Scientific Research and Essays Vol. 6(13), pp. 2800-2803, 4 July, 2011
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE11.304
ISSN 1992-2248 ©2011 Academic Journals

Full Length Research Paper

Changes in fruit yield and quality in response to foliar and soil humic acid application in cucumber

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Accepted 24 May, 2011

This study was designed to determine the influence of foliar and soil humic acid (HA) treatment on fruit quality and yield of cucumber grown under soil conditions in a greenhouse. Different concentrations of HA (0, 10, 20, 30 and 40 ml/L) were applied to cucumber plants through either foliar spraying or drenching in the root area. Foliar and soil HA applications led to significantly higher mean fruit weight, early and total yield than the control. HA treatments had no significant effect on skin chlorophyll b, mesocarp chlorophyll a, b and total chlorophyll contents, fruit length and diameter. Both soil and foliar HA treatments significantly increased total and reducing sugar contents. Moreover, HA application significantly influenced fruit skin total chlorophyll content and this effect was mainly on chlorophyll a content. The study shows that cucumber fruit yield and quality can significantly be improved with soil and foliar HA application.

Key words: Cucumber, humic acid, quality, yield.

INTRODUCTION

Humic substances are generated through organic matter decomposition and employed as soil fertilizers in order to improve soil structure and soil microorganisms. Foliar sprays of these substances also promote growth, and increases yield and quality in a number of plant species (Brownell et al., 1987; Yildirim, 2007; Karakurt et al., 2009) at least partially through increasing nutrient uptake, serving as a source of mineral plant nutrients and regulator of their release (Chen and Aviad, 1990; Atiyeh et al., 2002). Likewise, humic substances have been shown to stimulate shoot and root growth and nutrient uptake of vegetable crops (Tattini et al., 1990; Padem et al., 1997; Akinremi et al., 2000; Cimrin and Yilmaz, 2005). To elucidate the effects of humic substances, several hypotheses suggesting the formation of a complex between these substances and mineral ions, their involvement in the enhancement of enzyme catalysis, their influence of stimulating respiration, photosynthesis and nucleic acid metabolism, and their hormonal activity have been reported (Dell'Agnola and Nardi, 1987; Nardi et al., 1988; Muscolo et al., 1999; Serenella et al., 2002). In this study, we determine the influence of exogenously applied humic acid (HA) on fruit yield and quality of cucumber grown under direct soil conditions in a greenhouse.

MATERIALS AND METHODS

The study was performed in a greenhouse at the Research Farm of the College of Agriculture, Suleyman Demirel University, Isparta, Turkey, in 2006 and 2007. Cucumber (*Cucumis sativus* L.) cv. Mostar was used as plant material. Table 1 shows the physical and chemical properties of the experimental area's soil. Cattle manure (50 tons/ha) containing 1.7% N, 1.4% K_2O, 1.8% P_2O_5, with an EC value of 4.6 dS/m and 40 kg/da NPK (15:15:15) was applied uniformly to the plots before planting. Seeds were sown on 26 May 2006 and 24 May 2007, in rows 80 cm apart with an intra-row spacing of 50 cm. Each plot consisted of 10 plants. Plants were exposed to 0, 10, 20, 30 and 40 ml/l HA (Cukurova Tarim Lombrico, Adana, Turkey) solutions thus providing 0, 30, 60, 90 and 120 ml/da

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Table 1. Soil physical and chemical properties of the experimental area.

pH	$CaCO^3$ ($g.kg^{-1}$)	EC*10^6 (dS/m)	Sand (%)	Clay (%)	Silt (%)
7.9	252	345	15.5	41.2	42.3
OM ($g.kg^{-1}$)	**P ($mg.kg^{-1}$)**	**K ($cmol.kg^{-1}$)**	**Ca+Mg ($cmol.kg^{-1}$)**	**Fe^2O^3 (ppm)**	**N (ppm)**
20.4	13.80	1.72	33.31	3.28	16.3

Table 2. Yield and fruit characteristics of cucumber in response to foliar and soil fertilization with various concentrations of HA. Data represent the averages of the data obtained in 2006 and 2007.

