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Salicylic acid (SA) and α-tocopherol as effects on growth, fruit yield and quality of tomato (*Solanum lycopersicum* Mill.) crop

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Abstract

During the 2020 and 2021 seasons, two field experiments were conducted to investigate the effects of foliar application of 100 and 200 ppm salicylic acid (SA) and 75 and 150 ppm α-tocopherol (VE) and their combination on some growth aspects, photosynthetic pigments, minerals, endogenous phytohormones, fruiting and fruit quality of tomato cv. Alyssa hybrid tomato. Plants were sprayed twice after transplanting, at 15 and 30 days. The results showed that the various treatments considerably enhanced all the analyzed growth metrics, including the number of branches, leaves per plant, and leaf dry weight. In addition, the applicants had positive effects on increasing the weight and number of fruits per plant. Furthermore, the SA and/or VE applied to leaves significantly increased photosynthetic pigments, NPK, total carbohydrates, and crude protein concentrations when compared to leaves of untreated plants. Furthermore, salicylic acid 100 ppm + vitamin E 150 ppm produced the best early flowering and total yields, followed by SA 200 + VE 150 ppm, respectively. The same treatments also up-regulated the fruits content of minerals and other bio-constituents such as carbohydrates and total soluble solids in tomato fruits rose. As a result, the current study strongly suggests that the foliar application of salicylic acid and vitamin E boosted not only early and total yields, but also fruit quality.

Keywords: fruit quality, fruit yield, salicylic acid, α-tocopherol, tomato.

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1. Introduction

Tomato is one of the most important crops in the Solanaceae family, it is a self-pollinating crop and comes first in terms of annual planted area as well as in terms of consumption tomatoes are one of the most important crops in the Solanaceae family. Tomato *(Solanum Lycopersicum.* Mill*)* is the most cultivated vegetable worldwide, since it is the main ingredient in traditional and processed foods, in addition to the important nutraceutical content that this fruit contains (Islam *et al*., 2018). Yields and quality are heterogeneous due to genotypic variations, environmental conditions, production system, pests and diseases, which negatively impacts grower's economy (Pandey *et al*., 2017; Rai, 2020). In addition, SA can regulate the levels of reactive oxygen species in plants by controlling the activity of protective enzymes and avoiding or eliminating plant cell damage caused by oxygen stress. The above is due to increases in the activity of the enzymes phenylalanine ammonium lyase (PAL) and peroxidases (POD), which improve the biosynthesis of antioxidant compounds in the plant (Sariñana-Aldaco *et al*., 2020). Antioxidant compounds have a chemical structure that prevents the formation of free radicals and can prevent diseases caused by oxidative stress (Biruete-Guzmán *et al*., 2009) Among the most important antioxidants are phenolic compounds, vitamins, and carotenes (Calderon-Montano *et al*., 2011) which provide anti-inflammatory, anticancer, antiviral, and antiallergic benefits (Vicente and Boscaiu, 2018). SA, on the other hand, seems to work in tandem with auxin and gibberellins (Zaghlool *et al*., 2006). Furthermore, SA increased flowering in a number of species when combined with other plant growth regulators such as kinetin, indole acetic acid, and gibberellins (Shehata *et al*., 2000; Singh, 1984). Alpha-tocopherol is a small molecule that is synthesized in plants, mainly concentrated in plastids, and is one of the most effective single-oxygen quenchers (Fryer, 1992). Alpha tocopherol is a strong antioxidant that assists in maintaining membrane stability (Munné-Bosch and Alegre, 2002), intracellular signaling, and transport of electrons in the photosystem-II system (Munné-Bosch and Falk, 2004) and is photoprotective in nature (Munné-Bosch and Alegre, 2002). Foliar spray with α-tocopherol on faba bean plants induced increase in growth parameters, yield components, chlorophyll a, b and carotenoids content (El-Bassiouny *et al*., 2005). Alpha Tocopherols play a role in a range of different physiological phenomena including plant growth and development, senescence, preventing lipid peroxidation and interacting with the signal cascade that convey abiotic and biotic signals (Baffel and Ibrahim, 2008; Sattler *et al*., 2004). From this perspective, the objective of this research was to determine the effect of foliar application of salicylic acid (SA) and vitamin E (VE) and their combination on the growth, flowering and tomato fruits yield.

