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EFFECT OF IRRIGATION WATER QUANTITY AND SOME BIOSTIMULANTS ON PLANT WATER RELATIONSHIP, WATER USE EFFICIENCY AND PRODUCTIVITY OF TOMATO GROWN IN PLASTIC HOUSE

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ABSTRACT: Two plastic house experiments were conducted in 2014/2015 and 2015/2016 seasons at EL-Kassasein Research Station, Hort. Res. Inst., Agric. Res. Center, Ismailia Governorate, Egypt. It aims to study the effect of irrigation water quantities (IWQ), some bio-stimulants and their interactions on growth, plant water relationship and yield as well as water use efficiency of tomato plants under sandy soil conditions. The obtained results showed that, tomato plants which irrigated with high level of water (153 m^3/plastic house) combined with Actosol + Effective microorganism (EM) as soil application, significantly increased main stem length, number of leaves/main stem, and dry weight of main stem, total and free water (%) in leaf tissues, fruit weight, yield/plant and total yield/ plastic house in both seasons. While, the lowest values of the above-mentioned parameters were recorded with the interaction between the lowest level of IWQ (91 m^3/plastic house) and fertilized with the recommended mineral nitrogen dose (control) in both seasons. Bound water (%) in leaf tissues and water use efficiency as well as TSS (%) in tomato fruits were increased with the interaction between the lowest level of IWQ and Actosol + EM in both seasons.

Key words: Tomato, IWQ, yield, plant water relations, water use efficiency.

INTRODUCTION

Tomato (*Solanum lycopersicon* L.) is considered as one of the major and the most important vegetable crops in Egypt all over the year. It has the highest acreage of any vegetable crop in the world (Jensen *et al.,* 2010).

Water is the main limiting yield production in arid and semi aried regions. Though, irrigation programming is essential to maximize production per m^3 of irrigation water through maximizing water use efficiency.

Growing tomato is considered a high risk activity due to the great variety of environments and systems in which it is grown, high demand for in puts and services, *i.e.,* availability of water through life cycle, as tomato is sensitive to water stress. (Lopes *et al*., 2005).

Restricted irrigations such as drip irrigation are not only good in saving water. In addition irrigation must be controlled at a minimum sufficient level to achieve a good fruit quality and prevent fungal diseases (Xu *et al*., 2007).

Many investigators noticed that increasing of irrigation water quantities (IWQ) had an important role for enhancing plant growth characters, yield and its components of tomato (Dorais, 2007; Zhai *et al.,* 2010; Wahb-Allah and AI-Omran, 2012; Alaoui *et al.,* 2015). Total and free water were increased with increasing water quantity, but bound water was decreased (Abou EI-Khair, 2015) on Jerusalem artichoke and (Abou EI-Khair *et al*., 2015) on strawberry. Water use efficiency of tomato decreased with increasing irrigation water quantity (Singh,

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2007). Also, full irrigation regimes cause a reduction in total, soluble solids and firmness of tomato fruits (Favati *et al.*, 2009 ; Helyes *et al.,* 2012).

Actosol is a commercial liquid organic fertilizer contains humic acid which increase the soil water holding capacity, permitting soil structure, enhance the metabolic activity of soil microorganisms and act as a source of N P and S for plants (El-Seginy, 2006; Fawzy *et al*., 2012).

Bio-organic fertilizer as humic acid has been reported to be important in reducing the chemical fertilizers application and hence reducing the environmental pollution along with reducing the production cost. It plays a good role in enhancement of protein synthesis, photosynthesis, solublization of micronutrients soil, microbial population, soil structure and cation exchange capacity and water retention (Mac Carthy *et al.,* 1999 ; Leonard, 2008).

Addition of humic acid positively increased vegetative growth, total fruit yield and its components and tomato fruit quality (Kazemi, 2013 ; Abo Sedera *et al.,* 2014 on tomato), fruit diameter and length (Yildirim, 2007).

Effective microorganisms (EM) is a mixture of beneficial and effective micro-organism that can be added to soil or foliar spray. EM contains predominant populations of lactic acid bacteria, yeasts, smaller numbers of photosynthetic bacteria, actinomycetes and other types of organisms EM could be added to the soil or as foliar spray. On plant all of these are claimed to be mutually compatible with one another and are" able to coexist in culture (Swelam, 2012).

Treated tomato plants with EM enhanced plant growth characters, yield and its components as well as fruit quality than untreated ones (Idris *et al*., 2008; Lindani and Brutsch, 2012; Kleiber *et al*., 2014; Ahirwar *et al*., 2015).

The main target of this study is to evaluate the response of tomato plants to different irrigation levels and using some types of bio-stimulants which leads to reduce the recommended doses of mineral nitrogen fertilizers and positively affected on growth, yield and water use efficiency as well as fruit quality of tomato under sandy soil conditions.

