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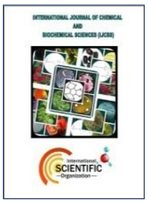

Effect of foliar spraying some nano fertilizers on physico – chemical attributes of Flame seedless grapes to minimize the conventional used fertilizers

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Abstract

This investigation carried out throughout two successive seasons 2016 and 2017, on 4 years-old Flame seedless grapevines grown in sandy soil at 2x3 m apart under drip irrigation system and vines were trellised with Y- shape system in a private vineyard at Belbies district, Sharkia Governorate, Egypt. The experiment included 8 treatments as follow: T1-Control vines will be fertilized according to the used fertilization program followed in the vineyard. T2-Spraying vines with mixture of a nano fertilizer containing potassium (36%), amino acid (5%), total nitrogen (5%), total phosphorus (2%) and micronutrient (2%) [Potacrystal at 3cm/L] (except potassium and 1/5 nitrogen). T3-Spraying vines with mixture of a nano fertilizer containing calcium (15%), magnesium (2%), boron (1.5%) with amino acid (2%) and nitrogen (10 %) [Kalmagbor at 3cm/L] (except 1/10 nitrogen). T4-Spraying vines with mixture of a nano fertilizer containing phosphorus (40 %), potassium (28 %), amino acid (5 %) and nitrogen (5 %) [Phosphoone at 3cm/L] (except potassium and phosphor and 1/5 nitrogen). T5-Spraying vines with mixture of nano micro nutrient + citric acid (Magro nano mix at 1 g/L). T6-Spraying vines with normal chelated iron at 2g/L. T7-Spraying vines with nano chelated iron at 3cm/L. T8-Spraying vines with normal potassium silicate at 5g/L. The results indicated that total yield per vine (kg) and per hectare (ton) significantly increased by application of all treatments (from T2 to T8) compared with T1 (Control). The uppermost values of total yield per hectare (38.52 & 49.25 and 42.27 & 54.62 ton) recorded for treatments T4 and T7 in the first and second season, respectively. The treatments T4, T5 and T7 gave the highest significant values in 100 berries weight (431.67 & 448.57, 420.00 & 444.33 and 418.33 & 450.33 g) in the first and second season, respectively. Berry shape index was non-significant differences between all treatments. Treatments T2, T3, T4 and T5 gave a significant increase in berry adherence strength. Treatments T7 and T8 significantly increased berry firmness. All treatments increased TSS/ acid ratio and decreased total acidity of juice grape berries compared with control. Treatments T1 and T5 recorded highest Anthocyanin content.

Keywords: Flame seedless, Potassium silicate, Micronutrients, Nano fertilizer, Fruit quality, Anthocyanin.

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1. Introduction

The grape (*Vitis vinifera* L.) considered one of the most popular and common fruit crops in the world, it ranks first in the world and fourth after citrus, mango and olive in Egypt. In Egypt the cultivated area with grape reached 187358 feddans out of them 133811 feddans are fruitful producing about 1183968 tons with an average of 8.85 ton/feddan [1]. Flame Seedless' is a popular table grape cultivar that previously introduced in Egypt and consider as a promising variety because its good qualities for local market and export [2]. The market value of 'Flame seedless grape cv. is depending upon its desirable appearance, especially homogeneity of the berries red color and cluster size and shape. Silicon (Si) exists in all plants grown in soil and its content in plant tissue varies greatly among species and genotypes ranging from 0.1 to 10% [3]. Silicon has a beneficial effect on plants, but crop plants differ radically in their ability to take up and accumulate this element [4]. Potassium silicate provides the plant a 100% available source of silicon and potassium that are essential for optimum plant growth and health. Potassium Silicate strengthens the plant's internal processes and external defenses. Potassium silicate is the name for a family of inorganic compounds. The most common potassium silicate has the formula K2SiO3, samples of which contain varying amounts of water. These are white solids or colorless solutions [5].

