INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 25, No. 6, p. 230-244, 2024

RESEARCH PAPER OPEN ACCESS

Impact of salicylic acid foliar spray on tomato growth, yield and quality under drought conditions

Md. Rezwan Sarker*[1], Fatima Farhana[2], Banalata Das[1], Md. Mofizur Rahman[1], Chaity Dey Puja[1], Shormin Choudhury[1]

[1]*Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh*

[2]*Department of Entomology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh*

Key words: Drought stress, Salicylic acid, SPAD value, Yield, Fruit quality

http://dx.doi.org/10.12692/ijb/25.6.230-244 Article published on December 06, 2024

Abstract

The experiment, conducted using BARI Tomato-14, was arranged in a Randomized Complete Block Design with three replications, resulting in 12 treatment combinations (3×4). The study examined two factors: Factor A, which included three levels of moisture availability (W1: 100%, W2: 75%, and W3: 50% evapotranspiration moisture), and Factor B, which tested four concentrations of salicylic acid (SA) as a drought stress mitigating agent (S0: Control, S1: 50 ppm, S2: 75 ppm, and S3: 100 ppm). Results indicated that both drought stress and salicylic acid application significantly influenced morphological, physiology, yield contributing features and fruit quality traits of tomato. The highest plant height (110.0 cm), SPAD value 49.73, Vitamin C 5.61 (mg/100g), protein content 2.52 (mg/100g), fruit weight (69.0g) and fruit yield per plant (2.3 kg) were recorded in the treatment combination of W_1S_2 (100% evapotranspiration moisture and 75 ppm salicylic acid). Conversely, the lowest value was found in W_3S_0 (50% evapotranspiration moisture and no salicylic acid). These findings suggest that foliar application of salicylic acid can effectively mitigate the harmful effects of drought stress in tomatoes, enhancing plant growth, productivity and nutritional quality of fruit.

* **Corresponding Author:** Md. Rezwan Sarker ✉ rezwansf@sau.edu.bd

Introduction

Tomato (*Solanum lycopersicum* L.) ranks among the most widely consumed crops globally. A significant part of the daily diet, tomatoes are a good source of vitamins, minerals, and antioxidants (Li *et al.,* 2021). In global vegetable production, tomatoes hold the third position, with a yield of 186,821 million tons, cultivated over more than 5.05 million hectares of land (Chanthini *et. al.,* 2022). Bangladesh produces 442 thousand tons (WPR, 2022), which is significantly less than the global average yield. Because of shifting biotic and abiotic environmental conditions. Global agriculture is seriously threatened by climate change as increasing temperatures and diminished water availability lead to reduced crop productivity. Forthcoming predictions suggest that by 2050, water scarcities will impact half of the agricultural land worldwide (Hasanuzzaman *et al.,* 2019). Water shortage is already the primary environmental factor reducing the growth and productivity of vegetables (Sirisuntornlak *et al.*, 2019). Tomato crops are mostly susceptible to drought stress, which negatively affects its growth, yield, and fruit quality. Therefore, water scarcity negatively impacts plant growth and development by hindering cell division and elongation, which in turn adversely affects the plant's morphology, physiology, and ecology (Farooq *et al.,* 2009). The reduction in photosynthesis is a primary reason for hampered growth. To mitigate the adverse effects of water scarcity on plants, applying plant growth regulators is a viable option. Additionally, advances in agronomical practices, traditional breeding, and new biotechnological tools have been employed to prevent yield losses due to drought stress (Jones *et al.,* 1991). Applying bio stimulants and phytohormones to foliage is recognized as one of the most effective adaptation methods (El-Mageed *et al.,* 2017). Among these, salicylic acid (SA), a phytohormone and phenolic compound, influences plant growth, ion absorption, and substance transport. SA is regarded as a crucial plant signaling molecule that enhances plant defense responses, thereby increasing tolerance to both biotic and abiotic stresses (Gorni *et al.,* 2017). Water deficit decreased stomatal conductance, transpiration, and CO2 assimilation in rice plants. However, the application of salicylic acid (SA) improved gas exchange characteristics in plants experiencing water deficit (Shemi *et al.*, 2021). Chavoushi *et al.*, 2020 reported that safflower (*Carthamus tinctorius* L.) treated with foliar application of SA under water deficit improved photosynthesis rate, enzyme activity and quality. A recent study showed that exogenous application of SA in grape tomatoes acts as water deficit alleviation (Chakma *et al.,* 2021). Natural biostimulants as environmentally friendly materials include any substances applied to plants to increase nutritional efficiency, abiotic stress tolerance, and quality traits of crop (Trivedi *et al.,* 2018). Given that the mechanism of action of salicylic acid (SA) can vary among plant species, stress levels, and environmental conditions, it is crucial to investigate its effects on tomato plants under water scarcity.

This examination aims to enhance the sustainability of tomato production and provide cultivation options for regions with limited water availability. Based on existing research, our study hypothesizes that foliar application of SA can mitigate the adverse effects of water deficit on tomato growth and fruit yield. To test this hypothesis, we evaluate the productivity, morpho-physiological traits, and yield-contributing characteristics of tomato plants under water stress with varying doses of SA application.

Materials and methods

Location of the experimental site

A pot experiment was carried out at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, located in the Madhupur Tract under AEZ No. 28. The coordinates of the site are 24.090N latitude and 90.260E longitude, with an altitude of 8 meters above sea level.

Characteristics of pot soil

The soil texture of the experiment was sandy loam. The experiment was conducted in pots with medium-high soil and adequate irrigation facilities.

Climatic condition of the experimental site

The experimental area is situated in a sub-tropical climate zone, marked by heavy rainfall from April to September and minimal rainfall during the remaining months of the year.

Planting material

Thirty (30) days old seedlings of BARI Tomato-14 were used as planting material. This variety is known for its tolerance to bacterial wilt, indeterminate growth habit, high yield, and widespread cultivation in Bangladesh. The seedlings were grown at the Horticulture Farm of Sher-e-Bangla Agricultural University. Seeds were collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh.

Treatment of the experiment

The experiment consisted of two factors:

Factor A: Different levels of moisture

i. W_1 = 100% evapotranspiration moisture

ii. W_2= 75% evapotranspiration moisture

iii. W_3= 50% evapotranspiration moisture

Factor B: Different levels of salicylic acid

i. S_0 = Control (Foliar spray of water without salicylic acid)

ii. S_1 = Foliar spray with 50 ppm salicylic acid

iii. S_2 = Foliar spray with 75 ppm salicylic acid

iv. S_3 = Foliar spray with 100 ppm salicylic acid

There were 12 (3×4) treatments combinations such as: W_1S_0, W_1S_1, W_1S_2, W_1S_3, W_2S_0, W_2S_1, W_2S_2, W_2S_3, W_3S_0, W_3S_1, W_3S_2 and W_3S_3.

