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Effect of reducing water requirement and foliar application with some stimulants on vegetative growth of some tomato genotypes grown in heavy clay soil under drip irrigation system

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ABSTRACT

A field experiment was conducted on tomato cultivars (Alia 123 F1, Arwa F1, and Super strain B) grown in heavy clay soil during the two successive seasons of 2020 and 2021 at the experimental farm of the Faculty of Agriculture, Benha University, Egypt to assess the response to foliar spray with four treatments, i.e., Amino power®, Hummer®, Caly-Bor® and distilled water under three levels of deficit irrigation i.e.100, 80 and 60% of ETo. Obtained results showed that foliar application of each amino acid, humic acid, or calcium + boron significantly improved the vegetative growth parameters of tomato plants, especially with irrigation using 100% of the water requirements. The foliar application of any foliar sprays and irrigated with 80% of the water requirements recorded significantly lower effects than those mentioned above (100% WR). The accumulation of elements (nitrogen, phosphorous, potassium) in leaves of the two hybrids, Alia 123 and Arwa, increases with a water level of 100% WR and foliar spraying with amino acids. The concentration of proline in leaves increases in leaves with water deficiency decreases from 100% to 60% WR in all the cultivars used in the two seasons.

KEYWORDS: tomato, genotypes, amino acid, humic acid, calcium, boron, deficit irrigation, and vegetative growth.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most popular vegetable crops globally and has the greatest area under cultivation compared to other vegetables (Nangare *et al*., 2016). In Egypt, tomato is an important vegetable crop, which occupies the largest cultivation area and consumes large quantities of water among vegetables. Agricultural water apportionment is reducing steadily in arid and semi-arid conditions, and equate irrigation water is not available in many parts of the world.

Water deficiency is one of the major environmental constraints that strongly affect cultivated plants, reducing growth and yield. Increasing the productivity of vegetable crops and saving water resources is an urgent need in Egypt, located in the arid and semi-arid regions. Plants grown in these regions face water stress conditions which cause a reduction in the growth and fruit production of vegetable crops (Souza *et al*., 2004). On the other hand, (Ozbahce and Tari *et al*. 2010. The irrigation system plays a vital role in vegetable growth and production, where the water should be given in a proper amount and accurate time application. Subsurface drip irrigation system (SSDI) can be used as an effective method for improving water use efficiency (Nalliah *et al*., 2009) and water conservation (Rajkumari *et al*., 2006). This technique (SSDI) may provide a tool for controlling crop evapotranspiration (ET) in tomato plants and increase saving irrigation water in drought areas (Al-Ghobari *et al*., 2014).

Aside from the challenge faced by agriculture in increasing production in an era of climate change, we also find another important challenge, such as the practice of sustainable agriculture that affects the environment the least. Thus, at present, new agronomic strategies are being designed and evaluated. Among these new agronomic strategies, we find the use of biostimulants (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, which can be applied in both ways, i.e., soil and foliar application. The foliar spray of humic acid ensures better nutrient uptake, improved permeability, and photosynthetic rate. Humic acid is a naturally existing polymeric organic compound converted due to the decay of organic matter and initiated in humus, peat, and lignite. Humic acid consists of organic acids, aromatic and contains various heterogeneous functional groups that have impervious interaction with different metal ions such as Mg, Zn, Ca, and Cu (Piccolo 2012). Both applications improved the shoot and root growth. They shared the capacity to increase the concentration of indole-3-acetic acid in roots and cytokinins in shoot and increased the root concentrations of jasmonic acid and jasmonoly-isoleucine. These hormonal changes caused by a foliar application could be stress-related symptoms (Hita *et al.*, 2020).

Amino acids play a vital role in mitigating excessive ROS activity through enzymatic and nonenzymatic detoxification (Mittler 2002). It also acts as a cell signaling modulator in numerous cellular processes, including cell division, expansion, and cell wall growth (Liso *et al*. 1984). It is a cofactor for several enzymes such as violaxanthin de-epoxidase (VDE, xanthophyll cycle), 1-aminocyclopropane-1-carboxylic acid (ACC) oxidase (ethylene biosynthesis), and 2-oxoacid dependent dioxygenases (ABA and GA biosynthesis) (Eskling et al. 1997; Davey et al. 2000; Smirnoff 2000).

Calcium (Ca^{2+}) is an important nutrient that plays a key role in the structure of cell walls and cell membranes, fruit growth and development, and general fruit quality Kadir (2004). It enhances resistance to bacterial and viral diseases. The Ca taken up from the soil is translocated to the leaves, but very little goes from the leaves to the fruit Usten (2006). Therefore, plants need a constant supply of Ca for vigorous leaf and root development canopy growth Del-Amor& Marcelis (2003). Calcium increases cell wall thickness and strengthens the cell. As an important cell wall component, calcium availability significantly strengthens the cell wall and enhances the structural integrity of stem and quality fruit. Calcium deficiency causes physiological disorders and influences some aspects, particularly in fruits, such as a decline in respiration rate, delaying ripening, enhancing shelf life, vitamin C contents, and fruit firmness Hudson (1981).

The main challenge in this study is improving the vegetative growth of some tomato genotypes under water stress by using amino acids or humic acid, or calcium boron.

