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Response of Tomato Plants to Foliar Application of Humic, Fulvic Acid and Chelated Calcium

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INFLUENCE of humic, fulvic acid and calcium foliar application on growth, yield and quality of tomato (H9663 hybrid) was investigated during 2013 and 2014 summer seasons. The experiment was designed in completely randomized block at the Experimental Station, Faculty of Agriculture, Cairo University, Giza, Egypt. Solutions of humic acid (0.4 %), fulvic acid (4%) and chelated calcium (0.25 %) were applied as foliar sprays alone or in combinations on tomato plants at four times after two, four, six and eight weeks from transplanting. Vegetative growth parameters and nutrients content (N, P, K and Ca) of tomato plants as well as yield, fruits quality and incidence percentage of blossom end rot in fruits were investigated on treated and untreated plants. Results indicated that the foliar application of humic, fulvic acid and calcium either individual or in combinations increased vegetative growth, yield, fruit quality and decreased the incidence of blossom end rot in tomato fruits.

Keywords: Humic acid, Fulvic acid, Calcium, Foliar application, Blossom end rot, Tomato

Tomato (*Solanum lycopersicum*) is one of the most important and popular fruit vegetable crops grown in many countries. The total cultivated area in Egypt was 515225 feddans (feddan equal 0.4 hectare), produced about 8571050 tons on annual basis with an average of productivity 16.636 tons/feddan in season (Ministry of Agriculture and Land_Reclamation, 2013). It has many nutrition values such as high content of potassium, vitamins C and E, flavonoids, chlorophyll, β-carotene, and lycopene (Jones, 2008). Increasing the production of tomato with high quality is considered an important aim and this aim could be achieved through using the foliar application of humic, fulvic acid and calcium.

Humic substances such as humic acid, fulvic acid are the major components (65-70%) of soil organic matter, increase plant growth enormously due to increasing cell membrane permeability, respiration, photosynthesis, oxygen and phosphorus uptake and supplying root cell growth (Cacco & Dell Agnolla, 1984**,** Russo & Berlyn, 1990 and Fahramand *et al.,* 2014). Foliar spraying of humic acid promoted growth in many plants such as tomato, cotton and grape (Brownell *et al.,* 1987). Karakurt *et al.* (2009) reported that humic acid application affected pepper growth and fruit characteristics and had positive influence on quantitative and qualitative of pepper plant. Ameri and Tehranifar (2012) investigated that spraying of humic acid on strawberry plants enhanced nutrient uptake (N, P and K) and physiological characteristics of fruits. Also, HosseiniFarahi *et al.* (2013) suggested that foliar application of humic acid led to improvement of quantitative and qualitative characteristics of strawberry (chlorophyll content, fruit number, total yield of plant, TSS and fruit firmness).Yildirim (2007) mentioned that foliar application of humic acid on tomato plants increased product quantity and quality.

Fulvic acid accelerates cellular division thus stimulates vegetable growth and development as well as increase of cellular energy and regulation of plant metabolism to prevent nitrate compounds from accumulating in plants and increase in resistance to insects and diseases by encouraging tolerance to extreme temperatures such as heat and coldness and many other physical factors (Jackson, 1993). Fulvic acid chelates and binds scores of minerals into a bio-available form used by cells. These trace minerals serve as catalysts to vitamins within the cell. Additionally, fulvic acid is one of the most efficient transporters of vitamins into the cell. Fulvic acid stimulates and balances cells, creating optimum growth and replication conditions (Pardoe *et al.*, 1990). It enhances the permeability of cell membranes (Christman and Gjessing, 1983). There were research revealed that the treated plants with fulvic acid had significant beneficial effects on roots and shoots (McCarly, 1985) on tomato and (Khang, 2011) on rice and radish. Fulvic acid is particularly preferred in that it allows surrounding stress to decrease, helps absorb other minerals and positively contributes to yield and quality (Bethke *et al.*, 1987).

Calcium is one of the nutrients which are multi-functional in plant physiology and vital for vegetative growth and development (Assmann, 1995 and Marschner, 1995).They are important intracellular messengers, mediating responses to hormones, biotic and abiotic stress signals and a variety of developmental processes (Reddy and Reddy, 2004). In most fruits, firmness retention is an important quality parameter in fresh-cut fruits and vegetable products. The preharvest nutritional status of fruit, especially with respect to calcium, is an important factor affecting potential storage life (Fallahi *et al.*, 1997). Foliar applications of calcium chloride improved fruits quality, delay ripening and retard fungal growth on strawberries (Wojcik and Lewandowski, 2003). Peyvast *et al.* (2009) reported that foliar application of calcium could increase tomato yield and yield components with high quality. Foliar application of humic acid and calcium alone or in combination improved growth parameters, yield and fruit quality of tomato; in the other hand it decreased the incidence of blossom end rot. The combination treatment was more effective than individual application (Kazemi, 2013). Foliar application of fulvic acid and calcium with trace elements enhances the yield, quality and nutritional status of tomato plants (Yildirim and Unay, 2011).

