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Impact of the Application of Some Friendly Environment Materials on Tomato Plants Grown under High Temperature Conditions

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Abstract

Providing human food has become the biggest challenge during climate change. Two Field experiments were conducted to evaluate the effect of some friendly materials i.e., seaweed extract at 100 and 200 ml/l, Jasmonic acid at 100 and 200 mg/l, Brassinolide at 100 and 200 mg/l and salicylic acid at 100 and 200 mg/l on growth, growth performance, flowering, fruit yield, fruit quality, chemical compositions and bio constituents indicators for heat stress tolerance of Tomato plants (*Solanum lycopersicum Mill*.) grown under heat stress conditions. Foliar application of tomato plants with seaweed extract at 200 ml/l significantly increased plant height, number of leaves, number of branches /plant, total leaf area cm^2/plant, leaves and shoots dry weights and leaves/ shoots ratio during 2021 and 2022 seasons. Flowering characteristics applied were increased with different treatments during both seasons. In addition, yield and yield components were increased with different applications during both seasons. The superior was the seaweed extract at 200 ml/l during the first and second seasons. Plant chemical compositions i. e, (N, P, K, Fe, Zn) Also, some bio constituents stress indicators (proline contents, total phenols, total free amino acids and total indoles) were increased with different applications especially seaweed extract at 200 ml/l during both seasons. Using friendly material especially seaweed extract can be exploited for high growth, mineral, fruit yield and yield components and fruit chemical quality under heat stress conditions.

Keywords: Seaweed extract, Jasmonic acid, Brassinolide, salicylic acid, proline, total indole

Introduction

Tomato (*Solanum lycopersicum Mill*.) is the main vegetable crop grown all over the world. In the lists of food commodities tomato placed at a ninth position and is the second most essential vegetable crop around the world, in the next to potato. In Egypt, the late summer market tomato crop is yielded from transplants raised from open field during May up to July during this period, temperature can exceed 35°C under field condition resulting in either non-uniform growth and poor fruit yield or even complete failure of tomato cropping in a great part of the cultivated area **(Fahad *et al*., 2017; Wen *et al.* 2019)**. High-temperature tension in tomatoes results in flower abortion, a small set of fruits, and weight **(Rodriguez-Ortega *et al*. 2016 ;Xu *et al*. 2017).** These conditions caused a harmful in the performance of all reproductive organs, pollen viability, pollen number, female fertility, fruit set, and flower number per inflorescence **Ruggieri *et al.* (2019) and Lee *et al.* (2022).** For all these problems recently most of the researchers are trying to get reason for decreasing these conditions. Seaweed extracts (SWE) are widely used in agriculture for their beneficial effects on plant growth and tolerance enhancement to biotic and abiotic stresses and used as supplements of nutrients, in agriculture and horticulture, bio stimulants or bio fertilizers to boost the growth and yield of plants **Sangha *et al.* (2014).** Algae extracts significantly increased tomato yield and the ability of leaves to photosynthesize and reduce the time of ripening of fruits. Moreover, it increases the firmness of tomato fruits **Yao *et al.* (2020); Carmody *et al.* (2020).** Seaweed extract significantly increased mineral elements (N, P and K) on tomato plants compared with control **Badr *et al.* (2019)**. Jasmonic acid (JA) is involved in many physiological and biochemical processes associated with plant growth and development, as well as stress resistance **Ali and Baek (2020); Kaushik *et al.*(2022).** Foliar spray with Jasmonic acid significantly increased shoot fresh and dry weight and photosynthetic pigments (a, b and total carotenoid) in leaves of strawberry plants **Imanparast *et al.* (2013);Yosefi and Javadi (2020).** Brassinolide (BR) are a class of phytohormones that control a variety of biological functions that enable plants to withstand diverse stressors **Raza *et al. (*2019), Ahanger *et al.* (2020); Jakhar *et al. (*2022); Surgun-Acar.** Salicylic acid (SA) plays a major role in many physiological processes of the plant, with SA being involved in resistance to biotic and a biotic stress **Shaheen *et al. (*2018); Liu *et al.* (2022).** In addition, salicylic acid acts to improve tomatoes' ability to tolerate heat by using it as external applying, it decreases the dropping of flowering, improves the yield, during the summer season, it can be also, increase the tomato growth period **Ahmed *et al.* (2016), Sharma *et al. (*2021);Aires *et al.* (2022).**Therefore, the main goal of this study was to investigate the effects of the combined application of foliar spraying of seaweed extract Jasmonic acid, brassinosteroids and salicylic acid on Tomato plants (*Solanum lycopersicum Mill*) grown under high temperature conditions on growth performance, bio constituents defense metabolism, electronic microscope transmission, abscission, flower setting and yield and yield components as well as fruit quality.