MATERIALS AND METHODS

The experiment was conducted in plastic house during 2014/2015 and 2015/2016 growing seasons at El-Kassasein Research Station, Hort. Res. Inst., Agric. Res. Center, Ismailia Governorate, Egypt. It aims to study the effect of irrigation water quantities (IWQ), some bio-stimulants and their interactions on growth, plant water relationship, water use efficiency and yield of tomato plants grown in sandy soil under plastic house. The physical and chemical properties of experimental soil in the two seasons was sandy in texture which had 0.08 and 0.09%, 8.22 and 8.25, 2.01 and 2.04 (dsm^{-1}), 5.22 and 4.98 ppm, 3.71 and 3.62 ppm as well as 10.02 and 9.87 ppm organic matter, pH, EC, available N, P and K, respectively.

The experiment included 12 treatments, which were the combinations between three irrigation levels; *i.e.,* 60, 80 and 100% of the recommended water quantity for tomato in sandy soil (according to central lab. For Agricultural Climate., Agriculture Research Center) these water levels equal 91, 122 and 153 m^3/plastic house (540 m^2). The four treatments were three bio stimulants, *i.e.,* Actosol as humic acid, effective micro organisms (EM) and Actosol + EM without mineral nitrogen fertilization and (control treatment which received the recommended dose of ammonium sulphate 20.5% N). These treatments were arranged in a split plot in a randomized complete block design with three replicates. Irrigation levels were randomly arranged in the main plots and fertilization treatments were randomly distributed in the sub plots.

Plot area was 9 m^2. It consisted of three dripper lines of 3m length and 1.0 m between each two dripper lines. The distance between each two plants in the row was 50 cm .One line (3.0 m^2) was used for plant samples to measure vegetative growth parameters and the other two lines (6.0 m^2) were used for yield determination. In addition, one row was left between each two experimental units as a guard row to avoid the overlapping of spraying solution and irrigation water transfer between treatments. Tomato seeds, of Charay F_1 hybrid produced from Green Seed Company Cairo Heliopolis were transplanted on 6th and 9th December in 2014/ 2015 and 2015/2016 seasons.

The amounts of irrigation water (m^3/plastic house) were added by using water counter and pressure gauge at 1.0 bar, which were calculated and expressed in terms of time based on the rate of water flow through the emitters with discharge (2 liters/hr., at 1 bar) to give such amounts of water. The irrigation treatments were added day by day. plots received equal amounts of irrigation water (2m^3/plastic house) through the first fifteen days after transplanting (DAT), irrigation treatments were started on 21st and 23rd December and ended on 28th May and 1th June in the 1st and 2nd seasons, respectively. Irrigation numbers allover the season and amounts of water (m^3/plot and/plastic house) every irrigation are shown in Schedule 1.

Mineral and bio fertilizers application numbers allover the season every fertilizer addition. Bio stimulants were added in five splits one was added at a rate of 30 cm^3/plot with FYM during soil preparation and the other four portions were applied to the soil (at a rate of 30 cm^3 of each) at 15, 45, 75 and 105 days after transplanting.

Control treatment received the recommended ammonium sulphate (20.5%) at a rate of 1.7 kg N/plot, one third of N fertilizer was added during soil preparation and the other two thirds were added to soil in four splits at 15, 30, 45 and 60 days after transplanting**.**

Actosol (contains 20% humic acid + NPK 10-7-2) was obtained from Egyptian American Company for Agricultural Investment and Development. EM stock solution contains (photosynthetic bacteria, actinomycestes and other types of organisms), was obtained from General Organization for Agricultural Equalization Found (GOAEF).

All experimental units received equal amounts of P and K fertilizers at rates of 40 and 30 kg/plastic house, as calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O), respectively. All the amount of calcium super phosphate was added at soil preparation with farmyard manure (FYM) at rate of 4m^3/ plastic house. The other normal agricultural treatments for growing tomato plants were practiced.

Data Recorded

Plant growth

Sample of three plants from each plot were randomly taken at 120 days after transplanting and the following parameters were determined; main stem length and number of leaves/ main stem. One hundred (g) of fresh main stem were dried at 70^{o}C till constant weight. Dry weight of the dried main stem was recorded.

Plant water relations

Total free and bound water of the fourth leaf on the main stem were determined for every treatment (at 120 days after transplanting) in both growing seasons according to the method described by Gosev (1960).

Yield and its components

Fruits of each plot were harvested at full-rip maturity stage, counted, weighed and the following data were calculated; average fruit weight, yield/plant and total yield/ plot. Relative increases in yield (RY%): was calculated according to the following equation.

$$RY(\%) = \frac{(\text{Treatment / control value}) \times 100}{\text{Control value}}$$

Water use efficiency (WUE)

It was calculated according to equation of Begg and Turner (1976) as follows :

$$WUE = Y / WQ$$

Where:

WUE = water use efficiency, Y =Yield (ton/ plastic house 540m^2) WQ = Water quantity (m^3/ plastic house 540 m^2).

