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(Original Article)

Effect of Zinc Applications on the Productivity of Thompson Seedless Grapevines

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Abstract

The most significant table grape cultivar in Egypt is the Thompson Seedless. Table grape production aims to improve grape quality attributes, primarily in response to market demand. A healthy grapevine's growth and development depend on zinc. To achieve optimal yield and berry quality, foliar treatment of zinc must be done while keeping an eye on suitable zinc levels. Twenty-eight uniform Thompson Seedless grapevines were used in the current experiment, which took place at the Fruit Section of the Faculty of Agriculture, Assiut University, at the Experimental Orchard throughout two consecutive seasons of 2021 and 2022. Seven treatments were conducted in four replicates (vines) and organized in a randomized complete block design. The treatments are: nano zinc oxide (1 and 2 ppm), zinc sulfate (100 and 200 ppm), chelated zinc (100 and 200 ppm), and control. Spraying was achieved when the new shoots reached 10-15 cm long, after fruit set, and one month later. The study's findings demonstrated that spraying the clusters with various forms and concentrations of zinc improved the Thompson Seedless grape cultivar's fruit quality and yield components in comparison to the control treatment. Following zinc sulfate at 100 ppm and chelated zinc at 100 ppm in that order, nano zinc oxide therapy at 2 ppm was likewise the most successful. Therefore, it might be suggested to spray the clusters with nano zinc at a concentration of 2 ppm or zinc sulfate at a concentration of 100 ppm for the best results.

Keywords: *Nano zinc, Zinc sulfate, Chelated zinc, Fruit quality, Yield components*

Introduction

The Thompson Seedless grape is Egypt's most important table grape cultivar. It is sweet, refreshing and natural source of minerals, and vitamins (B1, B2 and C). A notable variety for export, table grapes are also used to manufacture raisins. Increasing grape quality attributes such as cluster size; fruit size and shape, consistent coloration throughout the cluster, and enhanced transportation resistance are the main objectives of table grape production, which is based mostly on market demand (Creasy and Creasy, 2009).

Since it is quite expensive for plants to absorb certain micronutrients from the soil when they are not very efficient, spraying is one option that may be

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employed (Siavashi et al., 2004). According to Hemantaranjan & Gray (1988) and Stampar *et al*. (1998), foliar treatment can provide plants with access to nutrients that will ensure excellent performance.

One of the most important elements for plants is zinc (Zn), and deficiencies in Zn are prevalent in various crops (Marschner, 2012; Ojeda-Barrios *et al*., 2014). Zinc is necessary for many different enzymes to function, such as RNA and DNA polymerases, and cell division. It also plays a role in tryptophan synthesis, membrane structure maintenance, and photosynthesis. Finally, zinc functions as a regulatory cofactor in protein synthesis (Marschner, 2012 and Yadav *et al*., 2022).

Micronutrient fertilizers applied as nanoparticles have been shown to be a valuable means of supplying plants with nutrients in a regulated manner, which is necessary to reduce pollution issues associated with traditional fertilizer application (Naderi and Abedi, 2012). Zinc nanoparticles' tiny size and excellent surface area to size ratio make them appropriate for topical application or ingestion by plants. Both soil treatment methods and leaf application techniques effectively transfer the element (Czyzowska and Barbasz, 2022). Although zinc nanoparticles have been shown to be advantageous to horticultural crops, they can also be detrimental to plants. In general, zinc nanoparticles promote some aspects of plant growth and development. Aslani *et al*. (2014) state that zinc concentration has an effect on the production and quality of fruits, vegetables, and other crops. They are used in agriculture to improve seed germination and several other features.

The current study aims to provide further details on the effects of various zinc forms and dosages on the yield and berry quality of Thompson Seedless grapevines.