Materials and Methods

Two field experiments were conducted at the experimental farm station of the faculty of Agric., Benha Univ., Egypt. during late summer seasons of 2021 and 2022 in which, during this period, temperature can exceed 35°C under field conditions.

Before planting, random soil samples from the experimental soil were gathered and analyses for their physical and chemical characteristics at a depth of 0–30 cm. The protocols were used to determine the mechanical analysis of **Jackson (1973).**

Table 1. Physical and chemical properties of the experimental soil during 2021 and 2022 seasons.

Soil analysis	Seasons	
	2021	2022
Available N (mg/kg^{-1})	22.9	25
Available P (mg/kg^{-1})	9.52	11
Available K (mg/kg^{-1})	126	124
Particle size distribution (Mechanical analysis)		
Course sand %	6.25	7.12
Find Sand %	24.25	24.35
Silt %	14.10	14.78
Clay %	51.23	51.0
Soil texture	Heavy Clay	Heavy Clay

Transplanting

At the late of April during the two of the experimental seasons, seeds of the tomato two cultivars i.e (Hybrid Alissa and Hybrid 023) were sown transplanting the seedlings took place after 45 days from sowing in the open field at 30 cm apart on one side of ridge 3.5 m long and 0.75 m wide, and the experimental unit area was 10.5M^2 .

Experimental Treatments:

Seaweed extract at 100 ml/l and 200 ml/l., Jasmonic acid at 100 mg/l and 200 mg/l., Brassinolide at 100 mg/l and 200 mg/l, Salicylic acid at 100 mg/l and 200 mg/l as well as Control (Distilled water).

Management through Plant growth:

During the growth and development plants were sprayed 3 times with different assigned treatments, the first one was at 30 days after transplanting and repeated each 15 days intervals, the spraying solution volume was spraying until the solution run off from the plant. All other cultural practices were performed as the recommended.

Measurements and Recorded Data

1) Vegetative Growth Parameters. Different morphological characteristics of tomato plants at 50 days after transplanting following characteristics were inspected, Plant height (cm),at the first internode, number of leaves / plant, number of branches/ plant, leaves dry weight, dry weight of shoots (g) / plant., and total leaves area (cm^2) /plant using the disk method according to **Derieux *et al.* (1973).**

2) Flowering measurements. the following data were recorded:

Start of flower anthesis (days): Number of days passed from transplanting till anthesis of the first flower on the first cluster in tomato.

Total number of flowers/plant. The total number of the opened flowers per plant through the season were recorded for each treatment of tomato plants.

Abscission percentage: was calculated according to the equation:

$$\text{Abscission } \% = \frac{\text{Tot Total No. of formed flowers/plant} - \text{Total No. of setted fruits/plant}}{\text{Total No. of formed flowers / plant}} \times 100$$

Fruit setting percentage: Was calculated according to the following equation:

$$\text{Fruit setting } \% = \frac{\text{No. of setted fruits / plant}}{\text{No. of formed flowers / plant}} \times 100$$

3) Fruit yield and yield components: All harvested fruits (in the marketable color i.e., at the pink to light red stages) of tomato fruits from each treatment all over the season were used to calculate the following parameters: Early yield, Number of early fruits /plant, Early yield (g) / plant, Total number of fruits / plant, Total yield (kg) / plant.

4) Chemical analysis in leaves and fruits:

Total nitrogen were determined according to the method of **Piper (1947),** using microkjeldahl as described by **Horneck and Miller (1998),** then calculated as mg/g dry weight.

Phosphorus, Potassium It was determined colorimetrically according to the method of **Sandell (1950)**. **And Horneck and Hanson (1998),** respectively.

Iron, Zinc and Manganese. were determined according to the method of **A.O.A.C. (1990).**

Total carbohydrates and Total free amino acids were determined according to the method of **Dubois et al., (1956)** and **Muting and Kaiser (1963),** respectively.

Total phenols and total proline concentration were determined by using the Folin Denis reagent as described by **Gutfinger (1981).**

5) Statistical analysis

Analysis of variance of the obtained data from each attribute was computed using the Co-stat, Copyright(c) 1998-2005, software version 6.311. 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.