Fruit quality

Sample of five tomato fruits were taken randomly from the second harvest of all experimental unit and the following data were recorded: fruit diameter (cm), total soluble solids (TSS): by hand refractometer, and dry matter (%).

Statistical Analysis

Data recorded were subjected to the statistical analysis of variance according to Snedecor and Cochran (1980), and means separation were done according to Duncan (1955).

Schedule 1. Irrigation number over season and quantity per plot and per plastic house (540 m^2)

Water quantity (m^3/plastic house)	Irrigation number	Irrigation quantity in every irrigation/plastic house (540m^2)	Water quantity (m^3/plot, 9 m^2)/ in every irrigation
91	80	1.14	0.032
122	80	1.52	0.042
153	80	1.90	0.053

RESULTS AND DISCUSSION

Plant Growth

Effect of irrigation water quantities (IWQ)

Data presented in Table 1 show that main stem length, number of leaves/ main stem and dry weight of main stem were significantly increased with increasing irrigation water quantities (IWQ) up to the highest rate (153 m^3/ plastic house) in both seasons, without significant differences with the medium levels regarding number of leaves/ main stem in the 2nd season. While tomato plants grown under water stress (91 m^3/plastic house) gave the lowest values in main stem length, number of leaves/ main stem and dry weight of main stem in both seasons.

The relative increases in dry weight of main stem were about 11.92 and 11.18% for IWQ at 122 m^3/ plastic house and 21.95 and 19.06% for IWQ at 153 m^3/plastic house over the IWQ at 91 m^3/plastic house in the 1st and 2nd seasons, respectively.

The decline in main stem length, number of leaves/main stem and main stem dry weight/ plant resulted from application of low IWQ might be due to the decrease in cell elongation resulted from the inhibition effect of water shortage on plant growth promoting hormones which, in turn, led to a decrease in cell turgor, cell volume and eventually cell growth (Banon *et al.,* 2006).

These results agree with those reported by Zhai *et al*. (2010), Wahb-Allah and AI-Omran (2012) on tomato.

Effect of biostimulants

Data in Table 1 indicate that tomato plants treated with biostimulants such as Actosol (source of humic acid), Effective microorganisms (EM) and Actosol + EM had significant effect on main stem length, number of leaves/ main stem and the dry weight of main stem in both seasons.

Treating tomato plants with the combination of Actosol + EM significantly increased main stem length. Also, number of leaves/ main stem and the dry weight of main stem were increased due to the same treatment without significant differences with Actosol alone in both seasons. On the other hand, fertilizing tomato plants with recommended dose of mineral N (as control treatment) gave the lowest values of above-mentioned traits in both seasons.

The relative increases in dry weight of main stem were about 11.48 and 14.22% for Actosol, 11.78 and 18.04% for EM and 31.45 and 34.40% for Actosol + EM over the control treatment (mineral N as ammonium sulphate) in both studied seasons.

Humic acid is highly important to both plant and soil through stimulating soil microbial activity and nutrients availability. It is considered as a plant growth biostimulant and an effective soil conditioner, so it improves, vegetative plant growth and root growth parameters, chemical composition and leaf pigments content specially under sandy soil (Berlyn and Russo, 1990).

Present results supported by the findings of Kazemi (2013) and Abo Sedera *et al*. (2014) respecting the effect of humic acid on tomato plant growth and yield, Kyan *et al*. (1999) and Ahirwar *et al*. (2015) regarding the effect of EM.

Table 1. Effect of irrigation water quantity and some biostimulants on tomato growth (at 120 days after transplanting) under plastic house during 2014 /2015 and 2015/2016 seasons under sandy soil

Treatment	Main stem length (cm)		Number of leaves/main stem		Main stem dry weight (g)		Relative increase in main stem DW (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
				Effect of irrigation water quantities				
91 m^3	160.42c	171.25c	23.00c	22.33b	10.57c	10.28c	100.0	100.0
122 m^3	181.33b	185.50b	26.08b	28.75a	11.83b	11.43b	111.92	111.18
153 m^3	218.92a	221.67a	29.16a	31.41a	12.89a	12.24a	121.95	119.06
				Effect of bio stimulants				
Control *	165.56c	173.33b	21.44c	23.22c	10.27c	9.70d	100.0	100.0
Actosol	193.44ab	200.22a	26.44b	28.11b	11.45b	11.08c	111.48	114.22
EM	191.56b	196.78a	26.00b	27.77b	11.84b	11.45b	111.78	118.04
Actosol+ EM	197.00a	200.89a	30.44a	30.88a	13.50a	13.04a	131.45	134.40

Values having the same alphabetical litter (s) did not significantly differed according Duncan multiple range test at 0.05 level of probability.
*Control: Plots fertilized with the recommended nitrogen dose (60 kg ammonium sulphate/540 m^2).