The present work aims to study the effects of foliar spraying of humic, fulvic acid and calcium alone or in combination on the growth, yield, fruit quality characteristics and blossom end rot incidence of tomato fruits.

Materials and Methods

The field trial was conducted during the two growing summer seasons of 2013 and 2014 at the Agricultural Experimental Station, Faculty of Agriculture, Cairo University, El-Giza Governorate, Egypt to investigate the influence of humic, fulvic acid and calcium foliar application on growth, yield and fruits quality of tomato plants. Tomato transplants (H9663 hybrid) were transplanted in the field on 13 and 17 of February in the first and second seasons, respectively. The experimental soil was analyzed according to FAO (1980) and is presented in Table 1.

The soil of the experiment was ploughed after addition of 5 ton commercial compost / feddan and divided into ridges (1 m width and 10 m length); each plot contained three ridges. The space between plants was 50 cm, one row of plants on each ridge. The chemical analyses of compost are illustrated in Table 2. The drip irrigation system consisted of polyethylene hoses GR (4 l h^{-1}) of 16 mm in diameter, allocating one hose for each ridge. Irrigation frequency was every 2 days to maintain soil moisture above 50% according to Qassim and Ashcroft (2002), which is the optimum moisture level of tomato plants.

TABLE 1. The analyses of the experimental soil

Clay %	Silt %	Sand %	Texture	pH	EC dS/m	Cations meq/l				Anions meq/l			
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co_3^{-}	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
70.76	15.52	13.72	Clay	7.77	0.85	1.82	0.43	3.33	0.52	0.24	1.27	2.74	2.53

TABLE 2. The chemical analyses of commercial compost

pH 1:5	EC 1:10 dS/m	O.C (%)	O.M (%)	C/N Ratio	N	P	K
					(%)		
7.48	4.82	21.24	36.65	18.00	1.22	0.85	1.13

All plots received a recommended dose of NPK fertilizers (125 - 45 - 48 kg $feddan^{-1}$) according to Ministry of Agriculture and Land Reclamation (2009) as ammonium sulfate (20.5%N), phosphoric acid (58% P_2O_5) and potassium sulfate (48% K_2O). The fertilizer solutions were injected directly into the irrigation water using a venture injector at two doses weekly. Other recommended agricultural practices were followed as commonly used in the commercial production of tomato.

The individual and combination applications of humic acid (0.4 %), fulvic acid (4 %) and chelated calcium on amino acids (0.25 %) solutions were applied as foliar sprays on tomato plants at four times after 2, 4, 6 and 8 weeks from transplanting, while, the control plants untreated.

The treatments of this experiment were arranged in a completely randomized block design with three replicates.

After 60 days from transplanting, three plants from each replicate were randomly chosen to measure plant length, stem diameter, number of leaves and clusters for plant. Total nitrogen, phosphorous, potassium and calcium were determined in the dry matter of fourth leaf according to Cottenie *et al.* (1982). Total nitrogen was determined by Kjeldahl method according to the procedure described by FAO (1980). Phosphorus content was determined using spectrophotometer according to FAO (1980). Potassium and calcium content was determined spectrometrically using Phillips Unicum Atomic Absorption Spectrometer as described by FAO (1980). Fresh and dry shoot weight of plants was measured at harvesting.

Total yield for each plot was recorded accumulatively after each harvesting and collected for feddan. The percentage of blossom end rot incidence (BER) was estimated by counting the total number of fruits and fruits showing symptoms of blossom end rot in each treatment. The blossom end rot incidence is expressed as a percentage of total fruits.

Five ripe fruits (fully red color) were selected randomly to measure some fruit characteristics. Fruit firmness was measured by penetrometer (Lfra Texture Analyzer) using a penetrating needle of 1 mm of diameter, 3 mm in distance and speed of 2 mm/second and the peak of resistance was recorded as g mm^{-2}. Total soluble solids (TSS) were measured by using a digital Refractometer. Titratable acidity was determined in fresh juice of fruit samples by titration against sodium hydroxide (Na OH) using phenolphthalein as well as, vitamin C in fruits according to the described method in AOAC (2005).

