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EFFECTS OF NANO CARBON AND NITROGEN FERTILIZATION ON GROWTH, LEAF MINERAL CONTENT, YIELD AND FRUIT QUALITY OF FLAME SEEDLESS GRAPE

[105]

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ABSTRACT

This investigation was carried out through two successive seasons (2014 and 2015) to investigate the effects of nano-carbon and nitrogen fertilization levels on growth, leaf mineral content, yield and fruit quality of 3 years old flame seedless grapevines, cultivated in a private orchard with loamy soil texture, at Gharbiya Governorate. Ten treatments were applied as a randomized complete block design with three replications. The result indicated that 80%N from recommended requirment+0.6% carbon nano tubes (CNTs) increased significantly leaf area, fresh and dry weight, total carbohydrate% and concentration of N, P, K, Mg, and Fe in leaves, weight of 100 berries, and juice weight of 100 berries compared with control. Also results showed that yield of combined application of 80% conventional fertilizer of nitrogen and nano-carbon at 0.6%was equal to that with supplied 100% conventional fertilizer (control). This indicated that the utilization rate of nitrogen fertilizer was increased after combined application of nano-carbon, which can save the N fertilizer amounts in production practice.

INTRODUCTION

Grape is considered as one of the most popular and favorite fruit crops in the world, for being of an excellent flavor, nice taste and high nutritional value. In Egypt, it ranks the second fruit crops and is consumed mainly as fresh fruits. The cultivated area has grown rapidly in the last two decades and reached 196900 feddans **(M.A.L.R., 2015).**

Fertilizers have an axial role in enhancing the food production in developing countries especially after the introducing of high yielding and fertilizer responsive crop varieties. Moreover, excessive amounts of nitrogen fertilizers affect the groundwater and lead to eutrophication in aquatic ecosystems. Such cases along with the fact that the fertilizer use efficiency is about 20-50 percent for nitrogen fertilizers implies that food production will have to be much more efficient than ever before **(Shaviv, 2000; Chinnamuthu and Boopathi, 2009).**

Nitrogen has a pronounced role in improving production and quality of fruits. Nitrogen plays a key role in the nutrition of plants. As a matter of fact, plant life would not be possible without this element. Nitrogen has many functions in the synthesis of proteins, protoplasm, enzymes, and organic compounds such as nucleic proteins, amino acids, polypeptides and chlorophylls. **(Tisdale et al 1985)**

The effect of nanoparticles in plants varies according to their composition, size, physical and chemical properties, as well as the plant species since the nanoparticles interact through enhancing production or inhibitory effects on plant growth in the different developmental stages (**Ma et al 2010).**

These physical and chemical features of carbon nanomaterials have been used in agriculture to increase the crop yield, mainly in the germination process, root growth, and photosynthesis. However, many other plant interaction mechanisms exist, including absorption, accumulation,

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transportation, or rejection of the nanoparticles; which have not been fully studied despite of the rapid progress in the development of this technology (**Liu et al 2009).**

Carbon nanotubes can stimulate growth, gene and protein expression of aquaporin in tobacco cells (**Khodakovskaya et al 2012)** it may also trigger the reproductive genes in similar other plants. The penetration of CNTs into the plant system is inversely proportional to its size and it is the key factor to increase the plant growth and productivity. This investigation was carried out to study the effect of different concentrations of carbon nano tubes and nitrogen fertilization on growth, leaf mineral content, yield and fruit quality of Flame seedless grapevine.

MATERIALS AND METHODS

The present study was carried out during two successive seasons 2014 and 2015 on Flame seedless grapes (*Vitis vinifera* L.). Grapevines were about 3 years old and trained on cordon system with double cordon, spur pruning (each with 2-3 eyes) and planted at 1.5×3.5 meter apart under flood irrigation system on loamy soil in a private orchard, at Gharbiya Governorate, Egypt. Full description of the tested soil is given in **Table (1)**.

Table1. Physical and chemical properties of the experimental soil.