Effect of interaction between IWQ and biostimulants

Results in Table 2 show that tomato plants irrigated with high level of IWQ (153 m^3/plastic house) combined with Actosol + EM significantly increased main stem length, number of leaves/ main stem, and dry weight of main stem in both season without significant difference with the interaction between the high level of IWQ and treateing plants with EM regarding main stem length in both seasons and number of leaves/ main stem in the 2nd season.

The relative increases in dry weight of main stem due to the interaction between high level of IWQ and Actosol + EM were about 47.36 and 57.06% over the interaction between low level of IWQ and fertilizing plants with ammonium sulphate (control) in the 1st and 2nd seasons, respectively.

Plant Water Relations

Effect of IWQ

The obtained results in Table 3 show that total and free water (%) of tomato leaf tissue were significantly increased with increasing IWQ, while bound water had an opposite trend with increasing IWQ in both seasons. So, IWQ 153 at m^3/plastic house recorded the highest values of total and free water (%) in leaf tissues, whereas IWQ at 91 m^3/plastic house gave the lowest values bound water in leaf tissues in both seasons.

The increase in bound water and the decrease in free water under water stress were mainly due to the increases in osmotic pressure resulted from the conversion starch into soluble carbohydrates as indicated by Lancher (1993).

Present results are in harmony with those reported by Abou EI-Khair (2015) and Abou EI-Khair *et al.* (2015) on Jerusalem artichoke and strawberry, respectively. They concluded that total and free water were increased with increasing IWQ, but bound water was decreased.

Effect of biostimulants

The results in Table 3 show that treating tomato plants with biostimulants had significant effect on total, free water and bound water (%) of tomato leaf tissue in both seasons.

Table 2. Effect of interaction between irrigation water quantity and some biostimulants on tomato growth at 120 days after transplanting under plastic house during 2014 /2015 and 2015/ 2016 seasons under sandy soil

Treatment		Main stem length (cm)		Number of leaves/main stem		Main stem DW (g)		Relative increase in main stem DW (%)	
		1st season	2nd Season	1st season	2nd Season	1st season	2nd season	1st season	2nd season
91 m^3	Control *	134.33h	150.00g	16.66f	17.00f	9.88 d	8.85i	100.0	100.0
	Actosol	176.33f	193.00d	24.66de	25.66cde	10.00d	9.71h	101.21	109.72
	EM	161.00g	167.00ef	24.00de	22.66e	9.74 d	10.47g	98.58	118.31
	Actosol+ EM	170.00f	175.00e	26.66cd	24.00de	12.67bc	12.10cd	128.23	136.72
122 m^3	Control *	158.00g	165.00f	21.00e	25.00de	9.08d	9.03i	91.90	102.03
	Actosol	190.67d	192.67d	25.33d	28.66c	11.84c	12.00cde	119.83	135.59
	EM	183.67e	188.33d	24.66d	27.33cd	13.13b	11.60def	132.89	131.10
	Actosol+ EM	193.00d	196.00cd	33.33a	34.00ab	13.30b	13.12 b	134.61	148.24
153 m^3	Control *	204.33c	205.00c	26.66cd	27.66cd	11.85c	11.22 f	119.93	126.77
	Actosol	213.33b	215.00b	29.33bc	30.00bc	12.52bc	11.55ef	126.72	130.51
	EM	230.00a	235.00a	29.33bc	33.33ab	12.65bc	12.30 c	128.03	138.98
	Actosol+ EM	228.00 a	231.67a	31.33ab	34.66a	14.55a	13.90 a	147.36	157.06

Values having the same alphabetical litter (s) did not significantly differed according Duncan multiply range test at 0.05 level of probability
*Control : Plots fertilized with the recommended nitrogen dose (60 kg ammonium sulphate /540 m^2)

Table 3. Effect of irrigation water quantity and some biostimulants on plant water relationship in tomato leaves at 120 days after transplanting under plastic house 2014 /2015 and 2015/ 2016 seasons in sandy soil conditions

Treatment	Total water (%)		Free water (%)		Bound water (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
			Effect of irrigation water quantities			
91 m^3	79.24c	82.80c	51.44c	53.76c	27.79a	29.04a
122 m^3	83.21b	86.96b	57.81b	60.41b	25.40b	26.55b
153 m^3	85.01a	88.84a	62.61a	65.43a	22.40c	23.41c
			Effect of biostimulants			
Control *	80.52d	84.14d	55.62c	58.13d	24.89b	26.01b
Actosol	85.30a	89.14a	58.97a	61.62a	26.32a	27.51a
EM	81.30c	84.96c	56.50bc	59.05c	24.79b	25.91b
Actosol+ EM	82.84b	86.57b	58.05ab	60.66b	24.79b	25.90b

Values having the same alphabetical litter (s) did not significantly differed according Duncan multiply range test at 0.05 level of probability.
* Control: Plots fertilized with the recommended nitrogen dose (60 kg ammonium sulphate /540 m^2).

