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(Original Article)

Effect of Some Mineral and Nano-Fertilizers on Yield and Berries Quality of Thompson Seedless Grape Cultivar

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Abstract

Nanotechnology is currently being employed extensively in horticulture. Enhancing production and fruit quality could be achieved by using nano fertilizers. The current study was conducted on Thompson Seedless grapevines planted on clay loam soil in a field experiment in the Pomology Department Research orchard, Faculty of Agriculture, Assiut University, Egypt, throughout the two consecutive seasons of 2022 and 2023. The study examined the effect of mineral fertilizers versus nano-fertilizers foliar application on yield and berry quality. Vines were sprayed with zinc (250 and 500 ppm), nano zinc (25 and 50 ppm), boron (2000 and 3000 ppm), nano boron (1000 and 1500 ppm), micronutrients (450 and 1000 ppm), nano micronutrients (450 and 1000 ppm), and distilled water (control). During the two seasons under study, the foliar application of all treatments to grapevines significantly improved yield and chemical characteristics of berries as compared to the control. On the other hand, spraying nano zinc at 50 ppm resulted in maximum yield, cluster weight, total soluble solids percentage (TSS %), TSS/TA ratio, and reducing sugars, as well as the minimum acidity juice (TA). Hence, the application of nano foliar fertilizers is crucial for improving the productivity and berry quality of the Thompson Seedless grape cultivar under the climatic conditions of Assiut Governorate.

Keywords: *Chemical characteristics, Nano-boron, Nano-micronutrients, Nano-zinc, Yield.*

Introduction

Grape (*Vitis vinifera* L.) belongs to the Vitaceae family. It originated in temperate regions and is grown on large areas under tropical conditions for table purposes (Gowda *et al*., 2008; Sharma *et al*., 2023). Seedless grapes, like Thompson, is one of the most popular grape cultivars in Egypt for table purposes and raisin processing because the berries are sweet, refreshing, and a rich source of vitamins (B1, B2, and C) and minerals (Mg, Fe, and Ca). Additionally, it has high total soluble solids, a desired shape, and thin skin. It is also considered one of the most important grape cultivars for export. According to statistics from the Food and Agriculture Organization, Egypt ranks 12th in terms of grape productivity

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among countries in the world, producing about 1,572,000 tons (FAO, 2022). Grape vines need appropriate nutritional management. Whereas, in addition to their need for fertilization with macronutrients, microelements such as Fe, Zn, B, etc. are also important and necessary for metabolism, growth, and fruit quality. Also, they have a second role in activating many metabolic enzymes (Ashley, 2011). Plant nutrients are obtained by plants in two ways, i.e., added directly to the soil or sprayed on the leaves. It was noticed that foliar application of these nutrients is better than soil application because of many benefits, such as rapid response to certain micronutrients by foliage, which are 10 to 20 times more effective than soil applications (Gowda *et al*., 2008; El-Sheikh *et al*., 2007).

Zinc (Zn) is essential for several vital plant physiological processes, including glucose synthesis, photosynthesis through chlorophyll synthesis, protein synthesis, hormone synthesis, fruit set and retention, as well as fruit yield and quality. Also, zinc is necessary for the action of other enzymes, such as aldolases, dehydrogenases, transphosphorylases, isomerases, RNA and DNA polymerases, cell division, membrane structure maintenance, and photosynthesis (Cakmak, 2008; Marschner, 2012).

Boron is also an important microelement for the normal vegetative growth of the grapevine. Its deficiency in the plant causes yellowing of the vines, damage to the shoot tips, and an increase in shot berry percentage. Also, it plays a role in some plant metabolic processes, including activation of cell division, cell wall synthesis, phenolic and carbohydrate metabolism, pollen grain germination, and tube elongation for enhancing fertilization, flowering, yield, and the formation of new reproductive tissues. In addition, it has a significant role in the activation of plant hormones, nucleic acids, dehydrogenase enzymes, and sugar translocation (Mengel *et al*., 2001; Marschner, 2012; Davarpanah *et al*., 2016; García-Sánchez *et al*., 2020).