Data of the two seasons were arranged and statistically analyzed by the analysis of variance using one way ANOVA with SAS package. Comparison of treatment means was done using Tukey test at significance level 0.05.

Results and Discussion

The effects on tomato plants growth by treatments are presented in Tables 3 and 4. The results reveal that foliar application of humic, fulvic acid and calcium individual or in combination significantly increased fresh and dry shoot weight compared to control treatment. The highest values of fresh and dry shoot weight were obtained with plants sprayed mixture of humic, fulvic acid and calcium, whereas the untreated plants produced the lowest value. Similar results were obtained with other vegetative growth parameters (plant length, stem diameter and number of leaves) and number of cluster. This increment in plants growth may be due to a positive effect of humic substances (humic and fulvic acid) that increase cell membrane permeability, respiration, photosynthesis, oxygen and phosphorus uptake and root cells growth. In addition, fulvic acid is one of the most efficient transporters of vitamins into the cell (Christman & Gjessing 1983**;**

Cacco & Dell Agnolla, 1984; Russo & Berlyn, 1990; Jackson, 1993 and Fahramand *et al.,* 2014). Also, the good plants growth might be due to a benefit effect of calcium which is multi-functional in plant physiology and vital for vegetative growth and development (Assmann, 1995 and Marschner, 1995). These results are in the same line with those obtained by McCarly (1985), Brownell *et al.* (1987), Karakurt *et al.* (2009) and Khang (2011).

TABLE 3. The effect of foliar application of HA, FA and Ca on fresh and dry weight of shoot and stem diameter of tomato plants during 2013 and 2014 seasons

Treatments	Fresh weight Kg/plant		Dry weight g/plant		Stem diameter mm	
	1st season	2nd season	1st season	2nd season	1st season	2nd Season
Control	2.31 f	2.43 e	330 f	344 f	11.33 f	11.80 e
Humic acid	2.80 c	2.89 c	399 cd	410 c	15.93 c	16.33 bc
Fulvic acid	2.62 de	2.76 cd	377 de	390 de	14.00 de	14.57 cd
Calcium	2.50 e	2.61 de	359 e	371 e	13.33 e	13.88 d
HA + Ca	2.86 c	3.06 b	418 cd	438 b	16.33 c	16.83 b
FA + Ca	2.72 cd	2.83 c	389 d	402 cd	15.33 cd	16.00 bc
HA + F	3.19 b	3.57 a	457 b	513 a	18.33 b	19.17 a
HA + F + Ca	3.55 a	3.72 a	505 a	529 a	21.00 a	21.00 a

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

TABLE 4. The effect of foliar application of HA, FA and Ca on plant length, leaves and clusters number of tomato plants during 2013 and 2014 seasons

Treatments	Plant length cm		Leaves number		clusters number	
	1st season	2nd season	1st season	2nd season	1st season	2nd Season
Control	52.00 g	55.16 f	32.67 e	34.67 e	12.67 f	12.83 e
Humic acid	64.67 d	71.29 d	43.33 c	44.67 c	16.33 cd	18.00 c
Fulvic acid	60.67 ef	66.71 de	40.67 cd	42.67 cd	15.00 de	15.67 d
Calcium	57.33 f	62.09 ef	37.00 d	38.67 de	13.67 ef	14.67 de
HA + Ca	70.67 c	77.21 c	47.67 b	50.67 b	18.33 cd	19.00 c
FA + Ca	63.67 de	70.21 d	43.33 c	45.00 c	16.67 cd	17.67 c
HA + F	80.00 b	86.64 b	51.33 b	54.33 b	20.67 b	21.67 b
HA + F + Ca	88.67 a	93.53 a	57.00 a	60.33 a	24.33 a	24.77 a

Means followed in same column by similar letters are not statistically different at 0.05 levels according to Tukey test.

The effects of different treatments on nutrition status in tomato plants is illustrated in Table 5, data indicated that all foliar application treatments significantly increased all nutrients (N, P, K and Ca) in the leaves. The highest concentration of N was found in humic plus fulvic acid plus calcium treatment compared to other treatments. Also, the highest concentration of P was found in humic plus fulvic acid plus calcium treatment. There were not significant differences with humic plus fulvic acid treatment. Besides, the maximum concentrations of K and Ca were preceded by humic plus fulvic acid plus calcium treatment. There were not significant differences with humic acid plus calcium treatment. These results are in harmony with those obtained by Ameri and Tehranifar (2012), they investigated that spraying of humic acid on strawberry plants enhanced nutrient uptake (N, P and K). Also, these results are in agreement with those obtained by Bethke *et al.* (1987) who reported that fulvic acid helps the plants to absorb other minerals and Yildirim and Unay (2011) who indicated that foliar application of fulvic acid and calcium with trace elements enhances the nutritional status of tomato plants.

