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Effect of Foliar Application with Silicon and Seaweed Extract on the Vegetative Growth, Bunch Quality and Some Fungal Diseases of Red Globe and Superior Seedless Grapevines

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Abstract: This study was carried out during two consecutive seasons (2016 & 2017) to study the effect of the foliar application of potassium silicate and/or seaweed extract at (0.1 or 0.2%) in single or combination on Superior Seedless and Red Globe grapevines. Both cultivars are planted at 1.75 × 3 meters apart and trellised by Gable supporting system. The vines were pruned during the last week of December for Superior Seedless and the second week of January for Red Globe grapevines. Results showed that foliar application of seaweed extract and potassium silicate in combination or alone have positive effects on the vegetative growth characteristics, bunch and berry quality for both cultivars compared with the control. The best results for enhancing the vegetative growth characteristics, bunch and berry quality for both cultivars were obtained by using of foliar application with seaweed extract and potassium silicate in combination at 0.2%. Also, the best results of anthocyanin content for Red Globe were obtained from treatment of seaweed extract and potassium silicate in combination at 0.2%. Indeed, foliar spray of seaweed extract and potassium silicate in combination or alone was reducing percentage of powdery mildew infection in grape berries of Superior Seedless grapevines and reducing percentage of bunch rot of Red Globe grapevines compared with control. Eventually, the best results for controlling of powdery mildew and bunch rot were obtained from treatment of seaweed extract and potassium silicate in combination at a rate of 0.2%. Finally, it could be recommended to foliar application of silicon and seaweed extract for both cultivars to improving yield, berry quality and control the fungal diseases, thus, economic return.

Key words: Seaweed extract · Potassium silicate · Superior Seedless · Red Globe · Grapevines · Fungal diseases

INTRODUCTION

One of the main goals of scientists is to find of natural ways for enhancing plant defense system and productivity that lead to environmentally friendly agriculture [1]. Means of achieving this target through using the seaweed extract and potassium silicate on grapevines which would permit a reduction the using of agrochemicals and improving yield quantitatively and qualitatively.

Seaweed extract is containing on several substances, such as macro and microelements, amino acids, polyamines, plant growth regulators and vitamins which cause many beneficial effects on nutritional status, vegetative growth, yield and fruit quality [2]. The positive effects of seaweed extract on the vegetative growth due to its containing on oligosaccharides which resulted in improved photosynthesis, cell division and altered metabolic pathways for increased uptake and better assimilation of nitrogen [3]. Also, the increasing in the shoot length and leaf area could be ascribed to seaweed extract enriched in auxins and cytokinins. Furthermore, Nicolas *et al.* [4] stated that IAA has a vital role on control gene (VvCEB1) that responsible on the control of cell expansion and enhancing the cell-wall network and this positively reflected on vegetative growth characters.

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Therefore, seaweed extract may prevent chlorophyll degradation and increase chlorophyll content in leaf due to the presence of glycine betaines in seaweed extract that protect the thylakoid membrane by enhancing ion homeostasis and regulating osmotic adjustment [5]. In addition, seaweed extract has been reported to induce many positive changes in treated plants such as increased nutrient uptake, resistance to stress conditions and reduced incidence of the fungal [6]. Importantly, El-Sese *et al.* [7] mentioned that the foliar application of seaweed extract had an announced role on stimulating growth characters of three grapevines cultivars (Bez-El-Anza, Thompson Seedless and Red Roomy).

Silicon is the second most abundant soil element after oxygen in the Earth's crust [8]. Previous studies have shown that the silicon is benefits confers on plants, that enhanced growth, yield and fruit firmness, particularly in response to biotic and abiotic stresses as metal toxicity, high and low temperature, drought and salinity [9]. Thus, Iqbal *et al.* [10] reported that the foliar application of silicon improving enzymatic and non-enzymatic antioxidants in Muscadine grape, also vines that treated with silicon had a high accumulation of proline, then it have contributed to ROS scavenging to alleviate oxidative damage in cells. Also, potassium silicate was improved the vegetative growth characters, through its role in cell division and expansion by their effect on DNA and RNA synthesis [11]. Thus, it is role in protective mechanisms that avoid the damage of the photosynthetic apparatus [12]. In this concern, it can be deposited between cells or as part of the cell wall, with discrete silica bodies which record shapes of the cellular and intercellular spaces that they fill, result in the form of silicon polymerisation below the cuticle and strengthen the mechanical structure in the cell wall and this may be explain how silicon reduces or impedes fungal penetration as well as may be increasing the berry firmness [13, 14].

Powdery mildew and bunch rot had negative effects on the grape quality and productivity. In this concern, many fungicides are using to treat it, but this had negative effects on the environment. On the other hand, recently, using natural products such as potassium silicate and seaweed extract, which had positive effects on the environment and improving vegetative growth characters and berry quality of grapevines.

This study was under taken to evaluate the use of some natural compounds as potassium silicate and seaweed extract as foliar application on the vegetative growth, the bunch characteristics and some the fungal diseases of Superior Seedless and Red Globe grapevines.