In the era of climate change, global agricultural systems are facing numerous, unprecedented challenges. In order to achieve food security, advanced nano-engineering is a handy tool for boosting crop production and assuring sustainability. Nanotechnology helps to improve agricultural production by increasing the efficiency of inputs and minimizing relevant losses. Nanomaterials offer a wider specific surface area to fertilizers and pesticides [6]. Nanotechnology is a means useful for the development of agricultural, especially in fertilization programs, as nano fertilizers are an effective alternative to traditional fertilizers, as they achieve many advantages due to their use with lower chemicals and the speed of absorption by the plant and their high stability under different conditions, which increases the ability to store them for longer periods. Nanotechnology can also be used to detect and treat diseases, by increasing crop production, improving their quality and ensuring crop sustainability [7]. Green revolution had led to the increased consumption of chemical fertilizers which resulted in the higher productivity on one hand, whereas on the other hand it also caused environmental hazards. Nutrient use efficiency of conventional fertilizers is very low. To overcome all these drawbacks in a better way, nanotechnology can be a ray of hope. Nano fertilizer is an important tool in agriculture to improve crop growth, yield and quality parameters with increased nutrient use efficiency, reduction in wastage of fertilizers and cost of cultivation. Nano fertilizers are applied either to soil and/ or leaves. Foliar application can be done during unfavorable soil and weather conditions. In addition to this, it promotes the direct entry of nutrients into the plant system, thus reduce the wastage of fertilizer. Hence, foliar application of nanofertilizer leads to higher nutrient use efficiency (NUE) and has given a rapid response to the growth of crops. Nanofertilizers are more reactive and can penetrate through cuticle, ensuring controlled release and targeted delivery [8,9], due to the fact that nanofertilizer has unique properties due to its small surface area with high absorption, which causes an increase in photosynthesis and leaves area [10]. Nano materials are composed of components with very small size (1–100 nm), and these components have impacts on the properties of materials at the macro level. In this scale, physical, biological and chemical characteristics of materials have fundamentally different from each other and often unexpected actions are seen from them [11,12].

In plant, micronutrients play an important role in the production and productivity. Iron is an essential element for growth of plants, lack of iron causes young leaves to yellow and photosynthesis activity to reduce significantly and consequently biomass is produced [13]. Iron is a particularly crucial micronutrient in agricultural crops [14]. Micronutrients can improve plant growth characteristics and also increase plants resistance to the negative effects of toxic ions. Specifically, higher concentrations of iron in nutritional solutions can compensate for salinity impacts [15]. Application of iron nano-fertilizer in plants can increase the plant resistance to salinity stress by simultaneously increasing the permeability of the root’s selective plasma membrane and decreasing the absorption and accumulation of sodium, which improves the ratio of potassium to sodium in the shoot [16].

The aim of this study to investigate the effect of some nano fertilization treatments on yield and fruit physico-chemical characteristics of Flame Seedless grapevine in comparison with the conventional used fertilizers.

2. Materials and Methods

This investigation carried out throughout two successive seasons of 2016 and 2017 seasons on 4 years old of Flame Seedless cv. grapevines grown in sandy soil and cultivated at 2x3 m apart under drip irrigation system and vines were trellised with Y- shape system in a private vineyard at Belbies district, Sharkia Governorate, Egypt. The experiment included 8 treatments as follow:

T1. Control vines will be fertilized according to the used commercial fertilization program followed in the vineyard.
T2. Spraying vines with mixture of a nano fertilizer containing potassium (36%), amino acid (5%), total nitrogen (5%), total phosphorus (2%) and micronutrient (2%) [Potacrystal at 3cm/L] (except potassium and 1/5 nitrogen).
T3. Spraying vines with mixture of a nano fertilizer containing calcium (15%), magnesium (2%), boron (1.5%) with amino acid (2%) and nitrogen (10 %) [Kalmagbor at 3cm/L] (except 1/10 nitrogen).
T4. Spraying vines with mixture of a nano fertilizer containing phosphorus (40 %), potassium (28 %), amino acid (5 %) and nitrogen (5 %) [Phospho one at 3cm/L] (except potassium and phosphor and 1/5 nitrogen).
T5. Spraying vines with mixture of nano micro nutrient + citric acid (Magro nano mix at 1 g/L).
T6. Spraying vines with normal chelated iron (EDDTA13%) at 2g/L.
T7. Spraying vines with nano chelated iron at 3cm/L.
T8. Spraying vines with normal potassium silicate at 5g/L.