The use of traditional fertilizers results in many problems, such as atmospheric and groundwater pollution, soil acidification, eutrophication, biodiversity loss, and decreased soil fertility (Kourgialas *et al*., 2017). Therefore, modern science has focused on the use of nanotechnology in agricultural fields. The excessive attention given to the use of nano fertilizers instead of traditional fertilizers is because they are environmentally friendly, have high effectiveness, and are applied in fewer quantities compared to traditional fertilizers. Nanoparticles are small in size, which makes them characterized by a high specific surface, and they are smaller than the leaves and root pores. Consequently, they are more effective in nutrient delivery through plant surfaces and transport channels, which results in less cost and waste of fertilizers (Sasson *et al*., 2007; Davarpanah *et al*., 2016; Kah *et al*., 2018).

Based on the above, the main aim of this study was to compare the efficacy of the foliar application of nano fertilizers and conventional fertilizers on yield and berry quality of the Thompson Seedless grape cultivar.

Materials and Method

This experiment was executed during two consecutive seasons, 2022 and 2023, on fifty-two Thompson Seedless grapevines grown at the Experimental Orchard of the Faculty of Agriculture, Assiut University, where the soil is clay loam. The selected vines were about nineteen years old at the start of this study, planted at a distance of 2 × 2 m, and were subjected to similar horticultural practices. Using a head pruning strategy, all selected vines had 72 buds, with 16 fruiting spurs with four buds each and 4 replacement buds with two buds. The experiment consisted of thirteen treatments that were replicated four times. The treatments were applied with a knapsack sprayer in the early morning, with the addition of a tween-20 (2 mL L^{-1}) to the spraying solutions to reduce the surface tension.

The treatments were performed as follows:

1-Spraying with zinc at 250 ppm.

2-Spraying with zinc at 500 ppm.

3-Spraying with nano-zinc at 25 ppm.

4-Spraying with nano-zinc at 50 ppm.

5-Spraying with boron at 2000 ppm.

6-Spraying with boron at 3000 ppm.

7-Spraying with nano-boron 1000 ppm.

8-Spraying with nano-boron at 1500 ppm.

9-Spraying with micronutrients at 450 ppm.

10-Spraying with micronutrients at 1000 ppm.

11-Spraying with nano-micronutrients at 450 ppm.

12-Spraying with nano-micronutrients at 1000 ppm.

13-Spraying with distilled water (control).

The foliar applications of fertilizers were conducted three times per season; the first at early bloom (April 15th), the second just after fruit set (the first week of May), and the third in the first week of June. At the end of the two seasons, the following parameters were recorded:

Yield components

The yield was collected at the appropriate maturity stage (mid-July) in both seasons to determine the following parameters:

- Average cluster weight (g).

- Yield weight (kg/vine), which was calculated by multiplying the number of clusters/vine by the average cluster weight.

Chemical measurements:

- Total soluble solids:

Total soluble solids percentage (T.S.S. %) in berry juice was measured by the hand refractometer.

- Total acidity percentage:

Berry juice was titrated by NaOH (0.1 N) using an indicator (phenolphthalein), and total acidity % was expressed as gm of tartaric acid/100 ml juice (A.O.A.C., 1985) according to the following equation:

$$\text{Total acidity \%} = \frac{\text{NaOH used} \times \text{ standard solution of NaOH (N)} \times 75}{1000 \times \text{sample volume}} \times 100$$

* Standard solution of NaOH (N) = 0.1

*75 = the equivalent weight of tartaric acid

*Sample volume = 5 ml

- TSS / acid ratio

It was calculated by dividing TSS % by total acidity %.

- Reducing sugars percentage

Reducing sugars % in berry juice was determined according to the Lane and Eynon procedure as outlined in A.O.A.C. (1985).