Tomato plants treated with Actosol significantly had high values of total, free water and bound water (%) in leaf tissues, followed by plants treated by Actosol + EM in both seasons.

Effect of interaction between IWQ and biostimulants

Results in Table 4 show that the interaction between IWQ and bio-stimulants had significant effect on plant water relationship in leaf tissues of tomato plant in both seasons.

Total and free water (%) were at its maximum values with the interaction treatment between high IWQ and treating plants with Actosol in both seasons. while the interaction between the low level of IWQ and treating plants with Actosol gave the maximum percentage of bound water in both seasons.

Yield and Its Components

Effect of IWQ

Results presented in Table 5 show that, average fruit weight, yield/ plant, yield/ m^2 and total yield per plastic house, as well as water use efficiency (WUE) were affected significantly by irrigation treatments in both seasons.

Average fruit weight, yield/ plant and yield/ plastic house were significantly increased with increasing IWQ up to the highest used level. Meanwhile, the highest yield/m^2 and /plastic house (12.20 and 12.40 kg/ m^2 and 6.59 and 6.70 ton/ plastic house) were recorded with the highest level of IWQ in the 1st and 2nd seasons, respectively. On the other hand, the lowest yield was obtained by irrigation tomato plants with the lowest IWQ level (9.06 and 9.41 kg/ m^2 and 4.89 and 5.08 ton/ plastic house) in the 1st and 2nd seasons, respectively.

The relative increases in total yield/ plastic house were about 34.76 and 31.89% for high level of water and 25.77 and 19.68% for moderate level of water as compared to low level of water in the 1st and 2nd seasons, respectively.

Results in Table 5 were in agree with those reported by Dorais (2007), Wahb-Allah and AI-Omran (2012) and Alaoui *et al.* (2015) on tomato.

The highest WUE recorded (53.79 and 55.88 kg fruits/ m^3 water in the 1st and 2nd seasons, respectively) were obtained when tomato plants were irrigated the lowest rate of IWQ, (91 m^3/plastic house) (Table 5).

The increase in total yield of tomato plants might be due to the increase in average fruit weight (Table 5) obtained from plants which had vigorus vegetable growth (Table 1) caused by using the high level of IWQ

Results are agreeable with those reported by Tiwari *et al.* (1998) and Singh (2007) on tomato. They found that water use efficiency decreased with increasing irrigation water quantity.

Effect of biostimulants

Different biostimulant treatments had significant effect on average fruit weight, yield/ plant, yield/m^2 and total yield/ plastic house compared to control treatment (ammonium sulphate as N recommended dose) in both seasons. Treated tomato plants with Actosol + EM increased average fruit weight (101.0 and 99.4 g), yield/m^2 (11.85 and 12.13 kg/m^2) and total yield/ plastic house (6.34 and 6.55 ton/ plastic house) in the 1st and 2nd seasons, respectively. On the other side fertilizing tomato plants with mineral N recommended dose recorded the lowest values in this respect.

The relative increases in total yield/plastic house were about 17.63 and 28.94% for Actosol+ EM, 11.13 and 19.09% for Actosol alone, 6.30 and 20.67% for EM singly in the 1st and 2nd seasons, respectively.

Concerning water use efficiency, the same results indicate that, treated tomato plants with the mixture of Actosol + EM significantly increased WUE and recorded the highest values (53.26 and 55.03 kg/m^3 water), while the lowest values of WUE were recorded with the plants which received mineral N (45.11 and 42.29 kg/m^3 water) in the 1st and 2nd seasons, respectively.

The increase in total yield might be due to the increase in average fruit weight (Table 5) and main stem dry weight (Table 1).

Humic acid led to increase and promote the uptake of nutrients, and stimulate plant growth and this in turn led to increase tomato fruits yield (Bohme *et al*., 2003).

Table 4. Effect of interaction between irrigation water quantity and some biostimulants on plant water relationship in tomato leaves at 120 days after transplanting under plastic house during 2014 /2015 and 2015/2016 seasons under sandy soil

