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Implications of water stress and foliar application with some stimulants on productivity, fruit quality and water use efficiency of some tomato genotypes

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ABSTRACT

Afield experiment was carried out on tomato plants (*Solanum lycopersicum* L.) during summer seasons of 2020 and 2021 at the experimental farm of the Faculty of Agriculture, Benha University, Moshtohor, Touch, Kalubia Governorate, Egypt, in order to investigate the response of genotypes, three tomato genotype (Alia 123 F1, Arwa F1 and Super strain B) to deficit irrigation and foliar application with stimulate and their interaction on yield, fruit quality and water use efficiency of tomato plants grown under drip irrigation system in clay soil conditions. Obtained results showed that treatments that received 80% WR + amino acids as foliar spraying of Alia 123 recorded superior effects on early yield, marketable and total yield. The highest water use efficiency was recorded when using 80% WR and the foliar application of amino for Alia 123 cultivar with significant deferent as compared with all other treatments. Irrigation with 60% of the WR with the foliar application of any of the used foliar sprays i.e. amino, humic and calcium+boron on any of the used genotypes resulted the highest increases in TSS of tomato fruits. The same trend was found with the 100% of WR on vitamin C. highest acidity was found with 60% of WR with calcium boron or deionized water as a spray on super strain B with significant variations in the second growing season.

KEYWORDS: tomato, deficit irrigation, genotypes, biostimulants and water use efficiency

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an herbaceous plant and a member of the solanaceae family that includes eggplant, peppers, Irish potato and tobacco (Dobson *et al.,* 2002). Fresh tomatoes and other processed tomato products make a significant contribution to human nutrition owing to the concentration and availability of several nutrients in these products and to their widespread consumption. Tissues of most herbaceous vegetables have about 90% in their vacuoles.

Water deficits and insufficient water are the main limiting factors affecting worldwide crop production (Nuruddinet al 2001). Plants growing under suboptimal water levels are associated with slow growth and, in severe cases, dieback of stems, such plants are more susceptible to disease and less tolerant of insect feeding. In crops, water stress has been associated with reduced yields and possible crop failure. The effects of water stress however vary between plant species. As the plant undergoes water stress, the water pressure inside the leaves decreases and the plant wilts. The main consequence of moisture stress is decreased growth and development caused by reduced photosynthesis, a process in which plants combine water, carbon dioxide and light to make carbohydrates for energy.

Tomatoes are very sensitive to water deficits during and immediately after transplanting, at flowering and during fruit development (Nuruddin et al 2001). According to (Shamsul et al. 2008), the water stress at earlier stage of growth (20 day stage) is more inhibitory compared to the later stage (30 day stage). Photosynthetic response to drought is a highly complex in plants. Thus, at present, new agronomic strategies are being designed and evaluated, among these new agronomic strategies, we find the use of stimulants (Lucini et al., 2015). It has been observed that the use of these products significantly improves the performance of crops, as they have beneficial effects on the physiological processes of plants, such as the absorption of water and nutrients, among others (Mutale-Joan et al., 2020).

Biostimulants are composed of bioactive compounds such as humic acids, can be applied inAmino acids have been considered as precursors and constituents of proteins and other nitrogen compounds e.g., nucleic acids. Plants subjected to stress show accumulation of proline and other amino acids. The role played by accumulated amino acids in plants varied from acting as osmolyte, regulation of ion transport, modulating stomatal opening and detoxificacation of heavy metals. Amino acids also affected synthesis of some enzymes, gene expression and redox-homeostasis (Rai et al 2002).

Calcium (Ca) is a plant nutrient required as a structural component in the cell wall and membranes, counter ion in storage organelles and signalling molecule in the cytosol (White et al 2001). Conditions that restrict the Ca uptake, such as high salinity, excess or lack of moisture, root diseases, high temperatures and low levels of Ca in the soil, may cause Ca deficiency symptoms in plants (Saure 2014). These symptoms may occur even at ideal levels of Ca in the soil for the normal plant growth and development (Suzuki et al 2003).

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

The main objective of this study improving quality, productivity and water use efficiency of some tomato genotypes under water stress by using some stimulants.

2. MATERIALS AND METHODS

A field experiment was carried out during summer seasons of 2020 and 2021 at the experimental farm of the Faculty of Agriculture, Benha University, Egypt, in order to investigate the response of three tomato cultivars namely Alia 123 F1, Arwa F1 and Super strain B to deficit irrigation (three levels, i.e.100, 80 and 60% of ETo) and foliar application with biostimulants, i.e., Amino power (0.5 cm3/l), Hummer (0.25 g/l), Caly-Bor (2.5 cm3/l) and distilled water and their interaction on vegetative growth and chemical characteristics of tomato plant foliage grown under drip irrigation system in heavy clay soil conditions. Samples analyses of soil are shown in Table (1).

Table 1. Physical and chemical properties of experimental soil analysis.