2. MATERIALS AND METHODS

A field experiment was carried out during the summer seasons of 2020 and 2021 at the experimental farm of the Faculty of Agriculture, Benha University, Egypt, 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 the 1st and 2nd 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 consisting of one row of 10 m in length and 1.2 m in width, and the plants were transplanted 50 cm spaced in the rows. The experimental plots received three amounts of water, i.e., 100, 80, and 60 % ETo, using a 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 was 1.5 bar when all lines were opened, and the 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, located near the Faculty of Agriculture, Egypt. That affiliated with 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 March 17^{th}, 2020, and March 18^{th}, 2021, for the first and second seasons, respectively.

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

2.1. Data recorded

2.1.1. Vegetative growth characteristics:

Three plants were randomly chosen from each plot for 70 days after transplanting, and the following parameters were determined:

a. Morphological characteristics

1. Plant height (cm).
2. The number of branches/ plants.
3. Leaf area (cm^2): leaf area was determined by using the fresh weight method. The leaves were weighed, and then 10 disks of a constant area ($20m^2$) for each treatment were taken from the leaves with a puncher and weighted.
4. The leaf area was calculated according to the following formula:

Leaf area (cm^2) =

$$\frac{\text{fresh weight of leaves}}{\text{Fresh weight of disks}} \times \text{area of the disks}$$

5. Fresh weight of aerial part (stem and leaves) was determent in gm. / plant
6. Dry weight (g): the three plants were dried in an oven at 70^o C for 72 hr. until constant weight. The dried plants were weighted, and dry weight per plant was calculated.

2.1.2. Chemical characteristics:

1- Chlorophyll a and b contents were determined colorimetrically in fresh samples of the recently full mature leaf, i.e., 5th leaf, according to the method described in A.O.A.C. (1990).

2- Total nitrogen % was determined in the digested dry matter of plant leaves using micro-Kjeldahl methods according to pregl (1945).

3- The phosphorus % was determined using the spectrophotometer method described by John (1970).

4- The Potassium % was determined using the flame photometer method described by Brown and Lilleland (1964).

5- Calcium (%) was determined using the flame photometer method described by Brown and Lilleland (1964).

6- The proline content (Mg/100g dry weight): free proline content was extracted using 3% (w/v) aqueous sulfosalicylic acid and estimated by the ninhydrin reagent method according to Bates (1973).

2.2. Statistical analysis:

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

3. RESULTS AND DISCUSSION

3.1. Vegetative growth parameters of tomato plants

Effect of genotypes

Results in Table (3) show that the highest increases in plant height were recorded for both Arwa and Alia 123 genotypes in the first growing season. In the second growing one, Arwa recorded the highest increases in the following parameters plant fresh and dry weights and the number of branches, exceeding those recorded for the other genotypes. Such differences among the tested hybrids in vegetative growth aspects may be attributed to the genetic differences for such hybrids, which reported high variations among tomato genotypes for all vegetative growth parameters. Allia and Arwa's genotypes were able to endure drought injury better than sensitive super strain B.

Effect of water requirement

The highest increases in plant growth parameters were recorded in plants that received 100% of water requirements (WR), while decreased with water deficit following the sequence of 100>80> 60% WR during the two seasons of study

This may be due to the role of water in increasing the uptake of mineral elements from soil and translocation of photosynthetic assimilates, thus reflecting increases in the vegetative growth. Ragab *et al.* (2019), shahein *et al*. (2012).

Effect of foliar spray treatments

Spraying plants with either amino acids or humic acid recorded the highest values in plant height, number of branches, and plant fresh weight during the two seasons of study. A point to note is that the foliar application of "calcium+boron" resulted in comparable increases with the abovementioned foliar applications in both plant height and its fresh weight during the first season only. In general, the highest impacts in plant dry weights were recorded for the amino treatment during the first season of study, followed by the effects of either the foliar application of humic or calcium+boron, with no significant variations among these two treatments. Spraying plants with deionized water recorded the lowest significant reductions in all vegetative growth parameters in both seasons

The combined treatments of amino acids and micronutrients solution recorded higher increases in the vegetative growth parameters of tomato plants may be linked to increases in the endogenous concentrations of Fe, Mn, and Zn photosynthetic pigments and total soluble proteins with the combination treatments. (Sakya & Sulandjari, 2019; Sidhu et al., 2019; Salim et al., 2019).

Foliar applied with humic acid shared the capacity to increase the concentration of indole-3-acetic acid in roots and cytokinins in shoots. (Hita *et al.* 2020).

The combination with Calcium + Boron was proved more effective in producing taller plants, more branches per plant, and high leaf numbers, according to the results of Asad et al. (2003), because calcium is an essential constituent of the plant cell wall and plays a significant function in cell division and enlargement (Rashid, 2000; Ilyas et al., 2014).

Effect of the interaction

Tables (4 & 5) showed that the highest increases in plant height were recorded for Arwa and Alia 123 when irrigated with 100% WR and sprayed with amino within the two seasons of study. A point to note is that the cultivar Alia 123 recorded a comparable increase when irrigated with 80% WR and sprayed with amino. "This is a positive point in saving the water consumption of tomato plants".

Concerning the number of branches per plant, the highest increase was recorded for either Arwa or Alia 123 genotypes when irrigated with 100% WR and sprayed with the amino or humic. Also, comparable increases were detected for the Super strain B cultivar with 100% of WR and the foliar application of amino.

Also, Alia 123, Arwa, and Super strain B genotypes recorded the most significant increases in fresh plant weight when sprayed with humic or amino and irrigated plus 100% WR.

When using 100% WR, the foliar application with any of the investigated foliar spray with Alia 123 cultivar, the foliar spray of Arwa with amino spray, or the application of amino or humic with Super Strain B recorded the highest dry weight for tomato plants.