Physical analysis								
Soil depth	**Sand %**	**Silt %**	**Clay%**	**Texture**	**pH**	**EC (*ds/m*)**	**$CaCO_3$%**	**Organic matter%**
0 – 30 cm	10.8	44	45.2	loamy	8.4	0.5	1.2	1.6
30 – 60 cm	12.8	44	43.2	loamy	8.4	0.4	2	1.1
Chemical analysis								
Soil depth	**N %**	**P %**	**K %**	**Ca%**	**Mg%**	**Fe (*ppm*)**	**Zn(*ppm*)**	**Mn (*ppm*)**
0 – 30 cm	0.13	0.6	0.9	4.2	1.1	7.8	3.4	3.2
30 – 60 cm	0.10	0.6	0.6	3.4	0.9	5.5	2.4	1.8

Grapevines received normal cultural practices as well as soil fertilized with the recommended N fertilization level (50gN / vine / year) in both organic and mineral forms (control). The nitrogen used was ammonium sulphate.

In this study three rates of nitrogen fertilization (80%, 60% and 40%) from the recommended level + three rates of multi walled carbon nano tubes(MCNTs) (0.2%, 0.4% and 0.6%)from the nitrogen amount in each rate were applied to the vines. MCNTs were purchased from Sigma Aldrich; its diameter is 110-170 nm, length: 5-9 micron.

Treatments:

100%MN 50gN/Vine/year	(control)
80% MN (40gN/vine/year)	0.2 % CNTs from total nitrogen 0.4 % CNTs from total nitrogen 0.6 % CNTs from total nitrogen
60% MN (30gN/vine/year)	0.2 % CNTs from total nitrogen 0.4 % CNTs from total nitrogen 0.6 % CNTs from total nitrogen
40% MN (20gN/vine/year)	0.2 % CNTs from total nitrogen 0.4 % CNTs from total nitrogen 0.6 % CNTs from total nitrogen

MN: Mineral nitrogen CNTs: Carbon nano tubes

Statistical analysis

The experiment was set up in a randomized complete block design with three replicates and each replicate was one vine. All data obtained during this study were statistically analyzed and the differences between means at probability of 5% were differentiated using Duncan's multiple rang test **(Duncan, 1955).**

Measurements

1-Vegetative measurements

Average leaf area (cm^2) was measured using the fifth full expanded mature leaf from the shoot tip of each vine in mid-july by planimeter. Average leaf fresh and dry weight was determined as gram, average branch length and diameter were determined as cm and number of leaves /branch was counted.

2- Chemical measurements

2.1. Leaf total chlorophyll was colorimetrically determined in fresh leaf samples according to **Wood et al (1992)** by using Minolta chlorophyll meter SPAD 502.

2.2. Total carbohydrates% during the dormancy period (the last week of January), samples were taken from the basal part of shoots and were determined according to **Smith et al (1956).**

2.3. Leaf mineral content: Further in mid-July, 20 leaves sample include blade and petiole (6^{th} leaf from the shoot tip) of each vine were collected to determine leaf mineral contents. Leaves were washed with distilled water then oven dried at 60-70º c until a constant weight. The dried samples were ground in a stainless steel knife mill and 0.2 gram of the ground material of each sample was digested using a mixture of perchloric: sulphoric acid1:10(v/v)according to (**Jackson, 1967).** Nitrogen was determined as the method described by **Pregl (1945),** while phosphorus was colorimetrically determined as the method of **Truog and Meyer (1929)**, potassium was determined using flame photometer according to the method of **Brown and Lilleland (1946)** and iron, zinc and manganese were measured using the atomic absorption apparatus according to the method of **Cotteine et al (1982).**

3-Yield and fruit quality

3.1. Yield/vine (kg): harvested at the ripening stage when TSS% reached 16% and color covered all bunch berries, clusters number per vine were counted and weighted to estimate total yield per vine kg.

3.2 Fruit quality

a- Physical properties

Average cluster dimension (length and width as cm), average cluster weight (g), the weight of 100 berries (g) and juice weight/ 100 berries (g) were determined.

b- Chemical properties:

Total soluble solids percentage in berry juice (TSS %) were determined using hand refractometer and total titratable acidity% was expressed as tartaric acid/100ml juice **(A.O.A.C, 1985)**. Total anthocyanins of the berry skin (mg/100g fresh weight) were determined according to **Husia et al (1965).**

RESULTS AND DISCUSSION

1. Effect on vegetative growth

Results presented in **Table (2)** indicated that T4 was significantly affected leaf area, leaf fresh weight and leaf dry weight, comparing with all other treatments. On the other hand, the reverse was true with the vines which fertilized with T8 (40%N+0.2%CNT), since they reflected the least values of leaf area, leaf fresh weight and leaf dry weight in the two seasons of the study.