Treatment		Total water (%)		Free water (%)		Bound water (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
91 m^3	Control *	77.50 g	80.99 h	50.17 f	52.43 d	27.24 d	28.55 b
	Actosol	82.23 e	85.93 ef	52.20 d-f	54.55 d	30.02 a	31.38 a
	EM	77.60 g	81.09 h	50.88 ef	53.17 d	26.71 b	27.92 b
	Actosol+ EM	79.63 f	83.21 g	52.52 d-f	54.88 d	27.11 b	28.33 b
122 m^3	Control *	80.63 f	84.26 fg	56.47 c-e	59.01 c	24.15 cd	25.24 cd
	Actosol	85.56 b	89.42 b	59.85 a-c	62.54 bc	25.71 bc	26.88 bc
	EM	82.73 de	86.46 de	57.09 cd	59.66 c	25.63 bc	26.79 bc
	Actosol+ EM	83.93 cd	87.71 cd	57.82 b-d	60.42 bc	26.11 b	27.29 b
153 m^3	Control *	83.43de	87.19 de	60.23 a-c	62.94 bc	23.20 d	24.25 d
	Actosol	88.10 a	92.06 a	64.86 a	67.78 a	23.24 d	24.28 d
	EM	83.57 de	87.33 de	61.54 a-c	64.31 ab	22.02 de	23.01 de
	Actosol+ EM	84.96 bc	88.79 bc	63.81 ab	66.68 a	21.15 e	22.10 e

Values having the same alphabetical litter (s) did not significantly differed according Duncan multiply range test at 0.05 level of probability
*Control : Plots fertilized with the recommended nitrogen dose (60 kg ammonium sulphate /540 m^2)

Table 5. Effect of irrigation water quantity and some biostimulants on yield and its components of tomato under plastic house during 2014 /2015 and 2015/2016 seasons under sandy soil

Treatment	Average fruit weight (g)		Yield/plant (kg)		Yield/m^2 (kg)		Yield/plastic house (ton)		Relative yield increase (%)		WUE (kg fruit /m^3 water)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
	Effect of irrigation water quantities											
91 m^3	63.33c	63.00c	4.53c	4.70c	9.06c	9.41c	4.89c	5.08c	100.0	100.0	53.79a	55.88a
122 m^3	95.25b	94.58b	5.69b	5.63b	11.38b	11.26b	6.15b	6.08b	125.77	119.68	50.41b	49.84b
153 m^3	123.00a	121.87a	6.10a	6.20 a	12.20a	12.40a	6.59a	6.70a	134.76	131.89	43.09c	43.77c
	Effect of biostimulants											
Control *	87.44d	87.15d	4.99d	4.70 c	9.98d	9.40c	5.39d	5.08c	100.0	100	45.11d	42.29c
Actosol	96.00b	94.33b	5.54b	5.60 b	11.09b	11.21b	5.99b	6.05b	111.13	119.09	50.00b	50.48b
EM	91.00c	91.66c	5.30c	5.67 b	10.61c	11.35b	5.73c	6.13b	106.30	120.67	48.01c	51.53b
Actosol+ EM	101.0a	99.44a	5.92a	6.06a	11.85a	12.13a	6.34a	6.55a	117.63	128.94	53.26a	55.03a

Values having the same alphabetical litter (s) did not significantly differed according Duncan multiply range test at 0.05 level of probability.
* Control : Plots fertilized with the recommended nitrogen dose (60 kg ammonium sulphate /540 m^2).

These results are in harmony with those obtained by Kazemi (2013) and Abo Sedera *et al*. (2014) on tomato regarding the effect of humic acid and Idris *et al*. (2008), Lindani and Brutsch (2012), Kleiber *et al.* (2014) and Ahirwar *et al*. (2015) as for the effect of EM.

Effect of interaction between IWQ and biostimulants

Results in Table 6 show that tomato plants irrigated by high level of water and treated with Actosol + EM significantly increased average fruit weight, yield/ plant, yield/m^2 and total yield/ plastic house in both seasons without significant differences when compared with the same level of IWQ and treated with Actosol regarding average fruit weight in both seasons.

While the plants received low level of water and treated with ammonium sulphate gave the lowest values of yield and its components in both seasons.

The increase in total yield/plastic house., were about 62.42 and 68.96% for the interaction between high level of IWQ and treating plants with Actosol + EM over the interaction between low level of IWQ and treating plants with ammonium sulphate in the 1^{st} and 2^{nd} seasons, respectively.

Respecting WUE, the interaction between low rate of irrigation (91m^3/plastic house and treated plants with Actosal + EM gave the highest WUE (57.25 and 61.76 kg fruit/m^3 water) in the 1^{st} and 2^{nd} seasons, respectively.

It could be concluded that the plants received the high level of water and treated with Actosol + EM recorded the maximum dry weight of main stem and the highest values of average fruit weight and yield/ plant.

Fruit Quality

Effect of IWQ

There were significant differences between irrigation levels on tomato fruit quality (fruit weight; TSS and fruit dry matter contents) in both seasons (Table 7). Irrigation tomato plants with the highest level of IWQ significantly increased average fruit diameter in both seasons. While TSS in fruit was increased with the moderate IWQ level with no significant differences with the highest level in the 2^{nd} season. On the other hand, the highest DM (%) in tomato fruit was recorded with the low level in both season.