All spraying treatments carried out three times a year at monthly intervals i.e., the first week of each of March, April and May. Whereas, fertigation treatments conducted at the same times of fertigation was followed in the vineyard. Moreover, vines treated with potassium silicate and chelated iron spraying treatments received the same fertigation program followed in the vineyard. In both seasons, bunches from each tested vine harvested after most (60%) of the fruits were considered to have exceeded the minimum market requirements of 16.5- 18 % TSS and full red berry color. The harvested bunches transported immediately to the fruit laboratory of the Horticulture Department, College of Agriculture, Zagazig University to determine the bunch and berries physical and chemical characteristics as follow:

2.1: Total yield and some bunch characteristics

Total yield/vine (kg) determined as number of bunches/vine x average bunch weight (g) and calculated per hectare (ton). Bunch compactness Coefficient was calculated by [17] as follows:

$$\text{Coefficient} = \frac{\text{No. of berries / bunch}}{\text{Bunch length cm}}$$

2.2: Fruit quality

2.2.1: Berry physical and chemical characters

1) Average 100 berries weight (g) and juice volume (ml).
2) Berry dimension (berry length and width cm) and shape index
3) Average of 100 berries weight (g)
4) Juice volume of 100-berry (cm3)
5) Berry firmness (g/cm2) and berry adherence strength (g) were recorded using a texture analyzer instrument (Fruit Hardness Tester, No.510-1) as a small cylinder (3 mm in diameter) penetrates into a distance of 3 mm inside the berry with a speed of 0.2 mm/second, then the resistance of berry to this penetration force was recorded and taken as an expression of berry firmness (g / cm2 and adherence strength (g).

2.2.2: Berry chemical constituents

1) The percentage of total soluble solids (TSS%) in the juice measured using a hand Refractometer (A.S.T., Japan).
2) Titratable acidity percentage (%) in the juice as tartaric acid determined by titration with 0.1 N NaOH solutions in presence of phenolphthalein as indicator [18].
3) Maturity index (TSS/acid ratio).
4) Anthocyanin content in 1g fruit peel tissue determined according to [19].

2.3: Statistical Analysis

The obtained data tested by the one-way analysis of variance (ANOVA) technique, according to [20]. The treatments arranged in randomized complete block design with three replications. Treatments means separated and compared using [21] test at 0.05 level of significance.

3. Results

3.1: Total yield and some bunch characteristics

The concerned results in Table (1) indicated that total yield per hectare (ton) significantly increased by application of all treatments (from T2 to T8) compared with T1 (Control) in both seasons. The uppermost values of total yield per hectare (38.52 & 49.25 and 42.27 & 54.62 ton) recorded for treatments T4 (Phospho one) and T7 (Nano chelated iron) in the first and second season, respectively, as well as T2 (Potacrystal) (22.19 kg and 38.36 ton), T3 (Kalmgbor) (23.32 kg and 40.32 ton), T5 (Magro nano mix) (22.67 kg and 39.19 ton) and T8 (Normal potassium silicate) (22.55 kg and 37.26 ton) without significant differences between them in the first season only. The least values of total yield per hectare (ton) were for control T1 (29.51& 33.36 ton) in the two experimental seasons, respectively. The other tested treatments recorded intermediate values of total yield per hectare (ton) in the two seasons.

As indicated in Table (1) it is clear that the treatment T4 (Phospho one) recorded heaviest bunch weight (786.67 and 832.00 g) in the first and second season, respectively, as well as T7 (Nano chelated iron) in the second season (823.33g). Whereas the lowest bunch weight (573.33 and 613.67 g) was recorded by the control in the first and second season, respectively. The other tested treatments produced middle values of bunch weight (gm) in both seasons. Generally, bunch weight was from 573.33 to 786.67 g and from 613.67 to 823.33g in the first and second season, respectively.