Results and Discussion

I-Vegetative growth characteristics

Data presented in **Tables (2,3)** show the effects of bio stimulating materials i.e.,(seaweed extract at 100,200 ml/l, Jasmonic acid at 100, 200 mg/l, Brassinolide at 100, 200 mg/l and Salicylic acid at 100, 200 mg/l) on plant height, stem diameter, Num. of branches/plant, Num. of leaves/plant, leaves dry weight (g)/plant, shoots dry weight (g)/plant and SPAD during 2021 and 2022 seasons. The significantly increased value of these traits were excited with the applications of seaweed extract at 200 ml/l on plant height, stem diameters, number of branches/plant when compared with sensitive and resistant control during first and second seasons. While the number of leaves/plant at first season took place with the application of Brassinolide at 200 mg/l and at the second seasons with Jasmonic acid at 200 mg/l. In context seaweed extract at 200 ml/l gave the highest significant increase and SPAD during both experiment seasons. All other treatments increased the above-mentioned traits when compared with sensitive and resistant control during first and second seasons.

In this respect, the obtained significantly increase of the morphological characteristics with these bio stimulating applications attributed to the seaweed extracts (SWEs) are widely used in agriculture for their beneficial effects on plant growth and tolerance enhancement to biotic and abiotic stresses and used as supplements of nutrients, seaweed as a boost to the growth and yield of plants. **Sangha *et al.* (2014)** found that applying algae extracts significantly increased tomato yield and the ability of leaves to photosynthesize and reduce the time of ripening of fruits. Moreover, it increases the firmness of the tomato fruits. **(Yao *et al.*,2020).** The seaweed extract has been found to contain growth stimulators such as auxins, gibberellins and cytokinin (**Begum *et al.*,2018).** The extract also comprises growth promoting hormones (IAA and IBA), trace elements, vitamins and amino acids and have been reported to stimulate the growth and yield of plants, develop tolerance to environmental stress, increase nutrient uptake and enhance antioxidant properties (**Pramanick *et al.*,2014; Mohanty *et al.*2013).**

Jasmonic acid (JA) is involved in many physiological and biochemical processes associated with plant growth and development, as well as stress resistance **(Ali and Baek 2020) and** (**Kaushik *et al.* 2022**).Salicylic acid and its derivatives are synthesized from chorismate (derived from shikimate pathway). Salicylic acid or ortho-hydroxybenzoic acid belongs to a varied group of phenolic compounds well known in the plant kingdom. Salicylic acid is occur in plants as a free phenolic acid and as a conjugate form, which may be generated by glucosylation, methylation or hydroxylation of the aromatic ring. Salicylic acid is considered an important phytohormone that regulates various aspects of plant growth, environmental stress (**Lefevere *et al.* 2020).**Brassinosteroids (BRs) are one of the most important and indispensable plant hormones in developmental and physiological processes **(Fariduddin *et al.*2014).** Many thousands of BRtargeted genes are activated by transcription factors known as BR stimulate. to promote plant development under stress, BR control the activities of antioxidant enzymes, chlorophyll concentrations, photosynthetic capability, and glucose metabolism **(Jakhar *et al.*2022).**

Table 2. Effect of seaweed extract, Jasmonic acid, Brassinolide and salicylic acid on plant height, stem diameter, number of branches and number, of leaves/plant of tomato plants during 2021 and 2022 seasons.

Characters	Plant height (cm)		No. of branches /plant		No. of leaves/plant	
Treatments	2021	2022	2021	2022	2021	2022
Control Resistance	46.33[b]	71.11 [d]	4.00 [b]	3.83 [e]	29.00 [a]	56.83 [c]
Control Sensitive	41.66 [b]	72.33 [b]	4.00 [b]	3.66 [c]	26.33 [b]	34.00 [c]
Seaweed extract at 100 ml/l	45.66 [a]	86.16 [a]	6.33 [ab]	5.00 [bc]	40.00 [a]	39.00 [c]
Seaweed extract at 200 ml/l	50.33 [a]	90.13 [a]	7.66 [ab]	8.33 [a]	49.00 [a]	81.66 [a]
Jasmonic acid at 100 mg/l	47.00 [a]	84.40 [ab]	6.00 [ab]	5.00 [bc]	30.66 [a]	54.66 [bc]
Jasmonic acid at 200 mg/l	52.33[a]	88.23 [a]	7.33 [ab]	4.33 [bc]	43.00 [a]	86.00 [a]
Brassinolide at 100 mg/l	48.66 [a]	84.33 [ab]	6.66 [ab]	4.33 [bc]	35.00 [a]	42.66 [c]
Brassinolide at 200 mg/l	53.00 [a]	94.93[a]	7.66 [ab]	5.66 [bc]	49.66 [a]	65.00 [b]
Salicylic acid at 100 mg/l	47.33 [a]	82.66 [a]	7.00 [a]	4.66 [bc]	36.00 [a]	46.33 [bc]
Salicylic acid at 200 mg/l	49.00 [a]	90.50 [ab]	8.33 [ab]	6.33 [b]	38.66 [a]	52.66 [bc]
Mean	48.13	84.48	6.50	5.11	37.73	55.88
LSD 0.05	6.58	9.19	2.62	1.60	18.22	13.91

In the same column, means followed by the same letter are not statistically different, according to the Duncan's New Multiple Range at $p \leq 0.05$.

