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The effect of sodium humate on the growth of tomatoes and the accumulation of phosphorus and iron in mediums of different pH

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Abstract

The effect of sodium humate on changes in the phosphorus and iron content in shoots of tomatoes cultivated in mediums with a raised or lowered pH and phosphorus dose (compared with controls) were analysed. At low pH, sodium humate increased the accumulation of phosphorus and lessened the excessive accumulation of iron in plants cultivated under conditions of phosphours deficit. At a slightly alkaline pH, sodium humate prevented excessive, accumulation of phosphorus and raised low iron contents. A favorable effect of humate on dry mass production was clearly seen at pH 6.4.

Key words: phosphorus accumulation, iron accumulation, pH, humate

INTRODUCTION

The effectiveness of sodium humate on the phosphorus nutrition of plants depends on many factors, among which is the amount of iron and calcium cations in the medium, which was shown in a provious paper (Lisiak 1978). The levels of both of these macroelements, as well as the amount of phosphates in a form available to plants, are regulated by the pH of the medium. It may be expected then, that the effectiveness of humate on the phosphorus nutrition of plants will be dependent on the pH of the medium.

The positive effect of humic substances on plants under conditions of unsuitable pH has been described by many authors. Lhotsky (1955) and Kyć (1970) showed a favorable effect of humic substances on algae cultures when their development was halted by an unsuitable pH of the

medium. A similar stimulatory effect was described by Badura (1965) in his studies on the intensity of alkoholic fermentation and multiplication of yeast. According to these authors, the effect of humate in their experiments was not due to buffering the mediums. It was also not connected with the regulation of mineral-ion uptake by yeast (Gumiński and Sulej 1979). In respect to higher plants such as cucumbers and tomatoes, the protective effect of humate in both too low and too high pH was demonstrated by Gumińska et al. (1971). In the cultivation of higher plants which need intensive mineral fertilization, the favorable effect of humate may be connected with improving the conditions under which the uptake of minerals takes place; their sorption and accumulation depends on the pH. In this study, attention is paid to two nutritional elements: phosphorus and iron.

MATERIALS AND METHODS

In the experiments, seedlings of outdoor tomateos of the dwarf "Mory 33" variety were used. The experiments on the vegetation of the plants were

Table 1

The yield of dry mass (g) from 3 plants cultivated in the same jar on the pH 5.0 mediums with various phosphorus contents

Treatment	– Humate		+ Humate	
	shoots	roots	shoots	roots
0.1 P	0.092 a	0.031 a	0.196 b	0.059 a
1 P	2.054 c	0.456 b	1.753 c	0.382 b
10 P	1.570 c	0.301 a	1.490 c	0.341 a

Average values from 6 repetitions. The differences between the values marked by different letters are proven with a statistical probability of 95%.

carried out by means of water cultures in an unacclimatized green-house in the summer months of July and August. The plants were cultured as described by Lisiak (1978). A medium was used which contained in 1 dm^3 of distilled water: 0.71 g $Ca(NO_3)_2 \cdot 4\,H_2O$, 0.57 g KNO_3, 0.284 g $MgSO_4 \cdot 7\,H_2O$, 0.142 g $(NH_4)_2HPO_4$, 0.116 g $Fe_2(SO_4)_3 \cdot 9\,H_2O$. It was supplemented with microelements according to Delwiche et al. (1961) in $mg \cdot dm^{-3}$ of medium: H_3BO_3 — 1.54, $ZnSO_4 \cdot 7\,H_2O$ — 0.57, $CuSO_4 \cdot 5\,H_2O$ — 0.11. Na_2MoO_4 — 0.12, $MnCl_2 \cdot 4\,H_2O$ — 0.97. In order not to lower the ammonium nitrogen, NH_4Cl was added to the medium with the lower phosphorus content. The appropriate amount of $Na_2HPO_4 \cdot 10\,H_2O$ was added to the mediums used in the variants with increased phosphorus.

