additionally introduced in nitrogen supplementation;

2. under conditions of reduced calcium doses (Ca = 1/50), only the influence of fraction II was important and significant. The favourable influence of this fraction was observed in all the experiments: the dry weight of shoots and roots was increased in the Ca = 1/50 + fraction II combinations as shown in Figs. 3, 4 and 5.

When with a calcium dose of 1/50, nitrogen was supplemented, the

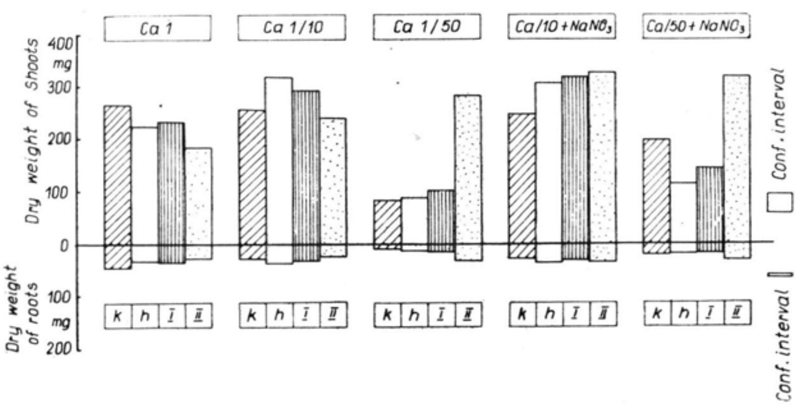


Fig. 3. Effect of the studied humic compounds on the dry weight of shoots and roots in the case of various calcium doses in the medium (nitrogen not supplemented and supplemented in the form of $NaNO_3$)

presence of fraction II in the medium significantly increased the dry weight of the plants as shown in Fig. 3 [N supplied as $NaNO_3$], Fig. 4 [N supplied as $Mg(NO_3)_2$] and Fig. 5 [N supplied as $KNO_3$].

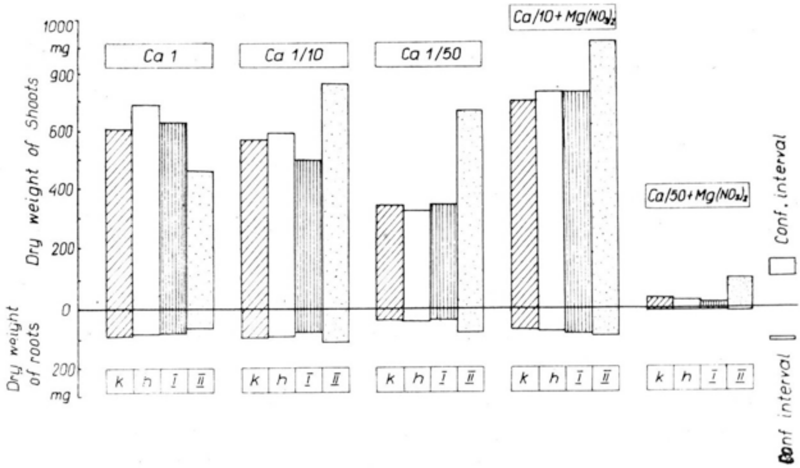


Fig. 4. Influence of the humic compounds on the dry weight of the shoots and roots in the case of various calcium doses in the medium (nitrogen not supplemented and added in the form of $Mg(NO_3)_2$)