Restricted irrigations such as drip irrigation are not only good in saving water but sometimes irrigation must be controlled at a minimum sufficient level to achieve good quality of products. For example, greenhouse production requires a modest drought in soil and/or a dry air condition to prevent fungal diseases and obtain a good fruit quality (Xu *et al*., 2007).

The present results are in agreement with those of Favati *et al*. (2009) and Helyes *et al*. (2012) on tomato. They found that full irrigation regimes cause a reduction in total soluble solids and less firmness of tomato fruits.

Effect of bio-stimulants

Fruit diameter, TSS and DM (%) content in fruits were affected by the different tested treatments in both seasons (Table 7).

Treating tomato plants with Actosol + EM significantly increased average fruit diameter, TSS and DM (%) in fruits without significant differences with Actosol regarding fruit diamter in both seasons or EM in the 1^{st} season regarding TSS in fruit. On the other hand, the lowest values of fruit quality were recorded with plants received mineral N only as control treatment.

Obtained results are in a good line with those reported by Yildirim (2007) who found a significant enhancement effect in fruit diameter and length as a result of HA application to tomato.

Effect of interaction between IWQ and biostimulants

The interaction between IWQ and bio-stimulants had significant effect on fruit diameter, TSS (%) and DM (%) in tomato fruits in both seasons (Table 8). The highest value of fruit diameter was recoded in tomato fruits obtained from plants received the highest rate of IWQ and treated with Actosol and EM in both seasons. However, TSS (%) in fruits was recorded with the interaction between the moderate rate of IWQ and Actosol+ EM in both seasons. While the interaction between the low rate of IWQ and Actosol+ EM gave the highest values of DM content in fruits in both seasons.

Table 6. Effect of interaction between irrigation water quantity and some biostimulants on yield and its components of tomato under plastic house during 2014 /2015 and 2015/ 2016 seasons under sandy soil

Treatment		Average fruit weight (g)		Yield/ plant (kg)		Yield/ kg (m^2)		Yield/plastic house (ton)		Relative yield increase (%)		WUE (kg fruit /m^3 water)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
91 m^3	Control *	55.33j	55.00j	4.13i	3.91i	8.27i	7.82i	4.47i	4.22i	100.0	100.0	49.12cd	46.37f-h
	Actosol	67.00h	65.00h	4.63g	4.65h	9.27g	9.30h	5.01g	5.02h	112.08	118.96	55.05ab	55.16cd
	EM	60.00i	62.00i	4.52h	5.07g	9.05h	10.15g	4.89h	5.48g	109.39	129.85	53.74b	60.22ab
	Actosol+ EM	71.00g	70.00g	4.82f	5.20f	9.65f	10.40f	5.21f	5.62f	116.55	133.18	57.25a	61.76a
122 m^3	Control *	87.00f	89.00f	5.38e	4.79h	10.77e	9.58h	5.82e	5.17h	130.20	122.5	47.70d	42.38h
	Actosol	96.00d	95.00e	5.71d	5.75c	11.42d	11.50c	6.17d	6.21c	138.03	147.16	50.57c	50.90de
	EM	92.00e	91.00f	5.45e	5.57d	10.90e	11.15d	5.89e	6.02d	131.77	142.65	48.28cd	49.34ef
	Actosol+ EM	106.00c	103.33d	6.22b	6.40b	12.45b	12.81b	6.72b	6.92b	150.34	163.98	55.08ab	56.72bc
153 m^3	Control *	120.00b	117.47c	5.45e	5.40e	10.90e	10.80e	5.89e	5.83e	131.77	138.15	38.5f	38.10i
	Actosol	125.00a	123.00ab	6.28 b	6.42b	12.57b	12.85b	6.79b	6.94b	151.90	164.45	44.38e	45.36f-h
	EM	121.00b	122.00b	5.95 c	6.37b	11.90c	12.75b	6.43c	6.89b	143.85	163.27	42.03e	45.03gh
	Actosol+ EM	126.00a	125.00a	6.72 a	6.60a	13.45a	13.20a	7.26a	7.13a	162.42	168.96	47.45d	46.60fg

Values having the same alphabetical litter (s) did not significantly differed according Duncan multiply range test at 0.05 level of probability.
*Control: Plots fertilized with the recommended nitrogen dose (60 kg ammonium sulphate/540 m^2).