Materials and Methods

Plant materials and treatments

The experiment was conducted on twenty-eight uniform Thompson Seedless grapevines during two consecutive seasons of 2021 and 2022 at the Experimental Orchard at Fruit Section, Faculty of Agriculture, Assiut University. The goal of the study was to determine the effects of different forms of zinc, namely nano zinc oxide (ZnO NPs), zinc sulfate ($ZnSO_4$), and chelated zinc (Zn EDTA), on fruit quality and yield. The chosen vines were split into seven treatments, one of which was control. Each treatment was applied to four vines (Replicates), which were organized in a randomized complete block design. The experiment started with 35-year-old vines that were planted at 2.5 × 2.5 m apart. Using a head pruning approach, all of the chosen vines had a total bud load of 72 buds/vine, which was calculated as 16 fruiting spurs x 4 buds + 4 replacement spurs x 2 buds/vine. The grapevines were planted on clay loam soil and were managed horticulturally in the same way. The vines are irrigated with the River Nile water using surface irrigation. The experimental site's soil was of the Torri Fluvents type, with a pH of 7.77, an ECe of 1.01 ds m-1, 66.48% clay, 12% silt, and 22.52% sand.. The chosen vines were subjected to seven spray treatments: nano zinc oxide (1 and 2 ppm), zinc sulfate (100 and 200 ppm), chelated zinc (100 and 200 ppm), and control. A back-held sprayer (2L per vine) was used for the foliar treatments, which were applied in the early morning. The designated quantity of zinc fertilizers was dissolved in the necessary distilled water to create solutions from various sources. As a surfactant, tween-20 was added to treatments (2 m L^{-1}) to aid in the absorption of spray solutions. Throughout the course of the two research seasons, the chosen vines were sprayed three times until runoff, which occurred when the new shoots reached 10-15 cm long, after fruit set, and one month later.

Plant measurements

Yield components

During harvest time in both seasons, the estimated yield weight (kg/vine) was determined by computing the average weight of each cluster and counting the number of clusters on each vine. The following features were evaluated using these clusters after the average cluster weight from samples of three randomly chosen clusters from each vine was determined.

Fruit quality

A vernier caliper was used to determine the cluster's length and width, and the weight of the cluster rachis was calculated. Estimates were made for the berry length, diameter, and weight, and juice volume of 100 berries were estimated. Using a hand refractometer, the berry's total soluble solids (TSS) were measured. Titratable acidity (TA) was then assessed, and the TSS/acid ratio was calculated. The following equation (A.O.A.C., 1995) was used to calculate titratable acidity (TA), which was measured by direct titration with 0.1N NaOH using phenolphthalein as an indicator. TA was expressed as mg tartaric acid per 100 ml juice.

$$\text{Acidity \%} = \frac{\text{NaOH volume in titration} \times \text{NaOH molarity} \times \text{equivalent weight of tartaric acid}}{1000 \times \text{sample volume}} \times 100$$

Where: Equivalent weight of tartaric acid = 75, NaOH molarity = 0.1M, Sample vol. = 5 ml.

The percentage of reducing sugars was determined, according to A.O.A.C. (1995).

Statistical analysis

The experiment was set up using a randomized complete blocked design (RCBD) with seven treatments and four replicates for each treatment. Procedure Analysis of variance (ANOVA) was performed using a combination of the SAS programme version 9.2 (SAS, 2008) and the Duncan's multiple range test, which compares differences across treatment means (Snedecor and Cochran, 1990).Results

Yield components

The findings showed how much each treatment differed from the control in both seasons in terms of its impact on total yield weight/vine and cluster weight (Table 1). The two ppm treatment with nano zinc oxide produced the highest yield/vine, increasing above the control by 75 and 80% in each of the two research seasons. Zinc sulphate at 100 ppm, chelated zinc at 100 ppm, and chelated zinc at 200 ppm were the next highest yields/vine. Conversely, the control treatment yielded the least amount of weight per vine.

The vines treated with nano zinc oxide at 2 ppm, an increment of 52.7% over the control treatment, produced the highest cluster weight in the 1st season. These treatments were followed by chelated zinc at 100 ppm, chelated zinc at 200 ppm, and zinc sulphate at 100 ppm, in that order. The highest cluster weight was obtained in the 2nd season by the vines treated with nano zinc oxide at 2 ppm, chelated zinc at 100 ppm, zinc sulphate at 100 ppm, and zinc sulphate at 200 ppm. With an increment of 47.7, 44.9, 42.9, and 41.4% over the control, the cluster weight of these treatments was 387.8, 380.3, 375.0, and 371.3 g, respectively.

Table 1. Effect of nano zinc oxide, zinc sulfate and chelated zinc foliar application on yield components of Thompson Seedless grape cultivar during 2021 and 2022 seasons.