2. Materials and methods

2.1 *Experimental site*

This experiment was conducted at research farm of the Faculty of

Agriculture, El-Azhar University (Assiut Branch), Assiut, Egypt (Longitude 031° 11' 09" E and latitude 27° 10' 39" N) in clay loam soil as presented in Table (1).

Table (1): The physical and chemical characteristics of the soil in the experiment site in the Research Farm of Al-Azhar University, Assiut, Egypt, during 2020 and 2021.

Characteristic	Value	Characteristic	Value
O.M.%	0.9	Mg^{+2}	1.8
$CaCO_3$%	1.62	Na^{+}	6.5
Sand%	25.4	K^{+}	0.22
Silt %	39.9	Available (ppm)	
Clay%	34.8	NH_4	48.0
Texture class	Clay loam	N	63.2
Ph	7.8	P	9.5
EC (dS/m)	1.3	Zn	2.5
Soluble ions (me/L)		Fe	9.6
CO_3	-	Mn	4.2
HCO_3	2.35	$SO4^{-2}$	6.5
Cl	2.3	Ca^{+2}	3.3

2.2 *Experimental materials*

Alyssa hybrid tomato seedlings were obtained from El-Salam Nursery, New Assuit City, Assuit, Egypt, then planted in two seasons of 10 December 2019/2020. Salicylic acid (SA) and vitamin E (VE) were obtained from Al-Gomhouria Company for Chemicals and Medical Supplies, Assuit, Egypt.

2.3 *Experimental design and treatments*

A randomized complete block design (RCBD) was used with three replicates. The seedlings were initially grown in a greenhouse and fertilized with soluble fertilizer 19:19:19 N.P.K. The seedlings (about 45 days old) were transplanted into rows 90 cm wide (with 40 cm distance between seedlings). Each plot size consisted of three rows with each row being 3.5 m long. During the plant-growing period, furrow irrigation was used. Treatments were (T_1) the experimental control, (T_2) Salicylic acid (SA) at 100 ppm, (T_3) Salicylic acid (SA) at 200 ppm, (T_4) Vitamin E (VE) at 75 ppm, (T_5) Vitamin E (VE) at 150 ppm, (T_6) SA at 100 ppm + VE at 75 ppm, (T_7) SA at 100 ppm + VE at 150 ppm, (T_8) SA at 200 ppm + VE at 75 ppm and (T_9) SA at 200 ppm + VE at 150 ppm were applied as foliar application at 15 and 30 days after transplanting. All the agricultural practices used for commercial tomato production were carried out in this experiment (Hassan, 1991).

2.4 *Data collected*

Different morphological traits at 80 days after transplantation were examined as follows: number of branches and leaves/plant, total leaves dry weight (g), sample of each treatment were dried in oven at 70°C till the constant weight**.** The quantity of early fruits per plant was calculated based on the first four pickings. The total quantity of fruits was computed as the total number of fruits in all picking. fruit weight per plant and fruit yield per feddan (feddan = 4200 m² = 0.420 hectares = 1.037 acres).

2.5 *Chemical and physiological analysis*

Total nitrogen, phosphorous and potassium of fruits at harvest were measured by methods described by Hornick and Hanson (2019). Total carbohydrates and crude protein percentage (%) were determined according to Bach *et al*. (2018). Total soluble solids (T.S.S.) were measured using a hand refractometer. Titratable acidity was determined according to the method described by A.O.A.C. (1990). Photosynthetic pigments such as chlorophyll a, b was determined using the calorimetric method described by Inskeep and Bloom (1985).

2.6 *Statistical analysis*

The analysis of variance of the data was carried out on the mean values of the tested treatments according to the procedures described by Gomez and Gomez (1984). The least significant differences (LSD) at 5% levels were used for testing the significance of the differences among the mean values of the tested treatments for each character.