The highest leaf area was recorded in case of the foliar application of amino on either Alia 123 or Arwa in the presence of 100% of the water requirements

Spraying plants with any of the foliar applications (for any of the studied genotypes) recorded insignificant variations in tomato vegetative growth parameters when received 60% WR.

Table 3. Effect of genotypes, water requirement, or foliar spray treatments on vegetative growth of tomato plants during the summer seasons of 2020 & 2021.

Characteristics / Treatments	Plant height (cm)	No. of branches/ plant	Fresh weight (g)	Dry weight (g)	Leaf area/ plant (cm^2)	Plant height (cm)	No. of branches/ plant	Fresh weight (g)	Dry weight (g)	Leaf area/ plant (cm^2)
	The first Seasons (2020)					The second season(2021)				
Genotypes										
Aliaa 123	83.66 a	7.54 a	728.76 a	121.76 a	81.65 a	77.92 a	6.70 ab	672.07 b	105.68 b	81.93 a
Arwa	82.55 a	6.95 a	737.76 a	115.33 b	80.66 a	77.26 a	6.97 a	706.07 a	110.29 a	81.59 a
Super strain	74.27 b	6.68 a	690.86 a	114.87 b	79.89 a	78.45 a	6.14 b	682.16 b	105.60 b	80.03 a
Water requirements (WR)										
100% WR	91.44 a	9.60 a	954.41 a	156.26 a	95.49 a	88.92 a	8.42 a	851.30 a	131.82 a	95.03 a
80% WR	87.73 b	6.89 b	821.75 b	131.98 b	83.56 b	82.91 b	7.17 b	750.17 b	117.07 b	84.79 b
60% WR	61.32 c	4.67 c	400.02 c	63.70 c	63.13 c	61.80 c	4.22 c	458.83 c	72.68 c	63.73 c
Foliar application										
Amino acid	84.43 a	8.01 a	758.10 a	131.69 a	84.37 a	80.77 a	7.28 a	739.18 a	117.26 a	85.2 a
Humic acid	82.08 a	7.64 ab	772.61 a	121.13 b	84.12 a	79.07ab	7.06 a	716.42ab	113.92 a	83.20 b
Calcium+ poron	81.33 a	6.98 b	745.43 a	122.56 b	82.75 a	78.04 b	6.80 a	698.08 b	109.28 b	81.56 c
Distilled water	72.81 b	5.59 c	603.64 b	93.88 c	71.67 b	73.61 c	5.28 b	593.38 c	88.30 c	74.76 d

Table 4. Effect of interaction among water requirement, genotypes, and foliar spray treatments on vegetative growth of tomato plants during the summer seasons of 2020.

Genotypes	water requirements	Foliar application	Plant height (cm)	No. of branches /plant	Fresh weight (g)	Dry weight(g)	Leaf area/ plant (cm^2)
			The first Seasons (2020)				
Aliaa 123	100% WR	Amino acid	99.73 a	11.30 a	1048.1 a	179.2 a	99.87 a
		Humic acid	95.87 a-d	11.27 a	1007.0 ab	164.3abc	98.57 abc
		Calcium+poron	93.83 a-f	9.00 cd	1039.0 a	164.0 abc	94.23 a-e
		Distilled water water	86.20 f-i	7.86 d-h	849.3 def	127.3 efg	84.47 a-i
	80% WR	Amino acid	97.20 abc	8.30 def	930.4 bcd	149.1 b-e	87.40 a-h
		Humic acid	96.50 abc	7.83 d-h	921.0 b-e	146.4 c-f	89.03 a-f
		Calcium+poron	94.83 a-e	7.40 e-h	879.8 c-f	145.3 c-f	87.93 a-g
		Distilled water water	81.18 hi	6.93 ghi	685.6 g	116.4 gh	75.83 c-j
	60% WR	Amino acid	69.07 j	4.86 klm	464.3 h	76.3 ij	71.00 f-l
		Humic acid	66.43 jk	5.50 jkl	453.4 h	72.3 jk	70.47 f-l
		Calcium+poron	65.20 jkl	4.40 lmn	444.4 h	69.0 jk	70.33 f-l
		Distilled water water	57.97 lm	5.83 ijk	342.2 ij	51.3 klm	50.72 l
Arwa	100% WR	Amino acid	99.20 ab	10.73 ab	1047 a	169.5 ab	101.40 a
		Humic acid	96.63 abc	10.63 ab	1039 a	149.9 b-e	99.13 ab
		Calcium+poron	95.97 a-d	9.96 bc	983.2 ab	162.4 abc	98.30 abc
		Distilled water water	89.30 c-h	8.06 d-g	877.1 c-f	132.3 efg	86.20 a-i
	80% WR	Amino acid	94.20 a-f	7.96 d-h	929.2 bcd	148.3 b-f	85.87 a-i
		Humic acid	91.43 b-g	7.06 f-i	912.3 b-e	125.4 fg	86.07 a-i
		Calcium+poron	91.53 a-g	6.73 hij	855.2 def	147.0 b-f	83.43 a-i
		Distilled water water	86.10 f-i	4.30 l-o	647.3 g	97.0 hi	74.73 d-k
	60% WR	Amino acid	64.27 jkl	5.20 klm	441.4 hi	76.3 ij	63.67 i-l
		Humic acid	63.43 j-m	4.96 klm	441.3 hi	68.3 jk	71.20 e-l
		Calcium+poron	62.73 j-m	4.73 km	399.3 hi	65.3 jkl	65.23 g-l
		Distilled water water	55.87 mn	3.10 o	280.9 j	42.0 1m	52.67 kl
Super strain	100% WR	Amino acid	87.83 d-g	11.30 a	983.0 ab	173.2 a	99.87 a
		Humic acid	87.27 e-h	9.93 bc	970.2 abc	161.4 abc	98.20 abc
		Calcium+poron	86.77 e-i	8.50 de	911.3 b-e	156.9 a-d	97.10 a-d
		Distilled water water	78.77 i	6.73 hij	792.5 f	134.7 d-g	88.63 a-f
	80% WR	Amino acid	83.77 ghi	7.63 e-h	821.7 ef	143.2 c-f	84.67 a-i
		Humic acid	82.53 hi	7.40 e-h	806.5 f	134.5 d-g	88.00 a-g
		Calcium+poron	83.07 hi	7.06 f-i	802 f	130.7 efg	83.6 a-i
		Distilled water water	70.40 j	4.06 mno	670.1 g	100.5 1h	76.23 b-j
	60% WR	Amino acid	64.63 jkl	4.83 klm	447.8 h	70.1 jk	63.40 i-l
		Humic acid	58.67 klm	4.16 mno	402.8 hi	67.6 jk	58.67 jkl
		Calcium+poron	58.07 lm	5.10 klm	394.7 hi	62.4 j-m	64.67 h-l
		Distilled water water	49.50 n	3.43 no	287.8 jj	43.1 lm	55.63 jkl