Humic acid treatments (ml/L)	Yield (tons/da)	Early yield (tons/da)	Mean fruit weight (g)	Fruit firmness (N)	Fruit diameter (mm)	Fruit length (cm)
Control	12.02 ^{d}	6.27 ^{d}	88.33	12.54 ^{bcd}	29.16	16.52
Foliar 10	13.62 ^{ab}	7.81 ^{ab}	97.90	13.23 ^{abc}	29.77	16.29
Foliar 20	13.81 ^{a}	8.06 ^{a}	103.22	14.01 ^{ab}	31.01	17.05
Foliar 30	13.39 ^{abc}	7.12 ^{bc}	94.13	13.72 ^{abc}	29.33	16.15
Foliar 40	12.66 ^{bcd}	7.05 ^{bc}	94.67	12.54 ^{bcd}	29.72	16.73
Soil 10	12.54 ^{cd}	6.96 ^{cd}	88.47	12.45 ^{cd}	30.65	16.82
Soil 20	13.11 ^{abc}	6.71 ^{cd}	97.90	14.70 ^{a}	29.00	15.89
Soil 30	13.77 ^{a}	7.79 ^{ab}	100.70	13.03 ^{bcd}	28.71	16.47
Soil 40	13.11 ^{abc}	7.36 ^{abc}	94.47	11.56 ^{d}	28.94	17.04

Means followed by the same letters are not significantly different at the 5% level of significance.

HA respectively. Plants were foliar-sprayed three times at 15 day intervals with different concentrations of HA four weeks after planting utilizing a hand-held sprayer. The bottom leaf surface of plants were totally wetted with HA solutions in order to accomplish faster and more effective absorption of HA during late afternoon or evening hours (Hull et al., 1975). Furthermore, the same concentrations of HA solutions were applied three times to the plant root area during the growth period at 15 day intervals. 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, 10 kg/da ammonium nitrate, 45 kg/da potassium nitrate, 8 kg/da potassium sulfate, 30 kg/da calcium nitrate, 24 kg/da mono ammonium phosphate and 15 kg/da micronutrients were applied to the plants with drip irrigation. Other cultural practices (weed control, pest control, irrigation, etc.) were also applied uniformly throughout all plots. The experiment was set up in a randomized complete block design with three replications (10 plants per replication). Harvesting was carried out twenty seven times at commercial ripening stage based on the criteria described by Sevgican (2002) from July 10 to October 9 in 2006, and from July 7 to October 4 in 2007. After harvest, fruit diameter, fruit height, mean fruit weight, fruit firmness, early and total yield were determined. The weights of the fruit harvested during the first 30 days of the harvest period were measured and considered as early yield (Alan and Padem, 1994).

Firmness was measured for 18 fruits from each sample employing a hand penetrometer. Measurements were taken on opposite cheeks at the center of each fruit. The probe was inserted to the bioyield point. Data were expressed as the force (N) required to reach the bioyield point.500 g of fruit tissue from each treatment were frozen in liquid nitrogen and used for total and reducing sugars, chlorophyll a and b and total chlorophyll determinations. Chlorophyll a, b and total chlorophyll contents were measured as described (Akcin, 1980).

Determination of total soluble and reducing sugars

Five grams of cucumber mesocarp tissue from 20 fruit of each treatment were grinded in 20 ml of 95% ethanol with a homogeniser for 2 min, and then incubated in a boiling water bath for 10 min. After cooling to room temperature the extracts were centrifuged at 8000 g for 15 min and then filtered through GF/C filter paper (Whatman). The residues were re-incubated with 20 ml of 80% ethanol at 25°C and both supernatants were combined. Total soluble sugars were measured by the method of Dubois et al. (1956) and reducing sugars were determined following the procedure of Honda et al. (1980). Glucose was employed as a standard for the calculation of total soluble and reducing sugars.

Statistical analyses

Statistical analysis was carried out with the GLM procedure of SAS (SAS, 1985). Data for 2006 and 2007 were pooled and then analysis of variance (ANOVA) was conducted to compare the effects of HA treatments. The means were separated using Duncan's Multiple Range test at the 5 % level of significance.

RESULTS AND DISCUSSION

The effects of HA treatments on yield and quality characteristics of cucumber fruit are shown in Tables 2 and 3. Both soil and foliar HA treatments significantly

Table 3. Chemical composition of cucumber fruit in response to foliar and soil fertilization with various concentrations of HA. Data represent the averages of the data obtained in 2006 and 2007.

Humic acid treatments (ml/L)	Total soluble sugars (mg/g)	Reducing sugars (mg/g)	Fruit skin chlorophyll a (µg/mg)	Fruit skin chlorophyll b (µg/mg)	Fruit skin total chlorophyll (µg/mg)
Control	142.76 bc	63.11 c	3.75 bc	2.37	6.13 bc
Foliar 10	163.35 a	79.10 a	4.03 abc	2.63	6.67 abc
Foliar 20	156.22 ab	76.50 ab	5.00 a	3.18	8.17 a
Foliar 30	148.84 abc	71.48 abc	3.68 bc	2.30	5.98 bc
Foliar 40	151.48 abc	70.37 abc	3.14 c	2.12	5.26 c
Soil 10	162.71 ab	72.32 ab	3.64 bc	2.40	6.04 bc
Soil 20	161.99 ab	75.18 ab	2.97 c	1.93	4.91 c
Soil 30	143.49 abc	71.26 abc	5.01 a	3.21	8.22 a
Soil 40	132.70 c	69.57 bc	4.47 ab	2.90	7.38 ab