3. Results and Discussion

The data in Table (2) clearly show that several spraying treatments, such as salicylic acid (SA) and vitamin E (VE) alone or in combination, considerably increased the estimated growth characteristics in the majority of cases since then, with the addition of SA at 100 ppm (T_2) and VE at 150 ppm (T_5), the number of branches and leaves per plant has climbed to its highest level. In addition, it was discovered that different combinations of SA and VE were more effective when used together than when used separately. Furthermore, dry weight the results were substantially identical to the above-mentioned features. It's worth noting that the combination of SA at 100 ppm and VE at 150 ppm (T_7) resulted in dry weight per plant. During the 2020and 2021 seasons, the above listed outcomes were practically identical the effect of SA and VE on endogenous phytohormones, particularly growth promoters such as auxins, gibberellins, and cytokinins, might be linked to the stimulatory effect of these components on several estimated parameters of tomato growth (Abd-El-Said *et al*., 1996; Shehata *et al*., 2000). It's also worth noting that the majority of the treatments raised the number of branches and leaves, which might be reversed depending on the quantity of produced flowers and fruits' set. Gharib (2007) on basil and marjoram and Fathy *et al*. (2003)

on eggplant both found that salicylic acid and vitamin E enhanced plant height, number of branches and leaves per plant, and dry weight.

Table (2): Effects of salicylic acid (SA) and vitamin E (VE) on some tomato development characteristics 80 days after transplanting across two seasons.

Treatments	2020			2021		
	Number/plant		Leaves dry weight/plant (g)	Number/plant		Leaves dry weight/plant (g)
	Leaves	Branches		Leaves	Branches	
T_1	8.90	23.70	16.80	9.43	21.18	18.57
T_2	11.20	28.40	22.00	11.35	27.30	22.40
T_3	12.10	30.30	23.00	11.80	29.80	23.78
T_4	11.30	30.90	23.50	10.90	30.20	24.32
T_5	12.90	34.00	25.30	11.95	32.40	26.48
T_6	13.12	35.70	24.80	12.25	31.45	28.01
T_7	15.70	44.30	32.30	14.55	41.15	34.58
T_8	12.95	35.30	26.60	12.40	33.70	27.74
T_9	14.30	37.50	28.40	13.70	36.40	29.50
LSD at 5%	2.10	4.92	3.20	2.04	5.16	3.42

T_1= The experimental control, T_2= Salicylic acid (SA) at 100 ppm, T_3= Salicylic acid (SA) at 200 ppm, T_4= Vitamin E (VE) at 75 ppm, T_5= Vitamin E (VE) at 150 ppm, T_6= SA at 100 ppm + VE at 75 ppm, T_7= SA at 100 ppm + VE at 150 ppm, T_8= SA at 200 ppm + VE at 75 ppm, T_9= SA at 200 ppm + VE at 150 ppm.

As demonstrated in Table (3), all administered treatments, either singly or in combination, resulted in significant increases in chlorophyll a and b during the two seasons of 2020 and 2021. During the two seasons, the only difference was a minor rise in chlorophyll a with SA at 100 ppm (T_2). In addition, while comparing the effectiveness of SA and VE when used independently, it was discovered that the combination of the two was more effective. In this regard, the current findings are consistent with those of Sweify and AbdelWahid (2008), who discovered that applying SA to *Syngonium podphyllum* plants increased chlorophyll a and b. Fathy *et al*. (2000) demonstrated that the foliar spraying of VE and other antioxidants boosted the amount of photosynthetic pigments in tomato plants. This stimulatory action of SA and VE could be attributed to their antioxidant scavenging effect, which preserved chloroplasts and prevented chlorophyll breakdown by harmful reactive oxygen radicals (Aono *et al*., 1993; Bowler *et al*., 1992). The data in Table (4) show that varied foliar applications resulted in a considerable increase in early fruits and total fruits yield during the two allocated seasons. The combination treatments yielded the highest results, with SA at100 ppm + VE at 150 ppm (T_7) coming out on top. In terms of fruit setting and total fruit output per plant, data in Table (4) revealed that all treatments significantly increased the number of selected fruits during harvest time throughout the 2020 and 2021 seasons. Also, when compared to the control, these results are more obvious. SA in soybean and broad bean (Awasthi *et al*., 1997; Zaghlool *et al*., 2001) produced similar results, as did VE in tomato (Awasthi *et al*., 1997; Fathy *et al*., 2000; Zaghlool *et al*., 2001).

Table (3): The effect of salicylic acid (SA) and vitamin E (VE) on the amount of photosynthetic pigments (mg/g fresh weight) during the two seasons, 50 days after transplanting, in tomato leaves.