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

Genotypes	% water requirement	Foliar application	Plant height (cm)	No. of branches/ plant	Fresh weight (g)	Dry weight (g)	Leaf area/ plant (cm^2)
			The second season(2021)				
Aliaa 123	100% WR	Amino acid	92.47a	9.533 ab	907.8 ab	148.2 ab	99.27 ab
		Humic acid	91.40 a	9.833 a	884.6 abc	138.0 a-d	96.43 cd
		Calcium+poron	90.37 a	9.100 abc	861.8 bcd	137.8 a-d	95.73 cde
		Distilled water	83.13 de	7.300 e-h	764.1 fgh	97.0 klm	89.67 f
	80% WR	Amino acid	89.53 ab	7.300 e-h	738.0 ghi	120.6 fgh	89.20 fg
		Humic acid	85.60 bcd	7.633 d-g	727.0 hij	118.0 g-j	88.17 fgh
		Calcium+poron	85.10 cd	6.833 g-j	672.0 j	107.7 h-k	86.40 hi
		Distilled water	76.97 fg	6.121 h-k	602.4 kl	90.3 mno	80.77 k
	60% WR	Amino acid	63.47 h	4.967 k-n	517.2 lm	82.3 nop	67.33 m
		Humic acid	62.30 h	4.167mno	499.1 lmn	81.8 nop	66.13 mn
		Calcium+poron	60.07 hi	4.433 l-o	487.4 l-o	81.1 nop	65.90 mn
		Distilled water	54.70 j	3.231 o	403.5 pqr	64.5 rst	58.17 o
Arwa	100% WR	Amino acid	91.27 a	10.100 a	925.1 a	150.4 a	101.00 a
		Humic acid	90.97 a	9.200 abc	890.3 abc	144.9 abc	96.57 c
		Calcium+poron	90.53 a	9.100 abc	884.6 abc	133.7 c-f	93.93 de
		Distilled water	82.33 de	7.100 f-i	697.1 ij	104.5 jkl	90.57 f
	80% WR	Amino acid	85.57 bcd	7.967 c-g	892.9 abc	136.7 b-e	89.87 f
		Humic acid	84.37 de	7.633 d-g	851.9 bcd	135.9 b-e	86.77 ghi
		Calcium+poron	82.97 de	8.300 b-f	839.8 cde	131.2 d-g	85.43 ij
		Distilled water	77.80 f	5.867 ijk	611.3 k	91.6 lmn	79.33 k
	60% WR	Amino acid	63.17 h	4.433 l-o	521.0 l	79.7 n-q	67.17 m
		Humic acid	61.33 h	5.300 klm	499.4 lmn	77.8 o-r	67.17 m
		Calcium+poron	60.60 hi	4.867 k-n	464.6 l-o	74.0 p-s	65.4 mn
		Distilled water	56.23 ij	3.867 no	394.9 qr	63.1 st	55.73 op
Super strain	100% WR	Amino acid	92.13 a	8.833 a-d	880.2 abc	137.4 a-d	98.3 bc
		Humic acid	90.77 a	8.300 b-f	868.5 a-d	137.3 a-d	96.93 bc
		Calcium+poron	89.53 ab	7.067 f-i	864.3 bcd	134.7 b-e	93.77 e
		Distilled water	82.33 de	5.633 jkl	787.3 efg	118.0 g-j	88.23 fgh
	80% WR	Amino acid	85.40 bcd	8.433 b-e	810.5 def	125.6 d-g	86.73 ghi
		Humic acid	84.53 de	7.633 d-g	780.6 e-h	123.5 efg	85.17 ij
		Calcium+poron	80.57 ef	7.100 f-i	772.9 fgh	117.6 g-j	83.37 j
		Distilled water	76.57 fg	5.321 klm	702.8 ij	105.4 ijk	76.23 l
	60% WR	Amino acid	64.03 h	3.967 no	460.0 m-p	74.4 p-s	67.93 m
		Humic acid	60.43 hi	3.867 no	446.4 n-q	67.23 q-t	65.40 mn
		Calcium+poron	62.70 h	4.433 l-o	435.4 o-r	65.77 rst	64.17 n
		Distilled water	72.57 g	3.167 o	377.1 r	60.30 t	54.17 p

3.2. Chemical composition of plant foliage

Effect of genotypes

data in Table (6) shows no significant variations in proline or calcium contents in shoots among the three cultivars during the two seasons of study and chlorophyll B and K content in the first growing season only. Calcium and Proline results indicate that the three cultivars used do not differ in drought tolerance. On the other hand, Arwa exhibited higher total chlorophyll content and chlorophyll A and P content, especially in the first season. But super strain B gave the lowest content of N in leaves in both seasons.