Clay %	51.0
Silt %	24.6
Sand %	24.4
Soil texture	Heavy clay
pH (1:2.5 w:v)	7.9
EC* (dSm^{-1})	2.16
OM (gkg^{-1})	1.41
$CaCO_3$(gkg^{-1})	1.53
Available N (mg kg^{-1})	23
Available P (mg kg^{-1})	9
Available K (mg kg^{-1})	120
Field capacity, FC (cm^3 cm^{-3})	37.89
Wetting point, WP (cm^3 cm^{-3})	14.74
Saturation capacitance	69.78

*Texture using International Soil Texture Triangle (Moeys 2016); EC of paste extract; NPK Extractants are KCl (N), $NaHCO_3$(P), NH_4Ac (K).

Tomato plants were sown on first and second of February for the first and second seasons, respectively in the nursery. The experiment was laid out in a split- split plot design with three replicates. Genotypes were arranged in the main plots, while, Deficit irrigation treatments were randomly distributed in the sup-plots and foliar application treatments were randomly assigned in the sub-sub plots. The area of the experimentation plot was 12 m^2 consisted of one row with 10 m length and 1.2 m width and the plants were transplanted 50 cm spaced in the rows. The experimental plots received three amount of water i.e. 100, 80 and 60 % ETo, using drip irrigation system; the used lines of irrigation were of model GR 16 mm and the flow rate of drippers was 4ℓ / hour. Water pressure 1.5 bar when all lines were opened and irrigation rate was two times weekly. Class A pan evapotranspiration equation was used to calculate daily irrigation water amount, according to local weather station data, which located near the experimental of the Faculty of Agriculture, Egypt. That affiliated to the Central Laboratory for Agricultural Climate (C.L.A.C) Ministry of Agriculture and Land Reclamation.

Table 2. Irrigation requirements (liter/plant per day) for irrigation treatments (100%, 80%, and 60% of ET_o) for tomato plants under open field conditions during both seasons of 2020 and 2021.

Month*	The first season (2020)			The second season (2021)		
	100%	80%	60%	100%	80%	60%
March	0.263	0.211	0.158	0.283	0.226	0.169
April	1.215	0.972	0.729	1.185	0.948	0.711
May	2.504	2.003	1.502	2.268	1.814	1.361
June	3.073	2.458	1.844	3.408	2.726	2.045
Jule	2.491	1.993	1.494	2.734	2.187	1.641
Total m^3 per fed.	1905.782	1524.625	1143.469	1962.812	1570.25	1177.687

*Starting from 17^{th} and 18^{th} of March (2020 and 2021 for the first and second seasons, respectively).

A commercial Amino power® consists of (free amino acids 19 %, micro elements 1500 ppm and potassium citrate 3.5 %). Hummer ® (humic acid 92 % and potassium humat 8 %). Caly-Bor ® consists of 10% Ca, 1%B, 6% N and amino acids. Foliar applications were added three times started after 30 days from transplanted and every 15 days intervals.

2.1. Data recorded

2.1.1. Yield and its components:

1- Average fruit weight (g): five fruit from each treatment were taken randomly from third picking as representative sample for determined average weight (g).
2- Early yield was calculated as the fruit yield of the first two picking as kg/plant and then calculated as kg plant and ton/fed.
3- Total fruit yield (ton/fed.) as the whole picked fruits, all over the season from each plot and then calculated per fed.
4- Marketable fruit yield per fed(ton/ fed): it was calculated as weight of harvested fruits after discarding the injured and misshaped fruits
5- Unmarketable yield per fed (ton/ fed): it was calculated as weight of discarded the all injured and misshaped fruits.
6- Water use efficiency (WUE) (kg/m3):
Irrigation water use efficiency under deficit irrigation treatments were determined using the following equations given by Howell *et al.* (1990):
WUE = Yield (kg/fed.)/Applied irrigation water amount (m^3/fed.).

2.1.2. Fruit chemical constituents

Three fruits of each treatment were taken at full- ripe maturity stage from the forth harvest to determine the following parameters:

1. Determination of total soluble solids (T.S.S %):
Total soluble solids (T.S.S %), was determined the percentage of soluble solids in juice by using hand refractometer according A.O.A.C. (1990)

2. Determination of titratable acidity:
Titratable acidity (g citric acid/100 g fresh weight), was determined by titration of the blended flesh against NaOH 0.01 N. using Phenolphthaline as an indicator A.O.A.C. (1990).

3. Determination of ascorbic acid (V.C.):
Ascorbic acid (mg/100g), was determined in fresh weight by using the 2, 6 Dichlorophenol-indolphenol methods described in A.O.A.C. (1990).

4. Determination of lycopene:
Lycopene concentration (mg kg^{-1} F.W.) in fruit was extracted as follows: samples were first chopped and homogenized in a laboratory homogenizer: Approximately 0.3 to 0.6 g samples were weighted and 5 ml of 0.05%(w/v) BHT in acetone, 5 ml of ethanol and 10ml of hexane were added. The recipient was introduced in ice and stirred on a magnetic stirring plate for 15 min. After shaking, 3 ml of deionized water were added to each vial and the samples were shaken for 5 min on ice. Samples were then left at room temperature for 5 min to allow the separation of both phase sand quantified spectrophotometrically at 472 nm. Apparatus UV-Vis. Spectral analysis has been done using a Janways spectrophotometer (Ravelo-Pérez *et al.*, 2008). Lycopene content (mg/kg) = absorption reading at 503* 31.2/g tissue