Characteristic / Treatment	Yield Weight (kg)		Cluster Weight (g)	
	2021	2022	2021	2022
Nano zinc oxide 1 ppm	5.6 C	6.7 C	238.5 D	334.0 B
Nano zinc oxide 2 ppm	7.7 A	9.0 A	316.0 A	387.8 A
Zinc sulfate 100 ppm	7.1 AB	8.5 AB	274.3 C	375.0 A
Zinc sulfate 200 ppm	5.8 C	7.4 BC	239.8 D	371.3 A
Chelated zinc 100 ppm	7.0 B	8.4 AB	301.8 AB	380.3 A
Chelated zinc 200 ppm	6.9 B	6.9 C	296.8 B	315.3 B
Control	4.4 D	5.0 D	207.0 E	262.5 C

The means that have the same letter (s) in each column do not differ substantially at the 5% level. According to Duncan's multiple range test, different letters denote different differences.

Cluster measurements

When compared to the control treatment, the tested treatments had a substantial impact on cluster rachis weight, width, and length throughout the course of the two study seasons (Table 2). The longest cluster and widest vines were those exposed to 2 ppm of nano zinc oxide, whereas the control treatment displayed the lowest values. The effects of the remaining treatments and the control treatment on the Thompson Seedless grape cultivar's cluster length and width did not differ significantly either.

During the 1st season, the therapy had no discernible impact on this feature, with the exception of nano zinc oxide at 2 ppm. Such a treatment yielded a cluster rachis weight of 7.5 g, whereas the control treatment produced the lowest result (4.4 g). The most successful treatments in this regard during the 2nd season were chelated zinc at 100 ppm and nano zinc oxide at 2 ppm. They provided a cluster rachis weight of 8.4 g, which was the same, whereas the least amount (6.4 g) was produced by the control treatment.

Table 2.Effect of nano zinc oxide, zinc sulfate and chelated zinc foliar application on cluster length (cm), cluster width (cm), cluster L/W ratio and cluster rachis wt. (g), of Thompson Seedless grape cultivar during 2021 and 2022 seasons.

Characteristic / Treatment	Cluster length (cm)		Cluster width (cm)		Cluster L/W ratio		Cluster rachis wt.(g)	
	2021	2022	2021	2022	2021	2022	2021	2022
Nano zinc oxide 1 ppm	19.5 E	23.1 AB	15.5 C	17.2 A	1.26 C	1.34 A	4.9 B	6.8 CD
Nano zinc oxide 2 ppm	22.4 A	24.3 A	16.8 A	17.2 A	1.33 ABC	1.41 A	7.5 A	8.4 A
Zinc sulfate 100 ppm	21.1 BC	23.4 AB	15.6 C	17.2 A	1.35 AB	1.36 A	5.5 B	7.5 ABC
Zinc sulfate 200 ppm	21.1 BC	23.4 AB	16.5 AB	17.0 A	1.28 BC	1.38 A	4.5 B	7.9 AB
Chelated zinc 100 ppm	21.9 AB	23.9 AB	16.1 BC	17.0 A	1.37 A	1.41 A	5.2 B	8.4 A
Chelated zinc 200 ppm	20.4 CD	22.9 AB	15.3 C	17.1 A	1.33 ABC	1.34 A	4.9 B	7.0 BCD
Control	18.6 E	22.7 B	14.1 D	16.5 A	1.32 ABC	1.38 A	4.4 B	6.4 D

The means that have the same letter(s) in each column do not differ substantially at the 5% level. According to Duncan's multiple range test, different letters denote different differences.

Berry attributes

According to Table 3, the treatments had no effect on berry length during the 1st season, but they did have an advantage over the control treatment during the 2nd season. The most successful treatments in the 1st season were zinc sulphate at 200 ppm and nano zinc oxide at 2 ppm, which produced the greatest value of berry length. They both provided 1.45 cm, the least amount (1.25 cm) compared to the control treatment. Zinc sulphate at 100 ppm and chelated zinc at 100 ppm both produced the same value of 1.43 cm in the 2nd season, while the control treatment produced the lowest value of 1.20 cm.

The same Table showed that, in comparison to the control treatment, nano zinc oxide at 2 ppm was preferred, although none of the treatments had a significant impact on berry diameter or berry L/D ratio during the 1st season. The treatments with zinc sulphate at 100 ppm, zinc sulphate at 200 ppm, and chelated zinc at 100 ppm showed the highest values in the 2nd season.

