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ORIGINAL ARTICLE

Foliar and soil fertilization of humic acid affect productivity and quality of tomato

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Abstract
The objective of the study was to determine the effect of foliar and soil fertilization with humic acid (HA) on quality, growth and yield of tomato under greenhouse conditions in 2004 and 2005. Tomato plants were treated with soil and foliar HA applications at different concentrations (0 ml/l, 10 ml/l and 20 ml/l). Three weeks after planting HA was sprayed four times during the vegetation period at 10-day intervals. Furthermore, 0, 10 and 20 ml/l HA solutions were applied as a drench to the plant root area four times during the vegetation period at 10-day intervals three weeks after planting. HA treatments had no effect on pH and titratable acidity (TA) of tomato. Total soluble solids (TSS) increased with both foliar and soil HA treatments. Foliar 20 ml/l HA application resulted in the highest ascorbic acid (AA) content. Foliar applications of HA led to higher leaf and stem dry matter contents than the control. Both foliar and soil HA treatments positively affected fruit characteristics including fruit diameter, fruit height, mean fruit weight and fruit number per plant. Similarly, HA treatments increased the early yield of tomato compared to control. The yield of tomato was significantly influenced by soil and foliar HA applications. The highest yield occurred in foliar 20 ml/l HA treatment. The study shows that 20 ml/l concentration of HA sprays could be successfully used to obtain better growth and yield in tomato.

Keywords: *Growth, hormone-like activity, Lycopersicon esculentum, yield.*

Introduction

Humic acid, which has hormone-like activity, not only enhances plant growth and nutrient uptake but also improves stress tolerance. The significance of humic acids is not limited to their function as a reservoir of mineral plant nutrients and regulator of their liberation. Recent literature has shown that humic acid could be used as a growth regulator to regulate hormone levels, improve plant growth and enhance stress tolerance (Serenella et al., 2002). Studies indicate that humic acid (HA) was in general not only beneficial to shoot and root growth but also nutrient uptake of vegetable crops (Padem et al., 1997; Akinremi et al., 2000; Dursun et al., 2002; Cimrin & Yilmaz, 2005).

Humic substances are usually applied to the soil, and favourably affect the soil structure and soil microbial populations. Foliar sprays of these substances also promote growth in a number of plant species including tomato (Brownell et al., 1987). Several hypotheses have been proposed to explain the effect of HA. These include the formation of a complex between HA and mineral ions, catalysis of HA to enzymes in the plant, influence of HA on respiration and photosynthesis, and stimulation of nucleic acid metabolism and hormone activity of HA (Serenella et al., 2002).

Tomato is the leading greenhouse vegetable crop in Turkey. Positive effects of humic substances on plant growth and yield have been well documented for tomato (David et al., 1994; Adani et al., 1998; Padem & Ocal, 1999; Dursun et al., 2002; Dogan & Demir, 2004; Turkmen et al., 2004). However, most of these studies were conducted either in aggregate culture, bag culture, solution culture or hydroponics culture. In Turkey, tomato is mainly grown under soil conditions in both field and greenhouse. There is little information on the effect of the soil application of humic acid on tomato under direct soil conditions. Therefore, the main objective of the work was

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to study and compare the effect of soil and foliar fertilization with humic acid on tomato production and quality under soil conditions in the greenhouse.

Material and methods

The study was conducted at Atatürk University, Hamza Polat Training Vocational School under greenhouse conditions in Turkey in 2004 and 2005. The first experiment was performed in a plastic tunnel and the second in a glasshouse. Tomato (*Lycopersicon esculentum* L.) cv. Target NF1 was used as plant material.

The soil physical and chemical properties of the experimental area in 2004 and 2005 are presented in Table I. Cattle manure (50 t/ha) was applied to the plots before planting. The manure used contained 1.5% N, 1.3% K_2O, 2.1% P_2O_5, and had an EC value of 4.8 dS/m. 200 kg/ha N, 170 kg/ha P_20_5 and 250 kg/ha K_2O from ammonium nitrate, triple superphosphate and potassium sulphate sources, respectively, were applied uniformly to the experimental area prior to planting (Hochmuth & Hanlon, 1995).

Tomato seeds were sown in plastic trays filled with peat (pH 5.5, EC 250 mmhos/cm, N 300 mg/l, P_2O_5 300 mg/l, K_2O 400 mg/l, organic matter 2%) on 1 April and 5 February 2004 and 2005, respectively. Trays measured 53 $\times$ 33 cm, with 45 cells (5 cm $\times$ 6 cm). The seedlings were grown in the greenhouse and fertilized with 20N:20P:20K soluble fertilizer once a week. Seedlings were transplanted on 10 May 2004 and 14 March 2005, in rows 0. 90 m apart with an intra-row spacing of 0.45 m. Each plot consisted of 10 plants.