2.2. Statistical analysis:

Analysis of variance of the obtained data from each attribute was computed using the MSTAT-C Computer Program (1988). The Duncan's New Multiple Range test at 5% level of probability was used to test the significance of differences among mean values of treatments (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

3.1. Yield and its compounds

Effect of genotype

By watching the results of Table (3) you will find that the results indicate that there were no significant variations in yield and its components (average fruit weight, the early yield and the marketable yield as well as the total yield and water use efficiency) between Alia 123 and Arwa hybrids in the first season only. Super Strain B recorded the least productivity in the two seasons of study

The reduction in photosynthesis during stress may decrease the availability of assimilates to the developing floral organs and leds to the abscission of flower and flower buds in susceptible genotypes of tomato. Sivakumar *et al*. (2016).

Effect of water requirement

For water inputs, it was noted that reducing the level of irrigation from 100 to 60% led to concurrent reductions in yield and yield components following the sequence of 100>80>60% of the WR. On the other hand, water use efficiency and the unmarketable product increased in the pattern of 60>80>100 WR during the two seasons of study.

This could be due to high up take of nutrients and build- up of sufficient photosynthates, enabling increase in size of fruit (length and breadth) resulting increased fruit weight and volume. Fruit weight plays an important role in the total yield of tomato and, therefore, similar trend was recorded for fruit yield per square meter area and fruit yield ton per hectare. Obtained results are in agreement with those reported by Celebi *et al* (2014), Al- Omran *et al*. (2010) and Shahein *et al* (2012).

Over-irrigation has been reported to result in lower water productivity, while a lack of irrigation caused very low water productivity on tomato plant. (Hamdi, 2017).

Effect of foliar spray treatments

Spraying plants with amino recorded the highest increases in yield and its component (average fruit weight, early yield, marketable yield and total yield) for the investigated two seasons. Spraying plants with humic recorded comparable effects to the ones that received amino as a foliar spray in average fruit weight, early yield, marketable yield and total yield during the first season while early yield in the second one. On the contrary, the highest water use efficiency was attained for either of the foliar applications in the two growing season versus the deionized water foliar application. The foliar application with "calcium+boron" recorded comparable effect for humic in average fruit weight, marketable yield and total yield in the first season and marketable yield and total yield in the second season. Spraying plants with any of the three foliar application recorded positive results versus deionized water as a foliar spray for early yield and unmarketable yield in both seasons of study.

Hildebrandt et al. (2015) suggested other useful functions of amino acids in plant cells, such as protein biosynthesis, signaling processes, energy producers, auxin biosynthesis and enzyme regulation influencing physiological processes, plant growth and development. micronutrients have tonic effects on the photosynthetic rate producing higher carbohydrate accumulation and its translocation from leaves (source) to fruits (sink) increasing the total yield (Marschner, 1995; Uchida, 2000; Jadhav et al., 2014; Sidhu et al., 2019).

Calcium may also inhibit tomato flower abscission and, thus, results in increased fruits plant-1 (Smit and Combrink, 2005). The foliar application of Boron enhances sugars levels of the stigma and helps in tomato fruit set by promoting the pollen tube growth along with pollen germination (Singh et al., 2013).

(Yildirim, 2007) foliar application with humic acids improve tomato plant physiological processes by enhancing the availability of major and minor nutrients as well as enchances the uptake vitamins, amino acids and also auxine, cytokinine and ABA contents of the plant.

Effect of the interaction

By watching the results of Tables (4 & 5) you will find that the results indicate that the treatments that received 100% WR + amino as a foliar spray in case of Alia 123 and Arwa genotypes recorded superior effects on average fruit weight, early yield, marketable and total yield in the two seasons under investigation. Similar results were attained for the foliar application of tomato plants (cv. Alia 123 F1) with amino and irrigated with 80% WR in marketable and total yield in the second growing season. Also, the highest early yield was recorded with any of used genotypes when irrigated with either 100 or 80% WR and spraying plants with any of the foliar application treatments i.e. amino, humic or calcium + boron. The highest water use efficiency was recorded when using 80% WR and the foliar application of amino for Alia 123 cultivar with significant deferent as compared with all other treatments in the first season of study. The least values were recorded for all genotypes in yield and its component when irrigated with 60% WR and deionized water as foliar spray in both seasons of study.

Table 3. Effect of genotypes, water requirement or foliar spray treatments on yield and its components of tomato plants during the summer seasons of 2020 & 2021.