Data presented in Table (1) indicated that bunch compactness coefficient was significantly increased by all treatments except treatment T6 (Normal chelated iron) which recorded lowest values of compactness coefficient in two seasons. This increment in compactness coefficient may be to the short length of bunch and low number berries per bunch. These results were true in both seasons. Generally, bunch compactness coefficient was ranged from 7.680 to 9.153 and from 7.630 to 9.050 in the first and second season, respectively.

3.2: Fruit quality

3.2.1: Berry physical characteristics

3.2.1.1: Average 100 berries weight (g)

Results in Table (2) showed that significantly effect of 100 berries weight (gm) in the both seasons. The treatments T4 {Phospho one (nano P 40 %+ K 28 %+ N 5%+ amino acid5 %)}, T5 {Magro nano mix (nano micro nutrient+ citric acid)}and T7 (Nano chelated iron) gave the highest significant values in 100 berries weight (431.67 & 448.57, 420.00 & 444.33 and 418.33 & 450.33 g) in the first and second season, respectively, and also T3 {Kalmgbor (nano Ca15 %+ Mg2 %+ B1.5%+ N10 % + amino acid10 %)}in the first season only (404.67g). The least values of 100 berries weight were for T1 (Control) (339.33 and 343.07 g) in the two seasons, respectively. The other tested treatments produced median values of 100 berries weight in the both seasons.

3.2.1.2: Juice volume of 100-berry (cm^3)

Data presented in Table (2) cleared that the treatments T4 {Phospho one (nano P 40 %+ K 28 %+ N 5%+ amino acid5 %)}and T7 (Nano chelated iron) recorded highest juice volume of 100-berry (172.33 & 184.00 and 173.33 & 190.73 cm3) in the two seasons, respectively, as well as treatment T3 {Kalmgbor (nano Ca15 %+ Mg2 %+ B1.5%+ N10 % + amino acid10 %)} in the first season. The least values of juice volume of 100 berries were for T1 (Control) (130.00 and137.33 cm3) in the two seasons, respectively.

3.2.1.3: Berry dimension (berry length and width cm) and shape index

The data in Table (3) indicated that values of berry length (cm) were from 1.740 to 1.893 and from 1.857 to 1.973 in the first and second season, respectively. All treatments except T1 (Control) recorded significantly increased berry length (cm) without significant differences between them in both seasons. The shortest berry was for T1 (Control) in the two seasons. Data in the same Table revealed that the least values of berry width (cm) were from treatments T1 (Control) and T6 (Normal chelated iron) (1.743 & 1.797 and 1.783 & 1.830 cm) in the first and second season, respectively, as well as, T8 (Normal potassium silicate) (1.797 cm) in the first season only. The other tested treatments produced higher berry width (cm) without significant differences between them in both seasons. With regard to the effect of treatments on berry shape index (L/D) of Flame Seedless grape cultivar data presented in Table (3) clearly show that berry shape index was non-significant differences between all treatments in the two seasons.

3.2.1.4: Berry firmness and berry adherence strength

Data in Table (4) illustrated that T7 (Nano chelated iron) and T8 (Normal potassium silicate) significantly increased berry firmness (393.33 & 393.33 and 381.50 & 386.90 g/cm2) in the first and second season, respectively. The other tested treatments produced low values of berry firmness (g/cm2) without significant differences between them in the two seasons of this study. As for berry adherence strength, results in the same Table showed that treatments T2, T3, T4 and T5 gave a significant increase in berry adherence strength (476.33 & 536.33, 477.70 & 500.00, 490.00 & 509.33 and 481.50 &499.73 g) during both seasons, respectively when compared with the other studied treatments. The lowest berry adherence strength (390.00 & 406.77 and 401.50 &423.33g) was for T1 (Control) and T6 (Normal chelated iron) in the first and second season, respectively. The other tested treatments produced mid values of berry adherence strength in both seasons.