These results are matched with those of **Haghighi and Teixeira da Silva (2014)** who found that fresh weight of radish seedlings was decreased as the CNTs concentration increased.

With regard to the response of Flame seedless grapes to nitrogen fertilization and CNTs rates. Results tabulated in **Table (3)** reveal obviously that the highest significant values of branch length and No. of leaves /branch were achieved when the vines were fertilized with T4 (80 %N + 0.6% CNT) with no significant difference than the control treatment (T1). Also it was found no significant difference among treatments in branch diameter compared to control. T4 affected significantly total

Table 2. Effect of nano carbon and nitrogen fertilization rates on leaf area, leaf fresh and dry weight of Flame seedless grapes in 2014 and 2015 seasons

Treatment	Leaf area(cm2)		Leaf fresh weight(g)		Leaf dry weight(g)	
	2014	2015	2014	2015	2014	2015
100%N(Cont.)	197.02 c	201.04 c	4.70 b	4.6b	1.39 bc	1.12d
80%N+0.2CNTS	180.71 d	191.38d	3.80 d	3.7 c	1.30 cd	1.14cd
80%N+0.4CNTS	206.51 b	208.51 b	4.13 c	4.3b	1.52 b	1.4b
80%N+0.6CNTS	218.71a	221.71 a	5.50 a	5.4 a	1.72 a	1.58a
60%N+0.2CNTS	144.03 j	171.43 e	3.13ef	3.4c	1.23 de	0.99de
60%N+0.4CNTS	176.62e	188.96 d	3.40 e	3.4c	1.33 cd	0.99de
60%N+0.6CNTS	176.61 f	190.60 d	3.40 e	3.7c	1.40 bc	1.3bc
40%N+0.2CNTS	157.61 i	161.27f	2.87 f	2.8d	1.11e	0.94e
40%N+0.4CNTS	163.11 h	166.11ef	3.20ef	3.3c	1.12 e	0.89e
40%N+0.6CNTS	165.71g	170.37 e	3.30 e	3.3c	1.23 de	0.91e

Means having the same letter(s) within a column are insignificantly different at 5% level

Table 3. Effect of nano carbon and nitrogen fertilization rates on branch length, branch diameter, no. of leaves /branch, total chlorophyll and total carbohydrate of Flame seedless grapes in 2014 and 2015 seasons

Treatment	Branch length (cm)		Branch diameter (mm)		No. leaves /branch		Total Chlorophyll (SPAD) value		Total Carbohydrate %	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
100%N(Cont.)	56.34 a	55.01ab	0.88 a	0.83a	26.98 a	26.60 ab	34.03ab	34.36 abc	5.80 b	6.13a
80%N+0.2CNTS	50.63ab	50.63 bc	0.83a	0.86a	22.66 bc	24.65b	30.00 bcde	31.33abcde	4.05 fg	5.11b
80%N+0.4CNTS	54.33 ab	55.32 ab	0.80a	0.80a	23.28 bc	25.94	32.50 abcd	33.23 abcd	4.84 d	5.18 b
80%N+0.6CNTS	56.67 a	58.66a	0.80a	0.90 a	27.45 a	29.11a	34.80 a	36.26a	6.08 a	6.61a
60%N+0.2CNTS	49.50 ab	50.86 bc	0.80a	0.76a	20.66 cde	21.32c	29.30 cde	29.2 cde	4.48 e	4.00 cd
60%N+0.4CNTS	47.3c	50.96 bc	0.73a	0.73a	21.23bcd	21.56c	30.20 bcde	30.93bcde	3.91 g	3.91 cd
60%N+0.6CNTS	49.37bc	51.37bc	0.80a	0.80a	23.67 b	25.33b	33.20 abc	34.63 ab	5.14 c	4.8 b
40%N+0.2CNTS	33.25d	44.25c	0.80a	0.76a	17.89 e	16.89d	27.40 e	27.76e	3.29 h	3.42 d
40%N+0.4CNTS	35.27d	45.94c	0.80a	0.76a	19.00 de	19.10cd	28.10 de	26.98e	4.22 f	3.93 cd
40%N+0.6CNTS	37.22d	45.22 c	0.83 a	0.83a	20.44 cde	20.50c	29.10 cde	28.63de	4.17 f	4.14 c

Means having the same letter(s) within a column are insignificantly different at 5% level.

chlorophyll and total carbohydrate comparing with all other treatments. T3 (80%N+4%CNT) increased significantly total chlorophyll in the both seasons comparing with all other treatments. On the other hand, the least values of branch length and No. of leaves /branch were detected with the vines which received T8 (40%N+0.2%CNT) in the two seasons of the study.

