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RESEARCH ARTICLE

Effect of bio stimulant on growth and fruiting of Thompson seedless grapevines under heat stress condition

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Abstract

This study aimed to investigate the effect of root stimulator and foliar spraying with salicylic acid, citric acid, boron, amino acids and potassium silicate, on vegetative and fruiting of Thompson seedless grapevines under heat stress. The experiment was conducted during two successive seasons of 2022 and 2023. The experimental design is a complete randomized block design in split plot arrangement with three replicates, two grapevines each. Root stimulator was applied twice at growth start and after one month later. Citric acid and Salicylic acid at (1500) ppm, Boron at 500 ppm, amino acids at 2000ppm and potassium silicate at 3000ppm were foliar sprayed three times during growing season, first when new shoots reached 20 cm, after berry set and one month later. Application forms of root stimulator, as well as Boron, amino acids, potassium silicate, citric and salicylic acids significantly stimulated the vegetative growth traits and yield components compared to untreated ones (control). Moreover, they significantly improved the berry juice attributes, in terms of increasing total soluble solids (TSS) and sugar contents and decreased the total acidity. It could be concluded that root stimulator, salicylic acid, citric acid, boron, amino acids and potassium silicate application were useful in improvement of vegetative growth status and productivity of grapevines where that tolerate the harmful effects of heat stress.

Keywords: Potassium silicate, Amino acids, Yield, Heat stress, Thompson seedless

1. *Introduction*

Grapevines are one of the major profitable, favorite, and delicious fruit crops grown in Egypt. It is the third fruit crop after citrus and mangoes, the cultivated area of grapevines reached 186735 feddan, producing about 1715410 tons of fruits, according to the recent statistics estimates by M.A.L.R. (2022). The grapevines need a well-drain soil, a suitable climate, and an optimal horticultural procedure. Potential effects of the impending climate change include the rise in the yearly temperature and the accumulation of extreme weather conditions, such as frequent and intense heat waves, as global warming on the growth and production of the grapevines. Abiotic stressors have a significant impact on plant development and agricultural output, accounting for almost 50% of global main crop yield loss each year. It is a significant worldwide issue that restricts crop productivity (Kumari et al., 2019a). In an open field setting, where all of these environmental factors are interrelated, it can be challenging to discern the distinct effects of each of the most prevalent abiotic stresses, which include high temperatures, droughts, salinities, soil acidification, and extreme radiation exposure. There have been numerous attempts to mitigate the negative impact of heat stress on grapevine productivity and berry quality when cultivated in hot climates. Thus, the notion that heat stress damages can be prevented by utilizing certain anti-stress agents, amino acids, or substances containing those (Kumari et al., 2019b). Potassium is essential for grapevines' growth and fruiting, being involved in numerous plant processes. It might be involved in the transport and metabolism of carbohydrates, and could act as an osmotic agent for the opening and closing of stomata—an