Table 3. Effect of seaweed extract, Jasmonic acid, Brassinolide and salicylic acid on leaves dry weight, shoots dry weight, SPAD of tomato plants during 2021 and 2022 seasons.

Characters	Leaves dry weight g/plant		Shoots dry weight g/plant		SPAD	
Treatments	2021	2022	2021	2022	2021	2022
Control resistance	19.21 [a]	41.36 [c]	31.76 [b]	64.14 [de]	36.47 [b]	41.90 [b]
Control sensitive	17.28 [b]	41.90 [b]	28.16 [b]	60.57 [b]	41.58 [b]	40.60 [b]
Seaweed extract at 100 ml/l	25.53 [a]	75.89 [a]	38.99 [a]	110.06 [ab]	49.23 [a]	51.4 [ab]
Seaweed extract at 200 ml/l	34.44 [a]	77.62 [a]	50.07 [a]	129.85 [a]	52.92 [a]	53.23 [a]
Jasmonic acid at 100 mg/l	27.90[a]	66.97 [a]	38.21 [a]	85.80 [ab]	49.29 [a]	48.16 [ab]
Jasmonic acid at 200 mg/l	31.94 [a]	68.63 [a]	43.11 [a]	107.34 [ab]	41.61 [a]	51.50 [ab]
Brassinolide at 100 mg/l	24.42 [a]	74.26 [a]	37.53 [a]	115.51 [a]	45.49 [a]	50.30 [ab]
Brassinolide at 200 mg/l	20.22 [a]	59.62 [a]	27.93 [a]	101.49 [ab]	51.71 [a]	58.90 [a]
Salicylic acid at 100 mg/l	24.21 [a]	71.67 [a]	37.40 [a]	106.36 [ab]	50.62 [a]	53.16 [a]
Salicylic acid at 200 mg/l	37.83 [a]	74.55 [a]	51.36 [a]	113.08 [ab]	53.87 [a]	57.93 [a]
Mean	26.30	65.25	38.45	99.42	47.28	50.71
LSD 0.05	13.66	17.55	16.27	33.56	10.28	7.86

In the same column, means followed by the same letter are not statistically different, according to the Duncan's New Multiple Range at $p \leq 0.05$.

III- Flowering characteristics

Data in Table (4) indicated that flowering characteristics of tomato plants grown under high temperature conditions a effects on start of flower anthesis (day), No. of flowers / plant, Total fruits (No./plant) and Early fruit Num./plant during first and the second seasons by the applications of seaweed extract at 100,200 ml/l, Jasmonic acid at 100, 200 mg/l, Brassinolide at 100, 200 mg/l and salicylic acid at 100, 200 mg/l. The highest a effected treatment with the start of flower anthesis (day) was the resistance control it start after 53 and 55 days for first and second seasons respectively. Meanwhile, the last treatment with the start of flower anthesis (day) was the Jasmonic acid at 100 ppm it start after 63.66 days in first season, but, in the second season sensitive control was the last it starts after 68.33 days after transplanting. For other flowering characteristics i.e., (No. Of flowers / plant, Total fruits (No./plant) and Early fruit No./plant) seaweed extract at 200 ml/l was the superior treatment during first and second seasons. In this context all other treatments significantly increased these traits but not reached the highest one during both seasons.

Table 4. Effect of seaweed extract, Jasmonic acid, Brassinolide and salicylic acid on Start of flower anthesis (days), number of flowers / plant, Total fruits (No./plant) and Early fruit No. / plant of tomato plants during 2021 and 2022 seasons.