These results go in line with those reported by **Srivastava and Rao (2014)** who worked on wheat, maize, peanut and garlic indicated that multi walled carbon nano tubes (CNTs) significantly enhanced plant growth, number and size of leaves and biomass compared to the control. **Lahiani et al (2016)** proved that carbon- nanomaterials can activate Tobacco growth which was increased by 22% - 46% when exposed to CNTs. Also, the growth of exposed tomato seedlings was significantly enhanced by the addition of all tested CNTs. On the contrary, the root and shoot lengths of red spinach, lettuce, and cucumber were significantly reduced following exposure to MCNTs compared to control **(Begum et al 2014)**.

2. Effect on leaf mineral content

2.a. Macro elements

In **Table (4)**, it could be observed that T4 had a significant increase in leaves content of N, P, K, and Mg compared with the control. Inconstant trend could be noticed on leaf calcium content between the two studied seasons.

These results are in harmony with those found by **Liu and Liao (2008)** who reported that the activity of water after addition of nano materials was increased and N, P, K were absorbed into plants during water absorption. **Taha et al (2016)** found that addition of CNTs to the growing medium of date palm increased the percentages of elements content in the leaves (N, P, K, Ca) except Na.

2.b. Micro elements

It observed from **Table (5)** that T4 increased significantly Fe concentration in the leaves in the second season only and insignificantly Mn and Zn concentration in the leaves compared with the control.

3. Effect on yield

Concerning yield of Flame seedless grapes results presented in **Table (6)** revealed that, the vines which fertilized with T4 have the highest values of No. Clusters /vine, cluster weight and yield inthe two seasons of the study without significant difference between T4 and the control treatment (T1). There was no significant difference among treatments for cluster weight. Treatments of T3, T4 increased insignificantly No. clusters/vine, cluster weight and yield (kg/vine).

On the other hand, the reverse was true when the vines received T8 (40%N+0.2% CNTs) such treatment gave the least No. clusters/vine, cluster weight and yield in the two seasons.

These results are matched those of **Fan et al (2012)** who worked on rice and reported that combined application of nitrogen fertilization and nano-carbon increased significantly yield. We found that the yield of combined application of 70% conventional fertilized and nano-carbon was equal to 100% conventional fertilizer. **Husen and Siddiqi (2014)** discovered that carbon nano materials in edible plants and vegetables increased fruit yield up to 118%**.**

4. Effect on physical properties

Regarding the effect of combined nitrogen and CNTs on Flame seedless grapes, results tabulated in **Table (7)** clearly indicate thatT4 scored the best effect among all treatments. T4 increased significantly weight of 100 berries and juice weight/100 berries compared with all other treatments.

On the other hand, the least value of cluster length and width, weight of 100 berries and juice weight/100 berries was detected with vines fertilized with T8. Such trend was true in the two seasons.

5. Effect on chemical properties

As shown in **Table (8)** results showed that, T4 increased insignificantly TSS and significantly anthocyanin compared with the control.T7 and T9 recorded lower significant acidity than control treatment. T3 gave similar result as the control treatment in TSS, acidity and anthocyanin as differences were insignificant. T7 had no effects in fruit content of anthocyanin.

Table 4. Effect of nano carbon and nitrogen fertilization rates on macro nutrients in leaves of Flame seedless grapes in 2014 and 2015 seasons