MATERIALS AND METHODS

This study was carried out during 2016 and 2017 seasons on uniform in vigour twelve-year old Superior Seedless and ten-year old Red Globe grapevines, grown in vineyard located at Samalot district, Minia Governorate. The texture of the soil is clay. Supporting system was Gable system. All the selected vines are planted at 1.75 × 3 meters apart and irrigated by flood irrigation system for both cultivars. The vines were pruned during the last week of December for Superior Seedless grapevines and the second week of January for Red Globe grapevines.

This study included the following nine treatments for both cultivars as follow:

T1: Control (untreated vines).
T2: Potassium silicateat 0.1%.
T3: Potassium silicate at 0.2%.
T4: Seaweed extract at 0.1%.
T5: Seaweed extract at 0.2%.
T6: Potassium silicate at 0.1% + seaweed extract at 0.1%.
T7: Potassium silicate at 0.2% + seaweed extract at 0.1%.
T8: Potassium silicate at 0.1% + seaweed extract at 0.2%.
T9: Potassium silicate at 0.2% + seaweed extract at 0.2%.

Each treatment was replicated five times and each replication had three vines. All treatments were applied four times (one week before flowering, just after berry setting, one month after berry setting and at veraison stage) during each season for each cultivar. Triton B as a wetting agent was applied at 0.05 % to all treatments.

Chemical constituents of seaweed extract are shown in Table (1) according to Ali *et al.* [2]. While, potassium silicate (K_2SiO_3) used as the silicon source (10% K_2O+25% SiO_2).

Table 1: Chemical constituents of seaweed extract.

Components	Value
O.M.%	30-50
Total N%	1.0-1.2
P%	0.03- 0.1
K%	2.0-8.1
Mg%	0.1-0.8
Ca %	0.2-1.3
S%	1-4
Mn (ppm)	13-15
Fe (ppm)	40-80
Zn (ppm)	20-30
Cu (ppm)	1.2-7.3
B (ppm)	15-25
Mo (ppm)	1-3
Phytohormones (ppm)	550
Glycine betaine (ppm)	0.03

The following measurements were adopted to evaluate the tested treatments:

Vegetative Growth Parameters: At the first week of June, the following morphological studies were conducted on five fruitful shoots/the conducted vines:

- Average shoots length (cm).
- Average leaf area (cm^2): ten leaves were randomly collected from the apical fruiting shoots for each vine was determined average leaf area (using leaf area meter, Model CI 203, U.S.A.).
- Cane thickness (cm): at the first week of December, five fruiting shoots selected and labeled per vine during season and measured it in the five basal internodes of five canes per vine by using a vernier caliper.

Leaf Chemical Analysis: At the second week of June, leaves were collected from the 5-7th apical leaves at harvest date from fruiting shoots top to measure the following parameters:

- Total leaf chlorophyll: was measured by using the nondestructive Minolta chlorophyll meter model SPAD 502 according to A.O.A.C.[15].
- N, P and K percentages were determined in leaves petioles according to A.O.A.C. [15].

Yield and Physical Properties of Bunch and Berries: At the first week of June for Superior seedless and the last week of July for Red Globe in both seasons, five bunches per vine were harvested at the ripening stage when juice T.S.S% reached about 16-17% in control treatment according to Tourky *et al.* [16] in both cultivars to estimate the following parameters:

- Yield: yield/vine (kg) was calculated by multiplying number of bunches/vine by bunch weight and expressed in weight (kg).
- Average bunch length, width (cm) and bunch weight (g).
- Average number of bunches/vine.
- Average berry weight (g).
- Average berry length and diameter (cm) by using a Vernier caliper.
- Average berry firmness (g/cm^2): was estimated by using Penetrometer, Model FT 011; Italy.

Chemical Properties of Berries:

- Total soluble solids (T.S.S %) in juice was determined by using a hand refractometer.
- Acidity was determined as gram tartaric acid/100ml juice according to A.O.A.C. [15].
- T.S.S / acid ratio.
- Total anthocyanin (mg/100g fresh weight) in berry skin was determined according to A.O.A.C. [15].
- Antioxidant activities in the berry juice (DPPH %): the antioxidant activities were evaluated by (2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging [17].

Total carbohydrates in the canes and pruning weight:

- Total carbohydrates were taken from fruiting canes by marked five fruiting shoots during season and determined at winter pruning according the methods of A.O.A.C.[15].
- Pruning weight /vine (kg) was measured at winter pruning time.

Data of Powdery Mildew and Bunch Rot: Powdery mildew severity of bunches was determined for Superior Seedless cultivar, while bunch rot was determined for Red Globe cultivar and each cultivar was determined the infection per bunch and yield after loss (kg) as following:

- Infection per bunches % : bunches were collected at harvest and count the number of infected berries in each bunch, total number of berries per bunch and number of infected bunches per vine and determined by the following equation:

$$\text{Infection of bunches/vine\%} = \frac{\text{no. of infected berries/bunch x no. of infected bunches/vine}}{\text{total no. of berries/bunch x total no. of bunches/vine}} \text{x100}$$

- Yield after loss (kg): it was the actual amount of yield that remained after subtracting the severity of infection % from the yield per vine by the following equation:

Yield/vine after loss (kg) = yield/vine – (yield/vine x infection of bunches/vine %)

Table 2: Cultivation cost (L.E/ fed)