TABLE 5. The effect of foliar application of HA, FA and Ca on nutrient content (N,P,K and Ca) of tomato plants during 2013 and 2014 seasons

Treatments	N		P		K		Ca	
	%							
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	2.40 f	2.44 g	0.338 f	0.464 e	2.33 e	2.37 d	0.95 e	1.10 f
Humic acid	3.20 cd	3.46 cd	0.740 bc	0.782 c	3.28 bc	3.44 b	1.58 d	1.66 e
Fulvic acid	2.90 cd	3.11 e	0.667 d	0.755 c	2.67 d	2.87 c	1.48 d	1.56 e
Calcium	2.63 ef	2.84 f	0.541 e	0.625 d	3.13 c	3.38 b	2.19 b	2.29 c
HA + Ca	3.43 bc	3.63 bc	0.770 b	0.835 b	3.46 ab	3.76 a	2.38 ab	2.54 ab
FA + Ca	3.13 cd	3.35 de	0.697 cd	0.775 c	3.27 bc	3.48 b	2.26 b	2.38 bc
HA + F	3.67 bc	3.88 b	0.840 a	0.903 a	3.32 bc	3.51 b	1.86 c	1.96 d
HA + F + Ca	4.09 a	4.23 a	0.857 a	0.917 a	3.65 a	3.87 a	2.55 a	2.62 a

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

The effects of different treatments on total yield and blossom end rot incidence in tomato fruits are showed in Table 6 the obtained results revealed that all spraying treatments of humic, fulvic acid and calcium significantly increased yield of tomato plants in comparison with untreated plants. Using third combination of humic, fulvic acid and calcium gave the highest value of total yield, while second combination of these solutions (humic plus fulvic acid, humic acid plus Ca and fulvic acid plus Ca) came in the second position in this respect, whereas individual treatments (humic acid, fulvic acid and Ca) came in the third position, finally untreated plants gave the lowest yield. These results are supported by Hosseini Farahi *et al.* (2013) they suggested that foliar application of humic acid led to improvement of quantitative and qualitative characteristics of tomato and strawberry, respectively. On the another hand, Peyvast *et al.* (2009) reported that foliar application of calcium could increase yield of tomato. Also, Yildirim and Unay (2011) indicated that foliar application of fulvic acid and calcium with trace elements enhanced the yield of tomato. As well, Osman *et al.*

(2013) mentioned that foliar application of humic and fulvic acid together increased rice yield and its components.

TABLE 6. The effect of foliar application of HA, FA and Ca on total yield and blossom end rot in fruits of tomato during 2013 and 2014 seasons

Treatments	(Ton/feddan) Total yield				Blossom end rot (%)			
	1st season		2nd season		1st season		2nd season	
Control	27.11	h	27.83	f	32.00	a	33.67	a
Humic acid	31.32	e	33.33	cd	14.00	cb	15.00	bc
Fulvic acid	30.49	f	31.83	d	16.33	b	17.00	b
Calcium	28.61	g	29.67	e	6.67	d	7.00	d
HA + Ca	33.53	c	35.17	b	5.67	d	5.67	d
FA + Ca	32.12	d	33.67	bc	6.00	d	6.50	d
HA + F	34.71	b	36.83	a	13.00	c	13.33	c
HA + F + Ca	35.48	a	37.50	a	4.67	d	5.00	d

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

Concerning the blossom end rot incidence in tomato fruits the results indicated that foliar application of humic, fulvic acid and calcium individual or in combination decreased the incidence of blossom end rot. All calcium treatments alone or in combination gave the lowest blossom end rot incidence in the fruits. These results agreed with that found by Kazemi (2013) who showed that foliar application of humic acid and Calcium alone or in combination decreased the incidence of blossom end rot in tomato fruits; with notice that the combination treatment was more effective than individual application. The blossom end rot of tomato fruit is a physiological disorder resulting from calcium deficiency (Del-Amor and Marcelis, 2003). It reduces fruit quality and market value (Taylor *et al.,* 2004). The blossom end rot incidence can be aggravated by the deficiency of other nutrients such as NH_4-N, K, and Mg (Navarro *et al.,* 2005).