Effect of water requirement

The irrigation level of 100% resulted in the highest chlorophyll content (A, B, and total) in the two seasons of study. The highest Ca, K, and N content was found with irrigation with either 80 or 100% of WR. The highest proline contents were found in leaves of plants irrigated with 60% WR compared with all other irrigation levels in both seasons.

The increase of NPK and Ca concentration in plant foliage due to increasing the irrigation rate may be due to the increase of absorbed and translocated water to the foliage of plant parts, which increases as the concentration of macro-nutrients in foliage cell of plants. Numerous investigators obtained similar results, i.e., Al-Mohammadi, Garg, et al. (2003).

The induction of proline accumulation may be due to the activation of proline synthesis through the glutamate pathway involving glutamyl kinase, glutamyl phosphate reductase, and –pyrroline-5-carboxylate reductase activities in tomato (Bray 1990 and Fujita et al. 2003).

Effect of foliar spray treatments

Foliar applications with amino acids have favorable essential roles in influencing nutrient uptake, chlorophyll synthesis, photosynthesis, metabolism, and enzyme activation in eggplant Salim et al. 2019 and Sidhu et al., 2019.

The Ca is directly involved in improving photosynthesis, resulting in a high leaf number on tomato plants (Hussain et al., 2001). The Ca improved the leaf area by activating enzymes, photosynthesis, and carbohydrates metabolism (Bergmann, 1992; Hussain et al., 2001).

Effect of the interaction

From the data recorded in Tables (7 &8), it was noted that in the case of the water level of 100% WR, the different spraying compounds cause an increase in the total chlorophyll pigment in the leaves of the two hybrids Alia 123 and Arwa, as well as spraying with amino acids with Super Strain B in the second season.

The accumulation of elements (nitrogen, phosphorous, potassium) in leaves of the two hybrids, Alia 123 and Arwa, increases with a water level of 100% WR and foliar spraying with amino acids. But the accumulation of these elements in leaves with water deficiency decreases from 100% to 60% WR in all the cultivars used (Alia 123, Arwa, and Super Strain B) when spraying with distilled water. However, the concentration of proline in leaves increases in this case in the two seasons.

4. CONCLUSION

It could be generally concluded that in the summer season, tomato plants (Alia 123 F1 or Arwa F1) responded better when sprayed with Amino power® (0.5 cm3/l), Hummer® (0.25 g/l), or Caly-Bor® (2.5 cm3/l) three times at 15 days intervals starting 30 days after transplanting and irrigated with 80% of water requirements (1547.44 m^3 per feddan as an average). Such treatments induced the best results regarding tomato foliage's vegetative growth and chemical characteristics when grown under drip irrigation systems in heavy clay soil.

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Table 6. Chlorophyll content (mg/100g fresh weight) and proline (mg/100g dry weight) in leaves of tomato plants at the flowering stage as affected by water requirement, genotypes, or foliar spray treatments during the summer seasons of 2020 & 2021.

Characteristics / Treatments	Chllorophyll a (mg/g F.W)	Chllorophyll b (mg/g F.W)	Total Chllorophyll mg/g F.W)	Proline (mg/100g d.W)	N %	P%	K%	Ca%	Chllorophyll a (mg/g F.W)	Chllorophyll b (mg/g F.W)	Total Chllorophyll mg/g F.W)	Proline (mg/100g d.w)	N %	P%	K%	Ca%
	2020								2021							
Genotypes																
Aliaa 123	1.864 b	1.211 a	3.075 b	7.131 a	2.887 a	0.4166 b	2.400 a	0.675 a	2.064 a	1.203 ab	3.267 a	7.019 a	2.943 a	0.444 b	2.442 a	0.687 a
Arwa	1.986 a	1.247 a	3.233 a	7.222 a	2.790 a	0.4276 a	2.479 a	0.73 a	2.047 ab	1.256 a	3.303 a	7.208 a	2.853 b	0.454 a	2.468 a	0.68 a
Super strain	1.750 c	1.219 a	2.969 b	7.106 a	2.564 b	0.3210 c	2.414 a	0.629 a	1.958 b	1.108 b	3.067 b	7.147 a	2.661 c	0.368 c	1.742 b	0.634 a
water requirements (WR)																
100% WR	2.042 a	1.311 a	3.353 a	6.978 c	2.879 a	0.4191 a	2.415 a	0.787 a	2.375 a	1.356 a	3.731 a	6.786 c	2.978 a	0.419 c	2.291 a	0.759 a
80% WR	1.783 b	1.208 b	2.992 b	7.164 b	2.771 a	0.3999 b	2.491 a	0.739 a	1.967 b	1.164 b	3.131 b	7.108 b	2.861 b	0.422 b	2.233 a	0.677 a
60% WR	1.775 b	1.158 b	2.933 b	7.317 a	2.591 b	0.3462 c	2.388 a	0.508 b	1.728 c	1.047 b	2.775 c	7.481 a	2.618 c	0.426 a	2.128 b	0.564 b
foliar application																
Amino acid	2.044 a	1.385 a	3.430 a	7.270 a	3.118 a	0.3998 a	2.533 a	0.734 a	2.148 a	1.348 a	3.496 a	7.141 a	3.176 a	0.426 a	2.378 a	0.731 a
Humic acid	1.885 b	1.304 a	3.189 b	7.263 a	2.792 b	0.3925 b	2.486 ab	0.665 ab	2.048 ab	1.196 ab	3.244 b	7.170 a	3.016 b	0.425 a	2.257 b	0.687 a
Calcium+ poron	1.896 b	1.193 b	3.089 b	7.115 ab	2.696 b	0.3873 c	2.373 ab	0.749 a	1.959 b	1.148 b	3.107 bc	7.159 a	2.673 c	0.421 b	2.176 b	0.757 a
Distilled water	1.641 c	1.022 c	2.663 c	6.963 b	2.380 c	0.3741 d	2.333 b	0.563 b	1.937 b	1.063 b	3.000 c	7.030 a	2.411 d	0.417 c	2.059 c	0.491 b