Characteristics / Treatments	Average fruit weight(g)	Early yield/ kg plant	Un marketable yield (t/ fed)	Marketable yield (t/ fed)	Total yield (ton/ fed)	WUE Kg/m³	Average fruit weight(g)	Early yield/ kg plant	Un marketable yield (t/ fed)	Marketable yield (t/ fed)	Total yield (ton/ fed)	WUE Kg /m³
	The first Seasons (2020)						The second season(2021)					
Genotypes												
Aliaa 123	97.433 a	11.829 a	2.381 a	22.654 a	25.035a	16.609a	89.463 a	11.57 a	2.051 b	22.497 a	24.548a	15.651 a
Arwa	95.956 a	11.542ab	2.448 a	22.282 a	24.731a	16.398a	84.204 a	11.44 a	2.110 b	22.223 a	24.334a	15.616 a
Super strain	84.532 b	11.197 b	2.361 a	18.314 b	20.675b	13.949b	71.772 b	10.87 b	2.446 a	18.046 b	20.493b	13.153 b
Water requirements (WR)												
100% WR	121.008 a	14.666 a	2.107 c	24.428 a	26.535a	13.923b	104.75 a	14.083a	2.028 b	25.092 a	27.12 a	13.817 b
80% WR	101.268b	13.254 b	2.309 b	22.226 b	24.535b	16.093a	87.152 b	13.202b	2.068 b	22.783 b	24.851b	15.826 a
60% WR	55.645 c	6.649 c	2.773 a	16.597 c	19.37 c	16.94 a	53.536 c	6.815 c	2.511 a	14.892 c	17.403c	14.777 a
Foliar application												
Amino acid	97.581 a	12.9433a	2.151 b	24.064 a	26.215a	17.389a	87.863 a	12.943a	2.053 b	22.978 a	25.032a	16.082 a
Humic acid	94.012 ab	12.6505a	2.202 b	21.936 ab	24.138ab	16.123ab	82.102 b	12.651a	2.058 b	21.337 b	23.396b	14.966ab
Calcium+ poron	90.908 bc	11.9704b	1.947 c	20.18 bc	22.127bc	14.772ab	78.98 c	11.97 b	1.663 c	20.643 b	22.306bc	14.267ab
Distilled water	88.061 c	8.52911c	3.286 a	18.154 c	21.441 c	14.324 b	78.307 c	7.242 c	3.035 a	18.73 c	21.765 c	13.912b

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Tale 4. Effect of interaction among water requirement, genotypes and foliar spray treatments on yield and its components of tomato plants during the summer seasons of 2020.

Genotypes	water requirements	Foliar application	Average fruit weight(g)	Early yield kg /plant	Un marketable yield (t/ fed)	Marketable yield (t/ fed)	Total yield (t/ fed)	WUE (kg/m3)
			The first Seasons (2020)					
Aliaa 123	100% WR	Amino acid	137.8 a	16.39 a	1.912 c	30.198 a	32.110 a	16.848b-g
		Humic acid	130.6abc	16.37 a	1.972 c	26.968 c	28.940bc	15.185 g-k
		Calcium+poron	121.7cde	15.38 ab	1.763 c	25.667 cd	27.430 bcd	14.393 h-l
		Distilled water water	120.4 de	11.83 b-f	2.320abc	24.100def	26.420c-f	13.863 i-l
	80% WR	Amino acid	108.6 fg	15.46 ab	2.065 c	29.965 ab	32.030 a	21.008 a
		Humic acid	106.0fgh	14.98 ab	2.163 c	25.927 cd	28.090 bcd	18.424 bc
		Calcium+poron	103.5ghi	14.39a-d	1.969 c	21.731 f-i	23.700 fgh	15.544d-k
		Distilled water water	100.5g-k	9.21 e-h	2.987abc	19.443 h-l	22.430 g-j	14.711 g-l
	60% WR	Amino acid	65.70 l	8.164 f-i	2.468abc	18.792 jkl	21.260 h-k	18.592 b
		Humic acid	60.8 lm	7.607ghi	2.427abc	17.943klm	20.370 i-o	17.814bcd
		Calcium+poron	58.2 lmn	7.17 g-j	2.037 c	17.113k-n	19.150 k-o	16.747 b-g
		Distilled water water	55.2 mn	5.00 ij	4.489ab	14.011 o	18.510 o	16.178 c-h
Arwa	100% WR	Amino acid	134.0 ab	16.33 a	1.962 c	31.428 a	33.390 a	17.52 b-f
		Humic acid	129.0 a-d	16.26 a	2.001 c	27.279 bc	29.280 b	15.363 f-k
		Calcium+poron	126.7 bcd	15.53 ab	1.599 c	25.381 cde	26.980 b-e	14.156 h-l
		Distilled water water	121.6 cde	10.81 c-g	3.299 abc	22.841 efg	26.140 def	13.716 jkl
	80% WR	Amino acid	109.6 fg	14.94 ab	2.246 abc	25.844 cd	28.090 bcd	18.424 bc
		Humic acid	107.1 fg	14.96 ab	2.334 abc	25.706 cd	28.040 bcd	18.391 bc
		Calcium+poron	104.7 f-i	13.84 a-d	2.172 bc	20.898 g-j	23.070 ghi	15.131 g-k
		Distilled water water	100.7 g-j	9.21e-h	3.402 abc	19.218 i-l	22.620 g-j	14.836 g-l
	60% WR	Amino acid	57.9 lmn	8.08 f-i	2.462 abc	18.868 jkl	21.330 h-k	18.653 b
		Humic acid	56.8 lmn	7.89 ghi	2.322 abc	17.918 klm	20.240 j-o	17.700 b-e
		Calcium+poron	53.6 mn	7.10 g-j	2.060 c	17.100 k-n	19.160 k-o	16.756 b-g
		Distilled water water	50.3 n	3.63 j	3.527 abc	14.913 no	18.440 mno	16.126 c-i
Super strain	100% WR	Amino acid	113.6 ef	15.31 ab	2.107 c	22.163 fgh	24.270 efg	12.734 l-o
		Humic acid	109.0 fg	15.08 ab	2.075 c	19.665 h-k	21.740 g-k	11.407 mno
		Calcium+poron	104.5 f-i	14.61 abc	1.820 c	19.44 h-l	21.260 h-k	11.155 no
		Distilled water water	102.6 ghi	12.10 b-e	2.461 abc	18.009 klm	20.470 i-n	10.741 o
	80% WR	Amino acid	97.09 h-k	14.29 a-d	1.746 c	22.414 fg	24.160 fg	15.846 d-j
		Humic acid	95.02 ijk	13.77 a-d	2.101 c	19.119 i-l	21.220 h-l	13.918 h-l
		Calcium+poron	92.5 jk	13.39 a-d	2.040 c	18.62 jkl	20.660 i-m	13.55 j-m
		Distilled water water	90.5 k	10.70 d-g	2.487 abc	17.833 klm	20.320 j-o	13.327 k-n
	60% WR	Amino acid	54.4 mn	7.52 ghi	2.393 abc	16.907 lmn	19.300 k-o	16.878 b-g
		Humic acid	51.0 mn	6.93 g-j	2.424 abc	16.906 lmn	19.330 k-o	16.904 b-g
		Calcium+poron	52.7 mn	6.319 hij	2.070 c	15.671 mno	17.741 no	15.515 d-k
		Distilled water water	50.6 n	4.35 ij	4.604 a	13.026 o	17.630 o	15.417 e-k