Treatment	N%		P%		K%		Ca%		Mg%	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
100%N(Cont.)	1.24 bc	1.28bc	0.21 a	0.23 a	1.62 cd	1.82 ab	1.43 ab	1.49 a	0.43 d	0.42 ab
80%N+0.2CNTS	1.11 bcd	1.03de	0.18 bc	0.18b	1.03 e	1.41cd	1.57 a	1.47 a	0.33 f g	0.35 cde
80%N+0.4CNTS	1.29 b	1.36 ab	0.19 b	0.19b	1.74 bc	1.73 b	1.34 ab	1.43 ab	0.53 b	0.38 bc
80%N+0.6CNTS	1.56 a	1.43 a	0.21 a	0.25 a	2.16 a	1.93 a	1.19 b	1.38 bcd	0.59 a	0.45 a
60%N+0.2CNTS	1.05 cd	1.04 de	0.17 c	0.17 bc	1.38 d	1.48 c	1.47ab	1.40 abc	0.43 d	0.39 bc
60%N+0.4CNTS	1.12 bcd	1.16cd	0.14 d	0.15c	1.91 ab	1.53 c	1.55 a	1.38 bcd	0.45 c	0.36 cde
60%N+0.6CNTS	1.28 b	1.31 ab	0.17 c	0.17bc	1.86 bc	1.76 ab	1.57 a	1.46 ab	0.36 e	0.38 bcd
40%N+0.2CNTS	0.92 d	0.98 e	0.17 c	0.17bc	0.98 e	1.16 e	1.56 a	1.37 bcd	0.34 f	0.34 de
40%N+0.4CNTS	0.92 d	0.93 e	0.17 c	0.17 bc	1.79 bc	1.30 de	1.42 ab	1.33cd	0.41 d	0.36 cd
40%N+0.6CNTS	0.98 d	0.98 e	0.17 c	0.16 bc	1.91 ab	1.27 de	1.46 ab	1.29 d	0.31 g	0.32e

Means having the same letter(s) within a column are insignificantly different at 5% level.

Table 5. Effect of nano carbon and nitrogen fertilization rates on micro nutrients in leaves of Flame seedless grapes in 2014 and 2015 seasons

Treatment	Fe (ppm)		Zn (ppm)		Mn(ppm)	
	2014	2015	2014	2015	2014	2015
100%N(Cont.)	135.50 a	133.70 b	50.07 a	49.09 ab	114.50 ab	116.83 ab
80%N+0.2CNTS	134.83 a	132.76 b	47.08abc	46.74 abc	112.97 ab	113.6 bcd
80%N+0.4CNTS	135.43 a	133.43 b	40.50 de	40.5 e	107.43 b	113.2 cd
80%N+0.6CNTS	136.40 a	138.73a	49.20 ab	49.9 a	117.43 a	118.8 a
60%N+0.2CNTS	110.50 d	128.16 c	39.97 de	41.62 de	111.43 ab	112.5 d
60%N+0.4CNTS	125.53 b	126.86 c	48.80 ab	43.13 cde	105.40 b	112.06 d
60%N+0.6CNTS	133.60 a	133.4 b	39.50 e	45.19 bcd	110.26ab	114.13 bcd
40%N+0.2CNTS	115.13 c	127.4 c	45.17bc	41.16 de	105.16 b	113.8 bcd
40%N+0.4CNTS	126.53 b	126.86 c	43.73 cd	42.4 de	111.03ab	113.13 d
40%N+0.6CNTS	116.93 c	128.93 c	38.73 e	42.4 de	114.50 ab	116.5 abc

Means having the same letter(s) within a column are insignificantly different at 5% level.

Table 6. Effect of nano carbon and nitrogen fertilization rates on yield, number and weight of cluster in Flame seedless grapes in 2014 and 2015 seasons

Treatment	No. clusters/vine		Cluster weight (g)		Yield(kg)	
	2014	2015	2014	2015	2014	2015
100%N(Cont.)	32.33 ab	33.00 ab	440.67 a	443.33a	14.53 a	14.79 ab
80%N+0.2CNTS	25.33abc	26.66bcd	356.33 a	358.00 a	8.92 b	9.47 bcd
80%N+0.4CNTS	28.33abc	29.66 abc	414.33 a	413.33 a	11.90 ab	12.37 abc
80%N+0.6CNTS	33.33 a	34.33a	459.00 a	468.00 a	15.00 a	15.79 a
60%N+0.2CNTS	22.67abc	28.33 abc	337.33 a	337.66a	9.73 ab	9.30bcd
60%N+0.4CNTS	25.00 c	23.33cd	341.33 a	345.00a	7.40 b	7.82cd
60%N+0.6CNTS	29.67abc	25.66cd	350.00 a	357.00a	8.67 b	9.23bcd
40%N+0.2CNTS	21.33 c	21.00 d	285.00 a	287.33 a	6.33 b	6.22d
40%N+0.4CNTS	23.33bc	23.33cd	326.67 a	331.00 a	7.65 b	7.7cd
40%N+0.6CNTS	25.33abc	25.33cd	329.00 a	328.66 a	8.17 b	8.21cd

Means having the same letter(s) within a column are insignificantly different at 5% level.

