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CHANGES IN FRUIT YIELD, QUALITY AND NUTRIENT CONCENTRATIONS IN RESPONSE TO SOIL HUMIC ACID APPLICATIONS IN PROCESSING TOMATO

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Abstract

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Humic acids (HA) provide formation of the organomineral in soil, thus they improve nutrient concentration of tomato leaves and agricultural production. The objective of this study was to find effects of soil HA applications on yield, fruit quality and nutrient concentration of processing tomato. Humic acid was sprayed on soil at the rate of 0, 40, 80, 120, 160 and 200 L ha^{-1} soil along with uniform dose of nitrogen-phosphorus-potassium (NPK) (180-60-210 kg ha^{-1}) was applied through drip irrigation. The experiment was conducted according to randomized complete block design with 4 replicates in 2011-2012 years. The humic acid applications caused a significant increase of yield. Titretable acidity, fruit weight and fruit diameter showed increase by ascending humic acid levels. Results showed that N, P, K, Ca, Zn and Mn concentration of leaves was increased by humic acid, especially 80 L ha^{-1} humic acid level provided the most important progress in the first year. In the second year, N, P, K, Fe and Mn concentration of leaves was positive changed by humic acid and high levels of humic acid caused decline. Therefore, mid-levels (80 and 120 L ha^{-1}) were found more effective.

Key words: Humic acid, nutrient concentration, yield, fruit quality, tomato

Introduction

Tomato (*Lycopersicum esculentum* Miller) is one of the most widely grown and consumed vegetables. In terms of human health, it is a major component in the daily diet, due to constitute an important source of minerals, vitamins and antioxidants (Chapagain and Wiesman, 2004).

Turkey produces 7 million tons of tomatoes in 160 thousand ha of land per year and occupies 7% of the world production. Of the production, 73% is consumed fresh, 25% is processed and 2% is exported (Yagmur et al., 2005). Today, Turkey is one of the largest tomato paste producers in the world along with the USA, the Republic of China and Italy. The number of countries importing tomato paste from Turkey increases every year. Therefore, increasing productivity of tomato with high quality is an important target by the growers for paste exportation. Production quality is affected various factors such as climate, irrigation, plant protection, soil properties and fertilization (Achilea, 1998). In order to increase yield and fruit quality, organic materials are widely used besides chemical fertilizer. Due to easy availability and applicability, use of humic acid preparations has been common as an organic material. It is a naturally occurring polymeric organic compound produced by decay of organic materials and is found in soil, peat and lignites (Sharif et al., 2002). It exerts either a direct effect such as on enzyme activities, membrane permeability, root growth, shoot development, uptake of some macro and micro elements or an indirect effect mainly by changing the soil structure (Chen and Aviad, 1990). Fagbenro and Agboola (1993) reported that soil humic acid applications increased the plant nutrient uptake. Likewise, humic acid has been shown to beneficial effects on nutrient uptake by plants, was particularly important for the transport and availability of micronutrients (Bohme and Lua, 1997). Thus, humic acid affect fruit quality, plant growth and yield. Some researchers reported that humic acid applications caused to increase of tomato yield and fruit quality (Yıldırım, 2007; Padem and Ocal, 1999).

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The effects of humic acid on plant growth are very complex and can be change depending on many factors. The main objective of this study was determined to effect of the humic acid on yield, fruit quality and nutrient concentrations of processing tomato plants.

Materials and Methods

Experimental Design

Field trials were conducted in Antalya, Turkey in 2011 and 2012. Experimental areas were located at 1020 m elevation. Generally, Mediterranean continental climates dominate in the region; summers are arid and hot while winters are warm and rainy. Some chemical and physical properties of the soils used in the research are shown in Table 1. The soil used in this study was taken from 30 cm depth of the field.

Kero F1 tomato (Lycopercium esculentum L.) paste variety, was used as test plant and 40 plants per plot were established (60 x 80) x 120 cm apart in 23 m^2. Seedlings were planted on May 6 in 2011 and May 17 in 2012. The field trials were arranged according to randomized complete block design with four replications. Humic acid used in trials was produced by Turkey Coal Enterprises Institution. This material was derived from leonardite and contains humic acid 15%, organic matter 5% and potassium oxide 2%. Soil application levels of humic acid were 0 (control), 40, 80, 120, 160, 200 L ha^{-1}. Humic acid was applied to soil at one time before planting and incorporated into soil. 180 kg ha^{-1} N, 60 kg ha^{-1} P, 210 kg ha^{-1} K being supplied from ammonium nitrate, mono ammonium phosphate and potassium nitrate. Nutrient solution was applied by drip irrigation.