Statistical analysis

The obtained data were statistically analyzed using a randomized complete block design (RCBD) by the SAS software program. The significance of mean differences was examined using Duncan's method.

Results

Yield components and cluster measurements:

Yield weight (kg/vine)

The results presented in Table 1 indicated that most of the treatments had a positive influence on yield compared to control. During the 1st season, the highest values were scored by the nano zinc treatment at 50 ppm, followed by each of the nano-micronutrients at 1000 ppm and nano-micronutrients at 450 ppm, with no significant differences between them. On the other hand, the maximum yield weight in the 2nd season was obtained from nano zinc treatment at 50 ppm, followed by each of the boron at 3000 ppm and nano-micronutrients at 1000 ppm with no significant differences between them. The combined analysis over the two seasons showed that the best treatments were nano zinc treatment at 50 ppm, followed by each of the nano-micronutrients at 1000 ppm and boron at 3000 ppm compared to the control, respectively.

Cluster weight (g)

It is clear from Table 1 that all treatments caused a significant increase in the cluster weight compared to control during both seasons. Nano zinc at 50 ppm, boron at 3000 ppm, and nano-micronutrients at 450 ppm were superior to the other treatments during the first season. Meanwhile, in the second season, the most effective treatments were nano zinc treatment at 50 ppm, followed by each of the nano-micronutrients at 1000 ppm and nano-micronutrients at 450 ppm. The highest values were obtained from nano zinc at 50 ppm, micronutrients at 1000 ppm, and boron at 3000 ppm, respectively, as an average of the two years of study.

Table 1. Effect of some mineral and nano-fertilizers on yield weight (kg) and cluster weight (g) of Thompson Seedless grape cultivar during 2022 and 2023 seasons.

Treatments	Yield weight (kg)			Cluster weight (g)		
	2022	2023	Mean	2022	2023	Mean
Control	5.12 d	5.17 e	5.15 e	168.33 k	201.75 l	185.04 l
Zn 250 ppm.	5.59 bcd	6.04 de	5.82 cde	188.33 j	224.83 k	206.58 k
Zn 500 ppm.	5.72 bcd	6.58 bcd	6.15 cde	231.83 h	272.92 h	252.38 i
N-Zn 25 ppm.	5.52 bcd	6.10 de	5.81 cde	231.33 h	246.67 j	239.00 j
N-Zn 50 ppm.	7.20 a	8.00 a	7.60 a	313.33 a	365.34 a	339.34 a
B 2000 ppm.	6.61 ab	6.64 bcde	6.63 abcd	255.33 d	279.25 f	267.29 e
B 3000 ppm.	6.28 abc	7.87 ab	7.08 abc	280.67 b	287.09 d	283.88 c
N-B 1000 ppm.	5.32 cd	6.16 de	5.74 de	252.08 e	275.00 g	263.54 f
N-B 1500 ppm.	5.24 d	6.46 cde	5.85 cde	251.67 e	265.83 i	258.75 g
Micro. 450 ppm.	5.35 cd	6.91 abcd	6.13 cde	229.00 i	284.17 e	256.59 h
Micro. 1000 ppm.	5.77 bcd	6.85 abcd	6.31 bcde	249.58 f	278.75 f	264.17 f
N-Micro. 450 ppm.	6.73 ab	7.07 abcd	6.90 abcd	260.63 c	292.08 c	276.36 d
N-Micro. 1000 ppm.	7.17 a	7.77 abc	7.47 ab	239.59 g	337.08 b	288.34 b

Means followed by the same letter in each column are not significantly different at $p \leq 0.05$ using Duncan's multiple range test.

Total soluble solids (TSS %)

Total soluble solids significantly increased in two seasons due to all studied treatments compared to control (Table 2). Moreover, the total soluble solids in the 2nd season were higher than in the 1st season. The nano zinc at 50 ppm surpassed all treatments in both studied seasons. The two seasons' average data illustrated that the nano zinc at 50 ppm, the nano-micronutrients at 1000 ppm, and the boron at 3000 ppm gave the highest percentage of total soluble solids compared to the control and other treatments.