3.2.2: Berry chemical constituents

3.2.2.1: Total soluble solids percentage (TSS%)

The data presented in Table (5) cleared significantly effect in TSS% of grape berries, which ranged from17.53 to 21.60 and from 18.87 to 23. in the first and second season, respectively. The treatment T7 (Nano chelated iron) recorded the highest increase for TSS % (21.60 and 23.00 %) in the first and second season, respectively. While, treatments T1 (Control) and T3 {Kalmgbor (nano Ca15 %+ Mg2 %+ B1.5%+ N10 % + amino acid10 %)} recorded the least TSS % (18.07 & 18.87 and 17.53 & 19.53 %) in the both seasons, respectively and also T6 (Normal chelated iron) in the second season (19.93%). The other tested treatments showed median values of TSS percentages in the two seasons.

3.2.2.2: Titratable acidity percentage (%)

As shown in Table (5) all treatments in this study decreased total acidity of juice grape berries during the two seasons when compared with T1 (Control) which recorded the uppermost percentage of total acidity (0.144 and 0.127 %) in the two seasons, respectively. The other tested treatments were in the middle percentages of total acidity in the both seasons.

3.2.2.3: TSS/ acid ratio

It is clear from obtained data in Table (6) that treatments T2, T3, T6, T7 and T8 gained highest values of TSS/ acid ratio (192.36, 170.80, 172.90, 200.30 and189.02) in juice grape berries during the first season, respectively, while in the second season the highest values were for the treatments T2 and T7 (294.77 and 277.53). The other tested treatments produced intermediate percentages of total acidity (%) in the both seasons. The other tested treatments produced middle values of TSS/ acid ratio in the two seasons.

3.2.2.4: Anthocyanin content

Data in Table (6) illustrated that treatments significantly effect in anthocyanin content of grape berries, which were 397.17–853.33 and 378.50-416.40 mg/100 g F.W.) in the first and second season, respectively. The highest values of anthocyanin content were for treatments T1 (Control) and T5 {Magro nano mix (nano micro nutrient+ citric acid)} without significant differences between them (823.37 & 799.87 and 853.33 & 823.33 mg/100 g F.W.) in the first and second season, respectively. The treatments T6 (Normal chelated iron) and T7 (Nano chelated iron) recorded least values of anthocyanin content in the two seasons. The other tested treatments produced intermediate values of anthocyanin content in the two seasons.

Table 1: Effect of spraying some nano fertilizers and potassium silicate on total yield per hectare (ton), bunch weight(g) and bunch compactness coefficient of Flame Seedless grapevine (2017 and 2018 seasons)

Treatments	Total yield/ hectare (ton)		Bunch weight (g)		Bunch compactness coefficient	
	First season	Second season	First season	Second season	First season	Second season
T1- Control	29.51 b	33.36 e	573.33 f	613.67 c	9.153 a	9.050 a
T2- mix a nano K 36%+ N 5%+ P 2% + amino acid 5 % (Potacrystal at 3cm/L)	38.36 a	42.89 cd	605.00 ef	646.67 bc	8.637 ab	8.797 ab
T3- mix a nano Ca15 %+ Mg2 %+ B1.5%+ N10 % + amino acid10 % (Kalmgbor at 3cm/L)	40.32 a	42.53 cd	680.33 c	689.00 b	8.623 ab	8.433 ab
T4- mix a nano P 40 %+ K 28 %+ N 5%+ amino acid5 % (Phospho one at 3cm/L)	38.52 a	49.25 ab	786.67 a	832.00 a	8.087 ab	8.153 ab
T5- mix a nano micro nutrient+ citric acid (Magro nano mix at 1 g/L)	39.19 a	44.10 bc	654.00 cd	695.33 b	8.430 ab	8.203 ab
T6 - Normal chelated iron at 2g/L	31.50 b	38.27 de	607.33 def	650.00 bc	7.680 b	7.630 b
T7- Nano chelated iron at 3cm/L	42.27 a	54.62 a	729.00 b	823.33 a	9.140 a	9.050 a
T8- Normal potassium silicate at 5g/L	37.26 a	40.21 cd	646.00 cde	683.33 b	8.313 ab	8.523 ab