Cultivation cost	Average two seasons
Common cost	
Land rent	11000
Vineyard maintenance	450
Winter pruning	3230
Farmyard manure	2110
Hoeing	400
Irrigations	1775
Fertilizers	4291
Foliar application of dormex	925
Insect control	1573
Fungal diseases control	2382
Weed control	570
Foliar application of growth regulators	980
Foliar application of nutrients	885
Total common cost	30571
Variable cost	
T1: control (untreated vines).	0
T2: potassium silicate at 0.1%.	1168
T3: potassium silicate at 0.2%.	1520
T4: seaweed extract at 0.1%.	1072
T5: seaweed extract at 0.2%.	1408
T6: potassium silicate at 0.1% + seaweed extract at 0.1%.	2240
T7: potassium silicate at 0.2% + seaweed extract at 0.1%.	2592
T8: potassium silicate at 0.1% + seaweed extract at 0.2%.	2576
T9: potassium silicate at 0.2% + seaweed extract at 0.2%.	2928

Economic Analysis: The economic analysis was performed to estimate the net return and beneficial cost ratio on both cultivars Superior Seedless and Red Globe. The cultivation cost and potassium silicate and seaweed extract treatments costs were determined as described in Table 2. The economic parameters were calculated as follow:

- Gross return (L.E/fed) = total yield/vine after loss (kg) x [total no. of vines/fed x price of grapes (L.E)].
- Net return (L.E/fed) = gross return – total cultivation cost

$$\text{Beneficial cost ratio} = \frac{\text{gross return}}{\text{total cultivation cost}}$$

Experimental Design and Statistical Analysis: The experiment was arranged in randomized complete block design (RCBD). The statistical analysis of the current data was carried out according to Snedecor and Cochran [18]. Averages were compared using new L.S.D. values at 5 % level; averages were compared [19].

RESULTS

Vegetative Growth Parameters: It is evident from the data in Tables (3 & 4) clearly show that single or combined foliar applications of seaweed extract and potassium silicate at different rates was significantly very effective in improving vegetative characters such as, shoot length, leaf area, cane thickness and pruning weight rather than control treatment in both cultivars Superior Seedless and Red Globe. Combined foliar applications of seaweed extract and potassium silicate were better than using each substance alone in this context. The highest values of vegetative parameters during both seasons in Superior Seedless and Red Globe grapevines were recorded with using seaweed extract and potassium silicate together at 0.2%. Meanwhile, untreated vines produced the lowest values in both cultivars in first and second seasons.

Chemical Constitutes of Leaves and Canes: Data in Tables (5 & 6) show that foliar application of seaweed extract and potassium silicate treatments at different doses on Superior Seedless and Red Globe grapevines either single or combined had significant differences on the total chlorophyll in leaves, total carbohydrates in fruiting canes, N, P and K in leaves petioles rather than untreated vines. Both cultivars Superior Seedless and Red Globe had better response in mentioned characters with using combined foliar applications of seaweed extract and potassium silicate rather than single application in both seasons.

The highest values of the total chlorophyll in leaves, total carbohydrates in fruiting canes, N and P were recorded by using treatment with seaweed extract + potassium silicate at 0.2% in both cultivars during two seasons. On the other hand, there are positive relationship between potassium silicate treatments and K contents in leaves petioles either in alone or combined application with seaweed extract of Superior Seedless and Red Globe grapevines during 2016 and 2017 seasons. In this concern, the best values of K in leaves petioles obtained from combined foliar application of seaweed extract at 0.2% + potassium silicate at 0.2% in both cultivars during the two seasons.

Yield and Physical Properties of Bunch and Berries: Data in Tables (7, 8, 9, 10) clearly show that single or combined foliar applications of seaweed extract and potassium silicate at different rates significantly was accompanied with enhancing the yield and physical properties of bunch such as, bunch length, bunch width,

Table 3: Effect of foliar application of potassium silicate and seaweed extract on some vegetative growth parameters of Superior Seedless grapevines during 2016 and 2017 seasons

	Shoot length (cm)		Leaf area (cm^2)		Cane thickness (cm)		Pruning weight (kg)	
Treatments	2016	2017	2016	2017	2016	2017	2016	2017
T1	160.1	160.5	105.0	105.2	0.94	0.94	3.40	3.41
T2	171.5	172.9	117.4	118.0	0.98	0.99	3.72	3.75
T3	175.4	177.3	122.2	124.0	1.04	1.06	3.80	3.82
T4	172.0	173.1	120.5	121.7	1.00	1.01	3.77	3.80
T5	180.0	183.2	128.9	131.2	1.08	1.11	3.83	3.88
T6	186.4	188.4	131.3	133.0	1.11	1.13	4.00	4.03
T7	190.7	192.5	135.6	143.4	1.14	1.17	4.05	4.11
T8	205.7	208.9	137.8	141.5	1.16	1.18	4.15	4.20
T9	214.4	218.1	141.0	148.4	1.19	1.23	4.31	4.34
New L.S.D at 5 %	3.2	3.5	1.7	1.9	0.02	0.02	0.03	0.02

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Table 4: Effect of foliar application of potassium silicate and seaweed extract on some vegetative growth parameters of Red Globe grapevines during 2016 and 2017 seasons