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essential process for vine water relations and heat stress resistance (Fogaça et al., 2007 and Cuéllar et al., 2013). Amino acids are involved in fortifying proteins, aiding in cell division, and generating plant pigments and natural hormones such as IAA, GA3, and ethylene. They can improve the physiological processes related to plant growth and development, whether directly or indirectly. The spraying of exogenous amino acids had enhanced the growth and fruiting. (Khan et al., 2012). Citric acid (CA) is categorized as a natural product and organic acid with little toxicity to microorganisms, reducing soil pH, which increases vegetative growth and physiological traits of olive trees (Beheiry et al., 2023). In addition, citric acid through soil application or foliar spraying can effectively regulate numerous plant growth responses under environmental circumstances. It plays an essential role in activating the biosynthesis process and acting as a non-enzymatic antioxidant that eliminates free radicals formed in plants under stress (Tahjib-Ul-Arif et al, 2021). Organic acids like citric acid, propionic acid, lactic acid, which help to improve the physical and chemical characteristics of the soil by forming micro and macro- aggregates that sustain ion homeostasis and produce siderophores which supply vines with irion, increased water potential, control stomatal movement by influencing transpiration rates. Halophilic bacteria (Verma & Verma, 2008 and Abdel-Wadoud et al., 2014). In addition, soil application of calcium silicate improved each of N, P, K, Ca, Fe, Zn, Mn, and K/Na ratio and lowered Na %. This may be due to the positive role of PGPR strains in mitigating the impacts of abiotic stresses such as soil salinity by improving plant nutrition through the supply of fixed nitrogen, zinc, soluble phosphate, and iron (Etesami and Beattie, 2018); decreasing the accumulation of Na+ within the plant by producing exopolysaccharides, which fix Na+ cation in the roots and restrict it from moving to the leaves and other parts of the plant and increasing the K/Na ratio (Saghafi et al., 2019; Otlewska et al., 2020 and Canseco et al., 2022); regulating the supply of water by plant roots (Bharti et al.2014); modifying the pH of the rhizosphere zone (Dodd & Perez Alfocea, 2012 and Lugtenberg et al., 2013). Moreover, due to the beneficial effect of the acidifying agents (calcium silicate in form of calcium or citric acid) on the decrease in soil pH, this increased the availability of the nutrients in the soil and improved their absorption (Beheiry et al., 2023). Boron is crucial for normal plant growth as an essential micronutrient, yet it is lacking in many soils. It is involved in various physiological processes., particularly in maintaining the structural and functional integrity of cell walls and membranes, regulating ion fluxes (H+, K+, PO4, Rb+, Ca2+) across membranes, facilitating cell division and elongation, contributing to nitrogen and carbohydrate metabolism, aiding sugar transport, and influencing cytoskeletal proteins as well as the metabolism and transport of nucleic acids, indole acetic acid, polyamines, ascorbic acid, and phenols. Simultaneously, boron stress occurs along with other factors such as extreme temperatures, excess light, high CO2 concentrations, drought, salinity, or heavy metal contamination (Zhou et al., 2014). Consequently, the aim of this research was to examine the impact of the soil inoculation with rood activity and application of citric acid, salicylic acid, potassium silicate and amino acid on growth, physiological responses, yield, and cluster quality of Thompson seedless grapevines grown under heat stress in newly reclaimed lands.

2. Materials and Methods

The current research was performed on 14-year-old Thompson seedless grapevines cultivated in clay soil at the experimental orchard of the Faculty of Agriculture, South Valley University, located in Qena Governorate, Egypt (30.42°N, 31.48°E), over two seasons in 2022 and 2023. Every selected vine was planted with a spacing of 2 x 3 m. The vines were trained using the conventional cane pruning method on arbors of the Spanish parron type. Using a cane pruning system, the winter pruning system was completed at the end of December, leaving 96 buds (8 fruiting canes x 10 buds + 8 renewal spurs x 2 buds). With the exception of the current treatments, the vines were subjected to standard horticultural procedures, including fertilizer, irrigation, and the control of weeds and pests. To conduct this study, 72 vines that were nearly consistent in vigor and showed no outward signs of nutrient deficiencies were selected and split. A complete randomized block design (CRBD) in split plot arrangement with three replicates, two vines each. The main plots (A) included the effect of root stimulator (Root Fast) (Commercial product produced by: Bio Nano Tech. for fertilizers development, Egypt). It contains Amino acids 3.5%, Vitamins 5%, Algae extracts 10%, Biosac 10%, Tricarboxylic acids 10% Root growth stimulators 0.2% (include Auxins like IAA & IBA), Boron 0.5%, Zinc 0.5%. Root stimulator was added at a concentration of 5 cm per vine, and applied as following:

A1- untreated (control)

A2- soil addressing with root stimulator

Whereas, the sub-plot (B) included the six foliar spray treatments as follow:

B1- Control (Water)

B2- Salicylic acid at (1500) ppm

B3- Citric acid at (1500) ppm

B4- Boron (500) ppm

B5- amino acids at 2000 ppm

B6- potassium silicate at 3000ppm.

Boron as boric acid (17.48 % B). The applied amino acids: Super Viga Max^R (Commercial product produced by: Union for Agricultural Development Co. (UAD), Egypt). It contains 17.5 % amino acid mixture W\V (Aspartic acid 1.56%, Threonine 1.08%, Serine 2.045, Glutamic acid 2.40%, Alanine 1.75%, Valine 1.37%, Isoleucine 0.61%, Leucine 0.69%, Histidine 0.18%, Argenine 1.45%, Proline 1.97%, Phenylalanine 0.67%, Glycin 1.04%, Lysin 0.49%, Tyrosin 0.23%). The amount of each treatment compounds was chosen according to producers' recommendations and previous investigations.

Meteorological data in Qena region during 2022 and 2023 seasons are presented in Table (1).