Total acidity percentage

The impact of treatments on total acidity % is shown in Table 2. In the first and second seasons, although there were decreases in total acidity due to different treatments studied compared with the control, the differences were not significant between most of the treatments. Moreover, the vines subjected to boron at 3000 ppm nano-microelements at 450 ppm and nano zinc at 50 ppm in both seasons produced the lowest values of total acidity compared to the control without significant difference between them. Data from the study's two-year averages showed that every treatment significantly affected the total acidity percentage with the exception of zinc at 250 ppm, 500 ppm, nano zinc at 25 ppm, and nano boron at 1000 ppm as compared to the control.

Table 2. Effect of some mineral and nano-fertilizers on total soluble solids % and total acidity % of Thompson Seedless grape cultivar during 2022 and 2023 seasons.

Treatment	Total soluble solids %			Total acidity %		
	2022	2023	Mean	2022	2023	Mean
Control	21.60 m	22.10 m	21.85 l	1.10 a	1.19 a	1.15 a
Zn 250 ppm.	22.25 l	23.40 k	22.83 k	0.93 abc	1.12 a	1.03 ab
Zn 500 ppm.	22.65 k	23.35 l	23.00 j	0.95 ab	0.89 ab	0.92 abc
N-Zn 25 ppm.	22.70 j	23.75 i	23.23 i	0.92 abcd	0.90 ab	0.91 abc
N-Zn 50 ppm.	24.90 a	26.60 a	25.75 a	0.57 cd	0.55 b	0.56 c
B 2000 ppm.	23.28 g	25.00 e	24.14 e	0.69 bcd	0.59 b	0.64 bc
B 3000 ppm.	23.65 d	25.78 b	24.72 c	0.55 d	0.48 b	0.52 c
N-B 1000 ppm.	23.45 e	23.60 j	23.53 g	0.72 bcd	0.61 b	0.67 abc
N-B 1500 ppm.	22.90 i	23.85 h	23.38 h	0.61 bcd	0.74 ab	0.68 bc
Micro. 450 ppm.	23.30 f	24.65 g	23.98 f	0.72 bcd	0.62 b	0.67 bc
Micro. 1000 ppm.	23.25 h	24.70 f	23.98 f	0.68 bcd	0.60 b	0.64 bc
N-Micro. 450 ppm.	24.25 c	25.05 d	24.65 d	0.55 d	0.48 b	0.52 c
N-Micro. 1000 ppm.	24.40 b	25.35 c	24.88 b	0.70 bcd	0.62 b	0.66 bc

Means followed by the same letter in each column are not significantly different at $p \leq 0.05$ using Duncan's multiple range test.

Total soluble solids/acid ratio

Throughout the two seasons, each treatment demonstrated significant superiority in its effects on the total soluble solids/acid ratio as compared to the control (Table 3). In the first season, the data manifested how superior nano-microelements at 450 ppm, nano zinc at 50 ppm, and boron at 3000 ppm treatments compared to control and other treatments, respectively. On the other side, in the second season, the highest ratio was obtained by boron at 3000 ppm, followed by the treatment of nano-microelements at 450 ppm and nano zinc at 50 ppm, respectively. Likewise, boron at 3000 ppm outperformed all treatments, followed by the treatment of nano-microelements at 450 ppm and nano zinc at 50 ppm, respectively, according to the combined analysis conducted over the course of the two-year study.

Reducing sugar

Evaluating the overall analysis for the two research seasons in Table 3 revealed that all treatments significantly increased reducing sugar % compared to the control. Additionally, spraying with nano zinc at 50 ppm, boron at 3000 ppm, and nano-micronutrients at 1000 ppm treatments scored the highest values in the first season, respectively. On the other hand, in the second season, the highest reducing sugar values were obtained using nano zinc at 50 ppm, nano-micronutrients at 1000, and nano-micronutrients at 450 ppm, respectively, with no significant difference between them.