Design and layout of the experiment

The experiment was carried out in randomized complete block design (RCBD) with three replications bring about 12 treatment combinations. The experimental area was divided into three equal blocks, each containing 48 pots with 12 treatment combinations assigned randomly. Four plants were placed in each treatment, totaling 144 pots in the experiment. Each pot, measuring 35 cm in diameter and 30 cm in height, contained 10 kg of soil.

Preparation of pot and transplanting of seedlings

A mixture of well-rotted cow dung and soil in a 1:3 ratio was prepared and used to fill the pots 15 days before transplanting. Healthy and uniform seedlings were carefully uprooted from the seedbed and transplanted into experimental pots in the afternoon, with two seedlings placed in each pot.

Application of manure and fertilizers

During the final pot preparation, each pot received 20g of cow dung, 600mg of TSP, 300mg of gypsum, 50mg of zinc, and half of the MoP (150mg). Urea was applied in three doses of 250mg each at 15, 30, and 45 days after transplanting using the ring method. The remaining half of the MoP (150mg) was applied in two split doses at 30 and 45 days after transplanting, coinciding with the second and third urea applications (BARC, 2012).

Application of the treatments

Creation of Moisture levels

Moisture stress was induced using the gravimetric method to determine the optimal irrigation strategy for pot plants. In this method, plastic pots filled with soil were weighed to ensure each pot, including soil, weighed 10 kg, with the empty pots weighing 0.8 kg. Water was added to each pot to achieve saturation. The difference in weight before and after saturation indicated the evaporation rate. The pots were then covered with polythene sheets and left for two days. After this period, the pots were reweighed to determine water loss, calculated as the difference between the saturated weight and the weight after two days. The water lost over the two days was fully replenished by irrigation for the control pots, while the other pots received 75% and 50% of the water added to the control plants.

Preparation for Salicylic acid treatment

Salicylic acid (SA) is a phytohormone crucial for plant defense mechanisms and various physiological processes. Lower concentrations of SA enhance antioxidant capacity and help mitigate drought stress in plants. Tomato plants were treated with salicylic acid at low concentrations of 50ppm, 75ppm, and 100ppm. prepared by dissolving 50, 75, and 100 mg of salicylic acid per liter of water, respectively. These solutions were applied as foliar sprays at 15, 30, 45, and 60 days after transplanting.

Harvesting

Fruits were harvested every three days during the early ripening stage, when they developed a slight red color. This indeterminate harvesting began in the last week of February and continued until the first week of April.

Data collection

The following experimental data were recorded 30 days after transplanting and continued until harvest-

Morphological and physiological features

Measurements of plant height (cm), along with the number of leaves and branches per plant were taken at 30, 40, 50, and 70 days after transplanting.

Leaf area (cm^2): Each leaf sample was measured for its maximum width (W) and length (L) using a ruler. The width was taken at the broadest part of the leaflet, while the length was measured along the rachis from the point of initial leaflet insertion to the distal end (Carmassi *et al.,* 2007).

SPAD value: The chlorophyll content of the first fully expanded leaves was measured using a SPAD-502 chlorophyll meter (Minolta, Tokyo, Japan).

Relative Water Content (%): The relative water content (RWC) was assessed using the method described by Smart and Bingham (1974). For each replicate, three leaves were combined, and their fresh weights (FW) were recorded.

The leaves were then soaked in water at room temperature for twelve hours to regain turgidity. After blotting to remove excess water, their turgid weights (TW) were measured. Finally, the samples were dried in an oven at 65°C for 24 hours to determine their dry weights (DW).

The RWC was calculated using the formula below:

RWC % = (FW-DW ÷ TW-DW) × 100

Dry matter content of leaves (%): dry mater of leaves was calculated by aggregating the dry matter weight of leaves.

Yield contributing features

The following parameters were taken into consideration: number of flower clusters per plant, number of flowers per cluster, total number of flowers per plant, number of fruits per cluster, total number of fruits per plant, fruit length (cm), fruit diameter (cm), individual fruit weight (g), yield per plant (kg), and yield per hectare (t/ha).

Fruit quality features

Vitamin-C content (mg/100g): Vitamin C content of fruits were determined by 2, 6- dichlorophenol indophenol staining method (Arya *et al.*, 2000).

lycopene content (mg/100g): The lycopene content was measured following a previously described procedure (Nagata & Yamashita, 1992). The absorbance of the extracts was measured at 453, 505, 645, and 663 nm. The lycopene content was then calculated using this equations and expressed in mg per 100 g of fresh weight: Lycopene (mg/100 mL) = -0.0458 × A_{663} + 0.204 × A_{645} - 0.304 × A_{505} + 0.452 × A_{453}.

Total soluble solid content (%): The soluble solid content was determined using a portable handheld refractometer, model PAL-1 (Atago, PR-1, Atago Co. Ltd., Tokyo, Japan) (Cao *et al.*, 2015).

Ash (%): The total ash content was determined using the AOAC method (1990).

Protein (%): Protein content of tomato fruits was determined by multiplication of total nitrogen with 6.25, which was analyzed by following the micro-Kjeldahl method (Kjeldahl, 1883).

Statistical analysis

The data for various characters were statistically analyzed using the MSTAT-C software. The significance of differences among the treatment combinations was determined by Duncan's Multiple Range Test (DMRT) at a 5% probability level (Gomez and Gomez, 1984).

Results and discussion

Growth and physiological features

Plant height (cm)

The effect of different levels of moisture and salicylic acid treatment combinations showed significant differences in the plant height of tomato at 30, 40, 50, 60, and 70 days after transplanting (DAT).

The tallest plant 110.0 cm was found from the W_1S_2 treatment combination, which was statistically similar to W_1S_0, W_1S_1, W_1S_3, W_2S_1, W_2S_2, W_3S_1, and W_3S_1 at 70 DAT while the shortest plant 92.08 cm was found from W_3S_0 treatment combination (Table 1).

Table 1. Effect of different levels of moisture and salicylic acid on plant height of tomato at different days after transplanting (DAT).