Table 1
Some Physical and Chemical Parameters of Experimental Areas

Measured parameters	2011	2012
N (%)	0.150	0.120
P (mg kg^{-1})	29	40
K (mg kg^{-1})	302	394
Ca (mg kg^{-1})	3288	3723
Mg (mg kg^{-1})	479	488
Fe (mg kg^{-1})	2.57	3.38
Zn (mg kg^{-1})	0.84	1.16
Mn (mg kg^{-1})	1.12	1.82
Cu (mg kg^{-1})	3.50	4.24
B (mg kg^{-1})	0.44	0.51
pH (1:2.5 distilled water)	7.90	8.00
EC_{25} (1:2.5 distilled water) (dS m^{-1})	0.160	0.240
$CaCO_3$ (%)	26.3	27
Organic matter (%)	1.80	1.70
Texture	Silty Clay Loam	

Laboratory Determinations

Harvest was performed when fruits reached the completely ripe stage, with 100% of their surface presenting red colorations. A representative sample (15 fruits) from each treatment was submitted for analytical processing. The following traits were analyzed in the fruits: a) Total soluble solids (TSS), determined with digital refractometer (Wang et al., 1996); b) titratable acidity (TA), determined by titration with 0.1 N NaOH and expressed as citric acid percentage (Cemeroglu, 1992); c) pH of the extracted fruit juice, measured by pH-meter; d) EC of the extracted fruit juice, measured by EC-meter; e) fruit weight determined by weighing; f) fruit diameter (mm) measured by digital compass; g) skin colour individual fruits marked at the equatorial region (3 opposite regions per fruit) and color recorded as L*, a* and b* values with a Minolta Chroma Meter CR-200 (Minolta Camera Co Ltd, Japan).

Fruits were separated as marketable and non-marketable (cracked, damaged and infected) and only marketable ones were used to calculate yield (Atiyeh et al., 2000). The first harvest was 111 days, the second 131 days after transplanting in the first year. In the second year, the first harvest was 100 days, the second 120 days after transplanting.

In the middle of the vegetation period, plant samples were taken, dried at 65°C, dry weights were determined and plant samples were wet digested by using HNO_3+ $HClO_4$ (4:1) mixture. P, K, Ca, Mg, Fe, Zn, Mn and Cu in the same solution were determined by using ICP-OES (Kacar and Inal, 2008). Total N content of the samples were analyzed according to a modified Kjeldahl method (Bremner, 1965).

Statistical analysis

Analysis of variance was performed to evaluate differences in measured parameters. Thereafter, parameters were compared by least significant difference test (LSD, $p \leq 0.05$)

Results and Discussion

Effect of Humic Acid on Yield and Fruit Quality of Tomato Plants: Humic acid applications had a significant effect on yield ($p < 0.001$) in first year, the yields varied between 4.60 and 7.51 kg $plant^{-1}$. The highest values were obtained from 200 L ha^{-1} and the lowest from 40 L ha^{-1} (Table 2). Except for application of 40 L ha^{-1}, all the applications increased yields compared to the control. Humic acid applications increased yield in the rate of about 8.72% to 42.5% compared to control. In the 2nd year, the effects of applications on the yield of tomato were found statistically significant ($p < 0.05$). There was no statistically difference between humic acid applications. At the same time, the highest yield value was obtained from 160 L ha^{-1} which was higher 30% over the control. Gezgin et al., (2010) found that mineral fertilization (NPK) with 120 L ha^{-1} humic acid application was the most appreciable effect on tuber yield (14.4% increase over the control). Saruhan et al. (2011) reported that wheat grain yield increased 43.86% as the average of two years depending on soil humic acid application. It is thought that the observed yield increase may not be associated with low amount of nutrients supplied by the HA, rather it might also be associated with its beneficial effect on soil physicochemical and biological properties (Brannon and Sommers, 1985). Furthermore, this increase may be concerned with plant photosynthetic rates. Liu et al. (1998) reported that the photosynthetic rates and root mass of creeping bent grass grown in Hoagland's nutrient solution were significantly increased by HA added at the rate of 400 mg L^{-1}.

Soluble solid content is of major economic value for the processing tomato industry, since even a small increase can significantly enhance yield and decrease the cost of dehydration of puree into sauce and paste. This quality criterion varies depends on a high leaf area: fruit ratio, the rate of assimilate export from leaves, rate of import of assimilates by fruits and fruit C metabolism (Hewitt et al., 1982). Results showed that there was no significant effect observed in the two years (Table 2). Similar results were reported by Selim et al. (2012).