Table 3. Effect of some mineral and nano-fertilizers on total soluble solids/acid ratio and reducing sugar % of Thompson Seedless grape cultivar during 2022 and 2023 seasons.

Treatments	Total soluble solids/acid ratio			Reducing sugar %		
	2022	2023	Mean	2022	2023	Mean
Control	19.64 m	18.57 m	19.10 m	15.18 f	15.88 ef	15.53 t
Zn 250 ppm.	23.92 k	20.89 l	22.41 l	15.96 ef	15.26 f	15.61 l
Zn 500 ppm.	23.84 l	26.24 k	25.04 k	15.85 ef	16.17 def	16.01 k
N-Zn 25 ppm.	24.67 j	26.39 j	25.53 j	16.29 def	16.29 def	16.29 j
N-Zn 50 ppm.	43.68 b	48.36 c	46.02 c	18.48 a	18.37 a	18.42 a
B 2000 ppm.	33.74 g	42.36 d	38.06 d	17.49 abcd	16.73 bcde	17.11 e
B 3000 ppm.	43 c	53.71 a	48.35 a	18.14 a	17.50 abc	17.82 c
N-B 1000 ppm.	32.57 h	38.69 h	35.63 h	16.28 def	17.28 abcd	16.78 g
N-B 1500 ppm.	37.54 d	32.23 i	34.89 i	16.53 cde	16.40 cdef	16.46 i
Micro. 450 ppm.	32.36 i	39.76 g	36.06 g	16.72 bcde	17.28 abcd	17 f
Micro. 1000 ppm.	34.19 f	41.16 e	37.68 f	16.83 bcde	16.62 bcde	16.72 h
N-Micro. 450 ppm.	44.09 a	52.19 b	48.14 b	17.71 abc	17.62 ab	17.66 d
N-Micro. 1000 ppm.	34.86 e	40.88 f	37.87 e	17.82 ab	18.15 a	17.98 b

Means followed by the same letter in each column are not significantly different at $p \leq 0.05$ using Duncan's multiple range test.

Discussion

Grapes are an important fruit in the world. Accordingly, scientific research focuses on enhancing fruits' specifications (Yao *et al*., 2019). Fertilization in the vineyard is a necessary practice that must be carried out every year in order to renew the vine's herbal mass and grape yield (Duletić and Mijović, 2014). In recent years, Egyptian soil has been suffering from a deficiency of micronutrients due to people's interest in applying macronutrients such as NPK fertilizers while neglecting the application of micronutrients. This deficiency causes physiological disturbance in plants, leading to decreasing yield and declining fruit quality. As these microelements not only are essential for plants but also are no less important than macroelements for plant growth (Aksentyuk and Zhuravel, 1985; Das, 2014; Yadav and Solanki, 2015; Yao *et al*., 2019).

Microelements application in the soil prevents their absorption by the plant because they bind to soil particles, which reduces the plant roots' ability to absorb them, causing a decrease in both root growth and quality of the final product (Kamiab and Zamanibahramabadi, 2016). Thus, foliar fertilization is an efficient method for tree nutrition. It decreases concerns related to soil application, including nutrient tie-up, loss, or fixation (Suman *et al*., 2017). There are several challenges related to using commercial chemical fertilizers, such as eutrophication, loss of biodiversity, soil acidification and groundwater, and air pollution (Kourgialas *et al*., 2017). Furthermore, in recent years, there have been several efforts to reduce the use of chemical fertilizers by replacing them with nano fertilizers (Liu and Lal, 2015).