Treatment	Plant height (cm) of tomato at different days after transplanting				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
W_1S_0	42.65 abcd	70.20 abc	89.39 bcd	93.98 bcde	100.40 abcd
W_1S_1	45.16 abc	73.16 a	94.46 abc	100.40 abc	105.70 ab
W_1S_2	46.21 a	75.41 a	98.87 a	104.40 a	110.00 a
W_1S_3	43.96 abcd	69.60 abc	87.45 bcde	96.89 abcd	103.50 abc
W_2S_0	40.55 de	64.57 cd	83.55 def	91.59 cdef	96.96 bcd
W_2S_1	44.26 abcd	71.41 ab	91.96 abcd	97.62 abcd	102.00 abcd
W_2S_2	45.29 ab	73.41 a	95.77 ab	101.60 ab	104.80 abc
W_2S_3	42.11 bcd	65.47 bcd	86.06 cde	94.55 bcde	97.68 bcd
W_3S_0	35.27 f	57.05 e	72.97 g	83.15 f	92.08 d
W_3S_1	41.44 bcde	60.98 de	75.18 fg	89.79 def	99.79 abcd
W_3S_2	41.37 cde	65.67 bcd	79.46 efg	94.61 bcde	100.40 abcd
W_3S_3	37.61 ef	59.44 de	74.08 g	85.86 ef	94.77 cd
LSD (0.05)	3.91	6.39	8.66	9.43	10.26
CV (%)	5.48	5.61	5.96	5.89	6.02

In a column means with the same letter did not significantly differ from each other at $p<0.05$. Here, W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture, W_3: 50% evapotranspiration moisture; S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid.

Drought stress has been linked to reduced plant development and production due to reduced photosynthetic rate and stomatal conductance (Khan *et al.,* 2015). Soil moisture shortage has a substantial impact on grape tomato plant development and fruit production data (Chakma *et al.,* 2021). This result is alien with Nezhad *et al*'s., (2014) findings, which indicated that drought stress and salicylic acid had significant impacts on plant height. In the current study, drought stress and the application of salicylic acid have significant consequences on plant height.

Number of leaves plant^{-1}

The number of leaves plant^{-1} of tomato showed significant differences due to the combined effect of different moisture and salicylic acid levels at 30, 40, 50, 60, and 70 DAT. The maximum number of leaves plant^{-1} 47.46 was found from the W_1S_2 treatment combination which was statistically similar to W_2S_2 at 70 DAT. The minimum number of leaves plant^{-1} 34.64 was found from the W_3S_0 treatment combination, which was statistically identical to W_2S_0, W_2S_3, and W_3S_3 at 70 DAT. At 50 DAT, the minimum number of leaves plant^{-1} 16.35 was found from the W_2S_0 treatment combination, which was statistically similar to W_1S_0, W_3S_0 and W_3S_3 (Table 2).

This is similar to the findings of Mady (2009) who found that salicylic acid varied significantly on the number of leaves plant^{-1} of tomato.

Table 2. Effect of different levels of moisture and salicylic acid **on** the number of leaves plant^{-1} of tomato at different days after transplanting (DAT).

Treatment	Number of leaves plant^{-1} of tomato at different days after transplanting				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
W_1S_0	8.41 cdef	12.52 cde	17.50 ef	27.45 efg	39.48 de
W_1S_1	9.41 b	14.72 b	22.76 bc	33.15 bc	44.32 b
W_1S_2	10.83 a	16.28 a	25.58 a	35.83 a	47.46 a
W_1S_3	8.88 bcd	13.56 bc	19.10 de	29.26 e	41.39 cd
W_2S_0	8.77 bcd	10.53 fgh	16.35 f	26.77 fgh	36.97 efg
W_2S_1	8.98 bc	12.97 cd	22.50 c	31.85 cd	43.72 bc
W_2S_2	10.22 a	14.54 b	25.05 ab	34.89 ab	46.54 ab
W_2S_3	8.12 def	11.59 def	18.99 de	28.91 ef	37.19 efg
W_3S_0	7.26 g	8.740 i	17.53 ef	24.47 h	34.64 g
W_3S_1	7.71 efg	10.07 ghi	20.64 cd	27.76 efg	38.65 def
W_3S_2	8.49 cde	11.14 efg	22.61 bc	29.67 de	40.56 d
W_3S_3	7.64 fg	9.403 hi	18.81 def	25.67 gh	36.30 fg
LSD $_{(0.05)}$	0.81	1.38	2.51	2.48	2.86
CV (%)	5.46	6.68	7.18	4.94	4.16

In a column means with the same letter did not significantly differ from each other at $p<0.05$. Here, W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture, W_3: 50% evapotranspiration moisture; S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid.

Table 3. Effect of different levels of moisture and salicylic acid on the number of branches plant^{-1} of tomato at different days after transplanting (DAT).

Treatment	Number of branches plant^{-1} of tomato at different days after transplanting				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
W_1S_0	3.75 bcde	6.02 fg	10.63 def	16.60 de	18.44 cde
W_1S_1	3.99 abc	7.59 bc	13.48 bc	18.85 abc	20.16 bc
W_1S_2	4.21 a	8.43 a	14.90 a	20.79 a	22.54 a
W_1S_3	3.91 abcd	6.11 efg	11.01 de	17.00 cde	18.97 cde
W_2S_0	3.50 def	5.59 g	10.04 efg	15.24 efg	17.55 ef
W_2S_1	3.68 cde	6.65 de	12.49 c	17.58 bcd	19.75 cd
W_2S_2	4.13 ab	7.81 b	13.60 b	19.35 ab	21.77 ab
W_2S_3	3.60 cdef	5.87 fg	10.73 def	16.13 def	18.06 def
W_3S_0	2.91 g	5.52 g	9.67 fg	13.82 g	15.59 g
W_3S_1	3.27 fg	6.45 ef	10.10 efg	15.59 defg	18.11 def
W_3S_2	3.46 ef	7.08 cd	11.22 d	16.54 de	19.14 cde
W_3S_3	3.20 fg	5.98 fg	9.02 g	14.08 fg	16.38 fg
LSD $_{(0.05)}$	0.41	0.59	1.08	2.11	1.85
CV (%)	6.64	5.28	5.6	7.43	5.8

In a column means with the same letter did not significantly differ from each other at $p<0.05$. Here, W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture, W_3: 50% evapotranspiration moisture; S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid.