Table 2: Effect of spraying some nano fertilizers and potassium silicate on juice volume of 100-berry of Flame Seedless grapevine (2017 and 2018 seasons)

Treatments	100-berries weight (g)		Juice volume of 100-berry (cm^3)	
	First season	Second season	First season	Second season
T1- Control	339.33 e	343.07 d	130.00 c	137.33 d
T2- mix a nano K 36%+ N 5%+ P 2% + amino acid 5 % (Potacrystal at 3cm/L)	388.33 cd	396.33 c	144.33 bc	152.00 c
T3- mix a nano Ca15 %+ Mg2 %+ B1.5%+ N10 % + amino acid10 % (Kalmgbor at 3cm/L)	404.67 abc	415.67 bc	170.33 a	174.67 b
T4- mix a nano P 40 %+ K 28 %+ N 5%+ amino acid5 % (Phospho one at 3cm/L)	431.67 a	448.57 a	172.33 a	184.00 ab
T5- mix a nano micro nutrient+ citric acid (Magro nano mix at 1 g/L)	420.00 ab	444.33 ab	147.00 b	159.00 c
T6 - Normal chelated iron at 2g/L	399.00 bcd	412.27 c	153.33 b	159.33 c
T7- Nano chelated iron at 3cm/L	418.33 abc	450.33 a	173.33 a	190.73 a
T8- Normal potassium silicate at 5g/L	383.67 d	395.00 c	140.33 bc	151.00 c

Table 3: Effect of spraying some nano fertilizers and potassium silicate on berry dimension and shape index of Flame Seedless grapevine (2017 and 2018 seasons)

Treatments	Berry length (cm)		Berry width (cm)		Berry shape index (L/D)	
	First season	Second season	First season	Second season	First season	Second season
T1- Control	1.740 b	1.857 b	1.743 b	1.797 b	0.998 a	1.030 a
T2- mix a nano K 36%+ N 5%+ P 2% + amino acid 5 % (Potacrystal at 3cm/L)	1.797 ab	1.970 ab	1.937 a	2.060 a	0.928 a	0.957 a
T3- mix a nano Ca15 %+ Mg2 %+ B1.5%+ N10 % + amino acid10 % (Kalmgbor at 3cm/L)	1.880 a	1.960 ab	1.843 ab	1.927 ab	1.017 a	1.017 a
T4- mix a nano P 40 %+ K 28 %+ N 5%+ amino acid5 % (Phospho one at 3cm/L)	1.860 ab	1.983 a	1.857 ab	1.947 ab	0.997 a	1.017 a
T5- mix a nano micro nutrient+ citric acid (Magro nano mix at 1 g/L)	1.893 a	1.973 ab	1.873 ab	1.913 ab	1.007 a	1.030 a
T6 - Normal chelated iron at 2g/L	1.867 ab	1.947 ab	1.783 b	1.830 b	1.043 a	1.060 a
T7- Nano chelated iron at 3cm/L	1.877 a	1.970 ab	1.817 ab	1.900 ab	1.033 a	1.030 a
T8- Normal potassium silicate at 5g/L	1.893 a	1.920 ab	1.797 b	1.880 ab	1.050 a	1.017 a

Table 4: Effect of spraying some nano fertilizers and potassium silicate on berry firmness and berry adherence strength of Flame Seedless grapevine (2017 and 2018 seasons)