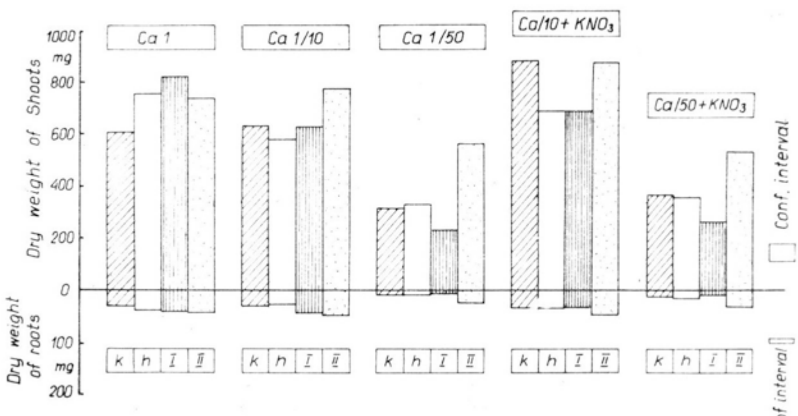


Fig. 5. Influence of the humic compounds on dry weight of shoots and roots in the case of various calcium doses in the medium (nitrogen not supplemented and added in the form of $KNO_3$)

Observations also brought evidence that the presence of fraction II in the medium, under conditions of deficient calcium supply, favourably affected the appearance of the plants in which the features of calcium deficiency were not so pronounced, as in the presence of other fractions. In the combination with $Ca = 1/50 + Mg(NO_3)_2$ the presence of fraction II saved the plants from death.

On the other hand, in combinations with normal calcium doses or with a 10-fold reduced amount, various effects of humic compounds, changing from one experiment to another were noted. For instance, as seen in Fig. 4, the dry weight of shoots and roots increased considerably under the influence of all humic compounds in combinations, with a full dose of calcium as compared with the control not receiving these compounds, in other experiments this phenomenon was not observed.

It would result therefrom that, at optimal supply of nutrient components to the plants under glasshouse conditions without air conditioning, the effect of humic compounds depends on factors other than those studied here.

The results of chemical analyses for $Ca^{++}$, $K^{+}$, $Na^{+}$, and $Mg^{++}$ content in the shoots of the experimental plants indicate that the effect of humic compounds on mineral salts uptake is dependent on the calcium dose and on the kind of cation additionally introduced with nitrogen supplementation.

Humic compounds do not show any influence on $Ca^{++}$, $K^{+}$, $Na^{+}$ and $Mg^{++}$ accumulation at full and tenfold reduced calcium doses, whereas at a dose 50 times reduced the influence of fraction II becomes manifest.

The mechanism of fraction II action may be traced by analysing the results of the experiments in which nitrogen was not supplemented in the