Table 1. Temperatures and humidity in Qena governorate, Egypt during the two seasons (2022 and 2023).

Month		Year											
		2022						2023					
		Temperature (°C)			Humidity (%)			Temperature (°C)			Humidity (%)		
		Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
1	January	24.35	16.31	8.32	73.71	51.19	28.71	19.71	13.22	6.39	69.06	48.57	26.35
2	February	25.04	18.02	10.54	65.82	45.16	26.50	23.54	16.20	8.68	63.46	41.93	21.50
3	March	30.03	21.98	13.06	52.65	34.02	17.55	26.87	19.32	10.94	48.10	30.11	14.42
4	April	35.23	27.27	17.57	39.13	24.08	12.20	37.97	29.44	19.70	31.70	19.27	8.90
5	May	40.23	33.57	25.77	35.29	22.66	14.03	38.45	31.13	21.94	31.71	19.21	9.45
6	June	40.67	33.66	26.13	35.00	22.45	12.40	40.17	33.57	25.40	35.70	23.52	12.97
7	July	41.16	34.67	26.42	35.58	23.66	13.16	40.87	33.67	25.77	36.65	24.21	13.48
8	August	41.61	34.31	26.84	37.10	23.77	13.84	41.10	34.38	27.10	39.35	27.47	16.19
9	September	38.40	31.67	24.93	45.10	30.57	17.97	39.07	31.93	23.83	46.17	30.82	17.30
10	October	35.45	27.91	20.81	53.23	34.27	20.35	33.87	27.39	21.30	55.07	37.55	22.87
11	November	30.63	22.99	15.93	57.10	40.36	24.30	28.13	21.54	15.30	60.40	42.27	26.87
12	December	22.97	16.22	9.48	65.94	47.45	26.90	24.81	17.75	10.32	66.42	48.28	29.61

2.1. Vegetative growth criteria

All vegetative growth criteria such as leaf area, pruning wood weight (kg/vine) and proline in leaves were measured in the mid of July.

2.1.1. Leaf area (cm^2)

The leaf area was measured using the following equation = 0.587 (L×W), a sample of ten mature leaves from each vine were taken from the top of the developing shoot (6^{th} or 7^{th} leaf): The leaf area (cm^2) was determined using the formula L = leaf blade length and W = leaf blade width (Montero *et al.,* 2000)**.** In mid-July, mature leaves were removed from the tops of shoots, and the petioles of the leaves were separated from the blades. Before being processed in a stainless steel mill, the petioles were cleaned with tap water, desilted water, air-dried, and oven-dried at 70°C to constant weight. Hydrogen peroxide and strong sulfuric acid were used for overnight wet digestion. In the digestion, the percentage of free proline in the leaf tissues was calculated using the Bates *et al.* (1973) recommended method.

2.1.2. Potassium content

Potassium (K,%) was calorimetrically measured according to Wilde et al. (1985) using Flame photometry instrument.

2.1.3. Leaf chlorophyll content

was calculated using the shoot's terminal spent leaf and a chlorophyll meter (SPAD 502 plus)**,** in mid-July, with four leaves per replicate and measurements taken from the fourth leaf.

2.1.4. Yield

at harvest date, the yield per vine was recorded in terms of weight (kg) per vine.

2.2. Cluster and berry characteristic

To determine the cluster and berry characteristics, two clusters were randomly selected from each vine on harvest day. A.O.A.C. (1985) were used to determine berry quality, which includes berry weight, reducing sugar percentages, total soluble solids, and total acidity (measured as g tartaric acid per 100 ml juice). According to Steel and Torrie (1980) all gathered data were organized into tables and analyzed with the New L.S.D. test in accordance with Gomez and Gomez (1984) in order to identify any significant differences between the means of the various treatments.

3. **3. Results**

4.

5. 3.1. Vegetative growth and leaf nutritional status

Data in Tables (2 to 6) demonstrated the impact of roots stimulator and potassium silicate, amino acids, boron as well as citric and salicylic acids on vegetative growth and leaf area, K% and proline% of Thompson Seedless grapevines during 2022 and 2023 seasons. It is obvious from the data that the results showed a similar trend during the two studied seasons. Concerning the effect of roots stimulator, the results indicated that pruning wood weight, leaf area, total chlorophyll, K% and proline% were significantly affected due to the use of roots stimulator compared to untreated one (control). The recorded pruning wood weight was (1.45; 1.54 kg/vine, leaf area 127.99; 128.56 cm^2, total chlorophyll 39.16; 34.28 SPAD, K % 0.89; 0.92% and proline % 56.47; 60.23 %) due to treated soil with root stimulator against and was (1.37 & 1.41 kg/vine, 121.88 & 124.34 cm^2, 28.76 & 31.97 SPAD, 0.81 & 0.85% and 51.63 & 54.35%) on untreated vine during the two studied seasons, respectively.