The current study focused on evaluating the foliar application of nano and traditional micro-fertilizers on the yield and berry quality of the Thompson

Seedless grape. The present study revealed that nano microelements had a significant effect on yield and berry quality of Thompson Seedless. These findings are in accordance with those indicated by Wassel *et al*. (2017), Mohamed (2018), Mekawy (2021), Uwakiem (2021), Arji *et al*. (2022), Abo-El-Ez *et al*. (2023), Awad *et al*. (2023), Belal *et al*. (2023), and Guillén-Enriquez *et al*. (2023).

Fruit weight increase may be the result of improved plant metabolism and fruit development brought on by the application of micronutrients (Tripathi *et al*., 2015). The previous positive impact of zinc on the cluster weight of grapes could be attributed to its essential role in mitotic cell division, causing protein synthesis and carbohydrate metabolism, increasing fruit weight, and decreasing fruit loss. Moreover, Zn has a key role in the synthesis of auxin, which may be responsible for the increased fruit weight (Gao *et al*., 2006; Rout and Das, 2009; and Bhosale *et al*., 2018). Also, zinc regulated the permeability of the plant cell membrane, resulting in the movement of large amounts of water that related to increasing fruit weight (Wali *et al*., 2005).

As for the increase in yield when zinc is applied, it may be due to reducing fruit drop because of preventing the formation of a fruit abscission layer. In addition, it is important to note that plants might be able to create more assimilates, which would have increased fruit production, due to the increase in leaf area, chlorophyll levels of the leaves, and relative water content (Laishram and Baruah, 2020). Other studies have shown that the positive impact of using boron on yield might be attributed to its beneficial effect on water retention, fruit retention, enhancing germination of pollens, sugar biosynthesis and translocation, initial fruit setting, cell division, natural hormones, and the tolerance of trees to salinity and drought stresses (Marschner, 2012).

Regarding the berries chemical parameters, the foliar application of bulk and nano zinc, boron, and other microelements led to a significant increment in the TSS%, TSS/TA, and sugars in juice compared with the control. This can be due to micronutrients having favorable actions on better fruit set, yield indices, and productivity, which affects plants metabolic pathways and photosynthetic activities, resulting in increased primary metabolite production such as higher total soluble solids and increased sugar production in fruit (Mohebbi *et al*., 2022). The increase in the concentration of sugar in berries treated with zinc could be attributed to a role of zinc in forming photosynthetic pigments in the leaves related to the manufacture of sugars by the photosynthesis process, which transfers to the fruits and then causes an increase in sugar content in the berries (Dart, J. 2007; Hadi and Saleh, 2021).

According to Bybordi and Shabanov (2010) and Nikkhah *et al.* (2013), vital micronutrients, such as zinc, are involved in the activation of the enzymes 6-bis phosphatase and fructose-1, which are crucial for metabolic processes that accumulate sugars in fruits. Higher plants depend on boron for the short- and long-distance transport of sugars through the production of borate-sugar complexes and cis-dol borate complexes. Additionally, boron may help leaves absorb sugar (Aashiq *et al*., 2017). On the other side, according to Gupta (1980), boron's action on many enzymes involved in the synthesis of various proteins, acids, and sugars may be the cause of the rise in total soluble solids.

The current results concerning the effect of bulk and nano micronutrients on TSS and sugars were reported by several workers, including Ramya and Subbarayappa (2017), Abou-Zaid and Shaaban (2019), Wassel *et al*. (2020), Abou El-Nasr *et al*. (2021), Ali *et al*. (2021), El-Sayed *et al*. (2021), Uwakiem (2021), Arji *et al*. (2022), Mohebbi (2022), Shoug (2022), Belal *et al*. (2023), and Shaaban *et al*. (2024).