Table 7. Effect of interaction among water requirement, genotypes, and foliar spray treatments on the chemical composition of tomato plants during the summer seasons of 2020.

Characteristics Treatment			Chllorophyll a (mg/g F.W)	Chllorophyll b (mg/g F.W)	Total Chllorophyll (mg/g F.W)	N%	P%	K%	Ca %	Proline (mg/100g D.W)
Genotype	**Water requirements**	**Foliar application**	**2020**							
Aliaa 123	**100% WR**	**Amino acid**	2.333 ab	1.467 ab	3.800 ab	3.663 a	0.4607c	2.697 a	0.823 a-d	7.100 b-d
		Humic acid	2.233 abc	1.367 a-e	3.600 a-d	3.070 c	0.4640 b	2.497 a-k	0.711 d-k	6.867cde
		Calcium+poron	2.000 a-f	1.233 a-h	3.233 b-j	2.880 c-g	0.4310 jj	2.361 c-l	0.898 abc	6.900 cde
		Distilled water	1.800 b-g	1.133 c-i	2.933 e-l	2.507 j-m	0.4433 gg	2.273 g-l	0.631 f-l	6.433 e
	80% WR	**Amino acid**	2.100 a-e	1.300 a-g	3.400 a-g	3.600 a	0.4510 e	2.573 a-e	0.763 b-h	7.200 a-d
		Humic acid	1.600 efg	1.367 a-e	2.967 d-l	2.930 c-g	0.4470 f	2.460 a-k	0.721 c-j	6.933 cde
		Calcium+poron	1.733 c-g	1.100 d-i	2.833 f-l	2.823 d-h	0.4383 i	2.323 d-l	0.834 a-d	7.300 a-d
		Distilled water	1.533 fg	0.966 hi	2.500 l	2.383 lmn	0.4170 k	2.243 jkl	0.601 h-m	6.933 cde
	60% WR	**Amino acid**	1.733 c-g	1.333 a-f	3.067 c-l	3.037cd	0.3780 n	2.443 a-k	0.563 i-n	7.733 a
		Humic acid	1.867 b-g	1.200 a-i	3.067 c-l	2.777 f-i	0.3780 n	2.523 a-h	0.532 k-o	7.667 ab
		Calcium+poron	1.767 c-g	1.167 b-i	2.933 e-l	2.713 g-j	0.3723 o	2.233 kl	0.551 i-m	7.333 a-d
		Distilled water	1.667 d-g	0.900 i	2.567 kl	2.257 n	0.3183 t	2.170 l	0.482 l-o	7.167 a-d
Arwa	**100% WR**	**Amino acid**	2.433 a	1.500 a	3.933 a	3.557 ab	0.4637 b	2.587 a-d	0.934 ab	7.067 c-d
		Humic acid	2.333 ab	1.467 ab	3.800 ab	3.017 c-d	0.4507 e	2.477 a-k	0.821 a-e	7.200 a-d
		Calcium+poron	1.967 a-g	1.467 ab	3.433 a-f	2.947 c-f	0.4620 c	2.470 a-k	0.978 a	7.033 cd
		Distilled water	1.733 c-g	0.966 hi	2.700 h-l	2.490 klm	0.4567 d	2.340 c-l	0.734 c-i	6.900 cde
	80% WR	**Amino acid**	2.000 a-f	1.300 a-g	3.300 a-h	3.340 b	0.4757 a	2.607 abc	0.854 a-d	7.400 abc
		Humic acid	2.100 a-e	1.300 a-g	3.400 a-g	2.887 c-g	0.4403 h	2.510 a-i	0.772 b-h	7.200 a-d
		Calcium+poron	2.233 abc	1.033 f-i	3.267 b-i	2.780 f-i	0.4457 f	2.450 a-k	0.858 a-d	7.167 a-d
		Distilled water	1.700 c-g	1.100 d-i	2.800 f-l	2.343 mn	0.4180 k	2.523 a-h	0.634 f-l	7.000 c-e
	60% WR	**Amino acid**	1.900 a-g	1.300 a-g	3.200 b-k	2.48 klm	0.3927 l	2.533 a-g	0.611 g-m	7.333 a-d
		Humic acid	1.667 d-g	1.300 a-g	2.967 d-l	2.763 f-i	0.3807 m	2.480 a-k	0.512 l-o	7.667 ab
		Calcium+poron	1.933 a-g	1.167 b-i	3.100 c-l	2.583 jkl	0.3793 mn	2.423 b-l	0.624 f-l	7.400 abc
		Distilled water	1.833 b-g	1.067 e-i	2.900 g-l	2.290 mn	0.3657 p	2.350 c-l	0.432 mno	7.300 a-d
Super strain	**100% WR**	**Amino acid**	2.200 a-d	1.433 abc	3.633 abc	2.860 c-g	0.3543 q	2.383 c-l	0.778 b-h	7.067 cd
		Humic acid	2.100 a-e	1.400 a-d	3.500 a-e	2.613 hjk	0.3530 q	2.350 c-l	0.705 d-k	7.100 bcd
		Calcium+poron	1.867 b-g	1.333 a-f	3.200 b-k	2.483 klm	0.3467 r	2.297 f-l	0.79 b-g	7.067 cd
		Distilled water	1.500 fg	0.966 hi	2.467 l	2.467 k-n	0.3430 s	2.250 jkl	0.645 e-l	7.000 cde
	80% WR	**Amino acid**	1.700 c-g	1.500 a	3.200 b-k	2.723 ghi	0.3193 t	2.657 ab	0.756 b-h	7.233 a-d
		Humic acid	1.533 fg	1.233 a-h	2.767 g-l	2.460 k-n	0.3187 t	2.553 a-f	0.732 c-i	7.367 abc
		Calcium+poron	1.733 c-g	1.233 a-h	2.967 d-l	2.577 j-l	0.3150 u	2.550 a-f	0.801 a-f	7.067cd
		Distilled water	1.433 g	1.067 e-i	2.500 l	2.400 k-n	0.3123 v	2.440 a-l	0.545 j-o	7.167 a-d
	60% WR	**Amino acid**	2.000 a-f	1.333 a-f	3.333 a-h	2.803 e-h	0.3027 w	2.313 e-l	0.531 k-o	7.300 a-d
		Humic acid	1.533 fg	1.100 d-i	2.633 i-l	2.617 h-k	0.3000 x	2.520 a-i	0.486 l	7.367 abc
		Calcium+poron	1.833 b-g	1.000 ghi	2.833 f-l	2.480 klm	0.2950 y	2.253 h-l	0.414 no	6.767 de
		Distilled water	1.567 efg	1.033 f-i	2.600 jkl	2.290 mn	0.2923 z	2.407 b-l	0.365 o	6.767 de