Characters / Treatments	Start of flower anthesis (days) 2021	Start of flower anthesis (days) 2022	No. Of flowers / plant 2021	No. Of flowers / plant 2022	Total fruits (No./plant) 2021	Total fruits (No./plant) 2022	Early fruit No. / plant 2021	Early fruit No. / plant 2022
Control resistance	53.00 c	55.00 c	64.00 e	55.00 f	20.33 h	21.66 h	2.66 b	3.66 cd
Control sensitive	63.25 b	68.33 a	57.30 d	44.00 e	19.75 g	16.00 e	2.50 b	3.33 d
Seaweed extract at 100 ml/l	60.00 a	62.00 cd	64.33 cd	79.66 cd	26.66 de	33.33 d	2.66 b	5.33 b-d
Seaweed extract at 200 ml/l	57.33 a	59.33 d	80.00 a	102.66 a	35.00 a	51.00 a	6.00 a	9.00 ab
Jasmonic acid at 100 mg/l	63.66 a	65.66 b	63.33 cd	76.33 d	23.00 f	36.00 cd	3.00 b	5.33 b-d
Jasmonic acid at 200 mg/l	58.33 a	60.33 d	78.66 a	94.00 b	30.00 bc	44.66 b	4.66 ab	7.66 a-d
Brassinolide at 100 mg/l	62.66 a	64.66 bc	67.33 bc	75.00 d	24.66 ef	33.66 d	2.66 b	4.66 b-d
Brassinolide at 200 mg/l	60.00 a	62.00 cd	72.00 a-c	87.00 bc	28.33 cd	40.00 bc	4.00 ab	7.33 a-d
Salicylic acid at 100 mg/l	61.33 a	63.33 bc	67.33 bc	82.00 cd	25.66 d-f	35.33 cd	2.66 b	4.66 b-d
Salicylic acid at 200 mg/l	57.00 a	59.00 d	75.66 ab	91.33 b	31.66 b	41.33 b	4.33 ab	7.33 a-d
Mean	59.66	61.96	68.99	78.70	26.51	35.30	3.51	5.83
LSD 0.05	4.84	2.20	6.25	7.00	2.71	3.94	1.97	2.58

In the same column, means followed by the same letter are not statistically different, according to the Duncan's New Multiple Range at $p \leq 0.05$.

IV- Fruit yield and fruit quality components

In Table (5) data show that early fruit yield g/plant, fruit setting (%), Total yield kg/plant and ton/hectare were significantly affected by the applications of seaweed extract at 100,200 ml/l, Jasmonic acid at 100, 200 mg/l, Brassinolide at 100, 200 mg/l and salicylic acid at 100, 200 mg/l when compared with sensitive and resistance control during both experimental seasons. Seaweed extract at 200 ml/l was the superior treatment for above maintained traits (yield and yield components) for tomato plants during first and second seasons. All other treatments i.e, seaweed extract at 100, ml/l, Jasmonic acid at 100, 200 mg/l, Brassinolide at 100, 200 mg/l and salicylic acid at 100, 200 mg/l significantly increased yield and yield components traits but, not reach to the superior one when compared with the sensitive and resistance control during 2021 and 2022 seasons. Meanwhile, abscission percentage was decreased with the application of different applied bio stimulating treatments when compared with sensitive and resistance control during both seasons.

This increase of the yield and yield components by the applications of bio stimulating materials as friendly treatments could be attributed for increasing the previous measurements Tables 2,3) as vegetative growth and Table (4) as flowering measurements specially number of flowers and flower setting per plants these increased could attributed to beneficial roles and effects for:

Seaweed extracts are bio stimulants rather than fertilizers because they stimulate the plant's defence and growth response when applied. Furthermore, it has not been demonstrated that the profiles of algal extracts naturally contain fertilizer compounds at the levels required it qualifies as fertilizer. Recent research has focused on seaweed-based extracts, which contain a variety of biostimulatory compounds such as various forms of carbohydrates, amino acids, small amounts of phytohormones, osmoprotectants, and proteins (**Du Jardin ,2015) and (Murtic *et al.* 2018).**

Many more complex organic compounds have been identified as bioactive components of seaweed extracts in a variety of applications. Polyamines, for example, have emerged as an intriguing bioactive group in seaweed extracts. These compounds are found in most plants and have the ability to regulate plant growth **(Chen *et al.* 2019).**Seaweed extracts contain compounds that act as signalling molecules microRNAs regulate key pathways at the transcriptional and/or posttranslational levels, resulting in differential expression of crops with essential genes that contribute to increased plant growth and resistance to abiotic stress transcriptome analysis revealed that exposure to influenced the expression of several genes. In nonstress conditions, Arabidopsis plants were exposed to seaweed extracts **(Goni *et al.* 2016).** Also in the same study emphazised that Genes involved in cell metabolism, such as lipid and amino acid metabolism glycolysis and transport, acid and nucleotide metabolisme Photosynthesis, as well as cell and cell wall development, were all observed. alterations in transcript levels. The greatest induction was observed for CAX3, a vacuolar cation exchanger, and COPT2, an ion transporter copper transporter, as well as genes for fatty acid and phospholipid synthesis were mostly suppressed.

Regarding our results in relations with those were working with **Zewail *et al.* (2020)** was working on Malabar spinach and **Mohamed *et al.* (2021)** on sweet paper plants.