Organic acids are not only important for the flavor of tomatoes, but also play an important part in the preservation of canned tomato products. Soil humic acid applications had a positive effect on titratable acidity (TA). In the first year, the highest value (0.37 g 100 ml^{-1}) was observed by 160 L ha^{-1} (15% increase with respect to the control). In the second year, humic acid applications increased titratable acidity content compared to control but there was no statistically difference between humic acid applications. Generally titratable acidity content of the samples was higher in the 2nd year than that of the 1st year. This situation may be resulted from soil K concentration, because 2nd year experimental area soil K concentration was higher than that of 1st year (Table 1). Wang et al. (2009) reported that increasing K fertilization enhanced TA levels in tomato fruits. Petro-Turza (1987) found that the soil K content most affects the TA concentration in the fruits, since plants have to produce more organic acids to neutralize absorbed K^+ when a large amount of K are applied.

Table 2
The Effects of Soil Humic Acid on Fruit Quality and Yield

Treatments	Yield (kg $plant^{-1}$)		TSS content (%)		Titratable acidity (%)		pH of fruit juice		EC of fruit juice	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
0 L ha^{-1}	5.27 c	4.12 b	3.53	3.75	0.32 d	0.41 b	4.43	4.50 b	4.22 d	4.47
40 L ha^{-1}	4.60 d	5.30 a	3.97	4.50	0.36 ab	0.43a	4.53	4.60 ab	4.96 c	5.51
80 L ha^{-1}	6.74 b	5.26 a	4.50	4.00	0.33 cd	0.44 a	4.54	4.70 a	5.26bc	4.85
120 L ha^{-1}	5.73 c	5.24 a	3.80	4.12	0.34 bcd	0.43 a	4.47	4.70 a	5.66ab	5.28
160 L ha^{-1}	7.39 a	5.38 a	3.78	4.50	0.37 a	0.43 a	4.48	4.63 a	5.30bc	5.09
200 L ha^{-1}	7.51 a	5.12 a	4.00	4.37	0.35 abc	0.46 a	4.53	4.67 a	5.76 a	4.84
Significance	***	*	ns	ns	**	*	ns	*	***	ns

Table 2
continued

Treatments	Fruit Weight (g)		Fruit diameter (mm)		L*-value		a*-value		b*-value	
0 L ha^{-1}	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
40 L ha^{-1}	101.67 b	114.77 c	42.37 b	49.45 b	41.8	43.2	34.6	32.2 a	28.7	31.8 a
80 L ha^{-1}	104.74 b	119.93 b	50.82 a	55.11 a	40.4	41.9	30.5	30.0 b	26.8	29.5bcd
120 L ha^{-1}	116.52 a	127.06 a	49.43 a	56.26 a	41.5	42.0	32.1	30.9 ab	28.8	30.2abc
160 L ha^{-1}	110.17ab	125.16 a	48.59 a	54.78 a	41.1	41.5	33.0	29.9 b	27.8	28.4d
200 L ha^{-1}	108.59ab	120.06 b	51.26 a	55.00 a	40.5	41.2	31.6	30.9 ab	26.7	28.7cd
Significance	116.42 a	120.94 b	50.70 a	56.56 a	40.7	42.8	32.2	31.0 ab	27.4	30.5 ab
*	**	**	*	ns	ns	ns	*	ns	**	*

Fruit juice pH is one important quality attribute of processing tomatoes because acidity influences the thermal processing conditions required for producing safe products. Humic acid applications were not found to be statistically important in the 1st year of the experiment while had a statistically significant effect on pH of the juice ($p < 0.05$) in the 2nd year. pH of the juice increased slightly compared to control. The present findings show similarities with those reported by Ferrara et al. (2007).

Fruit juice EC is a flavour indicator as described by Dorais et al. (2001). Fruit juice EC ranged from 4.22 to 5.76 dS m^{-1} in the 1st year and was taken from control and 200 L ha^{-1}, respectively. In the 2nd year, fruit juice EC was not affected by treatments.

In both years the highest and lowest fruit weight value were found with 80 L ha^{-1} and control, respectively. Fruit weights of tomato increased with humic acid applications. This increase in fruit weight as a consequence of humic acid applications is probably ascribed to the uptake of mineral nutrients by tomato. Sarhan et al. (2011) reported that humic acid applications increased eggplant fruit weight.