Number of branches plant^{-1}

Different moisture levels and salicylic acid showed significant differences due to their combined effect on the number of branches plant^{-1} of tomato at 30, 40, 50, 60, and 70 DAT. At 70 DAT, the maximum number of branches plant^{-1} is 22.54 was recorded from the W_1S_2 treatment combination which was statistically similar to W_2S_2 at 70 DAT. The minimum number of branches plant^{-1} 15.59 at 70 DAT was found from the W_3S_0 treatment combination, which was statistically identical with W_2S_0, and W_3S_3 at 70 DAT. At 50 DAT, the minimum number of branches plant^{-1} 9.02 was found from the W_3S_3 treatment combination, which was statistically similar to W_2S_0, W_3S_0 and W_3S_1 (Table 3). Nezhad *et al.* (2014) found that moisture and salicylic acid showed significant differences due to their combined effect on the number of branches plant^{-1} of tomato. Salicylic acid treatment has been observed to enhance cell division and cell expansion (Hayat *et al.,* 2005). The exogenous application of salicylic acid as a foliar spray has been documented to enhance growth characteristics in chickpeas (Imami *et al.,* 2011) and sweet basil (Damalas, 2019).

Table 4. Effect of different levels of moisture and salicylic acid on leaf area and SPAD value of tomato at flowering stage and 30 days after flowering (DAF).

Treatment	Leaf area (cm^2) and SPAD value of tomato at flowering stage and 30 days after flowering			
	Leaf area at first flowering	Leaf area 30 at DAF	SPAD value at first flowering	SPAD value at 30 DAF
W_1S_0	191.2 abcde	180.6 abcd	45.00 bc	41.95 abc
W_1S_1	201.0 ab	186.3 ab	47.97 ab	44.07 a
W_1S_2	205.3 a	193.2 a	49.73 a	45.66 a
W_1S_3	197.8 abc	182.3 abcd	46.93 ab	42.79 ab
W_2S_0	183.0 bcdef	176.0 bcd	39.28 def	35.66 de
W_2S_1	186.9 bcdef	183.6 abc	41.40 cde	37.13 de
W_2S_2	194.3 abcd	1917 ab	42.73 cd	39.08 bcd
W_2S_3	184.8 bcdef	178.9 abcd	40.08 def	38.25 cde
W_3S_0	170.9 f	165.9 d	37.13 f	34.34 e
W_3S_1	179.3 def	180.6 abcd	38.88 ef	35.20 de
W_3S_2	182.2 cdef	184.3 abc	39.00 def	36.29 de
W_3S_3	173.5 ef	168.3 cd	37.41 f	35.21 de
LSD (0.05)	18.23	16.87	3.76	4.41
CV (%)	5.74	5.5	5.27	6.71

In a column means with the same letter did not significantly differ from each other at $p<0.05$. Here, W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture, W_3: 50% evapotranspiration moisture; S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid.

Leaf area (cm^2) and SPAD value

The leaf area and SPAD value of the tomato showed significant differences due to the combined effect of moisture stress and salicylic acid at the flowering stage and 30 days after flowering. At the flowering stage and 30 days after flowering, the maximum leaf area (205.3 cm$^{2)}$ and (193.2 cm$^{2)}$ and also SPAD value (49.73) and (45.66), respectively was recorded from the W_1S_2 treatment combination which was statistically similar to W_1S_1, W_1S_3, W_2S_2 and W_1S_0 at the flowering stage; W_1S_1, W_2S_1, W_3S_2, W_1S_3, W_1S_0, W_2S_3, at 30 days after flowering, whereas the minimum leaf area 170.9 and 165.9 cm^2 and SPAD value 37.13 and 34.4 respectively was observed from W_3S_0 treatment combination (Table 4). One of the direct effects of drought stress is a disruption in cell division and cell elongation processes (Ilyas *et al.,* 2017; Ullah *et al.,* 2019), which might be responsible for the reduction in plant leaf area. Plant height, as well as leaf area progressively reduced with decreasing soil moisture regime in grape tomato plants (Chakma *et al.*, 2021).

The foliar application of salicylic acid enhanced the leaf area of sugarcane (Javaheri *et al.,* 2012). Hayat *et al.* (2010) and Chakma *et al.* (2021) revealed that the exogenous application of SA improved the growth response of tomato plants grown under drought stress. SA applications also improved SPAD reading levels (Yildirim *et al.*, 2009). Our results also support those of Ghai *et al.* (2002) in rutabaga, Moharekar *et al.* (2003) in wheat observed that applying SA to plant leaves consistently increased their chlorophyll content.

Table 5. Effect of different levels of moisture and salicylic acid on dry matter content and relative water content of tomato.

Treatment	Dry matter content (%)	Relative water content (%)
W_1S_0	16.91 cde	7.67 f
W_1S_1	18.20 b	7.58 ef
W_1S_2	19.57 a	8.66 ef
W_1S_3	17.61 bcd	10.00 e
W_2S_0	14.65 fg	25.33 cd
W_2S_1	16.37 de	28.67 bcd
W_2S_2	17.97 bc	26.67 cd
W_2S_3	15.79 ef	23.33 d
W_3S_0	10.40 i	36.65 a
W_3S_1	12.56 h	34.67 ab
W_3S_2	14.25 g	30.69 bcd
W_3S_3	11.67 hi	31.64 bc
LSD $_{(0.05)}$	1.29	1.46
CV (%)	4.91	6.45

In a column means with the same letter did not significantly differ from each other at $p<0.05$. Here, W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture, W_3: 50% evapotranspiration moisture; S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid.

Relative Water Content (%) and Dry matter of leaf (%)

Different levels of moisture and salicylic acid combined treatments showed significant differences on relative water content and dry matter of leaf. The highest relative water content, 36.65% was found from W_3S_0 than other treatment combinations while the lowest 7.67% from W_1S_0 treatment which was statistically similar with W_1S_1 and W_1S_2, whereas the greater dry matter content of leaf recorded from W_1S_2 19.57% and lower value 10.40% was from W_3S_0 treatment (Table 5). Pervez *et al.* (2009) similarly found that the dry weight reduced significantly under the drought stress. Seed pretreatment with salicylic acid induced a reduction sodium absorption and toxicity, which is further reflected in low membranes injury, high water content and dry matter production. The first sign of drought stress is decline in the RWC of plant cells, which inhabits water flow to new cell enlargement sites in tomato (Maggio *et al.,* 2007) and peach (Kongsri *et al.,* 2014).

Yield contributing features

Tomatoes are very sensitive to water deficits, especially at flowering and fruit development stages and terminal drought causes the abscission of flowers and fruits (Akbari Nodehi *et al.,* 2013). Drought is a major abiotic stress causing morphological, biochemical and physiological damage to the crop which can be mitigated by foliar application of salicylic acid (Fahad *et al*., 2017; Ullah *et al*., 2019).

The results presented in Table 6 revealed that the foliar application of salicylic acid and different levels of moisture had significant differences on number of flower clusters plant^{-1}, number of flowers cluster^{-1}, number of flowers plant^{-1} and number of fruits cluster^{-1}.