Table 5. Effect of seaweed extract, Jasmonic acid, Brassinolide and salicylic acid Early yield g/plant, Fruit setting (%), Abscission (%),Total yield (kg/plant) and total yield (ton/ ha) of tomato plants during 2021 and 2022 seasons.

Characters / Treatments	Early yield g/plant		Fruit setting (%)		Abscission (%)		Total yield (kg/plant)		Total yield (ton/ ha)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Control resistance	161.02 d	324.80 d	31.72 c	39.36 de	68.27 a	60.63 de	1.96 c	2.16 e	59.00 c	65.00 c
Control sensitive	162.26 b	305.33 c	34.41 c	36.30 c	65.59 a	63.69 a	2.09 b	2.83 e	62.88 b	85.00 b
Seaweed extract at 100 ml/l	168.85 b	542.13 bc	41.49 ab	41.83 b	58.50 bc	58.16 b	2.80 a	3.70 d	84.00 a	111.00 ab
Seaweed extract at 200 ml/l	523.38 a	954.90 a	43.78 a	49.70 a	56.21 c	50.29 c	3.30 a	4.20 a	99.00 a	126.00 a
Jasmonic acid at 100 mg/l	207.03 b	529.76 bc	36.26 b-c	47.16 ab	63.73 ab	52.83 bc	2.45 ab	3.24 cd	73.62 ab	97.20 ab
Jasmonic acid at 200 mg/l	312.70 b	782.16 ab	38.15 a-c	47.47 ab	61.84 a-c	52.52 bc	3.14 a	3.70 b	94.15 a	111.00 ab
Brassinolide at 100 mg/l	176.70 b	443.41 bc	36.75 bc	45.09 ab	63.25 ab	54.90 bc	2.46 ab	3.20 d	73.80 ab	96.00 ab
Brassinolide at 200 mg/l	280.97 b	751.12 ab	39.29 a-c	45.96 ab	60.70 a-c	54.03 bc	3.06 a	3.85 bc	91.80 a	115.60 ab
Salicylic acid at 100 mg/l	174.24 b	454.14 bc	38.14 bc	43.08 b	61.85 a-c	56.91 b	3.13 a	3.53 cd	93.90 a	106.00 ab
Salicylic acid at 200 mg/l	290.81 b	760.1 ab	41.80 ab	45.27 ab	58.19 bc	54.72 bc	3.06 a	3.97 b	92.00 a	119.23 a
Mean	245.80	584.79	38.18	44.12	61.81	55.87	5.72	7.16	82.42	103.20
LSD 0.05	134.85	262.20	3.72	3.71	3.72	3.71	0.52	0.65	15.71	19.74

In the same column, means followed by the same letter are not statistically different, according to the Duncan's New Multiple Range at $p \leq 0.05$.

VI- Chemical analysis of Tomato plants

In Tables (6 and 7) data reported that tomato chemical analysis i.e., (N, P, K,Fe, Zn, total carbohydrates, crude protein, Total free amino acids(mg/g F.W.), total indole (mg/100 g FW), Total phenols (mg/g F.W and Total sugars (mg/g fw) were significantly increased with the foliar applications of seaweed extract at 100 and 200 ml/l, Jasmonic acid at 100 and 200 mg/l, Brassinolide at 100 and 200 mg/l and salicylic acid at 100 and 200 mg/l when compared with sensitive and resistance control during the second growing seasons. The highest value of these traits was excited with applications of seaweed extract at 200 ml/l during second growing seasons. Meanwhile, proline content (mg/g F.W.) was decreased with those treatments when compared with controls during second experimental seasons. It is critical to exploit the information available on the role of SA in abiotic stress tolerance in plants in order to develop ideotypes for sustainable agriculture and to improve overall plant performance in the face of changing climate and increased severity of abiotic stresses. In the current effort, SA-induced plant abiotic stress-tolerance are discussed, and major aspects that have been overlooked in the current context are briefly highlighted **(Zewail *et al.*2020).** Exogenous SA application preserved protein content not only under salt stress conditions but also under optimum conditions. Our findings are consistent with those of **Kumar *et al.* (1999),** who reported that Total soluble protein content was found to be increased in soybean plants when sprayed with SA, which could be due to increased activity of nitrate reductase in response to SA application. Plant growth and development are regulated by BRs by promoting cell elongation and division **(Mohamed *et al.* 2021).** Treatment with BRs increased protein content in both saline and non-saline soybean. BRs induced the transcription and translation of specific stress tolerance genes by increasing protein content **(Kagale *et al.* 2007).** Proline concentration was found to increase in plants exposed to heat stress and aids in membrane function. It also traps free radicals, acts as a cytoplasmic osmoticum, and is a powerful nonenzymatic antioxidant