In the two experimental seasons, nano zinc oxide at 2 ppm treatment produced the highest 100 berry weight, with increases of 38.24 and 31.05% over the control, respectively. Nano zinc oxide at 1 ppm treatment came in second. Conversely, Table 4 shows that the control treatment yielded the lowest weight of 100 berries.

All tested treatments resulted in a substantial increase in 100 berry juice weight in both seasons when compared to the control treatment (Table 4). The vines treated with nano zinc oxide at 2 ppm showed the highest 100 berry juice weight in the 1st season, with an increment of 38.24% above the control treatment. These were followed by nano zinc oxide at 1 ppm, with no discernible differences between them. The vines treated with nano zinc oxide at 2 ppm, zinc sulphate at 100 ppm, and nano zinc oxide at 1 ppm produced the maximum 100 berry juice weight in the 2nd season, with no discernible differences between them. The 100 berry juice weight of such treatments were 74.8, 71.3 and 70.5 g with an increment of 48.7, 41.7 and 40.2 % over the control, respectively. On the other side, the control treatment produced the lowest value.

Table 3. Effect of nano zinc oxide, zinc sulfate and chelated zinc foliar application on berry length (cm), berry diameter (cm) and berry L/D ratio, of Thompson Seedless grape cultivar during 2021 and 2022 seasons.

Characteristic / Treatment	Berry length (cm)		Berry diameter (cm)		Berry L/D ratio	
	2021	2022	2021	2022	2021	2022
Nano zinc oxide 1 ppm	1.25^{B}	1.30^{C}	1.08^{AB}	1.13^{B}	1.16^{AB}	1.16^{AB}
Nano zinc oxide 2 ppm	1.45^{A}	1.33^{BC}	1.20^{A}	1.15^{AB}	1.21^{AB}	1.15^{AB}
Zinc sulfate 100 ppm	1.38^{AB}	1.43^{A}	1.18^{AB}	1.20^{A}	1.17^{AB}	1.19^{A}
Zinc sulfate 200 ppm	1.45^{A}	1.40^{AB}	1.18^{AB}	1.20^{A}	1.23^{A}	1.17^{AB}
Chelated zinc 100 ppm	1.30^{AB}	1.43^{A}	1.13^{AB}	1.20^{A}	1.15^{AB}	1.19^{A}
Chelated zinc 200 ppm	1.30^{AB}	1.33^{BC}	1.15^{AB}	1.15^{AB}	1.13^{B}	1.15^{AB}
Control	1.25^{B}	1.20^{D}	1.05^{B}	1.10^{B}	1.19^{AB}	1.09^{B}

The means that have the same letter(s) in each column do not differ substantially at the 5% level. According to Duncan's multiple range test, different letters denote different differences.

Table 4. Effect of nano zinc oxide, zinc sulfate and chelated zinc foliar application on 100 berry weight (g) and 100 berry juice weight (g), of Thompson Seedless grape cultivar during 2021 and 2022 seasons

Characteristic / Treatment	100 Berry weight (g)		100 Berry juice weight (g)	
	2021	2022	2021	2022
Nano zinc oxide 1 ppm	112.5^{AB}	143.8^{AB}	70.8^{A}	70.5^{AB}
Nano zinc oxide 2 ppm	119.3^{A}	155.3^{A}	72.5^{A}	74.8^{A}
Zinc sulfate 100 ppm	110.5^{AB}	133.0^{BCD}	62.5^{B}	71.3^{AB}
Zinc sulfate 200 ppm	103.0^{BC}	120.5^{CD}	58.5^{BC}	62.3^{CD}
Chelated zinc 100 ppm	103.5^{BC}	135.0^{BC}	63.8^{B}	66.0^{BC}
Chelated zinc 200 ppm	93.8^{CD}	126.0^{CD}	54.0^{CD}	58.0^{D}
Control	86.3^{D}	118.5^{D}	48.8^{D}	50.3^{E}

The means that have the same letter(s) in each column do not differ substantially at the 5% level. According to Duncan's multiple range test, different letters denote different differences.