Table 5. Effect of interaction among water requirement, genotypes and foliar spray treatments on yield and its components of tomato plants during the summer seasons of 2021.

Genotypes	% water requirement	Foliar application	Average fruit weight(g)	Early yield kg/ plant	Un marketable yield (t/ fed)	Marketable yield (t/ fed)	Total yield (t/ fed)	WUE (kg/m3)
			The second season(2021)					
Aliaa 123	100% WR	Amino acid	126.4 a	16.39 a	1.704 f-j	29.666 a	31.37 a	15.982 b-i
		Humic acid	111.8 cd	16.37 a	1.724 e-j	27.926 abc	29.65 abc	15.105 d-l
		Calcium+poron	111.4 cd	15.38 a	1.360 ij	27.340 bcd	28.70 b-e	14.621 e-m
		Distilled water	110.5 cd	10.83 bc	2.200 d-h	25.980 cde	28.18 b-f	14.356 f-m
	80% WR	Amino acid	105.5 d	15.46 a	1.878 e-j	25.792 def	27.67 c-f	17.621 abc
		Humic acid	93.9 ef	14.98 a	1.826 e-j	25.204 efg	27.03 d-g	17.213 a-d
		Calcium+poron	86.4 ghi	14.39 a	1.781 e-j	23.769 fgh	25.55 ghi	16.271 a-g
		Distilled water	85.9 ghi	8.21 cde	2.185 d-h	22.485 hij	24.67 hij	15.710 b-i
	60% WR	Amino acid	62.4 k	8.16 cde	2.426 c-g	17.064 no	19.49 no	16.549 a-f
		Humic acid	62.1 k	7.60 de	2.373 c-g	15.957 op	18.33 op	15.564 c-j
		Calcium+poron	59.0 kl	7.17 def	1.823 e-j	15.347 opq	17.17 pqr	14.579 e-m
		Distilled water	58.0 klm	4.00 f	3.331 a	13.439 qr	16.77 p-s	14.239 f-m
Arwa	100% WR	Amino acid	120.7 ab	16.33 a	1.738 e-j	28.242 ab	29.98 ab	15.274 c-k
		Humic acid	116.6 bc	16.26 a	1.538 hij	27.272 bcd	28.81 bcd	14.677 e-m
		Calcium+poron	106.4 d	15.53 a	1.247 j	25.913 cde	27.16 d-g	13.837 g-o
		Distilled water	105.0 d	9.81 cd	2.889 a-d	23.791 fgh	26.68 e-h	13.592 h-o
	80% WR	Amino acid	94.8 e	14.94 a	1.775 e-j	26.795 b-e	28.57 b-f	18.194 ab
		Humic acid	86.6 ghi	14.96 a	1.627 g-j	24.953 efg	26.58 fgh	16.927 a-e
		Calcium+poron	83.6 g-j	13.84 ab	1.366 ij	23.774 fgh	25.14 ghi	16.010 b-h
		Distilled water	83.1 g-j	7.00 def	3.070 abc	21.670 i-l	24.74 hij	15.755 b-i
	60% WR	Amino acid	57.1 k-n	8.08 cde	2.335 c-h	19.705 lm	22.04 klm	18.714 a
		Humic acid	54.3 l-o	8.08 cde	2.516 b-e	15.564 op	18.08 op	15.352 c-k
		Calcium+poron	51.5 m-p	7.10 def	1.699 f-j	15.661 op	17.36 pq	14.74 d-l
		Distilled water	50.5 nop	5.63 ef	3.523 a	13.347 qr	16.87 p-s	14.324 f-m
Super strain	100% WR	Amino acid	89.4 efg	15.31 a	2.175 d-h	23.445 ghi	25.62 ghi	13.052 k-o
		Humic acid	87.4 fgh	15.08 a	2.31 c-h	21.680 i-l	23.99 ijk	12.222 mno
		Calcium+poron	85.3 g-j	14.61 a	1.982 e-j	20.858 j-m	22.84 jkl	11.636 no
		Distilled water	85.9 ghi	7.10 def	3.475 a	18.995 mn	22.47 klm	11.447 o
	80% WR	Amino acid	85.9 ghi	14.29 a	2.109 d-i	21.831 h-k	23.94 ijk	15.245 c-k
		Humic acid	78.8 j	13.77 ab	2.121 d-i	20.099 klm	22.22 klm	14.15 f-m
		Calcium+poron	80.8 hij	13.39 ab	1.787 e-j	19.753 lm	21.54 lm	13.717 h-o
		Distilled water	80.1 ij	6.71 def	3.295 ab	17.275 no	20.57 mn	13.099 j-o
	60% WR	Amino acid	48.2 op	7.52 de	2.341 c-h	14.269 pq	16.61 p-s	14.103 f-n
		Humic acid	47.2 p	6.93 def	2.494 b-f	13.386 qr	15.88 qrs	13.484 i-o
		Calcium+poron	46.1 p	6.31 ef	1.922 e-j	13.378 qr	15.30 rs	12.991 k-o
		Distilled water	45.6 p	5.35 ef	3.352 a	11.588 r	14.94 s	12.685 l-o