Treatments	2020		2021	
	Chlorophyll a	Chlorophyll b	Chlorophyll a	Chlorophyll b
T_1	0.533	0.402	0.521	0.375
T_2	0.548	0.418	0.525	0.385
T_3	0.640	0.438	0.670	0.411
T_4	0.617	0.425	0.620	0.407
T_5	0.650	0.426	0.645	0.442
T_6	0.745	0.575	0.730	0.532
T_7	0.843	0.530	0.874	0.534
T_8	0.725	0.435	0.715	0.430
T_9	0.750	0.440	0.742	0.485
LSD at 5%	0.08	0.11	0.07	0.09

T_1= The experimental control, T_2= Salicylic acid (SA) at 100 ppm, T_3= Salicylic acid (SA) at 200 ppm, T_4= Vitamin E (VE) at 75 ppm, T_5= Vitamin E (VE) at 150 ppm, T_6= SA at 100 ppm + VE at 75 ppm, T_7= SA at 100 ppm + VE at 150 ppm, T_8= SA at 200 ppm + VE at 75 ppm, T_9= SA at 200 ppm + VE at 150 ppm.

Table (4): The effects of salicylic acid (SA) and vitamin E (VE) on tomato fruiting across two seasons.

Treatments	2020		2021	
	Number/plant		Number/plant	
	Early fruits	Total fruits	Early fruits	Total fruits
T_1	7.11	20.40	7.18	20.60
T_2	11.18	28.62	11.15	28.82
T_3	12.27	29.15	12.21	29.12
T_4	12.80	30.42	12.85	30.41
T_5	13.35	31.70	13.4	31.20
T_6	13.90	32.40	13.8	32.41
T_7	17.30	39.70	17.4	39.60
T_8	11.40	33.84	11.44	33.74
T_9	12.75	35.74	12.8	35.64
LSD at 5%	2.17	1.48	2.22	1.38

T_1= The experimental control, T_2= Salicylic acid (SA) at 100 ppm, T_3= Salicylic acid (SA) at 200 ppm, T_4= Vitamin E (VE) at 75 ppm, T_5= Vitamin E (VE) at 150 ppm, T_6= SA at 100 ppm + VE at 75 ppm, T_7= SA at 100 ppm + VE at 150 ppm, T_8= SA at 200 ppm + VE at 75 ppm, T_9= SA at 200 ppm + VE at 150 ppm.

During the two seasons, all treatments increased crude protein content in leaves insignificantly, with the exception of the SA at 100 ppm + VE at 150 ppm (T_7) treatment, which was considerable. Also, high total carbohydrate content is a direct outcome of high-efficiency photosynthesis, which was preceded by a large photosynthetic area (Table 5) as well as under the treatments, but it peaked with SA at 100 ppm + VE at 150 ppm (T_7) one. These findings are consistent with those of Zaghlool *et al*. (2001) and Fathy *et al*. (2000). According to the data in Table (5), several sprayed treatments improved N, P and K contents in marketable stage tomato fruits. In addition, SA at 100 ppm + VE at 150 ppm (T_7) resulted in the highest concentration of total N, P and K in ripened tomato fruits. In addition, the data in Table (6) showed that during the two seasons, all treatments enhanced the amount of total soluble solids (TSS), and titratable acidity in tomato fruits. These findings are significant in terms of fruit quality since they suggest that alternative treatments, such as SA at 100 ppm + VE at 150 ppm (T_7), could extend the shelf life of the fruit. VE in tomato (Fathy *et al*., 2000) and bean (Zaghlool *et al*., 2001) yielded essentially identical results.

Table (5): The effects of salicylic acid (SA) and vitamin E (VE) on NPK and certain bio-constituents in tomato fruits over the course of two seasons.

Treatments	2020					2021				
	N (%)	P (%)	K (%)	CP (%)	TC (mg)	N (%)	P (%)	K (%)	CP (%)	TC (mg)
T_1	1.31	0.27	1.52	8.90	625.25	1.26	0.28	1.45	7.88	612.72
T_2	1.86	0.28	1.60	11.25	663.15	1.92	0.29	1.53	12.00	650.22
T_3	2.15	0.32	1.66	13.44	672.40	2.05	0.30	1.64	12.81	676.05
T_4	2.22	0.35	1.62	13.88	678.80	2.24	0.31	1.55	13.63	680.75
T_5	2.28	0.37	1.75	14.25	664.90	2.86	0.36	1.73	14.00	710.35
T_6	2.43	0.36	1.77	15.26	725.35	2.80	0.33	1.75	14.75	711.28
T_7	2.75	0.42	2.11	17.19	740.26	2.45	0.43	2.04	17.50	734.40
T_8	2.50	0.39	1.92	15.63	718.86	2.52	0.38	1.81	15.31	705.14
T_9	2.62	0.38	1.96	16.38	714.33	2.22	0.37	1.86	15.75	690.72
LSD at 5%	0.23	0.11	0.15	1.21	27.30	0.35	0.08	0.13	1.17	23.80