	Shoot length (cm)		Leaf area (cm^2)		Cane thickness (cm)		Pruning weight (kg)	
Treatments	2016	2017	2016	2017	2016	2017	2016	2017
T1	139.2	140.7	107.0	107.5	0.89	0.89	2.70	2.71
T2	145.4	147.2	111.0	112.2	0.92	0.93	2.87	2.90
T3	151.5	154.0	114.5	116.0	0.96	0.98	2.91	2.94
T4	148.7	150.9	111.5	112.7	0.94	0.95	2.88	2.90
T5	156.1	159.0	117.0	118.1	0.98	1.00	3.00	3.07
T6	157.6	161.1	118.3	119.3	1.00	1.02	3.11	3.15
T7	161.3	165.0	120.6	121.1	1.07	1.90	3.29	3.44
T8	166.2	169.7	122.7	125.5	1.09	1.10	3.41	3.52
T9	179.5	182.3	127.7	128.7	1.13	1.15	3.63	3.91
New L.S.D at 5 %	1.5	2.1	1.3	1.2	0.02	0.03	0.03	0.04

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Table 5: Effect of foliar application of potassium silicate and seaweed extract on chemical constituents of leaves and canes in Superior Seedless grapevines during 2016 and 2017 seasons

	N (%)		P (%)		K (%)		Total chlorophyll (SPAD)		Total carbohydrates (g/100g)	
Treatments	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T1	1.80	1.81	0.19	0.20	1.70	1.71	25.0	25.1	22.0	22.1
T2	1.94	1.98	0.20	0.21	1.77	1.79	30.8	31.3	23.8	24.3
T3	2.00	2.30	0.23	0.24	1.80	1.83	33.2	34.0	24.3	25.0
T4	1.97	1.99	0.21	0.22	1.72	1.73	31.4	32.0	24.0	24.6
T5	2.04	2.07	0.24	0.26	1.74	1.75	34.8	35.3	25.1	26.0
T6	2.09	2.11	0.26	0.28	1.81	1.84	35.2	35.8	26.3	26.5
T7	2.13	2.18	0.28	0.30	1.90	1.92	37.3	38.0	27.5	27.7
T8	2.14	2.20	0.29	0.31	1.84	1.87	38.1	39.5	28.9	30.2
T9	2.28	2.32	0.30	0.33	1.92	1.94	40.1	41.6	30.8	31.5
New L.S.D at 5%	0.01	0.02	0.01	0.01	0.02	0.02	3.2	3.5	0.3	0.4

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Table 6: Effect of foliar application of potassium silicate and seaweed extract on chemical constituents of leaves and canes in Red Globe grapevines during 2016 and 2017 seasons

Treatments	N (%)		P (%)		K (%)		Total chlorophyll (SPAD)		Total carbohydrates (g/100g)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T1	1.77	1.78	0.20	0.20	1.58	1.59	27.0	27.2	20.2	20.4
T2	1.82	1.83	0.21	0.22	1.65	1.67	29.5	30.0	24.7	24.9
T3	1.89	1.92	0.23	0.23	1.69	1.72	31.2	32.0	25.7	26.0
T4	1.86	1.88	0.22	0.23	1.60	1.62	30.4	31.3	25.1	25.5
T5	1.92	1.94	0.23	0.24	1.62	1.63	32.0	33.1	26.1	26.6
T6	1.97	2.01	0.24	0.26	1.70	1.73	33.1	34.0	26.5	26.9
T7	1.99	2.04	0.25	0.26	1.75	1.77	35.2	36.3	27.3	28.2
T8	2.05	2.08	0.28	0.29	1.72	1.75	36.1	37.0	28.6	29.0
T9	2.13	2.18	0.30	0.32	1.76	1.84	39.0	40.3	30.1	31.0
New L.S.D at 5%	0.02	0.03	0.01	0.01	0.02	0.02	0.8	0.7	0.4	0.3

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Table 7: Effect of foliar application of potassium silicate and seaweed extract on the yield and physical properties of bunch in Superior Seedless grapevines during 2016 and 2017 seasons

Treatments	Yield/ vine (kg)		Bunch length (cm)		Bunch width (cm)		Bunch weight (g)		No. of bunches /vine	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T1	11.40	11.45	25.1	25.1	11.9	12.0	473.2	473.5	24.1	24.2
T2	14.62	14.10	27.1	27.3	12.5	12.8	562.5	564.2	26.0	25.0
T3	14.98	15.21	27.6	27.9	13.2	13.4	574.3	578.7	26.1	26.3
T4	13.94	14.46	27.2	27.5	12.7	13.0	564.7	569.3	24.7	25.4
T5	14.86	15.29	27.7	27.8	13.4	13.9	571.8	577.2	26.0	26.5
T6	14.53	15.72	27.8	28.1	13.8	14.2	576.9	582.4	25.2	27.0
T7	14.75	16.72	28.3	28.6	14.2	14.5	588.0	591.1	25.1	28.3
T8	14.91	18.10	28.7	28.9	14.7	14.9	594.3	599.5	25.1	30.2
T9	15.51	20.91	29.4	30.4	15.3	15.7	613.4	626.1	25.3	33.4
New L.S.D at 5 %	3.50	2.80	0.2	0.3	0.3	0.2	5.1	5.2	N.S.	0.5

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Table 8: Effect of foliar application of potassium silicate and seaweed extract on the yield and physical properties of bunch in Red Globe grapevines during 2016 and 2017 seasons

