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EFFECTS OF A SOIL FULVIC ACID ON THE GROWTH AND NUTRIENT CONTENT OF CUCUMBER (*CUCUMIS SATIVUS*) PLANTS

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Key words

Calcium Copper Flowers Iron Leaves Magnesium Nitrogen Nutrient uptake Phosphorus Potassium Roots Shoots Zinc

Summary

Cucumber (*Cucumis sativus*) plants were grown in Hoagland solution to which 20 to 2000 ppm of a soil fulvic acid (FA) were added. The addition of 100 to 300 ppm of FA produced highly significant increases in the growth and development of above and below ground plant parts, in the uptake of nutrient elements (N, P, K, Ca, Mg, Cu, Fe and Zn), and in the formation of numbers of flowers per plant. Effects of adding 500 and more ppm of FA were less beneficial.

Introduction

Beneficial effects of humic substances on plant growth have been recognized by many workers[10,11,18,19,21] but specific effects of these substances on various phases of plant growth and on nutrient uptake have not been adequately investigated. Applications of humic substances to soils low in organic matter, or in nutrient solutions, have produced very significant responses. Humic compounds may be absorbed by roots and translocated to shoots, thus enhancing the growth of the whole plant[1,14]. It has also been suggested that plant growth is influenced by increasing the absorption of ions, by facilitating the distribution of heavy metals as chelates within the plant and by affecting metabolic reactions[1,9]. Studies on stem elongation and formation of adventitious roots in peas have shown that FA affects plant growth and development[8,12,13,15]. Positive and stimulatory effects of humic acid (HA) and FA on the germination of different varieties of crop seeds have also been observed[4]. The presence of FA in nutrient media has been reported to produce considerable changes in the growth pattern of cultured tomato roots[8]. Also, HA has been shown to affect respiration rates of plant roots[19]. At low concentrations, humic substances enhance cell elongation in excised pea root segments, increase algal and microbial growth, but are inhibitory at higher concentrations[2,5,21,23]. Soil organic matter has also been reported to influence the activity of root invertase and phosphatase[23,24,25]. Greenhouse studies with paddy crops showed that the application

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of zinc along with soil humic substances significantly increased the zinc uptake over that of the control[3].

However, most of these investigations were limited to seed germination, shoot growth of very young seedlings or elongation of excised root segments *in vitro*. Little is known about the effect of humic compounds on the growth of whole plants over extended periods of time, crop productivity, and the optimum concentrations inducing beneficial effects on plants. Therefore, the objective of the present investigation was to study nutrient uptake and growth of plants in nutrient solutions containing various concentrations of a soil FA.

Materials and methods

The FA was extracted from the Bh horizon of the Armadale soil, a poorly drained Podzol in Prince Edward Island, Canada. Detailed methods of extraction and purification as well as physical and chemical characteristics of the FA have been described previously[6,16]. The purified FA contained 0.26% ash and was completely water-soluble.

Plant growth studies were conducted in a controlled environment chamber at 26°C during the day, 24°C during the night, a 16 hour photoperiod and light intensity of 1500 f.c. A stock solution of 20000 ppm of FA was prepared by dissolving the FA in distilled water and adjusting the pH to 6.2 with 0.2 *N* NaOH. Aliquots of the FA stock solution, to give final FA concentrations of 20 to 2000 ppm, were added to Hoagland solution (minus Ca, to avoid precipitation), mixed thoroughly and allowed to stand overnight. Ca was then added, the pH adjusted to 6.5, and the solutions divided into jars (300 ml/jar). The experiment was set up in three replicate jars with eleven different concentrations of FA, ranging from 0 to 2000 ppm.

Seeds of cucumber (Cucumis sativus), a Boston pickling variety, were surface sterilized with 50% Javex for 5 min., followed by washing 5–6 times with distilled water. Seeds were then spread over wet filter paper in a large pyrex tray, and kept in the growth cabinet at 27°C. Healthy 5-day old seedlings, supported by split foam plugs, were inserted into lid holes of 500 ml glass jars. Seedlings were first grown in distilled water for two days to acclimatize the system and then in treatment solutions. All jars were connected by air lines fitted with a Koby air purifier; the FA solution was replaced every six days. Plants were grown for six weeks, then harvested and divided into roots and shoots; fresh weight, height of plants, length of roots, number of leaves and flowers were recorded and the plant material freeze dried for analysis of N, P, K, Ca, Mg, Cu, Fe and Zn. Nitrogen was determined by the automated micro-Dumas method; Ca, Mg, K, Cu, Fe and Zn by atomic absorption spectrometry of perchloric acid-nitric acid digests of the samples; and P in the digest by the molybdovanadate method. Coefficients of variations between replicate metal ion analyses averaged 1.0%.

The results obtained were analyzed statistically by the Duncan multiple range test[20].

Results and discussion

The administration of increasing amounts of FA (0 to 300 ppm, see Table 1) brought about increases in heights of shoots, lengths of roots, dry weights of roots, shoots and whole plants, and in the numbers of leaves and flowers per plant. By comparison with controls, these increases were highly significant when between 100 and 300 ppm of FA was applied. Application of 200 ppm of FA produced effects which were similar to those resulting from the administration of 300 ppm of FA; therefore these data are not shown in Table 1. When 500 and more ppm of FA was applied, magnitudes of all growth parameters tended to decline.