The effect of the applications on the fruit diameter of tomato was found to be statistically significant in both years. Fruit diameter was found to be between 42.37 and 51.26 mm and was obtained from control and 160 L ha^{-1} in the 1st year. In the 2nd year, fruit diameter ranged from 49.45 to 56.56 mm and was observed from control and 200 L ha^{-1}, respectively. Yildirim (2007) have reported a significant enhancement in fruit diameter and length as a result of exogenous humic acid application in tomato. Vasilenko (2002) found that humates increased the average diameter of tomato fruit, increasing by 16-17 % larger than fruit from control.

Tomato fruit color is one of the most important and complex attributes of fruit quality. The complexity of tomato color is due to the presence of a diverse carotenoid pigment system. Their appearance is conditioned by pigment types and concentrations and subject to both genetic and environmental conditions (temperature, plant nutrition, fruit ripening stage) (Lopez Camelo and Gomez, 2004). According to our study results, increasing levels of humic acid did not affect skin color component. Carvajal et al. (1995) reported that foliar and soil humic acid applications were no effect on pepper color component.

Effect of Humic Acid on Macro and Micro Element Concentration of Tomato Leaves: The influence of the applications on the macro element concentrations of tomato leaves are given in Table 3. The N concentrations of tomato leaf were found to be statistically significant in both years. In the 1st year, the total N concentration of tomato leaves ranged from 4.47 to 5.0% within the applications and was taken from control and 80 L ha^{-1} (an increase with respect to the control of 10.6%). In the 2nd year, a decrease in the N concentration was realized and was fixed in the range of 4.13 and 4.64%, obtaining from control and 120 L ha^{-1} (11.0% increases over the control) (Table 3). This result could be attributed to the better use efficiency of applied nitrogen fertilizer in the presence of humic acid. Piccolo et al. (1992) found that the acid functionality of humic acid could stimulate the nitrate uptake by plants. The results of our study demonstrate that nitrogen uptake depends on application levels and HA decreases the absorption of nitrogen especially in higher concentrations. Adani et al. (1998) indicated that nitrogen uptake of root increased with middle dose (20 mg L^{-1}) of humic acid, but high doses (50 mg L^{-1}) HA application resulted in decrease for nitrogen uptake of root.

The effect of humic acid applications on P concentration of leaves was highly significant in both years. In the 1st year, 80 L ha^{-1} HA resulted in the highest leaf P (0.39%) concentration (20.5%, increase over the control). In the 2nd year, P concentration of leaves was increase by 16.3% at 120 L ha^{-1}.

Table 3
Effect of soil humic acid application on the macro element concentration of tomato leaves

Humic acid (L ha^{-1})	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Control	4.47 c	4.13 d	0.31 d	0.36 b	3.05 c	3.42 c	3.72 b	4.77	1.07	1.52
40	4.46 bc	4.47 ab	0.33 cd	0.42 a	3.25 bc	3.57 bc	3.85 b	5.12	1.09	1.58
80	5.00 a	4.44 b	0.39 a	0.40ab	3.55 a	3.63 b	4.21 a	4.78	1.05	1.42
120	4.83 ab	4.64 a	0.35 bc	0.43 a	3.49 a	3.82 a	3.92 b	4.95	1.15	1.44
160	4.81 ab	4.53 ab	0.36 b	0.39ab	3.51 a	3.60 bc	3.94 b	4.89	1.30	1.55
200	4.87 a	4.50 ab	0.36 b	0.39ab	3.41 ab	3.74 ab	3.94 b	4.90	1.12	1.57
Significance	***	**	***	*	**	**	*	ns	ns	ns

Means in the same column followed by the same letter are not significantly different at 5 % probability level by LSD test.

Humic acid likely increases P availability and uptake by inhibiting calcium phosphate (Ca-P) precipitation rates (Grossl and Inskeep, 1991), forming phosphohumates, competing for adsorption sites and/or decreasing the number of adsorption sites by promoting dissolution of metal solid phases via chelation (Guppy et al., 2005). Wang et al. (1995) found that addition of humic acids to soil with P fertilizer significantly increased the amount of water soluble phosphate, strongly retarded the formation of occluded phosphate and increased P uptake of wheat.