Table 7. Effect of nano carbon and nitrogen fertilization rates on length and width of cluster, weight of 100 berries weight on Flame seedless grapes in 2014 and 2015 seasons

Treatment	Cluster length (cm)		Cluster width (cm)		Weight of 100 berries (g)		Juice weight/100 berries (g)	
	2014	2015	2014	2015	2014	2015	2014	2015
100%N(Cont.)	22.83ab	24.00 a	15.3 ab	15.66abc	300.00 cd	320 .00b	136.00 b	147.66 b
80%N+0.2CNTS	21.67 b	22.16 ab	14 bc	14.00 bcde	295.00 de	291.33 cde	123.00 c	135.33 d
80%N+0.4CNTS	22.50ab	23.50 ab	15.6 ab	16.00 ab	306.00 b	314.66 b	135.00 b	141.33 c
80%N+0.6CNTS	24.33 a	24.33 a	16.6 a	16.66 a	312.00 a	336.66 a	181.00 a	178.00a
60%N+0.2CNTS	22.00 b	22.66 ab	13.3 bc	13.33de	291.33 e	289.66 cde	113.00 e	124.67 efg
60%N+0.4CNTS	22.00 b	22.33 ab	13.6 bc	14.00 bcde	286.00 f	287.67 cde	116.00 d	127.67 ef
60%N+0.6CNTS	22.00 b	23.00 ab	15 ab	15.16 abcd	304.00bc	296.66 c	117.00 d	129.00 e
40%N+0.2CNTS	21.33 b	21.66 b	12.3 c	12.83 e	260.00 h	275.00 e	109.00 f	114.33 h
40%N+0.4CNTS	22.67ab	22.66 ab	13.3 bc	13.50 cde	266.00 g	277.33 de	109.00 f	120.00 gh
40%N+0.6CNTS	22.67ab	22.66 ab	13.6 bc	13.00de	281.00 f	292.33 cd	119.00 d	122.00 fg

Means having the same letter(s) within a column are insignificantly different at 5% level.

Table 8. Effect of nano carbon and nitrogen fertilization rates on TSS, acidity and anthocyanin in Flame seedless grapes in 2014 and 2015 seasons

Treatment	TSS%		Acidity%		Anthocyanin (mg/100g)	
	2014	2015	2014	2015	2014	2015
100%N(Cont.)	17.67 ab	17.33 ab	0.83 a	0.83 a	34.72 b	36.74 b
80%N+0.2CNTS	16.63 bc	16.33bc	0.73 abc	0.66 b	34.16 b	26.90 cd
80%N+0.4CNTS	17.33 abc	17.33 ab	0.70 abc	0.70 ab	32.66 bc	30.52 c
80%N+0.6CNTS	18.00 a	17.66 a	0.76 ab	0.76 ab	40.12 a	40.84 a
60%N+0.2CNTS	16.55 bc	16.00 c	0.73 abc	0.73 ab	30.00 cd	24.66 d
60%N+0.4CNTS	17.00 abc	15.66 c	0.63 bc	0.73 ab	28.16 de	24.48 d
60%N+0.6CNTS	17.00 abc	17.33ab	0.66 bc	0.63b	32.00bc	27.02 cd
40%N+0.2CNTS	16.54 bc	16.33 bc	0.60c	0.70 ab	26.83 de	23.68 d
40%N+0.4CNTS	16.33 c	16.33 bc	0.63 bc	0.63 b	25.95 e	23.97 d
40%N+0.6CNTS	16.67 bc	16.66 abc	0.76 ab	0.76 ab	29.95 e	26.11d

Means having the same letter(s) within a column are insignificantly different at 5% level

These results are in agreement with those reported by **Husen and Siddiqi (2014)** who reported that both functionalized and non-functionalized carbon nanomaterials influenced onfruit and crop production.

Finally, It could be concluded that the fertilization with 80%N from recommended requirment+0.6%CNT was the most effective treatment for increasing some vegetative parameters (leaf area, leaf fresh weight and leaf dry weight), some leaf mineral content (N, P, K and Mg), total carbohydrate, total chlorophyll, fruit quality (weight of 100berries and juice weight of 100 berries and fruit skin anthocyanin content) of Flame seedless grapes.

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