Table 2. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on Leaf area (cm^2) of Thompson seedless grapevines during 2022 and 2023 seasons.

Treatment	Leaf area (cm^2)					
	2022			2023		
	A1	A2	Mean	A1	A2	Mean
B1	108.47e	111.29 e	109.26 e	112.22 e	118.33 d	110.79 e
B2	125.70c	126.76 c	126.23 c	130.33 b	131.16 b	130.75 ab
B3	122.63d	129.33 c	125.23 c	122.97 c	128.83 b	125.90 c
B4	118.37d	121.51 d	119.57 d	120.83 c	124.84 c	122.84 d
B5	124.93c	135.70 b	130.65 b	128.33 b	131.87 b	130.10 b
B6	131.17b	143.33 a	139.60 a	131.33 b	136.33 a	133.83 a
Mean	121.88b	*127.99a*		124.34 *b*	128.56 *a*	
LSD	A=0.85	B= 3.42	AB=4.83	A=2.60	B=3.12	AB=4.41

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

Table 3. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on total chlorophyll of Thompson seedless grapevines during 2022 and 2023 seasons.

Treatment	Total chlorophyll (SPAD)					
	2022			2023		
	A1	A2	Mean	A1	A2	Mean
B1	26.93 f	31.50 e	29.22 d	27.17 d	30.77 c	30.47 c
B2	27.73 f	34.50 d	31.12 c	31.07 c	32.57 b	31.82 c
B3	31.00 e	37.50 c	34.25 b	30.33 c	33.07 b	31.70 c
B4	28.07 f	40.50 b	34.28 b	33.70 b	35.50 a	34.60 ab
B5	29.73 e	46.50 a	38.12 a	35.00 b	38.10 a	36.55 a
B6	28.29 e	44.50 a	36.82 a	34.57 b	35.23 a	34.90 b
Mean	28.76 b	39.16 a		31.81 b	34.05 a	
LSD	A=2.48	B=1.71	AB=2.42	A=1.40	B=2.05	AB=2.90

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

Table 4. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on proline% of Thompson seedless grapevines during 2022 and 2023 seasons.

Treatment	Proline, %					
	2022			2023		
	A1	A2	Mean	A1	A2	Mean
B1	45.10 d	49.55 c	47.33 d	47.63 e	52.58 d	50.11 d
B2	48.95 c	53.65 b	51.30 c	51.48 d	57.13 c	54.31 c
B3	53.43 b	58.73 a	56.08 b	56.11 c	61.48 b	58.80 b
B4	51.48 c	56.63 b	54.06 b	54.10 c	60.10 a	57.10 b
B5	54.19 b	59.58 a	56.89 a	57.15 c	63.95 a	60.55 a
B6	56.64 b	62.31 a	59.48 a	59.62 b	66.11a	62.87 a
Mean	51.63 b	56.74 a		54.35 b	60.23 a	
LSD	A= 3.11	B= 2.86	AB= 4.06	A= 3.19	B= 2.79	AB= 3.97

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

Table 5. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on pruning wood weight of Thompson seedless grape vines during 2022 and 2023 seasons**.**

Treatment	Pruning wood weight (kg)					
	2022			2023		
	A1	A2	Mean	A1	A2	Mean
B1	1.23	1.28	1.26 c	1.26	1.39	1.33 b
B2	1.36	1.44	1.40 b	1.47	1.58	1.53 a
B3	1.38	1.46	1.42 ab	1.41	1.54	1.48 a
B4	1.37	1.48	1.43 ab	1.43	1.55	1.49 a
B5	1.42	1.51	1.47 ab	1.49	1.62	1.56 a
B6	1.46	1.55	1.51 a	1.46	1.60	1.47 a
Mean	1.37 b	1.45 a		1.41 b	1.54 a	
LSD	A= 0.07	B= .10	AB=0.14	A= 0.10	B= 0.11	AB=0.15

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

Table 6. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on k% of Thompson seedless grapevines during 2022 and 2023 seasons.