Plants were treated with 10 and 20 ml/l HA (extracted from leonardite, containing 23.0% humic acid as polymeric poly-hydroxyl obtained from Makro Tar Co., Ltd.) solutions which were made up with distilled water containing 0.02% Tween 20 as surfactant (polyoxyethylenesorbitan monolaurate, Sigma Chemicals, St. Louis, MO, USA). HA was applied as a spray four times during the vegetation period at 10-day intervals three weeks after planting using a hand-held sprayer. The lower leaf surface was sprayed until wetted as well as the upper surface, since it was reported that absorption by the lower leaf surface was rapid and effective (Hull et al., 1975). The plots were sprayed during late afternoon or evening hours. Also, 10 and 20 ml/l HA solutions prepared in distilled water were applied as a drench to the plant root area four times during the vegetative period at 10-day intervals three weeks after planting. Plants sprayed both with 0.02% Tween 20 and drenched with distilled water served as the control (0 ml/l HA).

During the growing period plants were drip irrigated as needed. There were no insecticide and fungicide treatments in both experiments. Weeds were controlled by hand. In both years, regular cultural practices such as pruning were applied uniformly through all plots.

The experimental design was a randomized complete block design with three replications. Treatments consisted of no HA application (control), foliar 10 ml/l HA, foliar 20 ml/l HA, drench 10 ml/l HA and drench 20 ml/l HA application.

The temperature ranged from 15°C to 33°C for the first experiment, and from 16°C to 35°C for the second experiment.

Harvesting was carried out from 8 July to 21 October in 2004, and from 7 June to 15 September in 2005. Tomato fruits were harvested when they were at the fully-red stage. In the study, fruit diameter, fruit height, mean fruit weight, fruit number per plant, fruit weight per plant, early and total yield were determined. The yield harvested in the first 30 days during the harvest period was considered as early yield (Alan & Padem, 1994).

Thirty fruits per plot were collected randomly as sub-samples for quality assessment. Fruits were homogenized in a blender and portions of the homogenate were taken to determine the pH, total soluble solids (TSS), titratable acidity (TA) and ascorbic acid contents (AA). TSS was determined by a hand refractometer (JENA 178512). TA was determined by the titration of fruit homogenate (5.0 g) with 0.1 *M* NaOH at pH 8.1, using citric acid as a control (Horwitz, 1975). AA was measured by classical titration method using 2,6-dichlorophenol indophenol solution, and expressed as mg/ 100 ml (Miller, 1998).

Statistical analysis was conducted using the GLM procedure of SAS (SAS, 1985). Data were subjected

Table I. Soil physical and chemical properties of experimental area.

Year	Sand (%)	Silt (%)	Clay (%)	N (ppm)	OM (%)	pH	CaCO3 (%)	EC $\times 10^6$	Ca (me/100g)	Mg (me/100g)	K (me/100g)	Na (me/100g)	P (ppm)
2004	14.3	33.8	52.5	4.8	2.15	7.95	9.30	3.00	13.22	3.30	1.50	0.20	10.55
2005	31.1	21.7	47.2	17.3	0.83	7.36	5.42	3.66	13.24	5.32	1.30	0.58	10.13

to analysis of variance (ANOVA) to compare the effects of HA treatments. The means were separated using least significant difference test (LSD, $p < 0.05$).

Results and discussion

The effects of humic acid treatments on quality characteristics of tomato fruit are summarized in Table II for both 2004 and 2005. The humic acid treatments did not significantly affect pH and TA of tomato in either year. TSS and AA was significantly ($p < 0.05$) affected by treatments in 2004 and 2005. Both soil and foliar humic acid treatments increased the AA and TSS content of tomato fruits. The highest AA content was obtained from 20 m/l foliar application (65.57 mg/100 ml and 53.45 mg/100 ml in 2004 and 2005, respectively). Similar results were reported by Padem and Ocal (1999) who showed that foliar HA applications increased the AA content of tomato fruits. Dogan and Demir (2004) reported that HA treatments did not affect pH of tomato fruits. On the other hand, they determined that TA was significantly affected by HA treatment but TSS was not. These findings did not agree with our results. This might be attributed to differences of climatic conditions and soil properties between our and their study.

There were significant differences among treatments with regard to leaf dry matter in both years. Foliar 20 ml/l HA application resulted in the highest leaf dry matter content in 2004 (14.96%) and in 2005 (12.67%). Furthermore, foliar 10 ml/l HA application had greater leaf dry matter content than that of control. In 2004, foliar HA applications increased the stem dry matter content compared to control, while there was no significant difference between treatments with regard to stem dry matter in 2005 (Table II). This difference might be attributed to the differences in the climatic conditions and soil chemical and physical properties in the 2004 and 2005 experiments. It was reported that HA applied into growing medium increased the shoot and root dry matter contents (Turkmen et al., 2004). Similarly, Pertuit et al. (2001) indicated that the addition of HA into a sand medium increased shoot dry matter content of tomato. Our results support the previous reports.