Concerning fruit characters of tomato, the results in Table 7 mentioned that fruit firmness, total soluble solid and vitamin C content of tomato fruits were increased significantly with all foliar application treatments individual or in combination, whereas titratable acidity in tomato fruits significantly was decreased in both seasons. The favorable fruit characters were obtained from plants that received the combination of humic, fulvic acid and calcium, while unfavorable effects on fruit quality were observed with untreated plants, whereas individual treatments were moderated. These results may be due to a positive effect of humic substances (humic and fulvic acid) that increase cell membrane permeability, respiration and photosynthesis in plant (Cacco & Dell Agnolla, 1984, Russo & Berlyn, 1990 and Fahramand *et al.,* 2014). As well, they may be due to a benefit effect of calcium which has physiological and vital roles for development processes and fruit quality (Assmann, 1995; Marschner, 1995, Fallahi *et al.*, 1997; Wojcik & Lewandowski, 2003 and Reddy & Reddy, 2004). These results are supported by the findings of Yildirim and Unay (2011) who found that foliar application of fulvic acid and calcium with trace elements enhance the yield and fruit quality of tomato. Also, these results are supported by Kazemi (2013) who reported that foliar application of humic acid and Ca alone or in combination improved yield and fruit quality of tomato with notice that the combination treatment was more effective than individual application.

TABLE 7. The effect of foliar application of HA, FA and Ca on fruit characters of tomato during 2013 and 2014 seasons.

Treatments	Fruit firmness g/mm^2		TSS %		Titratable acidity %		V.C Mg/100g	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	44.00 f	27.83 f	4.70 d	4.95 d	2.86 a	3.02 a	14.96 e	15.48 e
Humic acid	50.33 d	33.33 cd	5.60 c	5.93 c	2.60 bc	2.67 b	15.94 bc	16.51 bc
Fulvic acid	47.33 e	31.83 d	5.47 c	5.77 c	2.64 bc	2.71 b	15.69 cd	16.23 cd
Calcium	53.33 c	29.67 e	5.63 c	5.94 c	2.60 bc	2.64 b	15.56 d	16.09 d
HA + Ca	56.00 b	35.17 b	6.53 b	6.94 ab	2.54 bc	2.68 b	16.20 ab	16.76 ab
FA + Ca	54.67 bc	33.67 bc	5.97 bc	6.29 bc	2.60 bc	2.74 b	15.97 bc	16.56 bc
HA + F	50.67 d	36.83 a	6.07 bc	6.33 bc	2.55 bc	2.69 b	16.43 a	16.99 a
HA + F + Ca	58.67 a	37.50 a	7.40 a	7.67 a	2.52 c	2.35 c	16.52 a	17.09 a

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

Conclusion

In conclusion, foliar application of humic, fulvic acid and calcium individual or in combination improved vegetative growth parameters, yield and fruit quality of tomato; with a decrease in the fruits incidence of blossom end rot. The combination treatments were the most effective.

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استجابة نباتات الطماطم للرش الورقى بحمض الهيوميك والفولفيك والكالسيوم المخلبى

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1- المعمل المركزى للزراعة العضوية – مركز البحوث الزراعية – الجيزة – مصر.
2- قسم الاراضى – كلية الزراعة – جامعة القاهرة – الجيزة – مصر.

تم دراسة تاثير الرش الورقى بحمض الهيوميك وحمض الفولفيك والكالسيوم على نمو وانتاج وجودة الطماطم (هجين H9663) خلال موسمى صيف 2013 و2014. صممت تجربة حقلية فى قطاعات كاملة العشوائية فى المحطة البحثية التابعة لكلية الزراعة – جامعة القاهرة – جمهورية مصر العربية . تم استخدام محاليل من حمض الهيوميك (0.4٪) والفولفيك (4٪) والكالسيوم المخلبى (2.5٪) كرش ورقى على نباتات الطماطم بعد 2 و 4 و 6 و 8 اسابيع من الشتل . تم دراسة صفات النمو الخضرى والمحتوى الغذائى لنباتات الطماطم كما تم دراسة المحصول وجودة الثمار ونسبة الاصابة بعفن الطرف الزهرى بالثمار فى النباتات المعاملة والغير معاملة.

واشارت النتائج الى ان الرش الورقى بحمض الهيوميك والفولفيك والكالسيوم سواء منفردة او مخلوطة زادت من النمو الخضرى والمحصول وجودة الثمار و قللت من الاصابة بعفن الطرف الزهرى فى ثمار الطماطم.