Table 6. Effect of different levels of moisture and salicylic acid on number of flower cluster plant^{-1}, number of flower cluster^{-1}, number of flowers plant^{-1} and number of fruits cluster^{-1}.

Treatment	No. of flower clusters plant^{-1}	No. of flowers cluster^{-1}	No. of flowers plant^{-1}	No. of fruits cluster^{-1}	No. of fruits plant^{-1}
W_1S_0	14.20 cde	4.98 cd	70.94 d	3.43 abc	32.10 c
W_1S_1	16.24 ab	5.40 bc	87.64 b	3.50 ab	35.84 ab
W_1S_2	17.43 a	5.90 a	102.8 a	3.65 a	36.85 a
W_1S_3	15.35 bcd	5.08 cd	78.00 c	3.49 ab	35.05 ab
W_2S_0	12.85 fg	4.89 de	62.65 e	3.26 bcde	32.42 c
W_2S_1	14.09 def	5.18 bcd	72.96 cd	3.44 ab	32.03 c
W_2S_2	15.47 bc	5.56 ab	85.73 b	3.53 ab	35.44 ab
W_2S_3	13.35 efg	5.05 cd	67.41 de	3.30 bcd	32.44 c
W_3S_0	10.50 i	3.93 g	41.24 h	2.98 e	21.85 f
W_3S_1	11.50 hi	4.19 fg	48.01 g	3.13 cde	24.57 de
W_3S_2	12.37 gh	4.52 ef	55.86 f	3.24 bcde	26.35 d
W_3S_3	10.62 i	3.99 g	42.41 gh	3.07 de	22.95 ef
LSD $_{(0.05)}$	1.28	0.45	6.04	0.31	2.16
CV (%)	5.51	5.46	5.25	5.44	4.18

In a column means with the same letter did not significantly differ from each other at $p<0.05$. Here, W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture, W_3: 50% evapotranspiration moisture, S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid.

The treatment of 75ppm salicylic acid with 100% evapotranspiration (W_1S_2) moisture showed the highest values for all parameters, whereas all the phenotypic parameters reduced with decreasing soil moisture. So, the treatment combination of W_1S_2 showed the highest number of flower clusters plant^{-1} 17.43, number of flowers plant^{-1} 102.8, number of fruits cluster^{-1} 3.66 and number of fruits cluster^{-1} 3.65. However, W_3S_0 treatment combination resulted the lowest values for all the parameters. This study agreed with the findings of Salehi *et al.* (2011). Besides, Hayat *et al.* (2010) revealed that exogenous application of SA improved the growth response of tomato plant grown under drought stress. On the other hand, Senaratna *et al.* (2000) observed that higher dose of SA (concentrations over 1 mM) was unable to exhibit effective results, whereas lower concentration of SA showed positive results in bean and tomato grown under drought stress.

The number of fruits plant^{-1} was the highest when SA was applied at 75ppm concentration along with 100% evapotranspiration moisture 36.85 followed by W_2S_2 (Table 6). This is similar to the findings of Javaheri *et al.* (2014) who found that salicylic acid significantly influenced the number of fruits plant^{-1} of tomato. Besides, W_1S_2 treatment resulted in significantly longer fruits (6.33) than all other treatments.

In this study, fruit length progressively decreased with decreasing soil moisture attaining 3.48 cm in W_3S_0 treatment. The similar trend was evident in case of diameter of the fruits which supported Javaheri *et al.* (2014) who found that salicylic acid significantly influenced diameter of fruit of tomato.The weight of individual fruit was significantly highest in W_1S_2, W_1S_0, W_1S_1 and W_1S_3 69.06g treatments (Table 7). The interactive effect of salicylic acid and different levels of moisture on individual fruit weight indicated that the level of decrease was significantly higher in drought stress when subjected to low moisture levels 15 20% which was supported by (Giannakoula and Ilias, 2013).

The combined effect of SA and evapotranspiration moisture (%) had a significant effect on yield plant^{-1}, which was maximized at W_1S_2 treatment combination (2.35 kg) followed by W_2S_2 and lowest 1.15 kg at W_3S_0

treatment followed by W_3S_3 (Table 7). Pervez *et al.* (2009) observed that water stress throughout the growing season significantly reduced yield and fruit size. Kazemi (2014) also found that application of salicylic acid increased yield plant^{-1} of tomato under drought stress. It is evident from the present study that growth and fruit yield parameters of tomato were significantly decreased when plants were grown under severe drought stress at 50 % FC. These findings are in close agreement with Kuscu *et al.* (2014), who also reported tomato are very sensitive to water-deficit stress.

Table 7. Effect of different levels of moisture and salicylic acid on yield contributing features of tomato.

Treatment	Length of fruit (cm)	Diameter of fruit (cm)	Weight of individual fruit (g)	Yield plant^{-1} (kg)
W_1S_0	4.94 cd	5.22 bc	67.26 a	2.18 bc
W_1S_1	5.80 b	5.44 b	68.83 a	2.21 bc
W_1S_2	6.33 a	6.60 a	69.06 a	2.35 a
W_1S_3	5.06 c	5.63 b	66.67 a	2.16 bc
W_2S_0	5.05 c	5.46 b	57.85 bc	1.86 d
W_2S_1	5.91 b	6.29 a	60.07 b	2.15 bc
W_2S_2	6.11 ab	6.32 a	61.06 b	2.25 ab
W_2S_3	5.19 c	5.54 b	60.77 b	2.13 c
W_3S_0	3.48 f	3.77 e	52.55 d	1.15 g
W_3S_1	4.58 d	4.70 d	57.08 b-d	1.40 f
W_3S_2	4.66 d	4.81 cd	57.71bc	1.52 e
W_3S_3	4.04 e	4.43 d	53.85 cd	1.24 g
LSD $_{(0.05)}$	0.38	0.48	4.66	0.11
CV (%)	4.45	5.26	4.50	3.56

In a column means with the same letter did not significantly differ from each other at $p<0.05$. Were, W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture, W_3: 50% evapotranspiration moisture, S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid.