3.2. Fruit chemical constituents

Effect of genotypes

Results presented in Table (6) show that the three cultivars recorded comparable TSS contents in fruits. Alia 123 and Arwa exhibited the highest content of vitamin C in the second season only. The highest acidity was found in Super strain B in the second growing season and also recorded the highest content of lycopein in the first growing season

Effect of water requirement

By decreasing the level of irrigation from 100 to 80 and 60%, the TSS, acidity and lycopein in fruits increased while the fruit content in vitamin C decreased in the two seasons of study.

Among of plant antioxidants, ascorbic acid (Vitamin C) is amajor antioxidant playing a vital role in protecting against various environmental abiotic stresses (Venkatesh&Park 2014). This increase could be a result of the oxidative stress- induced formation of reactive oxygen species (ROS), where lycopene and B-carotene could also contribute to antioxidant defense mechanisms in fruits

Effect of foliar spray treatments

Foliar application with amino, humic or calcium+boron resulted in the highest values of TSS and vitamin C while decreased acidity versus spray with deionized water. Spraying plants with amino recorded positive results in lycopein versus deionized water in the first growing season

Effect of the interaction

Data in Tables (7 & 8) it appears that irrigation with 60% of the WR with the foliar application of any of the used foliar sprays i.e. amino, humic and calcium+boron on any of the used cultivars resulted the highest increases in TSS in fruits. The same trend was found with the 100% of WR on vitamin C.

The highest acidity was found with 60% of WR with calcium+boron or deionized water as a spray on superstreem B with significant variations in the second growing season.

There was no definite trend recorded for lecoben pigment in fruits among the three factors of study (irrigation level × cultivar × foliar application).

Table 6. Effect of genotypes, water requirement or foliar spray treatments on fruit chemical constituents of tomato plants during the summer seasons of 2020 & 2021.

Characteristics Treatments	T.S.S (%)	V.C (mg/100g)	Acidity (%)	Lycopen (mg/100g.f.w)	T.S.S (%)	V.C (mg/100g)	Acidity (%)	Lycopen (mg/100g.f.w)
	The first Seasons (2020)				The second season(2021)			
Genotypes								
Aliaa 123	4.192 A	26.95 A	1.528 A	4.967 C	4.811 A	29.28 A	1.353 B	5.783 A
Arwa	4.292 A	27.11 A	1.631 A	5.550 B	4.678 A	28.64AB	1.375 B	5.539 A
Super strain	4.103 A	27.38 A	1.661 A	6.067 A	4.764 A	27.56 B	1.603 A	5.261 B
Water requirements (WR)								
100% WR	3.706 C	31.25 A	1.269 C	4.878 C	3.911 C	32.96 A	0.994 C	4.967 C
80% WR	4.158 B	24.78 B	1.531 B	5.694 B	4.742 B	28.77 B	1.497 B	5.550 B
60% WR	4.722 A	25.41 B	2.019 A	6.164 A	5.600A	23.77 C	1.839 A	6.067 A
Foliar application								
Amino acid	4.448 A	28.48 A	1.426 C	5.841 A	5.063 A	31.01 A	1.315 C	5.652 A
Humic acid	4.219AB	27.97 A	1.556BC	5.596 AB	4.919AB	29.43AB	1.400BC	5.641 A
Calcium+ poron	4.237AB	26.87 B	1.674AB	5.496 AB	4.578BC	27.61 BC	1.470 B	5.433 A
Distilled water	3.878 B	25.27 C	1.770 A	5.381 B	4.444 C	25.94 C	1.589 A	5.385 A

Table 7. Effect of the third order interaction between tomato water requirements, genotypes and foliar application level treatments on chemical fruit characters in tomato plant during 2020 seasons.