Table 8. Effect of interaction among water requirement, genotypes, and foliar spray treatments on the chemical composition of tomato plants during the summer seasons of 2021.

Characteristics Treatment			Chllorophyll a mg/g F.W)(	Chllorophyll b mg/g F.W) (	Total Chllorophyll mg/g F.W) (	N%	P%	K%	Ca %	Proline (mg/100g D.W)
Genotypes	**Water requirements**	**Foliar application**	**2021**							
Aliaa 123	**100% WR**	**Amino acid**	2.600 a	1.533 ab	4.133 a	3.583 a	0.4627 a	2.707 a	0.864 abc	6.767 g-j
		Humic acid	2.500 ab	1.400 bcd	3.900 abc	3.443 bc	0.4503 ij	2.580 a-d	0.776 a-f	6.600 ij
		Calcium+poron	2.367 a-d	1.400 bcd	3.767 a-e	2.923 h	0.4457 l	2.517 b-e	0.878 ab	6.800 f-j
		Distilled water	2.400 a-d	1.300 c-f	3.700 b-e	2.563 op	0.4493 jk	2.410 eh	0.608 g-l	6.500 j
	80% WR	**Amino acid**	2.100 d-h	1.333 cde	3.433 d-h	3.427 bc	0.4607 bc	2.623 abc	0.737 b-g	6.967 d-j
		Humic acid	1.967 e-j	1.133 f-i	3.100 f-l	3.270 de	0.4553 fg	2.511 b-e	0.711 d-j	7.167 a-i
		Calcium+poron	1.933 f-j	1.200 e-h	3.133 f-k	2.780 jkl	0.4510 hi	2.403 e-h	0.794 a-e	7.067 b-j
		Distilled water	1.867 f-k	1.067g-k	2.933 j-o	2.497 pq	0.4463 l	2.271 hi	0.578 h-l	6.833 f-j
	60 % WR	**Amino acid**	1.733 i-l	1.233 d-g	2.967 i-n	3.123 fg	0.3503 r	2.517 b-e	0.634 f-k	7.367 a-f
		Humic acid	1.733 i-l	0.966 jkl	2.700 l-o	2.813 ijk	0.4573 e	2.307 f-i	0.566 jkl	7.300 a-g
		Calcium+poron	1.800 h-l	1.000 i-l	2.800 k-o	2.580 nop	0.4540 g	2.300 ghi	0.686 d-j	7.300 a-g
		Distilled water	1.767 i-l	0.866 l	2.633 mno	2.317 tu	0.4523 h	2.160 ij	0.413 m	7.567 abc
Arwa	**100% WR**	**Amino acid**	2.500 ab	1.600 a	4.100 ab	3.497 ab	0.4610 b	2.663 ab	0.888 a	6.767 g-j
		Humic acid	2.367 a-d	1.467 abc	3.833 a-d	3.393 c	0.4550 fg	2.597 a-d	0.787 a-e	6.933 e-j
		Calcium+poron	2.400 a-d	1.333 cde	3.733 a-e	2.833 hij	0.4507 ij	2.503 b-e	0.890 a	7.133 a-i
		Distilled water	2.133 efg	1.233 d-g	3.367 e-i	2.493 pqr	0.4483 k	2.303 f-i	0.579 h-l	6.800 f-j
	80% WR	**Amino acid**	2.333 a-d	1.400 bcd	3.733 a-e	3.363 cd	0.4557 f	2.627 ab	0.74 b-g	7.333 a-g
		Humic acid	2.167 c-f	1.300 c-f	3.467 d-g	3.187 ef	0.4523 h	2.530 b-e	0.728 c-g	7.200 a-h
		Calcium+poron	1.967 e-j	1.167 e-i	3.133 f-k	2.697lm	0.4540 g	2.443 d-g	0.75 a-g	6.967 d-j
		Distilled water	1.700 i-l	1.067 g-k	2.767 k-o	2.433 grs	0.4500 ij	2.227 i	0.49 klm	7.000 c-j
	60 % WR	**Amino acid**	1.867 f-k	1.200 e-h	3.067 g-l	2.883 hi	0.4483 k	2.463 c-f	0.654 e-j	7.567 ab
		Humic acid	1.667 jkl	1.167 e-i	2.833 j-o	2.717 klm	0.459 b-d	2.460 d-g	0.634 f-k	7.600 ab