Means followed by the same letters are not significantly different at the 5% level of significance.

increased the cucumber fruit yield (Table 2). The highest yield was determined from 20 ml/L foliar treatment (13.81 tons/da). Similarly, all HA treatments improved the early yield of cucumber significantly with the exception of soil 10 and 20 ml/L HA treatment as compared to the control. Both soil and foliar HA applications did not significantly affect fruit diameter and fruit length. Similar results were also obtained from pepper fruit treated with HA (Karakurt et al., 2009). However, in another study, Yildirim (2007) have reported a significant enhancement in fruit diameter and length as a result of exogenous HA application in tomato but the author did not find any significant difference between soil HA application and control in terms of fruit diameter. Mean fruit weight values changes between 88.33 to 103.22 g in response to foliar and soil HA applications. The highest mean fruit weight was obtained from foliar 20 ml/L followed by soil 30 ml/L. Soil or foliar HA application also significantly increased fruit firmness. The highest firmness was obtained from soil 20 ml/L treatment, but as HA concentration increased firmness declined significantly. Collectively, the reported findings that HA treatments improved growth and some fruit characteristics of various plants including cucumber, tomato, eggplant and pepper (Adani et al., 1998; Dogan and Demir, 2004; Karakurt et al., 2009; Arancon et al., 2006; Yildirim, 2007) were confirmed in our study. Moreover, Dogan and Demir (2004) indicated that HA application resulted in higher early yield as compared to the control. However, the authors reported that addition of HA to aggregate culture had no significant effect on total yield in tomato, and suggested that a complex medium such as soil was necessary to observe HA effects.

Both total and reducing sugar contents significantly influenced by HA treatment (Table 3). The highest total and reducing sugars were obtained from foliar 10 ml/L application. 40 ml/L soil and foliar HA applications significantly reduced both reducing and total sugars. Fruit skin chlorophyll content is a quality characteristic of cucumber fruit determining skin green color and thus influencing fruits appearance and consumer acceptance (Schouten et al., 2002). HA treatments significantly improved the green color of cucumber fruit skin. The highest total chlorophyll content was obtained from soil 30 ml/L and foliar 20 ml/L treatments. The change in total chlorophyll content in response to HA was mainly due to the change in chlorophyll a content since there was no significant effect of HA on chlorophyll b content. Chlorophyll a content showed a significant increase in response to both foliar and soil HA treatments increasing more than 33.6% with soil 30 ml/L HA and 33.3% with 20 ml/L foliar HA compared to that of the control fruit. On the other hand fruit mesocarp chlorophyll content showed no significant change in response to HA treatment (Data not shown).

In conclusion, foliar and soil HA applications can result in an increase and improvement in the cucumber fruit yield and quality. The results could be due to the reported enhancement in the growth of cucumber in response to the incorporation of HA into plant growth media (Chen and Aviad, 1990; Tattini et al., 1991; Atiyeh et al., 2002). This stimulatory effect may have also been related to increased uptake of mineral nutrients reported previously (Valdrighi et al., 1996; Padem et al., 1997) and the plant hormone-like activity of humic substances (Tattini et al., 1991; Serenella et al., 2002). For instance, it is reported that nitrogen uptake rate by the roots of container grown olive plants increased after application of HA concentrations in the range of 30 to 120 mg/pot, with the greater HA concentrations decreasing nitrogen uptake. Moreover, the positive influences of HAs on the productivity and quality of cucumber could also be primarily due to hormone-like activities of the HAs through their participation in cell respiration, photosynthesis, oxidative phosphorylation, protein synthesis, and various enzymatic reactions (Vaughan et al., 1985; Chen and Aviad, 1990; Muscolo et al., 1996; Muscolo et al., 1999). Hormone-like activity or plant-growth regulator effects of HAs was observed by Muscolo et al. (1999) who reported that treating carrots cells with humic substances obtained from the feces of the earthworm *Antennaria rosea* increased their growth and induced morphological changes similar to those produced by auxins. An alternative explanation is the hypothesis that plant growth regulators may adsorb on to humates and operate in combination with them to influence plant growth. In fact, Canellas et al. (2000) demonstrated that there were exchangeable auxin groups in the macrostructure of humic acids. Collectively, the results of the present study suggest that soil and/or foliar HA treatment might efficiently be utilized to obtain higher fruit yield and can significantly enhance fruit quality in cucumber.

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