Treatments	Yield/ vine (kg)		Bunch length (cm)		Bunch width (cm)		Bunch weight (g)		No. of bunches /vine	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T1	15.54	17.63	21.0	21.1	15.2	15.3	785.0	787.0	19.8	22.4
T2	16.22	20.61	23.1	23.5	16.1	16.3	819.4	821.1	19.8	25.1
T3	16.46	21.68	24.8	25.0	16.8	17.0	823.2	827.5	20.0	26.2
T4	16.32	21.01	23.6	24.0	16.5	16.7	820.0	823.9	19.9	25.5
T5	16.56	21.53	25.2	25.5	17.0	17.3	824.1	828.2	20.1	26.0
T6	16.88	21.92	25.6	25.8	17.3	17.4	827.5	833.6	20.4	26.3
T7	16.59	22.55	26.7	27.1	17.5	17.7	838.1	844.4	19.8	26.7
T8	17.01	22.85	27.2	27.5	17.8	18.1	842.2	849.3	20.2	26.9
T9	17.31	24.73	28.1	28.5	18.5	18.9	865.7	873.9	20.0	28.3
New L.S.D at 5%	0.20	0.30	0.4	0.3	0.1	0.3	3.2	3.6	N.S	0.2

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Table 9: Effect of foliar application of potassium silicate and seaweed extract on physical properties of berries in Superior Seedless grapevines during 2016 and 2017 seasons

	Berry weight (g)		Berry length (cm)		Berry diameter (cm)		Berry firmness (g/cm^2)	
Treatments	2016	2017	2016	2017	2016	2017	2016	2017
T1	4.12	4.13	1.79	1.79	1.44	1.45	494.1	494.3
T2	5.07	5.09	1.88	1.92	1.62	1.65	632.5	635.3
T3	5.29	5.33	1.93	1.96	1.69	1.74	645.7	650.8
T4	5.18	5.20	1.91	1.92	1.64	1.67	624.4	629.3
T5	5.30	5.33	1.94	1.96	1.71	1.75	633.5	637.9
T6	5.32	5.35	2.02	2.05	1.75	1.78	651.6	655.4
T7	5.35	5.37	2.12	2.16	1.79	1.84	665.2	673.0
T8	5.41	5.52	2.18	2.21	1.83	1.86	660.5	668.2
T9	5.47	5.56	2.23	2.25	1.87	1.94	675.1	690.5
New L.S.D at 5 %	0.02	0.02	0.02	0.03	0.02	0.02	0.2	0.3

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Table 10: Effect of foliar application of potassium silicate and seaweed extract on physical properties of berries in Red Globe grapevines during 2016 and 2017 seasons

	Berry weight (g)		Berry length (cm)		Berry diameter (cm)		Berry firmness (g/cm^2)	
Treatments	2016	2017	2016	2017	2016	2017	2016	2017
T1	11.00	11.02	2.55	2.54	2.45	2.45	321.2	322.2
T2	11.88	12.08	2.58	2.60	2.50	2.52	341.3	345.1
T3	12.23	12.30	2.65	2.69	2.54	2.56	346.1	349.4
T4	12.05	12.15	2.61	2.64	2.51	2.53	338.0	340.5
T5	12.55	12.62	2.70	2.72	2.57	2.60	342.2	345.7
T6	12.61	12.65	2.71	2.73	2.59	2.67	355.4	366.5
T7	12.67	12.73	2.76	2.79	2.61	2.63	380.5	386.8
T8	12.74	12.79	2.80	2.84	2.67	2.75	367.4	375.6
T9	13.22	13.35	2.83	2.86	2.71	2.79	413.0	420.1
New L.S.D at 5 %	0.02	0.02	0.02	0.03	0.02	0.02	4.8	4.3

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

bunch weight, number of bunches per vine, as well as, physical properties of berries, namely; berry weight, berry length, berry diameter and berry firmness relative to control of Superior Seedless and Red Globe grapevines during 2016 and 2017 seasons. The mentioned characters reached the highest values with foliar application of seaweed extract at 0.2% + potassium silicate at 0.2%, while the minimum values were obtained from control treatment in both cultivars during the two seasons.

Chemical Properties of Berries: Data in Tables (11 & 12) obviously reveal that single or combined foliar applications of seaweed extract and potassium silicate were significantly improving T.S.S %, T.S.S/ acidity ratio and reducing total acidity in relative to untreated vines in two cultivars Superior Seedless and Red Globe grapevines during both seasons. The treatment of seaweed extract at 0.2% + potassium silicate at 0.2% was enhancing T.S.S%, T.S.S/acidity ratio and reducing total acidity in both cultivars during the two seasons.

Antioxidants Activity (DPPH): It is worthy to mention from the data in Tables (11 & 12) that foliar application of seaweed extract and potassium silicate either alone or in combinations was significantly very effective in increasing the percentage of antioxidants activity of grape berries for both cultivars compared with the control. In this respect, treatment of seaweed extract at 0.2% + potassium silicate at 0.2% had the best results for antioxidants activity in grape berries in both cultivars during the two seasons.