Treatment	K%					
	2022			2023		
A/B	A1	A2	Mean	A1	A2	Mean
B1	0.71 d	0.78 c	0.74 d	0.74 d	0.81 c	0.78 c
B2	0.77 c	0.85 b	0.81 c	0.80 c	0.88 b	0.84 b
B3	0.84 b	0.91 ab	0.87 b	0.87 b	0.94 a	0.91 ab
B4	0.81 b	0.89 b	0.85 b	0.85 b	0.93 a	0.89 b
B5	0.85 b	0.94 a	0.89 ab	0.89b	0.97 a	0.93 a
B6	0.89 b	0.97 a	0.93 a	0.93 a	0.99 a	0.96 a
Mean	0.81 b	0.89 a		0.85 b	0.92 a	
LSD	A= .04	B= .04	AB= .06	A= 0.05	B= 0.05	AB= 0.07

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

As regards the effect of potassium silicate, Boron, amino acids as well as citric and salicylic acids in vegetative growth and leaf area, potassium% and proline contents, data in previous tables showed that all treatments significantly increased the weight of pruning wood, leaf area, total chlorophyll, potassium and proline contents of leaves compared to untreated ones (control). No significant variation seen in pruning wood weight and leaf area for potassium silicate or amino acids spraying. On other hand, the highest values of leaf K % and leaf- proline were seen for amino acids spray. The maximum values of pruning wood weight, leaf area, total chlorophyll, K% and proline % were recorded due to amino acids (B5) and potassium silicate spraying (B6). Conversely, the untreated vines (check vines) yielded the lowest values for growth criteria, as well as for K and proline contents. Then the highest pruning wood weight was (1.51 & 1.53 kg/vine), leaf area (139.60 &133.83 cm^2), total chlorophyll (38.12 & 36.55 SPAD), K% (0.93 & 0.96%) and proline % (59.48 & 62.87%) due to (B6), during the two studied seasons, respectively. On other hand, the least ones due to control (B1), were (1.26 & 1.33 kg/vine), (109.26 & 110.97 cm^2), (29.22 & 30.47 SPAD), (0.74 & 0.78 %) and (47.33 & 50.11%), respectively. Therefore, the corresponding increment of pruning wood weight was (19.84 & 15.03%), leaf area (27.77 & 20.07%), K% (25.67 & 23.08%) and proline % (25.67 & 25.46%), due to B6 compared to control (B1) in the two studied seasons, respectively. Thus, the application of potassium silicate and amino acids enhanced the total leaf area, nutritional condition, and vegetative growth of vines while mitigating the negative impacts of heat stress.. Data in Tables (2 to 6) indicated that the growth traits significantly responded to the interaction between the two studied factors. In general terms, the interaction between root stimulator applications with any studied treatments gives the highest significant values for the studied growth traits compared to other combinations. The results indicated that the combined effects significantly enhanced vegetative growth traits more than the individual effects of either the root stimulator or the treatments studied.

3.2. Yield and cluster traits

Data in Tables (7, 8 & 9) showed the effect of roots stimulator and potassium silicate, Boron, amino acids as well as citric and salicylic acids on yield, cluster weight and berry weight of Thompson Seedless during 2022 and 2023 seasons. It is obvious from the data that the results showed a similar trend during the two studied seasons. The results indicated that, yield and cluster traits were significantly enhanced due to the use of roots stimulator as compared with the untreated one (control),On the other hand, the lowest values of such traits were recorded on untreated ones. The recorded yield/vine was (13.92 & 14.03 kg/vine) , cluster weight was (415.00 & 433.97 g) and berry weight was (1.58 & 1.46 g) due to soil application with root stimulator against (12.34 & 12.87 kg/vine)in yield, in cluster weight was (364.22 & 393.94 g) and in berry weight was (1.49 & 1.32 g) on untreated vine during the two studied seasons, respectively. The highest value of cluster weight was (443.33 & 458.00 g), yield/vine was (14.88 & 15.45 kg/vine) and berry weight was (1.72 & 1.55 g) for spraying potassium silicate (B6) during the two studied seasons, respectively. Contrarily, these values on untreated vines was (327.00 & 335.33 g) and (11.05 & 10.61 kg/vine) respectively. Then the harmonious increment percentages for these features over untreated was (35.57 & 36.58) and (34.66 & 45.62%), during the two studied seasons respectively. Moreover, no significant difference was recorded due to using any of amino acids or potassium silicate treatments. The interaction between root stimulator applications with any studied treatments gives the highest significant values for the yield and cluster traits studied compared to other combinations. The heaviest yield/vine (15.59 & 19.83 Kg/vine) was recorded due to use root stimulator combined with potassium silicate, against (9.85 & 9.24 Kg/vine) due to untreated one in both seasons, respectively. Hence, the corresponding increment percentage was attained (58.27 & 71.32 %) during the two studied seasons, respectively.