Fruit quality features

Data regarding vitamin C, lycopene content, brix, ash content and protein content of tomato were significantly higher under the combined effect of different levels of moisture and salicylic acid (Table 8). Plants growing in W_1S_1 showed the superior vitamin C was 5.61 mg, which value statistically similar with W_1S_2, W_1S_0 and W_1S_3 while the least vitamin-C, 3.25 mg was seen in W_3S_3. These results are in line with the Baek *et al.* (2021) who found that lower concentration of salicylic acid enhanced the ascorbic acid content in tomatoes. By releasing plant stressors, SA assisted to raise the vitamin-C content of tomato fruits, which is in accordance with Naeem *et al.* (2020) who noted that SA has defensive and protective properties. The maximum lycopene content 4.98 mg was achieved in W_1S_2 treatment which was statistically similar with W_1S_1, W_1S_0 and W_1S_3 whereas the minimum lycopene content (4.01 mg was found in W_3S_3. SA had positive effect on lycopene content of tomato fruit. Plants treated with SA at a comparatively higher dose (1.2 mM) continuously increased lycopene and carotenoids while maintaining fruit quality characteristics (Mandal *et al.*, 2016). During ripening, lycopene content typically rises primarily as a result of carotenoids building up and chlorophyll gradually degrading (Brandt *et al.*, 2006). The findings of this study are consistent with other of those studies (Javanmardi & Kubota, 2006; Su *et al.*, 2015). The brix percentage 4.51 was superior in the treatment combination of W_1S_2 while the least percentage of brix 4.25 was observed in W_3S_3. TSS is the most important fruit quality parameter responsible for maintaining the flavour and volatile content of fruits. The findings of the current research are similar with the findings of Naz *et al.*, (2020) who concluded that foliar application of SA exogenously increased the TSS content of tomato fruits. The function of SA in membrane permeability may have contributed to the increase in TSS (% brix) of fruits by enabling photosynthetic assimilation, mineral content availability, and the translocation of more photo-assimilates.

Table 8. Effect of different levels of moisture and salicylic acid on fruit quality attributes of tomato.

Treatment	Vitamin-C (mg/100g)		Lycopene (mg/100g)		Brix (%)		Ash content (%)		Protein content (%)	
W_1S_0	5.21	ab	4.85	a	4.35	d	0.47	b	2.45	b
W_1S_1	5.54	a	4.88	a	4.38	c	0.53	b	2.45	b
W_1S_2	5.61	a	4.98	a	4.51	a	0.56	a	2.52	a
W_1S_3	5.19	ab	4.76	ab	4.41	b	0.54	b	2.35	b
W_2S_0	4.85	b	4.51	b	4.30	f	0.48	b	2.20	cd
W_2S_1	4.94	b	4.69	ab	4.32	e	0.45	bc	2.25	c
W_2S_2	4.77	b	4.53	b	4.40	b	0.44	bc	2.19	cde
W_2S_3	3.84	bc	4.49	b	4.37	c	0.43	c	2.18	cde
W_3S_0	3.53	c	4.25	c	4.27	g	0.39	d	2.15	de
W_3S_1	3.59	bc	4.37	bc	4.28	g	0.37	d	2.18	cde
W_3S_2	3.40	cd	4.35	bc	4.31	ef	0.37	d	2.14	de
W_3S_3	3.25	de	4.01	d	4.25	h	0.36	d	2.10	e
LSD $_{(0.05)}$	0.25		0.16		0.05		0.02		0.04	
CV (%)	3.97		2.94		1.35		4.29		2.20	

In a column means with the same letter did not significantly differ from each other at $p<0.05$. Were, W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture, W_3: 50% evapotranspiration moisture, S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid.

The maximal percentage of ash content 0.56 was found in W_1S_2 while the minimal percentage of ash content 0.36 was observed in W_3S_3. These results are in accordance with the Ride *et al.* (2024) who found positive effect of SA on the enhancement of ash content in tomatoes. The treatment combination W_1S_2 exposed the highest protein percentage 2.52 where the lowest protein percentage 2.10 was revealed in W_3S_3. The application of SA increased the protein content in tomato. This is because salicylic acid stimulates the enzymes that produce protein and aids in the fruit's absorption of essential components. The application of SA helps plants to generate more fruit biomass and alters membrane permeability, which promotes protein synthesis, according to Ride *et al.* (2024).

Conclusion

Above findings revealed that the growth, productivity and nutritional quality attributes of tomato is gradually decrease by the increasing of drought stress and this reduction rate is minimize by exogenous foliar application of salicylic acid. The combination of W_1S_2 (100% evapotranspiration moisture and 75 ppm salicylic acid) is more suitable in consideration of growth, yield and quality properties. However, 75 ppm salicylic acid highlights its efficiency as efficient and eco-friendly mitigating agent for sustainable agriculture supporting a favorable approach to enhance productivity and fruit quality of tomato under different moisture stress.

Acknowledgement

This work was financially supported by the R&D (Agriculture and Environment Group), Ministry of Science and Technology, Government of the People's Republic of Bangladesh. The authors are thankful for financial support to carry out this research.

References

Akbari Nodehi D, Azizi Zahan AA, Rezaei R. 2013. The study of relationship between yield and water uptake of tomato in Mazandaran. Water Researches in Agriculture **27(4),** 503-512.

Arya SP, Mahajan M, Jain P. 2000. Non-spectrophotometric methods for the determination of Vitamin C. Analytica Chimica Acta **417,** 1–14. https://doi.org/10.1016/S0003-2670(00)00909-0

Baek MW, Choi HR, Jae LY, Kang HM, Lee OH, Jeong CS Tilahun S. 2021. Preharvest Treatment of Methyl Jasmonate and Salicylic Acid Increase the Yield, Antioxidant Activity and GABA Content of Tomato. Agronomy **11,** 2293. https://doi.org/10.3390/agronomy11112293

BARC. 2012. Fertilizer Recommendation Guide (FRG). Bangladesh Agricultural Research Council, Dhaka.

Brandt S, Pék Z, Barna É, Lugasi A, Helyes L. 2006. Lycopene content and colour of ripening tomatoes as affected by environmental conditions. Journal of the Science of Food and Agriculture **86,** 568–572. https://doi.org/10.1002/jsfa.2390

Cao F, Guan C, Dai H, Li X, Zhang Z. 2015. Soluble solids content is positively correlated with phosphorus content in ripening strawberry fruits. Scientia Horticulturae **195,** 183–187. https://doi.org/10.1016/j.scienta.2015.09.018

Carmassi G, Incrocci L, Incrocci G, Pardossi A. 2007. Non-destructive estimation of leaf area in *Solanum lycopersicum* L. and gerbera (*Gerbera jamesonii* H. Bolus). Agricultura Mediterranea **137,** 172–176.