Treatments	Berry firmness (g/cm^2)		Berry adherence strength (g)	
	First season	Second season	First season	Second season
T1- Control	305.33 c	317.67 d	390.00 c	406.77 c
T2- mix a nano K 36%+ N 5%+ P 2% + amino acid 5 % (Potacrystal at 3cm/L)	308.50 c	315.33 d	476.33 ab	536.33 a
T3- mix a nano Ca15 %+ Mg2 %+ B1.5%+ N10 % + amino acid10 % (Kalmgbor at 3cm/L)	331.50 bc	344.27 cd	477.70 ab	500.00 ab
T4- mix a nano P 40 %+ K 28 %+ N 5%+ amino acid5 % (Phospho one at 3cm/L)	305.33 c	319.80 d	490.00 a	509.33 ab
T5- mix a nano micro nutrient+ citric acid (Magro nano mix at 1 g/L)	309.67 c	328.27 d	481.50 ab	499.73 ab
T6 - Normal chelated iron at 2g/L	343.50 b	361.20 bc	401.50 c	423.33 c
T7- Nano chelated iron at 3cm/L	393.33 a	393.33 a	466.17 ab	477.00 b
T8- Normal potassium silicate at 5g/L	381.50 a	386.90 ab	449.83 b	484.33 b

Table 5: Effect of spraying some nano fertilizers and potassium silicate on TSS (%) and Total acidity (%) of Flame Seedless grapevine (2017 and 2018 seasons)

Treatments	TSS (%)		Total acidity (%)	
	First season	Second season	First season	Second season
T1- Control	18.07 cd	18.87 d	0.144 a	0.127 a
T2- mix a nano K 36%+ N 5%+ P 2% + amino acid 5 % (Potacrystal at 3cm/L)	18.97 bc	20.67 bc	0.099 c	0.069 e
T3- mix a nano Ca15 %+ Mg2 %+ B1.5%+ N10 % + amino acid10 % (Kalmgbor at 3cm/L)	17.53 d	19.53 cd	0.103 c	0.079 de
T4- mix a nano P 40 %+ K 28 %+ N 5%+ amino acid5 % (Phospho one at 3cm/L)	19.33 b	20.57 bc	0.115 bc	0.107 bc
T5- mix a nano micro nutrient+ citric acid (Magro nano mix at 1 g/L)	19.80 b	21.67 b	0.123 b	0.110 b
T6 - Normal chelated iron at 2g/L	19.10 bc	19.93 cd	0.111 bc	0.092 cd
T7- Nano chelated iron at 3cm/L	21.60 a	23.00 a	0.109 bc	0.083 de
T8- Normal potassium silicate at 5g/L	19.53 b	20.23 c	0.104 c	0.082 de

Table 6: Effect of spraying some nano fertilizers and potassium silicate on TSS /acid ratio and anthocyanin content of Flame Seedless grapevine (2017 and 2018 seasons)

Treatments	TSS /acid ratio		Anthocyanin content (mg/100gF.W.)	
	First season	Second season	First season	Second season
T1- Control	126.13 c	149.27 f	82.337 ab	79.987 ab
T2- mix a nano K 36%+ N 5%+ P 2% + amino acid 5 % (Potacrystal at 3cm/L)	192.36 ab	294.77 a	61.507 e	57.197 d
T3- mix a nano Ca15 %+ Mg2 %+ B1.5%+ N10 % + amino acid10 % (Kalmgbor at 3cm/L)	170.80 ab	247.27 bc	62.717 de	57.563 d
T4- mix a nano P 40 %+ K 28 %+ N 5%+ amino acid5 % (Phospho one at 3cm/L)	168.60 b	177.70 ef	69.673 cd	66.433 cd
T5- mix a nano micro nutrient+ citric acid (Magro nano mix at 1 g/L)	163.13 b	197.13 de	85.333 a	82.333 a
T6 - Normal chelated iron at 2g/L	172.90 ab	219.93 cd	45.567 f	41.640 e
T7- Nano chelated iron at 3cm/L	200.30 a	277.53 ab	39.717 f	37.850 e
T8- Normal potassium silicate at 5g/L	189.02 ab	246.70 bc	76.667 bc	70.987 bc