Table 7. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on yield of Thompson seedless grapevines during 2022 and 2023 seasons.

Treatment	Yield (kg)					
	2022			2023		
A/B	A1	A2	Mean	A1	A2	Mean
B1	9.85 d	12.25 c	11.05 e	9.24 e	11.98 d	10.61 e
B2	12.49 b	14.26 a	13.37 bc	13.16 c	13.87 b	13.51 c
B3	11.15 c	13.31 b	12.23 d	12.10 c	13.14 b	12.62 d
B4	12.52 b	13.59 b	13.06 cd	13.63 b	14.33 b	13.98 bc
B5	13.86 b	14.52 a	14.19 ab	14.04 b	15.01 a	14.52 b
B6	14.16 a	15.59 a	14.88 a	15.06 a	15.83 a	15.45 a
Mean	12.34 b	13.92 a		12.87 b	14.03 a	
LSD	A= 1.32	B=1.07	AB=1.51	A=0.99	B= 0.67	AB=0.95

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

Table 8. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on cluster weight of Thompson seedless during 2022 and 2023 seasons

Treatment	Cluster weight (g)					
	2022			2023		
	A1	A2	Mean	A1	A2	Mean
B1	298.67 i	355.33 g	327.00 e	280.00 d	390.67 d	335.33 d
B2	378.33 f	415.33 d	396.83 c	413.00 c	433.33 b	423.17 b
B3	327.33 h	385.33 e	356.33 d	382.33 d	425.50 b	403.92 c
B4	379.33 e	410.00 d	394.67 c	424.67 b	434.67 b	429.67 b
B5	381.67 e	457.33 b	419.50 b	428.00 b	439.33 b	433.67 b
B6	420.00 c	466.67 a	443.33 a	435.67 b	480.33 a	458.00 a
Mean	364.22 b	415.00 a		393.94 b	433.97 a	
LSD	A= 8.75	B=2.19	AB=3.09	A=6.98	B=10.53	AB=14.89

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

3.3. Berry quality

Data in Tables (10, 11 & 12) showed the effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids on berry quality of Thompson Seedless grapes during 2022 and 2023 seasons. All studied treatments significantly improved the berry quality in terms of raise total soluble solids (TSS), sugar contents and decreased the total acidity compared to untreated ones (control). It is obvious from the data that the results showed a similar trend during the two studied seasons. The maximum values of total soluble solids (TSS), sugar contents and least value of total acidity were recorded on the vines that applied with root stimulator. On the other hand, the lowest values of total soluble solids (TSS), sugar contents and highest values of total acidity were recorded on untreated one. The highest total soluble solids (TSS) recorded were (23.01 & 24.07%) and reducing sugar was (19.55 & 21.16%) due to the application with root stimulator against (21.44 & 23.06 %) in TSS, reducing sugar was (17.62 & 19.20 %) on untreated vine during the two studied seasons, respectively. The highest total soluble solids were (24.04 & 24.75%), reducing sugar was (20.22 & 21.09%) and the least total acidity was (0.400 & 0.345%) due to potassium silicate spraying during the two studied seasons, respectively. Hence the corresponding increment percentage of TSS attained (18.89 & 19.35%), during the two studied seasons, respectively. The results may be attributable to a tolerance for the detrimental effects of heat stress. Based on the current findings, it may be advisable to use a root stimulator application and spray vines with potassium silicate or amino acid sources to enhance berry quality, as these methods could help increase tolerance to the harmful effects of heat stress.

Table 9. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on berry weight (g) of Thompson seedless during 2022 and 2023 seasons.