Table 11: Effect of foliar application of potassium silicate and seaweed extract on chemical properties of berries in Superior Seedless grapevines during 2016 and 2017 seasons

Treatments	T.S.S (%)		Acidity (%)		T.S.S/ acid ratio		Antioxidants (DPPH %)	
	2016	2017	2016	2017	2016	2017	2016	2017
T1	16.01	16.02	0.82	0.81	19.52	19.77	40.0	39.1
T2	16.78	16.82	0.73	0.69	22.98	24.37	48.4	49.3
T3	16.84	16.90	0.70	0.65	24.05	26.00	50.0	51.1
T4	16.71	16.73	0.79	0.74	21.15	22.60	44.2	44.5
T5	16.74	16.76	0.76	0.72	22.02	23.27	47.0	47.9
T6	16.97	17.03	0.69	0.65	24.59	26.20	51.2	51.6
T7	17.15	17.19	0.62	0.58	27.66	29.63	53.0	53.7
T8	17.01	17.06	0.64	0.61	26.57	27.96	52.4	53.2
T9	17.37	17.48	0.59	0.51	29.44	34.27	56.5	57.8
New L.S.D at 5 %	0.03	0.03	0.02	0.03	0.5	0.6	0.6	0.5

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Table 12: Effect of foliar application of potassium silicate and seaweed extract on chemical properties of berries in Red Globe grapevines during 2016 and 2017 seasons

Treatments	T.S.S (%)		Acidity (%)		T.S.S/ acid ratio		Total anthocyanin (g/100g)		Antioxidants (DPPH %)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T1	16.15	16.15	0.67	0.67	24.10	24.10	21.0	22.0	50.2	50.0
T2	17.36	17.42	0.63	0.61	27.56	28.56	24.4	24.9	62.7	64.0
T3	17.80	17.84	0.61	0.59	29.18	30.24	25.1	25.6	64.6	66.3
T4	17.27	17.30	0.68	0.65	25.40	26.62	23.8	24.1	58.2	59.4
T5	17.31	17.33	0.65	0.63	26.63	27.51	24.1	24.4	60.5	61.9
T6	17.83	17.85	0.57	0.54	31.28	33.06	25.8	26.0	66.5	67.1
T7	17.94	18.08	0.53	0.50	33.85	36.16	26.4	26.7	69.9	70.2
T8	17.89	17.97	0.55	0.53	32.53	33.91	26.0	26.4	67.3	68.2
T9	18.25	18.53	0.49	0.44	37.24	42.11	27.1	27.8	72.1	73.5
New L.S.D at 5 %	0.04	0.03	0.02	0.02	1.23	0.89	0.3	0.3	0.9	1.4

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Anthocyanin for Red Globe: Data obtained in Table (12) show that foliar application of seaweed extract or potassium silicate gave positive effects on anthocyanin content in berry skin of Red Globe cultivar in both seasons. Combined treatment was better than each material alone in this context. The highest values of anthocyanin content in berry skin of Red Globe grape cultivar was obtained from seaweed extract at 0.2% + potassium silicate at 0.2% compared with the other treatments during 2016 and 2017 seasons.

Powdery Mildew Progression for Superior Seedless: Foliar application of seaweed extract and potassium silicate either alone or together form had significantly effective on reducing powdery mildew progression in bunches of Superior Seedless grapevines compared with the control treatment (Table 13). On the other hand, the control treatment had the highest values in this respect. The best results of mentioned character were obtained from seaweed extract at 0.2% + potassium silicate at 0.2% for reducing powdery mildew progression in bunches of Superior Seedless grapevines during the two seasons.

Bunch Rot for Red Globe: Bunch rot of Red Globe cultivar significantly affected by foliar application with seaweed extract and potassium silicate either in combined or alone during 2016 and 2017 seasons. Foliar application with combined seaweed extract and potassium silicate reduced percentage of bunch rot compared other treatments (Table 14). The best results of reducing bunch rot of Red Globe cultivar obtained by using the foliar application of seaweed extract at 0.2% + potassium silicate at 0.2% for reducing progression of bunch rot of Red Globe cultivar.

Table 13: Effect of foliar application of potassium silicate and seaweed extract on powdery mildew progression of Superior Seedless grapevines during 2016 and 2017 seasons

	No. of berries/ bunch		No. of infected berries/ bunch		No. of infected bunches/vine		Infection of bunches/vine %		Yield/vine after loss (Kg)	
Treatments	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T1	114.9	114.6	34.3	36.0	17.0	18.1	21.07	23.49	9.00	8.76
T2	110.9	110.8	18.0	17.6	8.7	8.1	5.43	5.14	13.83	13.37
T3	108.6	108.6	15.0	14.7	6.7	6.2	3.55	3.19	14.45	14.72
T4	109.0	109.5	22.6	21.9	9.7	9.5	8.14	7.48	12.81	13.38
T5	107.9	108.3	17.0	16.6	8.3	6.9	5.03	3.99	14.11	14.68
T6	108.4	108.9	14.0	14.3	7.7	7.4	3.94	3.60	13.96	15.15
T7	109.9	110.0	12.8	12.2	4.9	4.6	2.27	1.80	14.41	16.42
T8	109.9	108.6	13.1	12.6	5.7	5.4	2.71	2.07	14.51	17.72
T9	112.1	112.6	6.4	5.7	4.7	3.9	1.06	0.59	15.35	20.79
New L.S.D at 5 %	N.S	N.S	0.2	0.3	0.1	0.1	0.11	0.14	0.10	0.12