4. Discussion

Nano fertilizers which contain any or combine of nano N, P, K, Ca, Mg, B, Fe, Zn (Potacrystal, Kalmgbor, Phospho one, Magro nano mix and Nano iron) had a positive effect in increasing yield and chemical attributes, agreeing with those stated by [22.23,24,25,26,27,28]. Iron is required for metabolic processes such as DNA synthesis, respiration, and photosynthesis, so it is an essential micronutrient for all living creatures [29,30]. Furthermore, because iron is a prosthetic group constituent of many enzymes such as cytochromes in the electron transport chain, it is required for many biological tasks [31]. It also participates in chlorophyll synthesis, so it is required for the chloroplast’s structure and function. This could be attributed to Fe interfering with the structural and catalytic components of proteins and enzymes, which are required for the normal development of pigment biosynthesis and photosynthesis activation [32]. Several studies have found that Fe, in its natural or nanoform, improves leaf photosynthetic pigments and photosynthesis parameters [33,34,35]. Due to the preliminary improvement of vegetative growth and photosynthesis in response to the application of different iron forms (nano, sulfate, and chelated), the fruit aspects and shelf life improved significantly. A few studies [36,37] provided scientific evidence for increased fruit quality and yield in many crops using Fe fertilization.

Foliar spray of nano Zinc and nano Boron increased pomegranate fruit quality, yield, TSS, maturity indices, juice and decreased the total acidity [38]. Similarly, nano Boron shows positive effect in increasing yield and chemical properties of fruit and enhanced the content of chlorophyll and essential nutrients like Nitrogen, Potassium, phosphorus, Manganese, Magnesium, Boron, Zinc and Iron in leaves [39]. Combining 80 % nitrogen with 0.6 % carbon nano tubes (CNTs) enhanced leaf area, fresh and dry weight, total carbohydrate % and concentration of N, P, K, Fe, and Mg in leaves, weight and juice content of 100 berries in seedless grapevines. When nitrogen fertilizer was mixed with nano Carbon, fertilization rate of nitrogen fertilizer improved, potentially save the Nitrogen fertilizers amounts in production [23]. Nano Calcium based fertilizers improve foliage development, chlorophyll content provides best yield and improves quality of grape berry and nutrient content of leaf [40] and fruit quality was best on vines fed with 0.1 % amino mineral nano fertilizer [22]. Nano Calcium effect on quantitative and qualitative characteristics of apple was evaluated. 5 sprays at 2-week interval of growing season show positive effect on fruit quality and quantity. It increases the total phenolic content, total antioxidant activity fiber and starch content and decreases the TSS, Total sugars and anthocyanin content [41].

Spraying pomegranate fruits of Ardestani cultivar with Nano Nitrogen (nN) at 1.8 kg ha-1 gave highest yield and a greater number of fruits per tree [42]. The positive effect of potassium silicate application on yield and berry quality of Flame seedless grapevine are in line with those reported by [43,43,44,45,46,47,48]. Potassium controls several enzymes activities in plants, by the modulation of photosynthesis rate as well as an increase in the translocation rate from leaves through the phloem to storage tissue, leading to improve the yield and fruit quality [49]. The increase in fruit weight and length may be attributed to higher cell division and photosynthetic activities [50]. The decrease in acidity with foliar application of potassium salt might be due to maintenance of assimilating power and increased translocation of carbohydrates [51]. The decrease in acidity following potassium sprays can also be due to conversion of acids to sugars [52]. The foliar applications also improved the TSS acid ratio. Potassium enhances the translocation of sugars and starch [53]. The increase in SSC might be due to the hydrolyzation of starch into simple sugars with the role of potassium in translocation of sugar from leaves to fruits [50].

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 [54]. 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 [55]. 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 [56]. Eventually, [57] 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 has 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.

5. Conclusions

It concluded that the use of nano fertilizers which contain any or combine of nano N, P, K, Ca, Mg, B, Fe, Zn had a positive effect on improving yield, physical and chemical attributes. Similar trend for potassium silicate application or nano-iron (Fe) on yield and physico – chemical parameters Flame seedless grapes to minimize the conventional used fertilizers.

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