Sodium humate was obtained from one-year-old leaf compost (Gumiński 1950) and dissolved in 0.01 N NaOH. Ten cm^3 of this solution, containing 100 mg of Na-humate, were added to 1 dm^3 of medium. The pH of the medium was set at 6.4, 5.0 or 7.2, using 0.1 N HCl or 0.1 N NaOH. The mediums were mixed and aerated every day by pouring into previously prepared jars.

Each of the three experiments lasted 21 days. After this time the yield in dry mass of shoots and roots of the test plants was determined.

The dry and ground plant material was digested in concentrated H_2SO_4 and HNO_3, after which phosphorus was colorimetrically assayed using the Fiske-Subbarow method (1925); iron was determined using α-α'dipyrydyl as a reagent (Marczenko 1968).

Table 2

The content of phosphorus and iron in the dry mass of tomato shoots; plants cultivated in the pH 5.0 medium

Treatment	mg P · 100 mg^{-1} dry wt.		mg Fe · 100 mg^{-1} dry wt.	
	−humate	+humate	−humate	+humate
0.1 P	0.178	0.191	0.154	0.158
1 P	0.573	0.626	0.017	0.019
10 P	0.772	0.816	0.019	0.020

Average values from 3 analyses.

RESULTS

After lowering the pH of the medium with the reduced phosphorus level (0.1 P), a strong inhibition of shoot and root growth took place (Tables 1 and 3) in spite of the increase in the phosphorus and iron content in dry mass of the shoots (Tables 2 and 4) compared with the same combination, that is, 0.1 P but with pH 6.4. The presence of humate caused a large rise in the dry mass of seedlings (Table 1) and an increase in the phosphorus content calculated per unit of dry mass (Table 2). Increasing the phosphorus content (10 P) in the medium with a lowered pH caused a fall in the dry mass of the shoots and roots of the plants (Table 1) and an increase in their phosphorus content (Table 2) but not as high as in the combination 10 P at pH 6.4. (Table 4); the iron content was higher in the combination with the lowered pH. Humate increased the shoot phosphorus content (Table 2) but did not have a significant influence on a change in the iron content.

The ten-fold lowering of the phosphorus dose (0.1 P) caused a drop in the seedling shoot and root dry mass yield (Table 5) in the medium

Table 3

The yield of dry mass (g) from 3 plants cultivated in the same jar on the pH 6.4 mediums with various phosphorus contents

Treatment	– Humate		+ Humate	
	shoots	roots	shoots	roots
0.1 P	0.17 a	0.04 a	0.41 b	0.13 b
1 P	1.34 bd	0.24 b	1.17 bd	0.22 b
10 P	0.86 c	0.15 b	0.80 c	0.14 b

Average values from 6 repetitions. The differences between the values marked by different letters are proven with statistical probability of 95%.

Table 4

The content of phosphorus and iron in the dry mass of tomato shoots; plats cultivated in the pH 6.4 medium

Treatment	mg P · 100 mg^{-1} dry wt.		mg Fe · 100 mg^{-1} dry wt.	
	–humate	+humate	–humate	+humate
0.1 P	0.135	0.133	0.105	0.092
1 P	0.553	0.596	0.029	0.026
10 P	1.091	0.750	0.011	0.011

Average values from 3 analyses.

Table 5

The yield of dry mass (g) from 3 plants cultivated in the same jar on the pH 7.2 mediums with various phosphorus contents

Treatments	– Humate		+ Humate	
	shoots	roots	shoots	roots
0.1 P	0.25 a	0.06 a	0.49 bc	0.13 ab
1 P	1.68 bd	0.30 c	1.71 bd	0.31 c
10 P	0.41 bc	0.08 ab	0.46 bc	0.11 ab

Average values from 6 repetitions. The differences between the values marked by different letters are proven with a statistical probability 95%.

with pH 7.2. However, although the phosphorus content in the tomato shoots was lower than in the controls (1 P), it was still higher than in the 0.1 P pH 6.4 combination. The iron content in the seedling shoots was lowered when the pH of the medium was raised. Humate stimulated

Table 6

The content of phosphorus and iron in the dry mass of tomato shoots; plants cultivated in the pH 7.2 medium

Treatment	mg P·100 mg^{-1} dry wt.		mg Fe·100 mg^{-1} dry wt.	
	−humate	+humate	−humate	+humate
0.1 P	0.183	0.143	0.091	0.069
1 P	0.553	0.540	0.023	0.016
10 P	2.208	1.272	0.017	0.025

Average values from 3 analyses.

the increase in the dry mass of the tomato shoots and roots (Table 5) but lowered the phosphorus content (calculated per unit of dry mass) (Table 6).