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Table 14: Effect of foliar application of potassium silicate and seaweed extract on bunch rot progression of Red Globe grapevines during 2016 and 2017 seasons

	No. of berries/ bunch		No. of infected berries/ bunch		No. of infected bunches/vine %		Infection of bunches/vine %		Yield after loss (Kg)	
Treatments	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T1	71.36	71.42	17.1	17.8	11.2	11.3	13.55	12.58	13.43	15.41
T2	68.97	67.97	8.4	8.1	8.2	7.6	5.04	3.61	15.40	19.87
T3	67.31	67.28	7.3	7.0	6.2	5.8	3.36	2.30	15.91	21.18
T4	68.05	67.81	9.2	8.3	9.2	9.0	6.25	4.32	15.30	20.10
T5	65.67	65.63	7.7	6.9	7.8	6.4	4.55	2.59	15.81	20.97
T6	65.62	65.90	4.4	4.2	7.2	7.0	2.37	1.70	16.48	21.55
T7	66.14	66.33	3.1	2.7	4.4	4.1	1.04	0.63	16.42	22.41
T8	66.11	66.40	3.8	3.3	5.1	4.9	1.45	0.91	16.76	22.64
T9	65.48	65.46	1.7	1.6	4.2	3.4	0.55	0.29	17.22	24.66
New L.S.D at 5 %	N.S	N.S	0.5	0.4	0.1	0.1	0.20	0.30	0.03	0.04

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Table 15: Effect of foliar application of potassium silicate and seaweed extract on gross return, net return and beneficial cost ratio of Superior Seedless and Red Globe grapevines

	Superior Seedless			Red Globe		
Treatments	Gross return (L.E./ fed)	Net return (L.E./ fed)	Beneficial cost Ratio	Gross return (L.E./ fed)	Net return (L.E./ fed)	Beneficial cost ratio
T1	26639	-3931	0.89	46144	15573	1.51
T2	40801	9062	1.29	56432	24693	1.78
T3	43759	11668	1.37	59344	27253	1.85
T4	39274	7631	1.25	56640	24997	1.79
T5	43188	11209	1.35	58848	26869	1.84
T6	43666	10855	1.33	60848	28037	1.85
T7	46250	13087	1.40	62128	28965	1.87
T8	48346	15199	1.46	63040	29893	1.90
T9	54197	20698	1.62	67008	33509	2.00
New L.S.D at 5 %	150	355	0.02	180	210	0.01

T1: Control (untreated vines), T2: Potassium silicate at 0.1%, T3: Potassium silicate at 0.2%, T4: Seaweed extract at 0.1%, T5: Seaweed extract at 0.2%, T6: Potassium silicate at 0.1% + seaweed extract at 0.1%, T7: Potassium silicate at 0.2% + seaweed extract at 0.1%, T8: Potassium silicate at 0.1% + seaweed extract at 0.2%, T9: Potassium silicate at 0.2% + seaweed extract at 0.2%

Economic Analysis: The economic analysis in (Table 15) showed that the highest values of gross return of 54197 (L.E/fed), net return of 20698 (L.E/fed) and cost beneficial ratio of 1.62 as average of two growing seasons for Superior Seedless cultivar were obtained from the treatment of foliar spraying of seaweed extract at 0.2% + potassium silicate at 0.2%.While, the highest values of gross return of 67008 (L.E/fed), net return of 33509 (L.E/fed) and cost beneficial ratio of 2.00 as average of two growing seasons for Red Globe cultivar. This may be attributed to its role in increasing total vine yield (Table 7 & 8) in both cultivars. On the contrary, the control treatment was exhibited the lowest economic parameters.

DISCUSSION

Potassium silicate and seaweed extract either in combination or alone have distinct effects on the vegetative growth and berry quality and that reflect on increasing yield of Superior seedless and Red Globe grapevines. Also, seaweed extract or potassium silicate in single or combined were effective in reducing bunch infection of powdery mildew in grape berries of Superior Seedless, that reflect on berry quality and yield. Therefore, bunch rot of Red Globe affected by foliar application of potassium silicate and seaweed extract either alone or in combination.

The positive effects of seaweed extract on the vegetative growth due to its containing on oligosaccharides which resulted in improved photosynthesis, cell division and altered metabolic pathways for increased uptake and better assimilation of nitrogen [3]. Also, seaweed extract enhanced stomata control gas exchange between the interior of a leaf, stomata densities and the atmosphere and this reflected on the ability of plants to control their water relations and to enhance the photosynthesis capacity, which reflected on improving vegetative growth as described by Hetherington and Woodward [20]. Moreover, the increasing in shoot length and leaf area could be ascribed to seaweed extract enriched in auxins and cytokinins. Furthermore, Nicolas *et al.* [4] stated that IAA has a vital role on control gene (VvCEB1) that responsible on the control of cell expansion and enhancing the cell-wall network and this positively reflected on vegetative growth characters. In addition to, seaweed extract is containing on mineral nutrients which that increasing N, P and K in leaves petioles and this reflected on stimulating vegetative growth of Superior Seedless and Red Globe grapevines. Thus, seaweed extract may prevent chlorophyll degradation and increase chlorophyll content in leaf due to the presence of glycine betaines in seaweed extract, that protect the thylakoid membrane by enhancing ion homeostasis and regulating osmotic adjustment [5]. Also, magnesium in seaweed extract component has a vital role in chlorophyll synthesis and this may be increase the chlorophyll content in leaves and then reflected on accumulation of carbohydrates reserves in canes in both cultivars. Importantly, as mentioned before seaweed extract enhancing cell wall network, for this reason seaweed extract may be increased berry firmness. Additionally, Calvo *et al.* [21] reported that seaweed extract have been found to contain significant amounts of polysaccharides amino acids, organic acids, enzymes and abscisic acid, which that may be increased T.S.S%, T.S.S/acidity ratio, antioxidants activity (DPPH%) and reducing acidity in grape berries of Superior Seedless and Red Globe grapevines. Also, polyphenols and abscisic acid are found in seaweed extract [2], which that may be related to the increasing of anthocyanin in berry skin of Red Globe cultivar.