Concerning acidity, the accumulation of reducing sugars as a result of an increase in TSS and the activation of enzymes that convert organic acids into sugars, as well as the increase in juice content within the fruits and the dilution process used to augment it, can all be considered contributing factors to the decrease in acidity (Brahmachari *et al*., 1997; Davarpanah *et al*., 2013; and Hussein *et al*., 2023). Zinc helps hydrolyze complex polysaccharides into simple sugars, which improves TSS. This could be the cause of the increase in total soluble solids content and decrease in acidity % (Rawat *et al*., 2010). The positive effects of nano and bulk zinc, boron, and a mixture of microelements on the acidity of berry juice have been noticed by Ramya and Subbarayappa (2017), Al-Atrushy (2019), Fawzi *et al*. (2019), El-Sayed *et al*. (2021), Abou El-Nasr *et al*. (2021), Arji *et al*. (2022), Lateef *et al*. (2022), and Awad *et al*. (2023). While Ranjit Pal and Ghosh (2017) found that acidity in the berry juice of grapes was not significantly influenced by foliar application with zinc at 0.2 % and borax at 0.3 %.

Under the conditions of the present study, the best results related to yield and berry quality of the Thompson Seedless grape cultivar were obtained by nano fertilizers. This could be attributed to synchronizing nutrient release, preventing unwanted nutrient losses to soil, air, and water through direct crop internalization, avoiding nutrient interactions with soil, water, and air microorganisms, improving their efficiency, and lowering soil toxicity. They primarily prolong the fertilizer impact time and postpone the release of nutrients (Rai *et al*., 2012, and Prasad *et al*., 2014).

Conclusion

Grape productivity and berry quality improved by spraying mineral and nano-fertilizers. Foliar application of nano-nutrients resulted in the greatest improvements, especially nano-zinc at 50 ppm. Subsequently, the application of nano foliar fertilizers is crucial for improving the productivity and berry quality of the Thompson Seedless grape cultivar under the climatic conditions of Assiut Governorate.

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تأثير بعض الأسـمدة المعدنية والنانوية على المحصـول وجودة حبات صـنف العنب الطومسـون سيدلس

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الملخص

في وقتنا الحالي تُستخدم تقنية النانو على نطاق واسع في الزراعة حيث يتطلب تحسين الإنتاج وجودة الثمار استخدام الأسمدة النانوية. لذلك أجريت الدراسة الحالية على كروم العنب الطومسون سيدلس (البناتى الابيض) المزروعة في تربة طينية في المزرعة البحثية لقسم الفاكهة، كلية الزراعة، جامعة أسيوط خلال موسمي 2022 و2023. بهدف دراسة تأثير الأسمدة المعدنية مقابل الأسمدة النانوية كأسمدة ورقية على المحصول وجودة الحبات. تم رش الكروم بالزنك (250 ، 500 جزء في المليون)، الزنك النانوي (25 ، 50 جزء في المليون)، البورون (2000 ، 3000 جزء في المليون)، البورون النانوي (1000 ، 1500 جزء في المليون)، العناصر الغذائية الصغرى (450 ، 1000 جزء في المليون)، العناصر الغذائية الصغرى النانوية (450 ، 1000 جزء في المليون)، والماء المقطر (الكنترول). خلال الموسمين قيد الدراسة، أدى الرش الورقي لجميع المعاملات على الكروم إلى تحسين المحصول والخصائص الكيميائية للحبات بشكل ملحوظ مقارنة بالكنترول. من ناحية أخرى، أدى رش الزنك النانوي بتركيز 50 جزء في المليون إلى أقصى إنتاج ووزن العنقود ونسبة المواد الصلبة الذائبة الكلية (TSS) ونسبة TSS / TA والسكريات المختزلة وكذلك أقل نسبة من حموضة العصير (TA)، ومن ثم يعد تطبيق الأسمدة الورقية النانوية أمر بالغ الأهمية لتحسين إنتاجية وجودة الحبات لصنف العنب الطومسون سيدلس في ظل الظروف المناخية لمحافظة أسيوط.

الكلمات المفتاحية: *البورون النانوي، الخصائص الكيميائية، الزنك النانوي، العناصر الغذائية الصغرى النانوية، المحصول*