Chakma R, Biswas A, Saekong P, Ullah H, Datta A. 2021. Foliar Application and Seed Priming of Salicylic Acid Affect Growth, Fruit Yield, and Quality of Grape Tomato under Drought Stress. Scientia Horticulturae **280,** 109904. https://doi.org/10.1016/j.scienta.2021.109904

Chakma R, Biswas A, Saekong P, Ullah H, Datta A. 2021. Foliar application and seed priming of salicylic acid affect growth, fruit yield, and quality of grape tomato under drought stress. Scientia Horticulturae **280,** 109904. https://doi.org/10.1016/j.scienta.2021.109904

Chanthini KM, Senthil-Nathan S, Pavithra G, Asahel A, Malarvizhi P, Murugan P, Deva-Andrews A, Sivanesh H, Stanley-Raja V, Ramasubramanian R. 2022. The Macroalgal Biostimulant Improves the Functional Quality of Tomato Fruits Produced from Plants Grown under Salt Stress. Agriculture **13,** 6. https://doi.org/10.3390/agriculture13010006

Chavoushi M, Najafi F, Salimi A, Angaji SA. 2020. Effect of Salicylic Acid and Sodium Nitroprusside on Growth Parameters, Photosynthetic Pigments and Secondary Metabolites of Safflower under Drought Stress. Scientia Horticulturae **259,** 108823. https://doi.org/10.1016/j.scienta.2019.108823

Damalas CA. 2019. Improving drought tolerance in sweet basil (*Ocimum basilicum*) with salicylic acid. Scientia Horticulturae **246,** 360–365. https://doi.org/10.1016/j.scienta.2018.11.005

El-Mageed TA, Semida WM, Rady MM. 2017. Moringa Leaf Extract as Biostimulant Improves Water Use Efficiency, PhysioBiochemical Attributes of Squash Plants under Deficit Irrigation. Agricultural Water Management **193,** 46–54. https://doi.org/10.1016/j.agwat.2017.08.004

Fahad S, Bajwa AA, Nazir U, Anjum SA, Farooq A, Zohaib A, Sadia S, Nasim W, Adkins S, Saud S, Ihsan MZ, Alharby H, Wu C, Wang D, Huang J. 2017. Crop production under drought and heat stress: plant responses and management options. Frontiers in Plant Science **8,** 1147. https://doi.org/10.3389/fpls.2017.01147

Farooq M, Wahid A, Kobayashi NSMA, Fujita DBSMA, Basra SMA. 2009. Plant Drought Stress: Effects, Mechanisms and Management. *In Sustainable Agriculture*; Springer: Dordrecht, The Netherlands, 153–188 p.

Ghai N, Setia RC, Setia N. 2002. Effects of paclobutrazol and salicylic acid on chlorophyll content, hill activity and yield components in (*Brassica napus* L.). Phytomorphology **52,** 83-87.

Giannakoula AE, Ilias IF. 2013. The effect of water stress and salinity on growth and physiology of tomato (*Lycopersicon esculentum* Mill.). Archives of Biological Sciences **65(2),** 611-620. https://doi.org/10.2298/ABS1302611G

Gomez KA, Gomez AA. 1984. Statistical procedures for agricultural research (2 ed.). John wiley and sons, NewYork, 680 p.

Gorni PH, Brozulato MO, Lourenção RS, Konrad ECG. 2017. Increased Biomass and Salicylic Acid Elicitor Activity in Fennel (*Foeniculum vulgare* Miller). Brazalian Journal of Food Technology **20,** 1-7. https://doi.org/10.1590/1981-6723.17216

Hasanuzzaman M, Fugita M, Oku H, Islam MT. 2019. Plant Tolerance to Environmental Stress: Role of Phytoprotectants, 1st ed.; CRC Press: Boca Raton, FL, USA, p. 488. https://doi.org/10.1201/9780203705315

Hayat Q, Hayat S, Irfan M, Ahmad A. 2010. Effect of exogenous salicylic acid under changing environment. Environmental and Experimental Botany **68,** 14–25 https://doi.org/10.1016/j.envexpbot.2009.08.005

Hayat S, Fariduddin Q, Ali B, Ahmad A. 2005. Effect of salicylic acid on growth and enzyme activities of wheat seedlings. Acta Agronomica Hungarica **53,** 433–437. https://doi.org/10.17582/journal.pjar/2020/33.5.789.797

Ilyas N, Gull R, Mazhar R, Saeed M, Kanwal S, Shabir S, Bibi F. 2017. Influence of salicylic acid and jasmonic acid on wheat under drought stress. Communications in Soil Science and Plant Analysis **48,** 2715–2723. https://doi.org/10.1080/00103624.2017.1418370

Imami S, Jamshidi S, Shahrokhi S. 2011. Salicylic acid foliar and soil application effect on chickpea resistance to chilling stress. In: International Conference on Biology, Environment and Chemistry. IPCBEE, Volume 24. IACSIT Press, Singapore.

Javaheri M, Dadar A, Babaeian M. 2014. Effect of Salicylic Acid Spray in Seedling Stage on Yield and Yield Components of Tomato. Journal of Applied Science & Agriculture **9(3),** 924-928.

Javaheri M, Mashayekhi K, Dadkhah, Alireza, Tavallaee FZ. 2012. Effects of salicylic acid on yield and quality characters of tomato fruit (*Lycopersicon esculentum* mill.). International Journal of Agriculture and Crop Sciences **4,** 1184-1187.

Javanmardi J, Kubota C. 2006. Variation of lycopene, antioxidant activity, total soluble solids and weight loss of tomato during postharvest storage. Postharvest Biology and Technology **41,** 151–155. https://doi.org/10.1016/j.postharvbio.2006.03.008

Jones HG, Sutherlan RA. 1991. Stomatal Control of Xylem Embolism. Plant Cell Environment **11,** 11–121. https://doi.org/10.1111/j.1365-3040.1991.tb01532.x

Kazemi M. 2014. Effect of Foliar Application with Salicylic Acid and Methyl Jasmonate on Growth, Flowering, Yield and Fruit Quality of Tomato. Agricultural and Food Science **3(2),** 154-158.