Results revealed that leaf K concentration was significantly ($p < 0.01$) influenced by HA applications in both years. The K concentration of tomato ranged from 3.05 to 3.55% in the 1st year and was taken from control and 80 L ha^{-1}, respectively. In the 2nd year, an increase in the K concentration was realized and was fixed in the range of 3.42 and 3.82%, obtaining from control and 120 L ha^{-1}, respectively. According to Samson and Visser (1989) HA can induce an increase in the permeability of biomembranes for electrolytes, resulting in increased uptake of K. Humic substances modify membrane bound ATPase activity and the relation between membrane ATPase activity, H extrusion and the ion uptake suggested that humic substance influence active uptake of potassium by interfering with specific ion carrier. After the mid-levels, high doses of humic acid decreased potassium concentration of tomato. Similar findings, that HA applications caused to improve K contents of leaves but high levels lead to decrease was reported by Nikbakht et al. (2008).

The effect of humic acid on Ca concentration of leaves was highly significant and could increase it by 11.6% in the 1st year. Calcium concentration in leaves did not increase significantly in the 2nd year. Akinci et al. (2009) reported that humic acid increased bean Ca content but this boost did not significant statistically. Humic acid application was not significant on Mg concentration of tomato leaves in both years.

Table 4 shows the effect of humic acid on the micronutrients concentration of tomato leaves. The application of humic acid had no significant effect on Fe concentration of leaves in 1st year, but significant effect ($p < 0.05$) was observed in the 2nd year. Compared with the control application, the Fe concentration of tomato leaves increased with all the humic acid levels. Humic substances improve the growth of roots and hair roots increases the radicle surface, and favor the uptake of elements such as K, P or Fe (Marschner, 2002). Furthermore, humic compounds possess reducing capacity and are capable of reducing Fe(III) to Fe(II) in a microbial mediated reaction (Scott et al., 1998). As plants take up Fe as Fe(II), this ability may contribute greatly to Fe uptake.

The effect of the applications on Zn concentration of tomato leaves was found to be statistically significant ($p < 0.05$) in 1st year, but insignificant effect was observed in 2nd year for Zn. The Zn concentration of tomato ranged from 5.77 to 9.82 mg kg^{-1} in 1st year. The beneficial effect of humic acid in soil might have prevented the formation of insoluble complexes of zinc and facilitated their uptake by plant (Chen et al., 2001). In general, the Zn concentration of samples was higher in the 2nd year than that of the 1st year. Experimental areas were different, therefore soil Zn contents indicated discrepancy. As seen Table 1, first year soil Zn content was 0.84 mg kg^{-1} while it was 1.16 mg kg^{-1} in 2nd year.

The Mn concentration of leaves ranged from 58.33 to 76.95 mg kg^{-1} in the 1st year and was taken from control and 80 L ha^{-1}, respectively. In the 2nd year, Mn concentration of leaves was fixed in the range of 71.57 and 81.16 mg kg^{-1}, obtaining from control and 40 L ha^{-1} humic acid application, respectively. Eyheraguibel et al. (2008) found that humic substances increased Mn uptake of Maize. The treatments did not statistically significant effect on Cu concentration of tomato leaves in both years. As seen, plant Cu concentrations are sufficient in both years.

Table 4
Effect of soil humic acid application on the micro element concentration of tomato leaves

Humic acid (L ha^{-1})	Fe (mg kg^{-1})		Zn (mg kg^{-1})		Mn (mg kg^{-1})		Cu (mg kg^{-1})	
	2011	2012	2011	2012	2011	2012	2011	2012
Control	115.57	122.84 b	5.77 b	11.57	58.33 b	71.57 c	114.45	120.62
40	133.45	142.14 a	7.37 ab	12.64	64.60 ab	81.16 a	127.97	120.41
80	138.00	135.90 a	8.52 a	13.67	76.95 a	74.32 bc	128.92	135.47
120	135.07	137.55 a	9.80 a	13.10	74.97 a	78.96 ab	134.25	140.52
160	128.87	140.84 a	8.73 a	15.06	76.82 a	78.91 ab	133.60	137.97
200	132.42	139.78 a	9.82 a	13.34	76.35 a	80.12 ab	135.82	135.33
Significance	öd	*	*	ns	*	*	ns	ns

Means in the same column followed by the same letter are not significantly different at 5 % probability level by LSD test.

Conclusions

Results showed that compared with the control, humic acid applications had positive effect on yield and fruit quality criteria of tomato. Moreover, it can be stated that the results obtained suggested a better state of most nutrients uptake. Using humic acid can be considered as a way to enhance nutrients uptake combining with chemical fertilizers. It concluded that the requirement for nitrogen, phosphorus and potassium fertilizer applications may be reduced when adequate humic acids are present within the soil.

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