		Calcium+poron	1.500 l	1.067 g-k	2.567 no	2.510 pq	0.459 cd	2.397 e-g	0.67 d-j	7.667 a
		Distilled water	1.967 e-j	1.067 g-k	3.033 h-m	2.230 u	0.4587 de	2.403 e-h	0.354 m	7.533 a-d
Super strain	**100% WR**	**Amino acid**	2.433 abc	1.400 bcd	3.833 a-d	3.033 g	0.3570 p	2.023 j	0.741 b-g	6.800 f-i
		Humic acid	2.433 abc	1.233 d-g	3.667 cde	2.873 hij	0.3557 pq	1.847 lm	0.734 b-g	6.800 f-j
		Calcium+poron	2.267 b-e	1.230 d-g	3.500 cdf	2.673 mn	0.3487 st	1.670 nop	0.801 a-d	6.833 f-j
		Distilled water	2.100 d-h	1.133 f-j	3.233 f-j	2.430 grs	0.3467 u	1.673 nop	0.568 i-l	6.700 hij
	80% WR	**Amino acid**	2.100 d-h	1.300 c-f	3.400 e-h	2.897 hi	0.3883 m	1.990 kl	0.713 d-i	7.100 a-i
		Humic acid	2.000 e-i	1.067 g-k	3.067 g-l	2.810 ijk	0.3570 p	1.810 mn	0.678 d-j	7.467 a-e
		Calcium+poron	1.800 h-l	1.000 i-l	2.800 k-o	2.577 nop	0.3473 tu	1.757mno	0.720 c-h	7.067 b-j
		Distilled water	1.667 jkl	0.933 kl	2.600 no	2.393 rst	0.3490 rs	1.603 opq	0.487 lm	7.133 a-i
	60% WR	**Amino acid**	1.667 jkl	1.133 f-j	2.800 k-o	2.780 jkl	0.4503 ij	1.787 mn	0.612 g-l	7.600 ab
		Humic acid	1.600 kl	1.033 h-l	2.633 mno	2.640 m-o	0.3857 n	1.673 nop	0.577 h-l	7.467 a-e
		Calcium+poron	1.600 kl	0.933 kl	2.533 o	2.480 pqr	0.3827 o	1.593 pq	0.631 f-l	7.600 ab
		Distilled water	1.833 g-k	0.900 kl	2.733 k-o	2.340 st	0.3553 q	1.480 q	0.346 m	7.200 a-h

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الملخص العربي

تأثير تقليل الاحتياج المائي والرش ببعض المنشطات علي النمو الخضري لبعض اصناف الطماطم المزروعه في تربه طينيه ثقيله تحت نظام الري بالتنقيط

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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 مثل عاليا ١٢٣ وأروي والصنف سوبر إسترين بي بنقص المياه و إستخدام الرش الورقى ببعض المنشطات الحيوية (الاحماض الامينيه و الهيومك والكالسيوم+ بورون) والتفاعل بينهم علي النمو الخضري علي نبات الطماطم المنزرع تحت ظروف الري بالتنقيط في التربه الطينيه.

أوضحت النتائج أن إعطاء النباتات كامل إحتياجاتها المائيه ١٠٠% من البخر نتح والرش بالاحماض الامينيه مع الهجين عاليا ١٢٣ أعطي أعلي القيم لصفات النمو الخضري متمثله في إرتفاع النبات وعدد الافرع والوزن الطازج والوزن الجاف ومساحه الاوراق. إزداد تراكم العناصر النتروجين والفوسفور والبوتاسيوم في الاوراق عند الري ب١٠٠% من الاحتياجات المائيه والرش بالاحماض الامينيه علي الهجين عاليا أو أروي وتناقص تراكم هذه العناصر مع تناقص مستوي الري من ١٠٠ الي ٨٠ الي ٦٠% من الاحتياجات مع أي من الطرز الثلاثه وأي من مركبات الرش إلا أن تركيز البرولين زاد في الاوراق مع هذا التناقص في مستوي الماء.

الكلمات المفتاحية : الطماطم– الطرز الوراثية– الأحماض الأمينيه– الهيومك أسد– الكالسيوم – البورو– نقص المياه – النمو الخضري