Increasing the phosphorus dose (10 P) in the medium with an elevated pH significantly limited the yield (Table 5), higly raised the phosphorus content, which exceeded 2% of the shoot dry mass, and lowered the iron content compared with the control (1 P) (Table 6), although the iron content was higher than in the 10 P and 6.4 pH combiantion. The presence of sodium humate in the medium caused a slight increase in the dry mass of the shoots and a slightly higher one in that of the seedling roots (Table 5). It lowered the phosphorus content in the dry mass of the shoots and also raised the iron content (Table 6).

DISCUSSION

The influence of the pH of a medium on plants is of a complex nature and it is hard to separate the direct effect of an excess of hydrogen or hydroxide ions from the indirect effect connected with changes in the solubility of various biologically important mineral elements. Lowering the pH of a medium to 5.0, as was done in these experiments, did not cause any symptoms of injury to plants, which in the case of tomatoes only takes place starting from pH 4.0 and has been described by Islam et al. (1980). It also did not manifest itself in a fall in dry mass of plants cultured in the complete medium. Raising the pH to slightly alkaline (7.2) was also not a factor limiting the growth of plants in the experiment carried out here. The changes in the pH used here did, however, have a great effect on the accumulation of phosphorus and, to a lesser extent, on the accumulation of iron in the above-ground parts of plants, especially under the phosphorus-deficit conditions.

The regulation of the iron and phosphorus metabolism by sodium humate under conditions of unsuitable pH, is probably connected with the creation of phospho-iron-humic links which have been demonstrated by Sinha (1972)

or of phospho-humic ones described by Szymański (1960). They are a sources of phosphorus or iron for plants when these macroelements in ionic form begin to become scarce in the vicinity of the roots. The creation of these links may also protect plants from excess phosphorus or iron caused by an imbalance in the proportions among ions. The results found in this study indirectly confirm Szymański's (1960) suggestions that mineral-humic links do not arise under conditions of pH lower than 5.5. and that their stability increases with the increase in pH. The formation and functioning of mineral-humic links in only one of the many ways humic substances affect plants.

A different mechanism of humate action on plants probably functions in the acidic pH range (Ghosh and Schnitzer 1980) since the structure of the humic acid macromolecules and their chemical activity change under the influence of changes in the pH. Maybe humate enables the young tomato seedlings to take up cations. This type of hypothesis is confirmed by the results of authors cited above.

The possibility of the direct action of sodium humate on the permeability of cell mebranes and the enzymes functioning in the palsmalemma cannot be excluded. This may in consequence lead to deep changes in the roots metabolism.

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Wpływ humianu sodu na wzrost pomidorów oraz akumulację fosforu i żelaza przy różnym pH pożywki

Streszczenie

Badano wpływ humianu sodowego na plon suchej masy i akumulację P i Fe w pędach pomidorów uprawianych w pożywkach o odczynie pH 5,0, 6,4 i 7,2 oraz 10-krotnie zwiększonej lub 10-krotnie zmniejszonej dawce fosforu. W odczynie kwaśnym u roślin z deficytem fosforu zwiększyła się akumulacja tego pierwiastka pod wpływem humianu, zaś w pH lekko alkalicznym uległa obniżeniu. Ze wzrostem pH humian obniżał u tych roślin nadmierną akumulację żelaza. Przy podwyższonym pH zapobiegał zbyt dużej akumulacji P oraz podwyższał ograniczoną w tych warunkach zawartość Fe. Efekty wywołane przez humian w warunkach podwyższonego pH dają się wytłumaczyć funkcjonowaniem połączeń fosforo-huminowych.