T_1= The experimental control, T_2= Salicylic acid (SA) at 100 ppm, T_3= Salicylic acid (SA) at 200 ppm, T_4= Vitamin E (VE) at 75 ppm, T_5= Vitamin E (VE) at 150 ppm, T_6= SA at 100 ppm + VE at 75 ppm, T_7= SA at 100 ppm + VE at 150 ppm, T_8= SA at 200 ppm + VE at 75 ppm, T_9= SA at 200 ppm + VE at 150 ppm. CP (%) = Crude protein (%), TC (mg) = Total carbohydrate (mg).

Table (6): The effects of salicylic acid (SA) and vitamin E (VE) on tomato flowering and fruiting across two seasons.

Treatments	2020		2021	
	TSS (%)	TA (%)	TSS (%)	TA (%)
T_1	3.71	0.311	3.89	0.314
T_2	3.77	0.321	3.93	0.326
T_3	3.80	0.328	3.82	0.344
T_4	3.94	0.337	4.10	0.352
T_5	3.90	0.347	4.23	0.355
T_6	4.02	0.355	4.33	0.360
T_7	4.12	0.364	4.90	0.375
T_8	4.21	0.352	4.74	0.362
T_9	4.15	0.354	4.80	0.366
LSD at 5%	1.23	0.090	1.21	0.070

T_1= The experimental control, T_2= Salicylic acid (SA) at 100 ppm, T_3= Salicylic acid (SA) at 200 ppm, T_4= Vitamin E (VE) at 75 ppm, T_5= Vitamin E (VE) at 150 ppm, T_6= SA at 100 ppm + VE at 75 ppm, T_7= SA at 100 ppm + VE at 150 ppm, T_8= SA at 200 ppm + VE at 75 ppm, T_9= SA at 200 ppm + VE at 150 ppm. TSS (%) = Total soluble solids (%), TA (%) = Titratable acidity (%).

The data presented in Table (7) show that the different foliar applications led to a significant increase in the weight of fruits for each plant, and thus a significant increase in feddans and total productivity during the two seasons.

Table (7): The effect of salicylic acid (SA) and vitamin E (VE) on fruit weight per plant and fruit yield per acre during two seasons.

Treatments	2020		2021	
	Fruit weight/plant (kg)	fruit yield/feddan (ton)	Fruit weight/plant (kg)	fruit yield/feddan (ton)
T_1	1.20	9.14	1.13	8.60
T_2	2.19	16.70	2.08	15.20
T_3	3.11	23.60	2.84	21.60
T_4	1.27	9.20	1.19	8.80
T_5	1.73	13.20	1.70	12.90
T_6	3.07	23.20	2.66	21.50
T_7	3.90	29.60	3.80	28.90
T_8	3.20	24.20	3.10	23.50
T_9	3.60	27.20	3.50	26.80
LSD at 5%	0.87	1.30	0.85	1.40

T_1= The experimental control, T_2= Salicylic acid (SA) at 100 ppm, T_3= Salicylic acid (SA) at 200 ppm, T_4= Vitamin E (VE) at 75 ppm, T_5= Vitamin E (VE) at 150 ppm, T_6= SA at 100 ppm + VE at 75 ppm, T_7= SA at 100 ppm + VE at 150 ppm, T_8= SA at 200 ppm + VE at 75 ppm, T_9= SA at 200 ppm + VE at 150 ppm.

Combined treatments yielded the highest results, with SA at 100 ppm + VE at 150 (T_7) ppm. With regard to the weight of fruits per plant and the total fruit production per feddan, the data in Table (4) showed that all treatments led to a significant increase in the number of fruits selected during the harvest season throughout the 2020 and 2021 seasons. Compared with the control group, these results are clearer. Use of SA in soybeans and broad beans yielded similar results (Awasthi *et al*., 1997; Zaghlool *et al*., 2001), as did VE in tomatoes (Awasthi *et al*., 1997; Fatehi *et al*., 2000; Zaghlool *et al*., 2001).

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