Table 2

$Ca^{++}$, $K^{+}$, $Na^{+}$ and $Mg^{++}$ content in tomato shoots

| Combinations | mg/g.s.m. | | | | mg/yield from one jar | | | |
|---|---|---|---|---|---|---|---|---|
| | $Ca^{++}$ | $K^{+}$ | $Na^{+}$ | $Mg^{++}$ | $Ca^{++}$ | $K^{+}$ | $Na^{+}$ | $Mg^{++}$ |
| Ca=1 | 21.0 | 52.5 | 35.0 | 8.10 | 13.15 | 32.88 | 21.92 | 5.07 |
| Ca=1+h.c. | 20.0 | 49.0 | 30.0 | 5.15 | 14.12 | 34.58 | 21.17 | 3.63 |
| Ca=1+I fr. | 22.0 | 60.5 | 40.0 | 6.60 | 14.23 | 39.13 | 25.87 | 4.27 |
| Ca=1+II fr. | 20.5 | 54.0 | 45.0 | 13.00 | 9.80 | 25.82 | 21.51 | 6.21 |
| Ca=1/10 | 8.5 | 65.0 | 40.0 | 13.29 | 5.03 | 38.46 | 23.67 | 7.85 |
| Ca=1/10+h.c. | 10.0 | 62.0 | 45.0 | 14.16 | 6.11 | 37.90 | 23.23 | 8.66 |
| Ca=1/10+I fr. | 10.0 | 59.0 | 40.0 | 14.40 | 5.17 | 30.51 | 20.69 | 7.45 |
| Ca=1/10+II fr. | 10.5 | 84.0 | 74.0 | 12.00 | 8.22 | 65.79 | 57.96 | 9.39 |
| Ca=1/50 | 5.5 | 85.0 | 54.0 | 14.86 | 1.99 | 30.77 | 19.55 | 5.37 |
| Ca=1/50+h.c. | 6.0 | 70.5 | 58.0 | 17.19 | 2.06 | 24.25 | 19.95 | 5.91 |
| Ca=1/50+I fr. | 6.5 | 78.0 | 67.2 | 15.86 | 2.38 | 28.56 | 24.60 | 5.80 |
| Ca=1/50+II fr. | 7,0 | 60.0 | 100.0 | 13.40 | 4.68 | 40.84 | 68.06 | 9.12 |
| Ca=1/10+$Mg(NO_3)_2$ | 6.0 | 59.0 | 45.0 | 16.30 | 4.41 | 43.32 | 33.04 | 11.84 |
| Ca=1/10+$Mg(NO_3)_2$+h.c. | 5.5 | 56.0 | 50.0 | 17.27 | 4.11 | 41.87 | 37.38 | 12.91 |
| Ca=1/10+$Mg(NO_3)_2$+I fr. | 6.5 | 49.0 | 40.0 | 16.13 | 4.85 | 36.55 | 29.84 | 12.32 |
| Ca=1/10+$Mg(NO_3)_2$+II fr. | 6.5 | 47.0 | 56.0 | 14.00 | 5.90 | 42.68 | 50.85 | 12.71 |
| Ca=1/50+$Mg(NO_3)_2$ | 4.8 | 6.66 | 34.0 | 2.94 | 0.19 | 0.26 | 1.33 | 0.114 |
| Ca=1/50+$Mg(NO_3)_2$+h.c. | 3.7 | 5.60 | 36.0 | 1.88 | 0.10 | 0.15 | 0.97 | 0.050 |
| Ca=1/50+$Mg(NO_3)_2$+I fr. | 4.7 | 6.62 | 35.0 | 1.14 | 0.16 | 0.22 | 1.17 | 0.038 |
| Ca=1/50+$Mg(NO_3)_2$+II fr. | 6.0 | 20.00 | 28.0 | 1.40 | 0.61 | 2.03 | 2.83 | 0.105 |

case of a reduced calcium dose or it was introduced in the form of $Mg(NO_3)_2$ (Table 2).

Under the influence of fraction II, under conditions of reduced calcium supply in the medium [Ca = 1/50 and Ca = 1/50 + $Mg(NO_3)_2$] not only calcium accumulation, but above all the univalent elements content increased in the plants.

In combinations with a high magnesium supply and low amount of calcium in the medium [Ca = 1/50 + $Mg(NO_3)_2$], that is with a greatly reduced Ca/Mg ratio in the culture medium, the plants take up much less potassium (similar results were obtained by Buczek and Leonowicz-Babiak, 1971). The presence of fraction II in the medium has a favourable effect on:

1. potassium uptake, and in turn on the K/Mg and K/Ca ratios;
2. in combinations with a 50 times lower calcium dose (without suplementation of nitrogen) on sodium accumulation, thus on the Na/Mg and Na/Ca ratios (as compared with analogous combinations without fraction II added);
3. on the Ca/Mg ratio in the dry weight of shoots, increasing it slightly, since in the presence of this fraction $Ca^{++}$ accumulation is enhanced.

## DISCUSSION

A significant effect of fraction II of Na-humate on the increase of dry weight of tomato shoots and roots was noted in each of the vegetative experiments performed under conditions of reduced calcium content in the culture medium.

Chemical analysis of the examined fractions for calcium content indicates that fraction II contains only a small amount of this element, although in the process of preparation of humic compounds this fraction was submitted to demineralization by means of hydrochloric acid. This shows that calcium in this fraction is strongly bound.

The same fraction also strongly binds iron (Unger, 1965; Gumiński, Gumińska and Sulej, 1965). The positive influence of fraction II in the case of low calcium doses does not explain, however, its positive influence when iron is lacking in the medium.

Czerwiński (1967) found in experiments with tomatoes that, in nonaerated cultures, iron precipitated from the medium falls to the bottom of the vessel, thus becoming unavailable to the plant roots, and that unfractionated sodium humate prevents iron precipitation. Gumiński and Sulej (1967) demonstrated that fraction II plays the same role in respect to iron as does sodium humate (h.c.).