Treatment	Berry weight (g)					
	2022			2023		
	A1	A2	Mean	A1	A2	Mean
B1	1.16 e	1.33 d	1.24 c	0.97 e	1.15 d	1.06 c
B2	1.45 c	1.64 b	1.54 b	1.40 b	1.48 b	1.44 b
B3	1.53 b	1.68 a	1.60 b	1.34 c	1.40 b	1.37 b
B4	1.53 b	1.53 b	1.53 b	1.36 b	1.56 a	1.46 ab
B5	1.54 b	1.54 b	1.54 b	1.39 b	1.52 a	1.45 b
B6	1.69 a	1.76 a	1.72 a	1.47 b	1.64 a	1.55 a
Mean	1.49 b	1.58 a		1.32 b	1.46 a	
LSD	A= 0.09	B= 0.08	AB=0.11	A=0.10	B= 0.09	AB=0.13

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

Table 10. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on TSS of Thompson seedless grapes during 2022 and 2023 seasons

Treatment	TSS					
	2022			2023		
	A1	A2	Mean	A1	A2	Mean
B1	19.25 d	21.18 c	20.22 d	20.48 c	21.69 c	21.09 c
B2	22.65 b	24.18 a	23.42 a	23.69 b	24.97 a	24.33 a
B3	20.33 d	21.96 c	21.15 c	22.58 b	23.32 b	22.95 b
B4	21.28 c	22.73 b	22.01 b	23.47 b	24.39 a	23.93 a
B5	21.78 c	23.28 b	22.53 b	23.68 b	24.98 a	24.33 a
B6	23.32 b	24.75 a	24.04 a	24.43 a	25.07 a	24.75 a
Mean	21.44 b	23.01 a		23.06 b	24.07 a	
LSD	A= 0.34	B=0.80	AB=1.14	A=0.55	B= 0.95	AB=1.35

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

Table 11. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on reducing sugar % of Thompson seedless grapes during 2022 and 2023 seasons.

Treatment	Reducing sugar, %					
	2022			2023		
A/B	A1	A2	Mean	A1	A2	Mean
B1	15.30 e	16.80 d	16.05 d	17.20 d	18.40 c	17.80 e
B2	18.07 c	20.70 a	19.37 b	20.10 c	22.31 b	21.21 ab
B3	17.13 c	18.50 b	17.82 c	18.70 c	20.29 b	19.50 bc
B4	18.00 c	20.00 b	19.00 b	19.00 c	20.82 b	19.91 d
B5	18.03 c	20.00 b	19.02 b	19.20 c	21.33 b	20.27 c
B6	19.17 b	21.30 a	20.50 a	21.00 b	23.81 b	22.41 a
Mean	17.62 b	19.55 a		19.2 b	21.16 a	
LSD	A= 1.23	B=0.85	AB= 1.20	A= 1.26	B=1.17	AB= 1.65

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

Table 12. Effect of roots stimulator and potassium silicate, boron, amino acids as well as citric and salicylic acids, on acidity of Thompson seedless grapes during 2022 and 2023 seasons.

Treatment	Acidity					
	2022			2023		
	A1	A2	Mean	A1	A2	Mean
B1	0.613 a	0.548 b	0.580 a	0.467 a	0.440 a	0.453 a
B2	0.540 b	0.449 d	0.495 bc	0.425 b	0.400 b	0.413 bc
B3	0.579 a	0.354 e	0.467 d	0.448 a	0.417 b	0.433 b
B4	0.546 b	0.488 c	0.517 b	0.417 b	0.408 b	0.412 bc
B5	0.560 b	0.388 e	0.474 cd	0.425 b	0.363 c	0.394 c
B6	0.517 c	0.283 f	0.400 e	0.338 c	0.353 c	0.345 d
Mean	0.559 a	0.418 b		0.420 a	0.396 b	
LSD	A= 0.045	B=0.028	AB=0.039	A=0.019	B=0.020	AB=0.028

A1=Non roots stimulator; A2 = Roots stimulate; B1=Control; B2= Salicylic acid; B3=Citric acid; B4=Boron; B5=Amino acids; B6= Potassium silicate