(Abbaspour,2012). Pre-treatment of plants with SA also contributes to plant adaptation. accumulation of this amino acid during stress, possibly by maintaining an elevated level of ABA in the vegetation **(Ervin, 2005).** According to **Rohwar and Erwin (2008)**, proline content was highest in drought stressed plants. Methyl jasmonate was supplemented with shooting tips. Similarly, **(Anjum *et al.*2011; Billard *et al.*2014 and El Boukhari *et al.*2020).**

Table 6. Effect of seaweed extract, Jasmonic acid, Brassinosteroid and salicylic acid on (N, P, K, Mg, Fe, Zn, total carbohydrates, crude protein of tomato plants during 2021 and 2022 seasons.

Characters / Treatments	N %	P %	K %	Fe PPM	Zn PPM	Total Carbohydrate%	Crude protein
	2022	2022	2022	2022	2022	2022	2022
Control resistance	0.94 $^{a-d}$	0.515 ^{c}	2.02 ^{b}	2016.75 ^{b}	268.25 ^{cd}	11.89 ^{c}	5.90 $^{a-d}$
Control sensitive	0.735 ^{bc}	0.362 ^{f}	1.04 ^{c}	1418.00 ^{b}	242.00 ^{d}	11.77 ^{c}	4.59 ^{bc}
Seaweed extract at 100 ml/l	1.05 $^{a-c}$	0.474 ^{d}	2.26 ^{ab}	1424.00 ^{a}	270.50 ^{cd}	13.15 $^{a-c}$	6.56 $^{a-c}$
Seaweed extract at 200 ml/l	1.47 ^{a}	0.567 ^{a}	2.52 ^{ab}	2763.75 ^{a}	427.25 ^{a}	14.62 ^{ab}	9.18 ^{a}
Jasmonic acid at 100 mg/l	1.15 $^{a-c}$	0.450 ^{c}	2.86 ^{a}	2907.00 ^{a}	402.25 ^{ab}	12.69 $^{a-c}$	7.21 $^{a-c}$
Jasmonic acid at 200 mg/l	0.63 ^{c}	0.503 ^{c}	1.72 ^{b}	1790.25 ^{a}	264.75 ^{cd}	14.46 ^{ab}	3.93 ^{c}
Brassinolide at 100 mg/l	0.64 ^{c}	0.431 ^{e}	2.36 ^{ab}	3115.5 ^{a}	240.75 ^{d}	12.80 $^{a-c}$	4.03 ^{c}
Brassinolide at 200 mg/l	0.64 ^{c}	0.533 ^{b}	2.24 ^{ab}	2298.5 ^{a}	274.25 ^{cd}	14.00 ^{ab}	4.03 ^{c}
Salicylic acid at 100 mg/l	0.84 $^{a-c}$	0.434 ^{e}	2.42 ^{ab}	1962.25 ^{a}	252.75 ^{cd}	12.50 ^{bc}	5.25 $^{a-c}$
Salicylic acid at 200 mg/l	1.36 ^{ab}	0.507 ^{c}	2.22 ^{ab}	284.25 ^{cd}	353.25 $^{a-d}$	14.30 ^{ab}	8.53 ^{ab}
Mean	0.95	0.48	2.17	292.70	348.35	13.22	5.92
LSD 0.05	0.444	0.015	0.623	84.11	35.73	1.38	2.77

In the same column, means followed by the same letter are not statistically different, according to the Duncan's New Multiple Range at $p \leq 0.05$.

Table 7. Effect of seaweed extract, Jasmonic acid, Brassinolide and salicylic acid on Total free amino acids (mg/g F.W.), Proline (mg/g F.W.), total indole (mg/100 g FW), Total phenols (mg/g F.W.), Total sugars mg/g f.w of tomato plants during 2021 and 2022 seasons.