Calcium is not precipitated in the Versalles medium, as found be performing suitable chemical analyses, therefore the fraction II of Na-humate cannot play the same role in experiments with calcium as it does in experiments with iron. This conclusion is confirmed by the fact that sodium humate (whole), the effect of which in conditions of iron deficit is similar to that of fraction II exerts no influence under conditions of reduced calcium doses.

Together with fraction II a small amount of calcium (1.48 mg Ca/l.) is introduced, this increasing not only its absolute amount, but also the Ca/Mg ratio in the medium, and this decides of the uptake by the plants of univalent elements as shown by the present investigations.

It also results from the investigations of Tanada (1962), Jacobson (1960, 1961), Epstein (1961), Nashara et al. (1966) and Hooymans (1965) that calcium influences the uptake of univalent elements. Magnesium also has an effect on potassium and sodium uptake (Nashar et al., 1966; Bange et al., 1968). On the other hand $Ca^{++}$ and $Mg^{++}$ uptake depend on their mutual relation (Nowotny-Mieczyńska, 1965).

As shown by the investigations of Buczek and Leonowicz-Babiak (1971) and Buczek, Suder-Moraw and Leonowicz-Babiak (1973), an excess of magnesium in the medium enhances accumulation of this element, and a wrong Ca/Mg ratio affects nitrogen metabolism by reducing protein synthesis.

It was found in the present study that in the case of a Ca/Mg ratio in the medium unfavourable to plant growth, only the presence of fraction II of Na-humate protected the plants from death.

## CONCLUSIONS

1. The effectiveness of humic compunds measured in terms of dry weight of shoots and roots of the experimental plants, is correlated with the amount of calcium in the culture medium (there is an interaction between humic compounds and calcium doses).

2. Under conditions of considerably reduced calcium supply in the medium the positive effect (increase of experimental tomato dry weight of shoots and roots, normal habitus and colour) was noted only in the presence of fraction II; unfractionated sodium humate (h.c.) and fraction I showed no influence.

3. The favourable effect of fraction II becomes manifest only when the calcium content in the medium is very low.

4. Reduction of the calcium amount in the medium diminishes the Ca/Mg ratio in the medium, and, consequently, in the plant. The reduction

of the Ca/Mg ratio inhibits accumulation of univalent elements — sodium and potassium.

The author wishes to express her thanks to professor dr hab. Stefan Gumiński, Head of the Department of Experimental Botany of the Wrocław University for suggesting the subject of this paper and for valuable advice and guidance in the course of this work.

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## *Efektywność związków próchnicznych w odniesieniu do wielkości dawek wapnia w kulturach wodnych pomidorów*

### Streszczenie

W pracy opisano wyniki badań nad wpływem Na-humianu i jego dwóch frakcji I, II na przyrost suchej masy siewek pomidorów odmiany „Stenora" oraz na ich odżywianie się wapnem w warunkach zmniejszonych ilości tego pierwiastka w pożywce.

Doświadczenia wegetacyjne trwały trzy tygodnie i prowadzone były metodą kultur wodnych.

Badania wykazały, że Na-humian nierozfrakcjonowany oraz jego frakcja I nie wykazują żadnego działania przy zmniejszonej ilości wapnia w pożywce; Korzystny wpływ (wzrost suchej masy — pędów i korzeni) uwidocznia się w obecności tylko frakcji II. Frakcja II nie wykazuje dodatniego wpływu na wzrost s.m., gdy w pożywce znajduje się optymalna ilość wapnia.

Zmniejszenie ilości wapnia w pożywce powoduje zmniejszenie stosunku Ca : Mg zarówno w pożywce jak i w roślinach oraz zmniejszenie akumulacji pierwiastków jednowartościowych potasu i sodu w roślinach testowych.

W obecności frakcji II zwiększa się akumulacja pierwiastków jednowartościowych w pędach siewek pomidorów.