Table 1. Influence of FA on plant growth and production of flowers

Treatments ppm	Height of shoot cm	Length of root cm	Freeze-dried weight, g/plant			Number/plant	
			Roots	Shoots	Whole plant	Leaves	Flowers
0	22.3d	37.0bc	.08cd	.95d	1.0d	10.0	5.3b
20	27.0cd	44.0abc	.10cd	1.2cd	1.3cd	12.3ab	6.3b
50	29.0bcd	53.0a	.14abc	1.2cd	1.4cd	13.0ab	6.5b
100	40.3a	48.3ab	.18a	2.1ab	2.3ab	14.3a	13.0a
300	38.6ab	51.6a	.18a	2.3a	2.4a	14.3a	12.0a
500	34.3abc	48.6ab	.13abc	1.6bcd	1.7bcd	13.0ab	7.6b
700	32.3abcd	49.3ab	.13abc	1.5bcd	1.6bcd	12.6ab	7.3b
1000	34.3abc	48.3ab	.12c	1.7abc	1.9abc	13.3ab	7.3b
1500	27.0cd	35.0c	.08cd	1.2cd	1.3cd	11.0ab	5.5b
2000	26.0cd	21.6d	.07d	.97d	1.0d	11.0ab	4.0b

a–d The treatment followed by the same letter did not differ significantly at the 1% level according to Duncan's multiple range test[20].

The application of 100 to 300 ppm of FA yielded highly significant increases (compared to controls) in concentrations of N, P, K, Ca, Mg, Cu, Fe and Zn in shoots and also in the N content of roots (Table 2). Under these conditions, concentrations of all elements in the shoots, with the exception of Fe, more than doubled. Also, concentrations of N in roots greatly increased. Roots were analyzed only for N because not sufficient material was available for analysis of other elements. When 500 and more ppm of FA was applied, however, concentrations of all of elements tended to decrease, although Fe and Zn concentrations already began to decrease when 300 ppm of FA was administered. Compared to applications of 500, 700 and 1500 ppm of FA, relatively small increases in freeze-dried weights of whole plants (Table 1) and in the total metal contents of shoots (Table 2) were observed when 1000 ppm of FA was administered. The application of 2000 ppm of FA depressed concentrations of N, P, K, Fe and Zn in the shoots to levels that were below those in controls.

The data presented herein show that for cucumber plants the presence of 100 to 300 ppm of FA in the nutrient solution significantly enhances:

(a) the growth and development of above- and below-ground plant parts;
(b) the uptake of nutrient elements from the surrounding nutrient solution with a concomitant increase in physiological processes; and
(c) the formation of numbers of flowers, which suggests that FA may affect enzyme(s) active in the production of flowers. The number of flowers is directly related to yield.

We observed that when 100 to 300 ppm of FA was applied, the roots were highly branched and rich in hairs, which increased the surface area and could have facilitated more efficient nutrient uptake. Also, FA, which is known to be surface active, could have increased the permeability of root membranes and so enhanced nutrient uptake. Additional plausible explanations for the activity of FA are that it contains structures that act like hormones, that it facilitates the translocation of nutrients throughout the plant, and that by complexing with metal ions it increases their solubility and availability to plant

Table 2. Effect of FA on the elemental contents of shoots and N content of roots (Freeze-dried weights)

Treatments ppm	Total content mg/plant (shoots)					μg/plant (shoot)			Roots N mg/plant
	N	P	K	Ca	Mg	Cu	Fe	Zn	
0	55.3d	15.9b	61.5de	48.6bc	8.3d	9.6e	199.9d	37.7d	4.1de
20	74.3cd	20.7b	94.2cde	55.4bc	8.9cd	17.0cde	196.0bcd	50.6d	5.9cd
50	75.2cd	18.8b	82.8cde	63.9bc	9.6cd	16.9cde	178.7bcd	56.8cd	7.5abc
100	110.9ab	34.2a	142.9ab	101.9a	16.7ab	30.8ab	316.5a	98.0a	9.4a
300	128.9a	35.6a	152.9a	109.1a	18.2a	37.7a	285.7a	88.7ab	9.2ab
500	81.7bcd	24.5b	102.9bcd	71.3b	11.7bcd	18.4cde	266.4ab	74.0abc	7.0c
700	81.5bcd	22.3b	93.0cde	62.6bc	11.2cd	20.1cd	196.1bcd	55.3cd	7.3bc
1000	95.0bc	25.2b	109.3bc	73.5b	14.2abc	25.9bc	235.9abc	65.9bc	6.8c
1500	66.5cd	19.9b	72.1cde	44.9bc	9.8cd	13.9de	155.1cd	38.0d	4.5de
2000	50.0d	14.9b	58.3e	37.0c	8.5d	12.0de	149.1cd	31.7d	3.4e

a–e The treatment followed by the same letter did not differ significantly at the 1% level according to Duncan's multiple range test [20].

roots. The application of > 300 ppm of FA appears to provide more ligands with which the metal ion can complex so that the metals becomes less available to plant roots. Further research is needed to find out which of these explanations has the greatest merit. What our data show is that the administration of 100 to 300 ppm of FA to a nutrient solution in which cucumber plants are grown significantly affects the growth and development of these plants.

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