Both soil and foliar HA applications significantly ($p < 0.05$) affected fruit diameter and fruit height in both years. The lowest fruit diameter occurred in the control treatment (6.25 cm) in 2004. However, there was no significant difference between soil HA application and control with regard to fruit diameter in 2005. Foliar HA applications increased fruit height compared to the other treatments in 2004, whereas both soil and foliar HA treatments increased fruit height compared to the control in 2005 (Table III). Mean fruit weight was consistently higher in HA treatments than the control treatment in both years except in soil 10 ml/l HA treatment. A significant effect of soil and foliar HA application on fruit number per plant was found in 2004. Similarly, HA applications apart from the soil 10 ml/l HA treatment increased the fruit number compared to control in 2005. The highest fruit number was determined from 20 ml/l foliar HA application with 63 and 70 in 2004 and 2005, respectively. In 2004, all HA applications improved the early yield of tomato while only 20 ml/l foliar HA application increased statistically the early yield compared to control in 2005 (Table III). Similar findings, that HA applications improved growth and some fruit characteristics of tomato were reported by Adani et al. (1998), Padem and Ocal (1999), and Dursun et al. (2002). Moreover, Dogan and Demir (2004) indicated that HA application resulted in higher early yield compared to control.

The yield of tomato was significantly ($p < 0.05$) influenced by soil and foliar HA applications in 2004 and 2005 (Table IV). The highest yield was obtained from 20 ml/l foliar HA application in both 2004

Table II. Quality characteristics of tomato in response to foliar and soil fertilization with HA at different rates.

	pH		AA (mg/100 ml)		TSS (%)		TA (%)		Leaf dry matter (%)		Stem dry matter (%)	
Treatment	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Control	4.69	4.78	47.02 d*	33.16 c*	5.6 b*	5.5 b*	1.17	1.18	13.12 c*	11.11 b*	19.62 c*	19.06
Foliar 10 ml/l	4.57	4.72	59.70 b	46.23 b	6.4 a	6.2 a	1.21	1.18	14.30 ab	12.61 a	21.51 ab	19.23
Foliar 20 ml/l	4.59	4.62	65.57 a	53.45 a	6.6 a	6.5 a	1.22	1.21	14.96 a	12.67 a	22.21 a	19.73
Soil 10 ml/l	4.54	4.60	52.69 c	42.06 b	5.9 b	6.5 a	1.24	1.11	13.42 bc	11.79 ab	20.69 abc	19.23
Soil 20 ml/l	4.49	4.58	54.25 c	44.82 b	6.5 a	6.5 a	1.07	1.19	13.42 bc	11.87 ab	20.13 bc	19.22
LSD (0.05)	n.s	n.s	3.11	4.60	0.32	0.36	n.s	n.s	1.01	1.26	1.63	n.s.

* Number with the same letters are not statistically different ($p < 0.05$).
n.s.: non-significant.

Table III. Some fruit characteristics of tomato in response to foliar and soil fertilization with HA at different rates.

	Fruit diameter (cm)		Fruit height (cm)		Mean fruit weight (g)		Fruit number (per plant)		Early yield (g/plant)	
Treatment	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Control	6.25 c*	7.18 b*	5.13 c*	5.45 b*	88.49 b*	110.57 d*	48 c*	54 d*	935 c*	1676 b*
Foliar 10 ml/l	6.69 ab	7.43 a	5.47 ab	5.69 a	94.44 a	114.63 c	60 a	65 ab	1253 ab	1869 ab
Foliar 20 ml/l	6.83 a	7.45 a	5.63 a	5.76 a	96.46 a	119.73 a	63 a	70 a	1379 a	1949 a
Soil 10 ml/l	6.50 b	7.35 ab	5.20 c	5.76 a	87.63 b	110.57 d	52 b	58 cd	1175 b	1695 b
Soil 20 ml/l	6.66 ab	7.25 ab	5.36 bc	5.70 a	94.48 a	117.60 b	55 b	62 bc	1137 b	1801 ab
LSD (0.05)	0.21	0.24	0.23	0.31	3.47	1.99	3.55	4.66	179	196

* Number with the same letters are not statistically different ($p < 0.05$).

(5575 g/plant) and 2005 (7693 g/plant). This yield variation between years could result from differences in climatic conditions such as temperature, light and soil chemical and physical properties in the 2004 and 2005 experimental years. Our results agree with those of Padem and Ocal (1999) who determined that HA application at different concentrations improved tomato yield. However, Dogan and Demir (2004) reported that addition of HA to aggregate culture had no significant effect on tomato yield, suggesting that HA can show its effect in a complex medium such as soil.

The stimulating effect of humic substances on plant growth and yield of tomato may have been related to enhanced uptake of mineral nutrients (Padem et al., 1997; Adani et al., 1998; Dursun et al., 2002) and the plant hormone-like activity of humic substances (Serenella et al., 2002).

In conclusion, foliar and soil HA applications can result in an increase and improvement in the growth and yield of tomato. The results of the present study indicate that especially foliar HA application would be an advisable treatment in terms of producing higher yields. Based on these findings, 20 ml/l foliar HA application may be advised to obtain better quality and yield of tomato.

Table IV. Yield of tomato in response to various HA treatments.

	Total yield (g/plant)	
Treatments	2004	2005
Control	4630 d*	6435 d*
Foliar 10 ml/l	5258 b	7471 b
Foliar 20 ml/l	5575 a	7693 a
Soil 10 ml/l	4913 c	6832 c
Soil 20 ml/l	5194 b	6978 c
LSD (0.05)	233	162

* Number with the same letters are not statistically different ($p < 0.05$).

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