Genotypes	Water requirements	Foliar application	T.S.S (%)	V.C (mg/100g)	Acidity (%)	Lycopene (mg/100f.w)
			The first Seasons (2020)			
Aliaa 123	100% water requirements	Amino acid	3.867 g-l	32.40 ab	0.9333 i	5.733 f-j
		Humic acid	3.633 j-m	31.87 abc	1.100 hi	5.533 f-l
		Calcium+poron	3.533 klm	31.73 abc	1.200 f-i	5.100 k-p
		Distilled water	3.300 lm	31.10 a-d	1.267 f-i	5.200 i-o
	80% water requirements	Amino acid	4.500 b-g	25.50 efg	1.300 f-i	6.067 d-g
		Humic acid	4.067 f-k	25.00 efg	1.433 f-h	5.867 e-h
		Calcium+poron	4.433 b-g	24.53 efg	1.500 efg	5.967 efg
		Distilled water	3.867 g-l	22.43 g	1.567 c-f	5.700 f-k
	60% water requirements	Amino acid	5.167 a	26.07 d-g	1.933abc	6.400 a-e
		Humic acid	4.967 abc	25.40 efg	1.900 bcd	6.367 b-e
		Calcium+poron	4.767 a-e	24.53 efg	2.100 ab	5.967 efg
		Distilled water	4.200 e-k	22.87 g	2.100 ab	7.000 a
Arwa	100% water requirements	Amino acid	4.100 f-k	32.97 a	1.000 i	5.067 l-p
		Humic acid	3.867 g-l	32.43 ab	1.167 ghi	4.633 opq
		Calcium+poron	3.767 h-m	29.53 a-f	1.433 fgh	5.133 j-o
		Distilled water	3.633 j-m	24.97 efg	1.567 c-f	4.700 n-q
	80% water requirements	Amino acid	4.400 c-h	26.10 d-g	1.433 fgh	6.600 a-d
		Humic acid	4.200 e-j	25.30 efg	1.567 c-f	6.133 c-f
		Calcium+poron	4.200 e-j	25.07 efg	1.567 c-f	5.700 f-k
		Distilled water	3.767h-m	24.83 efg	1.567 c-f	5.267 h-n
	60% water requirements	Amino acid	5.067 ab	27.10 c-g	1.833 b-e	6.967 ab
		Humic acid	4.867 a-d	27.00 c-g	2.067 ab	6.700 abc
		Calcium+poron	4.867 a-d	25.20 efg	2.067 ab	5.933 efg
		Distilled water	4.767a-e	24.77 efg	2.300 a	5.800 e-i
Super strain	100% water requirements	Amino acid	4.200 e-j	33.43 a	1.167 ghi	3.933 r
		Humic acid	3.733 i-m	33.30 a	1.300 f-i	4.133 qr
		Calcium+poron	3.633 i-m	32.07 abc	1.567 c-f	4.867 m-p
		Distilled water	3.200 m	29.20 a-f	1.533 d-g	4.500 pqr
	80% water requirements	Amino acid	4.100 f-k	25.53 efg	1.400 fgh	5.833 e-h
		Humic acid	4.100 f-k	24.57 efg	1.567 c-f	5.467 g-m
		Calcium+poron	4.400 c-h	24.30 efg	1.533 d-g	4.933 l-p
		Distilled water	3.867 g-l	24.20 fg	1.933 abc	4.800 nop
	60% water requirements	Amino acid	4.633 a-f	27.20 b-g	1.833 b-e	5.967 efg
		Humic acid	4.533 a-f	26.83 c-g	1.900 bcd	5.533 f-l
		Calcium+poron	4.533 a-f	24.87 efg	2.100 ab	5.867 e-h
		Distilled water	4.300 d-i	23.07 g	2.100 ab	5.467 g-m

Table 8. Effect of the third order interaction between tomato water requirements, genotypes and foliar application level treatments on chemical fruit characters in tomato plant during 2021 seasons.