4. Discussion

Stress from extreme temperatures affects blooming, slows berry growth, and prevents sugar accumulation, which delays harvest and lowers berry quality and output. Given a persistent decline in net the process of photosynthesis these results could be explained (Greer and Weston, 2010; Greer and Weedon, 2012 and Greer, 2019). Bio root stimulator reduced the effect of stress, which was shown in a significantly increased in all vegetative growth and leaf area, potassium and proline content. The yield and cluster characters' and berry quality compared to the control, this may be due to biostimulants influence plants through hormonal modulation Seaweed extracts e.g., (*Ascophyllum nodosum*) and PHs contain auxin-like compounds that promote root development, as well as, to that Polysaccharides from seaweed mitigate salinity stress by reducing oxidative damage (Zou *et al*., 2021). Potassium silicate significantly increased in all vegetative growth and leaf nutritional status, the yield and cluster characters and berry quality compared to all treatments, this may be due to potassium is particularly vital for the growth, flowering, and fruiting of all fruit trees. Furthermore, it shields plants from both biotic and abiotic stress by preserving turgor, minimizing wilting and water loss, and enhancing cold tolerance. Potassium plays a crucial role in various metabolic activities, including protein and carbohydrate synthesis, enzyme stimulation, membrane transport, charge balancing, and turgor pressure production (Dordas., 2008). When potassium levels in vineyards are at their ideal levels, yields rise and berry characteristics improved. These findings concur with those of Belal *et al*. (2017); El-Badawy (2019) and Ahmed-Mona (2020). The significant increase in all vegetative growth, leaf nutritional status, yield, cluster characters and berry quality compared to the control, caused by boron application can be explained by its critical role in various physiological and biochemical processes in plants. Boron, an essential micronutrient often deficient in soils, is required for maintaining the structural and functional integrity of cell walls and membranes. It regulates ion fluxes (H^+, K^+, PO_4^{3-}, Rb^+, and Ca^{2+}) across membranes; influences cell division and elongation, and participates in nitrogen and carbohydrate metabolism. Additionally, boron is involved in sugar transport, cytoskeletal protein organization, plasma membrane-associated enzyme activity, nucleic acid synthesis, and the metabolism and transport of indole acetic acid, polyamines, ascorbic acid, and phenols. Boron stress in plants is exacerbated by environmental factors such as extreme temperatures, high light intensity, elevated CO_2 levels, drought, salinity, and heavy metal contamination. These stressors can intensify the plant's susceptibility to either boron toxicity or deficiency, further disrupting its physiological functions (Chowdhury *et al.,* 2008). This study's findings indicate that foliar application of amino acids significantly affects the enhancement of vegetative growth characteristics, fruit set, fruit yield, and fruit quality, along with improvements in nutritional status. This may be due to the ability of amino acids to influence physiological processes associated with plant growth and development, whether directly or indirectly. They are regarded as precursors and components of proteins, which are crucial because they promote cell division. Furthermore, the development, yield, and biochemical quality of fruit have all been influenced by the exogenous administration of amino acids (Shiraishi *et al*., 2010 and Khan *et al*., 2012) Amino acids are crucial for improving vine nutritional status and growth, and their beneficial effects on boosting physiological activity undoubtedly contributed to improved fruit quality, growth, and maturity. These findings contradict those of Abdel-Aal *et al*. (2010), Khan *et al*. (2012) and Khan *et al*. (2019). Salicylic acid and citric acid are noteworthy as they achieved the highest significant values when compared to the control. In this connection, this increase may be due to salicylic acid (SA) has emerged as a key phytohormone and signaling molecule that plays a vital role in enhancing plant resilience to abiotic stresses, such as salinity. It mitigates the adverse effects of stress by modulating physiological and biochemical processes, including improving antioxidant enzyme activities (e.g., catalase and peroxidase), maintaining membrane stability, and optimizing ion homeostasis (e.g., K^+/Na^+ ratio). Studies demonstrate that exogenous SA application significantly improves growth parameters, chlorophyll content, and stress tolerance in crops like sour orange under saline conditions (El-Shady *et al*., 2015). Citric acid plays a vital role in plant metabolism, particularly in the Krebs cycle discovered by Krebs (1937), where it serves as a key intermediate in energy production. It acts as a chelator, enhancing nutrient uptake by solubilizing metals like iron and phosphorus in the soil. Additionally, citric acid contributes to stress tolerance, helping plants withstand heavy metals and oxidative damage. Its presence in fruits, such as lemons and limes (up to 7000 mg/100 mL), influences flavor and preservation Ciriminna *et al.*, (2017).

5. Conclusion

Root stimulant, Salicylic acid, citric acid, boron, potassium silicate, and amino acids can be applied topically to grapevines to improve their nutritional status. This results in a high crop with good cluster traits and berry quality that was enabling them to withstand the negative effects of heat stress.

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All authors are contributed in this research

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Conflicts of Interest
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