Characters / Treatments	Total free amino acids(mg/g F.W.)	Proline (mg/g F.W.)	total indole (mg/100 g FW)	Total phenols (mg/g F.W.)	Total sugars mg/g fw
	2022	2022	2022	2022	2022
Control resistance	28.63 ^{c}	16.49 ^{a}	121.22 ^{d}	119.12 ^{d}	53.58 ^{g}
Control sensitive	29.60 ^{c}	15.87 ^{a}	124.81 ^{d}	125.20 ^{c}	46.57 ^{e}
Seaweed extract at 100 ml/l	31.41 ^{b}	15.49 ^{a}	138.91 ^{cd}	134.40 ^{b}	54.04 ^{e}
Seaweed extract at 200 ml/l	40.08 ^{a}	10.63 ^{d}	183.24 ^{a}	156.35 ^{a}	85.27 ^{a}
Jasmonic acid at 100 mg/l	34.08 ^{b}	13.45 ^{b}	150.10 $^{b-d}$	137.20 ^{b}	60.79 ^{d}
Jasmonic acid at 200 mg/l	39.41 ^{a}	10.47 ^{d}	153.52 $^{b-d}$	154.20 ^{a}	67.68 ^{c}
Brassinolide at 100 mg/l	33.96 ^{b}	13.57 ^{b}	133.99 ^{cd}	141.20 ^{b}	60.78 ^{d}
Brassinolide at 200 mg/l	39.09 ^{a}	12.39 ^{c}	166.55 $^{a-c}$	153.86 ^{a}	70.09 ^{c}
Salicylic acid at 100 mg/l	34.28 ^{b}	12.32 ^{c}	139.58 ^{cd}	139.50 ^{b}	60.30 ^{d}
Salicylic acid at 200 mg/l	39.94 ^{a}	10.18 ^{d}	177.57 ^{ab}	155.90 ^{a}	75.09 ^{b}
Mean	35.05	13.09	148.95	141.69	63.42
LSD 0.05	6.29	0.787	21.99	6.56	2.79

In the same column, means followed by the same letter are not statistically different, according to the Duncan's New Multiple Range at $p \leq 0.05$.

Conclusion

This study concluded that foliar application of tomato plants three times with , inter action of 15 days after trans planting with seaweed extract at 100 and 200 ml/l, Jasmonic acid at 100 and 200 mg/l, Brassinolide at 100 and 200 mg/l and salicylic acid each at 100 and 200 mg/l significantly increased vegetative growth measurements, flowering and yield and yield components. Also, chemical composition of tomato plants and fruits including fruit quality were increased with different applied treatments. Due to its positive effects on plant growth and yield and yield components of seaweed extract application on tomato plants it has the potential effect to enhance growth, growth performance, chemicals, flowering, yield and yield components.

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تأثير تطبيق بعض المواد الصديقة للبيئة على نباتات الطماطم المنزرعة تحت ظروف درجات الحرارة المرتفعة.

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***قسم النبات الزراعى – كلية الزراعة – جامعة بنها – مصر**

أصبح توفير الغذاء للانسان التحدي الأكبر خلال التغيرات المناخيه، تم إجراء تجربتين حقليتين لتقييم تأثير بعض المواد الصديقة مثل(مستخلص الطحالب البحرية عند 100،200 مل / لتر وحمض الجاسمونيك بتركيز 100 ، 200 مجم / لتر والبراسينوسترويد عند 100 ، 200 مجم / لتر وحمض الساليسيليك عند 100 ، 200 مجم / لتر). على النمو ، وطبيعة النمو ، والإزهار ، و الثمارالناتجة ، وجودة الثمار ، والتركيب الكيميائى ، ومؤشرات المكونات الحيوية لتحمل الإجهاد الحراري لنباتات الطماطم *(Solanum lycopersicum Mill.)* المنزرعة تحت ظروف الإجهاد الحراري. أدى الرش بمستخلص الأعشاب البحرية بمعدل 200 مل / لتر إلى زيادة معنوية في طول النبات ، عدد الأوراق ، عدد الأفرع / نبات ، إجمالي مساحة الورقة سم 2 / نبات ، الوزن الجاف للأوراق والمجموع الخضرى ونسبة الأوراق للمجموع الخضرى خلال موسمي 2021 و 2022 . وزادت صفات التزهير مع معاملات مختلفة خلال الموسمين. بالإضافة إلى ذلك تم زيادة المحصول ومكوناته مع المعاملات المختلفة خلال الموسمين. وقد أعطى مستخلص الطحالب البحرية أعلى قيم معنوية بمعدل 200 مل / لتر خلال الموسمين الأول والثاني. التركيب الكيميائي (نيتروجين ، فوسفور ، بوتاسيوم ، منجنيز ، حديد ، زنك). كما تم زيادة مؤشرات الإجهاد للمكونات الحيوية (محتوي البرولين الكلى ، إجمالي الفينولات الكلى ، إجمالي الأحماض الأمينية الحرة والإندولات الكلية) مع تطبيقات مختلفة خاصة مستخلص الأعشاب البحرية بمعدل 200 مل / لتر خلال موسمى النمو. يمكن الاستفادة من استخدام مستخلص الأعشاب البحرية الصديق للبيئة بشكل خاص في زيادة النمو ، وتراكم المعادن ، وإنتاجية الثمار وجودة المحصول ، والجودة الكيميائية للثمار في ظل ظروف الإجهاد الحراري.