Table 7. Effect of irrigation water quantity and some biostimulants on fruit quality of tomato under plastic house during 2014 /2015 and 2015/2016 seasons under sandy soil

Treatments	Fruit diameter (cm)		TSS (%)		DM (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
			Effect of irrigation water quantities			
91 m^3	3.87 c	4.16 c	3.33 c	3.54 b	2.08 a	2.00 a
122 m^3	5.45 b	5.75 b	4.70 a	4.87 a	1.90 b	1.86 b
153 m^3	6.25 a	6.45 a	4.29 b	4.54 a	1.59 c	1.58 c
			Effect of biostimulants			
Control *	4.38 c	4.66 c	3.50 c	3.66 c	1.55 c	1.53 c
Actosol	5.50 a	5.72 ab	3.83 bc	4.11 b	1.85 b	1.80 b
EM	5.16 b	5.38 b	4.33 ab	4.50 b	1.93 b	1.89 b
Actosol+ EM	5.72 a	6.05 a	4.77 a	5.00 a	2.09 a	2.03 a

Values having the same alphabetical litter (s) did not significantly differed according Duncan multiply range test at 0.05 level of probability.
*Control : Plots fertilized with the recommended nitrogen dose (60 kg ammonium sulphate /540 m^2).

Table 8. Effect of interaction between irrigation water quantity and some biostimulants on fruit quality of tomato under plastic house during 2014 /2015 and 2015/2016 seasons under sandy soil

Treatment		Fruit diameter (cm)		TSS (%)		DM (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
91 m^3	Control *	3.33 h	3.66 g	3.00 d	3.16 f	1.81de	1.78 de
	Actosol	4.16 fg	4.33 ef	3.00 d	3.33 ef	2.08 abc	1.98 bc
	EM	3.66 gh	3.83 fg	3.50 cd	3.66 def	2.17 ab	2.07 ab
	Actosol+ EM	4.33 f	4.83 e	3.83 cd	4.00cde	2.26 a	2.16 a
122 m^3	Control *	4.50 f	4.66 e	3.83 cd	4.00 cde	1.55 f	1.52 f
	Actosol	5.83cde	6.16 bcd	4.50 abc	4.66 bc	1.93 cd	1.87 cd
	EM	5.50 de	5.83 cd	5.00 ab	5.16ab	1.96 bcd	1.96 bcd
	Actosol+ EM	6.00 bcd	6.33 bc	5.50 a	5.66 a	2.17 ab	2.09 ab
153 m^3	Control *	5.33 e	5.66 d	3.66cd	3.83def	1.30 g	1.30 g
	Actosol	6.50 ab	6.66 ab	4.00 bcd	4.33 cd	1.55 f	1.55 f
	EM	6.33abc	6.50 ab	4.50abc	4.66 bc	1.67 ef	1.64 ef
	Actosol+ EM	6.83 a	7.00 a	5.00 ab	5.33 ab	1.84 de	1.84 cd

Values having the same alphabetical litter (s) did not significantly differed according Duncan multiply range test at 0.05 level of probability.
*Control : Plots fertilized with the recommended nitrogen dose (60 kg ammonium sulphate /540 m^2).

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تأثير كميات مياه الري وبعض المنشطات الحيوية على العلاقات المائية للنبات وكفاءة استخدام مياه الري وإنتاجية الطماطم النامية في البيوت البلاستيكية

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المعمل المركزي للزراعة العضوية – مركز البحوث الزراعية – مصر

أجريت تجربة تحت ظروف البيوت المحمية خلال موسمي ٢٠١٤/ ٢٠١٥، ٢٠١٥/٢٠١٦ بمحطة بحوث القصاصين – معهد بحوث البساتين – مركز البحوث الزراعية – محافظة الإسماعيلية – مصر، لدراسة تأثير كميات مياه الري وبعض المنشطات الحيوية والتفاعل بينهما على النمو، والعلاقات المائية للنبات، والمحصول، وكذلك كفاءة استخدام مياه الري على الطماطم النامية تحت ظروف الأراضي الرملية، وقد أوضحت النتائج أن معاملة التفاعل بين ري نباتات الطماطم بالمستوى المرتفع من الماء (١٥٣م^{٣}/ للصوبة) مع الإضافة الأرضية للأكتوسول والكائنات الدقيقة قد أدى إلى زيادة معنوية في كل من طول الساق الرئيسي، عدد الأوراق على الساق الرئيسي، المادة الجافة للأوراق، النسبة المئوية للماء الكلى والحر في أنسجة الورقة، ووزن الثمرة، ومحصول كل من النبات والصوبة، وقطر الثمرة في كلا الموسمين، بينما إزدادت كل من النسبة المئوية للماء المرتبط في أنسجة الورقة، وكفاءة استخدام النبات لمياه الري، ونسبة المواد الصلبة الكلية الذائبة في الثمار بمعاملة التفاعل بين مستوى الماء المنخفض مع الإضافة الأرضية للأكتوسول والكائنات الدقيقة، وعلى جانب أخر فقد لوحظت أقل القيم للصفات سابقة الذكر بمعاملة التفاعل بين مستوى الماء المنخفض (٩١م^{٣} ماء/الصوبة) والإضافة الأرضية للسماد النتيروجيني المعدني الموصى به كمعاملة كنترول في كلا الموسمين.

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