Genotypes	Water requirements	Foliar application	T.S.S (%)	V.C (mg/100g)	Acidity (%)	Lycopene (mg/100f.w)
			The second season(2021)			
Aliaa 123	100% water requirements	Amino acid	4.300 h-o	34.93 ab	0.700 q	5.500 c-h
		Humic acid	4.533 f-m	34.40 a-d	0.800 pq	5.633 b-g
		Calcium+poron	3.633mno	32.40 b-g	0.933nop	5.133 f-j
		Distilled water	3.867 k-o	31.50 e-h	1.067 no	4.667 ij
	80% water requirements	Amino acid	5.200 b-h	32.10 c-h	1.400 jkl	6.200 abc
		Humic acid	4.867 c-j	30.67 f-i	1.400 jkl	6.100 a-d
		Calcium+poron	4.400 g-n	29.53 h-l	1.400 jkl	5.733 a-g
		Distilled water	4.633 e-l	27.73 j-m	1.600 e-j	5.633 b-g
	80% water requirements	Amino acid	5.667 a-d	27.10 klm	1.667 d-h	6.267 ab
		Humic acid	5.667 a-d	25.10 mno	1.767 c-f	6.200 abc
		Calcium+poron	5.867 ab	23.87 op	1.733 c-f	6.300 ab
		Distilled water	5.100 b-h	22.07 pqr	1.767 c-f	6.033 a-e
Arwa	100% water requirements	Amino acid	4.300 h-o	35.30 a	0. 700 q	4.833 hij
		Humic acid	4.067 i-o	34.20 a-e	0.866opq	5.233 f-i
		Calcium+poron	3.833 l-o	32.73 a-f	0.800 pq	5.300 e-i
		Distilled water	3.400 o	30.40 f-j	1.10 mn	4.700 ij
	80% water requirements	Amino acid	4.967 b-i	31.77 d-h	1.367 kl	5.000 g-j
		Humic acid	4.767 d-k	28.67 i-l	1.433 ijkl	5.300 e-i
		Calcium+poron	4.433 g-n	27.07 klm	1.50 g-l	5.167 f-j
		Distilled water	4.300 h-o	25.40 mno	1.567 f-k	6.100 a-d
	60% water requirements	Amino acid	5.667 a-d	27.20 klm	1.767 c-f	6.133 abc
		Humic acid	5.767 abc	25.73 mno	1.733 c-f	6.233 abc
		Calcium+poron	5.433 a-f	24.20 nop	1.8 cde	6.200 abc
		Distilled water	5.200 b-h	21.07 qr	1.867 cd	6.267 ab
Super strain	100% water requirements	Amino acid	3.967 j-o	34.53 abc	1.067 no	5.033 g-j
		Humic acid	3.967 j-o	34.07 a-e	1.10 mn	4.633 ij
		Calcium+poron	3.533 no	31.30 f-i	1.300 lm	4.467 j
		Distilled water	3.533 no	29.73 g-k	1.50 g-l	4.467 j
	80% water requirements	Amino acid	5.300 a-g	30.83 f-i	1.467 h-l	5.500 c-h
		Humic acid	4.967 b-i	28.73 i-l	1.567 f-k	5.633 b-g
		Calcium+poron	4.533 f-m	26.87 lmn	1.633 e-i	5.367 d-i
		Distilled water	4.533 f-m	25.83 mno	1.633 e-i	4.867 hij
	60% water requirements	Amino acid	6.200 a	25.30 mno	1.700 d-g	6.400 a
		Humic acid	5.667 a-d	23.30 opq	1.933 bc	5.800 a-f
		Calcium+poron	5.533 a-e	20.53 r	2.133 ab	5.233 f-i
		Distilled water	5.433 a-f	19.73 r	2.200 a	5.733 a-g

4. CONCLUSION

It could be concluded that in summer season, tomato plants cv. Alia 123 F1 responded better when sprayed with Amino power® (0.5 cm3/l) three times at 15 days intervals starting 30 days after transplanting and irrigated with 80% of water requirements. Such treatments induced the best results regarding total, marketable yield and water use efficiency as well as fruit quality of tomato when grown under drip irrigation systems in heavy clay soil.

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الملخص العربي

تأثير الإجهاد المائي والرش الورقي ببعض المنشطات علي الإنتاجيه وجوده الثمار وكفاءة استخدام مياة الرى لبعض اصناف الطماطم

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أجريت تجربه حقليه خلال الموسمين الصيفي ٢٠٢٠ و ٢٠٢١ في المزرعه البحثيه بكليه الزراعه جامعه بنها– مصر، لدراسه تأثر بعض الطرز الوراثية للطماطم مثل عاليا ١٢٣ وأروي والصنف سوبر إسترين بي بنقص المياه و استخدام الرش ببعض المنشطات الحيويه (الاحماض الامينيه و الهيومك والكالسيوم+ بورون) والتفاعل بينهم علي المحصول وصفات الجوده وكفاءة استخدام مياة الرى لنباتات الطماطم المنزرعة تحت ظروف الري بالتنقيط في التربه الطينيه.

أوضحت النتائج ان إعطاء النبات ٨٠% من إحتياجاتها المائيه مع الرش بالاحماض الأمينيه مع الهجين عاليا ١٢٣ أعطي تفوق ملحوظ في المحصول المبكر المحصول التسويقي والمحصول الكلي خلال الموسم الثاني و أعلي كفاءه للإستخدام المياه في الموسم الأول. إستخدام مستوي الري ٦٠% من الاحتياج المائي والرش بأي من مركبات الرش ولكنها حسنت من نسبه المواد الصلبه الذائبه مع أي من الطرز الثلاثه ونسبه الحموضه عند الرش بالكالسيوم أو الماء المقطر علي الصنف سوبر إسترين بي . كما حدثت زياده في محتوي الثمار من فيتامين سي عند الري ب ١٠٠% من الاحتياجات المائيه مع الطرز الثلاثه (عاليا ١٢٣ – أروي – سوبر إسترين بي) والرش بأي من المركبات (الاحماض الامينيه – الهيومك– الكالسيوم بورو).

الكلمات المفتاحية: الطماطم– نقص المياه– الطرز الوراثية– المنشطات الحيوية– كفاءة استخدام مياه الرى