Khan MIR, Fatma M, Per TS, Anjum NA, Khan NA. 2015. Salicylic acid-induced abiotic stress tolerance and underlying mechanisms in plants. Frontiers in Plant Science **6,** 462. https://doi.org/10.3389/fpls.2015.00462

Kjeldahl J. 1883. Neue methode zur bestimmung des stickstoffs in organischen korpern. Fresenius' Journal of Analytical Chemistry **22,** 366–382. http://dx.doi.org/10.1007/BF01338151

Kongsri S, Boonprakob U, Byrne DH. 2014. Assessment of morphological and physiological responses of peach rootstocks under drought and aluminum stress. Acta Horticulturae **1059,** 229–236. https://doi.org/10.17660/ActaHortic.2014.1059.30

Kuscu H, Turhan A, Demir A. 2014. The response of processing tomato to deficit irrigation at various phenological stages in a sub-humid environment. Agricultural Water Management **133,** 92–103. https://doi.org/10.1016/j.agwat.2013.11.008

Li N, Wu X Zhuang W Xia L Chen Y, Wu C, Rao Z, Du L, Zhao R, Yi M. 2021. Tomato and lycopene and multiple health outcomes: Umbrella review. Food Chemistry **343,** 128396. https://doi.org/10.1016/j.foodchem.2020.128396

Mady M. 2009. Effect of foliar application with salicylic acid and vitamin e on growth and productivity of tomato (*Lycopersicon esculentum,* Mill.) plant. Journal of Plant Production **34,** 6715–6726. https://doi.org/10.21608/jpp.2009.118654

Maggio A, Raimondi G, Martino A. 2007. Salt stress response in tomato beyond the salinity tolerance threshold. Environmental and Experimental Botany **59(3),** 276–282. https://doi.org/10.1016/j.envexpbot.2006.02.002

Mandal D, Pautu L, Hazarika TK, Nautiyal BP, Shukla AC. 2016. Effect of Salicylic Acid on Physico-chemical Attributes and Shelf Life of Tomato Fruits at Refrigerated Storage. International Journal of Bio-Resource and Stress Management **7,** 1272–1278. https://doi.org/10.23910/IJBSM/2016.7.6.1683b

Moharekar ST, Lokhande SD, Hara T, Tanaka R, Tanaka A, Chavan PD. 2003. Effect of salicylic acid on chlorophyll and carotenoid contents of wheat and moong seedlings. Photosynthetica **41,** 315-317.

Naeem M, Basit A, Ahmad I. 2020. Effect of Salicylic Acid and Salinity Stress on the Performance of Tomato Plants. Gesunde Pflanzen **72,** 393–402. https://doi.org/10.1007/s10343-020-00521-7

Nagata M, Yamashita I. 1992. Method Tomato Masayasu * National NAGATA * and Ichiji YAMASHITA * of Vegetables rnamental Plants and Tea , Ministry of Agriculture, Forestry and Fisheries, Forestry **39,** 1–4. https://doi.org/10.3136/nskkk1962.39.925

Naz S, Naqvi SAH, Siddique B. 2020. Exogenous Application of Selected Antioxidants and Phyto Development Directors Influenced the Development, Output and Biochemical Attributes of Tomato (*Lycopersicum esculentum* Mill.). Pakistan Journal of Agricultural Research **33,** 789–797. http://dx.doi.org/10.17582/journal.pjar/2020/33.5.789.797

Nezhad AH, Hamid RMHR, Dahmardeh M, karimian MA. 2014. Effect of foliar application of salicylic acid anddrought stress on quantitative yield of mungbean(*Vigna radiata* L.), Journal of Novel Applied Sciences **3,** 512-515.

Pervez MA, Ayub CM, Khan HA, Shahid MA, Ashraf I. 2009. Effect of drought stress on growth, yield and seed quality of tomato (*Lycopersicon esculentum* l.). Pakistan Journal of Agricultural Sciences **46(3),** 174-178.

Ride RS, Ahmed S, Monami SA, Sarkar MD. 2024. Improvement in growth, yield, and fruit quality of tomato by foliar application of humic and salicylic acids. Research Square, PREPRINT **(1).** https://doi.org/10.21203/rs.3.rs-4964537/v1

Salehi S, Khajehzadeh A, Khorsandi F. 2011. Growth of Tomato as Affected by Foliar Application of Salicylic Acid and Salinity. American-Eurasian Journal of Agricultural & Environment Sciences **11(4),** 564-567.

Senaratna T, Touchell D, Bunn E, Dixon K. 2000. Acetyl Salicylic Acid (Aspirin) and Salicylic Acid Induce Multiple Stress Tolerance in Bean and Tomato Plants. Plant Growth Regulator **30,** 157–161.

Sharma S, Chen C, Khatri K, Rathore MS, Pandey SP. 2019. Gracilaria Dura Extract Confers Drought Tolerance in Wheat by Modulating Abscisic Acid Homeostasis. Plant Physioogy and Biochemistry **136,** 143–154. https://doi.org/10.1016/j.plaphy.2019.01.015

Shemi R, Wang R, Gheith ESM, Hussain HA, Hussain S, Irfan M, Wang L. 2021. Effects of Salicylic Acid, Zinc and Glycine Betaine on Morpho-Physiological Growth and Yield of Maize under Drought Stress. Scientific Report **11,** 3195. https://doi.org/10.1038/s41598-021-82264-7

Sirisuntornlak N, Ghafoori S, Datta A, Arirob W. 2019. Seed Priming and Soil Incorporation with Silicon Influence Growth and Yield of Maize under Water-Deficit Stress. Archive of Agronomy and Soil Science **65,** 197–207. https://doi.org/10.1080/03650340.2018.1492713

Smart RE, and Bingham GE. 1974. Rapid estimates of relative water content. Plant Physiology **53(2),** 258–260. https://doi.org/10.1104/pp.53.2.258

Su L, Diretto G, Purgatto E, Danoun S, Zouine M, Li Z, Roustan JP, Bouzayen M, Giuliano G, Chervin C. 2015. Carotenoid accumulation during tomato fruit ripening is modulated by the auxin-ethylene balance. BMC Plant Biology **15,** 1–12.

Trivedi K, Vijay Anand KG, Kubava D, Patidar R, Ghosh A. 2018. Drought Alleviatory Potential of Kappaphycus Seaweed Extract and the Role of the Quaternary Ammonium Compounds as Its Constituents Towards Imparting Drought Tolerance in (*Zea mays* L). Journal of Applied Phycology **30,** 2001–2015. https://doi.org/10.1007/s10811-017-1375-0

Ullah H, Santiago-Arenas R, Ferdous Z, Attia A. Datta A. 2019. Improving water use efficiency, nitrogen use efficiency, and radiation use efficiency in field crops under drought stress. Advances in Agronomy **156,** 109-157. https://doi.org/10.1016/bs.agron.2019.02.002

World Population Review (WPR). 2022. Tomato Production by country 2024. https://worldpopulationreview.com/country-rankings/tomato-production-by-country.

Yildirim E, Dursun A. 2009. Effect of foliar salicylic acid applications on plant growth and yield of tomato under greenhouse conditions. Acta Horticulturae **807,** 395-400. https://doi.org/10.17660/ActaHortic.2009.807.56

Yildirim E, Guvenc I, Karatas A. 2006. Effect of different numbers foliar salicylic acid applications on plant growth and yield of cucumber. VI. Turkey National Vegetable Symposium. Kahramanmaras, Turkey, 90-94 p.