The mechanism of control fungal diseases such as powdery mildew and bunch rot in grape berries was discussed by Raj *et al.* [22] who mentioned that seaweed extract induced systemic resistance through mechanical strength of the cell wall and fortifying the physical; as well as physiological, chemical and biochemical reactions within host cells, result in synthesis of defense chemicals against pathogens. Also, they reported that defense reaction occurs due to accumulation of peroxidase as result of foliar application of seaweed extract.

Potassium silicate was improved the vegetative growth characters, through its role in cel1 division and expansion by their effect on DNA and RNA synthesis [11]. Thus, it is role in protective mechanisms that avoid the damage of the photosynthetic apparatus [12]. Also, Iqbal *et al.* [10] mentioned that the role of silicon in maintained growth by modulating stomatal conductance, higher green pigments, internal CO_2 and photosynthetic activity in grape leaves thereby enabling them to produce biomass and this may be contributed in improving of vegetative growth characteristics and chlorophyll content in leaves of Superior Seedless and Red Globe grapevines by using foliar application with potassium silicate. Meanwhile, accumulation of carbohydrates in canes of both cultivars as a result of increasing chlorophyll content in leaves.The increasing of potassium in leaves petioles as result of foliar application with potassium silicate. Also, Iqbal *et al.* [10] stated that foliar application of silicon regulating nutrient uptake in Muscadine grape, for this reason the foliar application of potassium silicate may be enhance N, P and K in leaves petioles of Superior Seedless and Red Globe grapevines. In addition to the functions of Potassium silicate in increasing berry firmness by affecting activities of major cell wall from degrading enzymes such as poly galacturonase, cellulose and xylanase [23]. In this connection, it can be deposited between cells oras part of the cell wall, with discrete silica bodies which record shapes of the cellular and intercellular spaces that they fill [13], which that may be increasing the berry firmness of Superior Seedless and Red Globe grapevines. Thus, the beneficial effects of foliar application of potassium silicate on enhancing T.S.S., T.S.S./acid ratio and reducing acidity due to the role of silicon in improving the growth and vine nutritional status surely reflected on increasing the formation of plant pigments that were responsible for building sugars in the grape berry [24]. Also, potassium has a strong role in regulating the membrane potential of the cell and therefore is critical to the uptake of other ions and sugars [25]. Eventually, Iqbal *et al.* [10] reported that foliar application of silicon improved both enzymatic and non-enzymatic antioxidants in Muscadine grape, also vines that treated with silicon had a high accumulation of proline, then it have contributed to ROS scavenging to alleviate oxidative damage in cells, so potassium silicate have vital role in enhancing antioxidants activity content in Superior Seedless and Red Globe grapevines. Furthermore, anthoncyanin content in berry skin was improved by using foliar application of potassium silicate by their effects on photosynthetic activity and potassium content in leaves petioles and this may be reflected on enhancing the anthoncyanin content in berry skin of Red Globe cultivar.

The mechanism of control fungal diseases such as powdery mildew and bunch rot was discussed by using the foliar application of potassium silicate due to silicon which directly improves plant resistance to such stressors by acting as a signal for induced chemical defenses in plants [26]. Also, it can be deposited between cells or as part of the cell wall, with discrete silica bodies which record shapes of the cellular and intercellular spaces that they fill, result in the form of silicon polymerisation below the cuticle and strengthen the mechanical structure in the cell wall and this may be explain how silicon reduces or impedes fungal penetration [14]. These results are in lines with those obtained by Raj *et al*. [22]; El-Sese *et al*. [7] and Iqbal *et al*. [10].

CONCLUSION

The results of this study highlight the role of foliar application with seaweed extract and potassium silicate in either combination or single on enhancement of vegetative growth characters and berry quality, as well as reducing some fungal diseases infections of grape berries for both Superior Seedless and Red Globe grapevines. For enhancing vegetative characters and berry quality parameters it is recommended to foliar application with potassium silicate + seaweed extract at rate of 0.2%. Also, the best results for reducing powdery mildew of grape berries of Superior Seedless grapevines and reducing bunch rot in Red Globe grapevines were obtained from treatment of potassium silicate at 0.2% + seaweed extract at 0.2%. Eventually, foliar application of seaweed extract at 0.2% + potassium silicate at 0.2% gave the highest values of total gross return, net return and beneficial cost ratio for both Superior Seedless and Red Globe grapevines.

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