Chemical constituents

When compared to the control therapy, all treatments increased the percentage of TSS, however this increase was not statistically significant (Table 5). Furthermore, in comparison to the control treatment (21.60%), the treatments of nano zinc oxide at 2 ppm and chelated zinc at 100 ppm had a greater impact on the percentage of TSS in the 1st season (23.75 and 23.50%, respectively). In contrast, each treatment of nano zinc oxide at 2 ppm and zinc sulphate at 100 ppm showed superiority in the percentage of total soluble solids (TSS) in the 2nd season (26.00 and 25.85%, respectively).

All of the treatments in the 1st season had a lower acidity % than the control treatment, with no discernible variations between them, according to the results shown in Table 5. In addition, when compared to the other treatments, nano zinc oxide at a dosage of 2 ppm produced the lowest acidity percentage (0.36%), with chelated zinc at a dosage of 100 ppm coming in second. The majority of the treatments showed no discernible impact in the 2nd study season, however zinc sulphate at 100 ppm and nano zinc oxide at 2 ppm showed a substantial effect (0.40 %).

Over the course of the two study seasons, the nano zinc oxide treatment at 2 ppm yielded the greatest TSS/acid ratio (68.42 and 65.99), whereas the control treatment yielded the lowest ratio (46.92 and 48.27), respectively.

Compared to the control treatment, there was an increase in reducing sugars for a number of treatments (Table 5); nevertheless, in most cases, the differences were not statistically significant. Although the treatments with nano zinc oxide at 2 ppm were preferred, the differences in the 1st season were not statistically significant. Only the vines treated to 2 ppm of nano zinc oxide showed a discernible effect in the 2nd growing season.

Table 5. Effect of nano zinc oxide, zinc sulfate and chelated zinc foliar application on TSS %, total acidity %, TSS/acid ratio and reducing sugars %, of Thompson Seedless grape cultivar during 2021 and 2022 seasons

Characteristic / Treatment	TSS %		Total acidity %		TSS/Acid ratio		Reducing Sugars %	
	2021	2022	2021	2022	2021	2022	2021	2022
Nano zinc oxide 1 ppm	22.50 AB	24.00 AB	0.44 A	0.43 AB	52.61 AB	55.71 BCD	14.76 A	15.21 AB
Nano zinc oxide 2 ppm	23.75 A	26.00 A	0.36 A	0.40 B	68.42 A	65.99 A	15.23 A	16.36 A
Zinc sulfate 100 ppm	23.15 AB	25.85 A	0.42 A	0.40 B	56.32 AB	65.24 AB	15.48 A	15.84 AB
Zinc sulfate 200 ppm	22.60 AB	24.35 AB	0.42 A	0.45 AB	56.47 AB	54.39 CD	14.99 A	14.80 AB
Chelated zinc 100 ppm	23.50 A	25.35 AB	0.41 A	0.44 AB	59.01 AB	59.50 ABC	14.99 A	16.10 AB
Chelated zinc 200 ppm	22.20 AB	24.30 AB	0.43 A	0.45 AB	51.67 AB	54.00 CD	14.95 A	15.00 AB
Control	21.60 B	23.45 B	0.47 A	0.49 A	46.92 B	48.27 D	14.73 A	14.34 B

The means that have the same letter(s) in each column do not differ substantially at the 5% level. According to Duncan's multiple range test, different letters denote different differences.

Discussion

Zinc is an essential element for plants to develop and reproduce in a regular and healthy way. When plants do not receive enough zinc, crop yields are decreased and crop products often have inferior quality (Sarwar, 2011). This is because zinc fertilizer has a positive effect on auxin production, which can enhance cell division and improve the absorption of minerals, ultimately leading to an increase in plant growth (Cakmak, 2000). El-Tohamy and El-Greadly (2007) suggest that zinc may work by increasing natural auxin (IAA), which triggers cell division and growth. This might account for the increased levels of growth-promoting hormones that occur when zinc is applied. Zinc is an essential component of many distinct enzymes and functions as a regulatory co-factor or structural element in many important plant biochemical processes. The metabolism of carbohydrates, proteins, and auxins, the production of pollen, the preservation of cellular membrane integrity, and the ability to fend off infection by certain pathogens are the key issues addressed by these pathways (Alloway, 2008). Zinc nanoparticles (ZnNPs) have a surface area to weight ratio, greater penetrability, and distinct morphologies that make them smaller than traditional materials. The total amount of carbohydrates in canes, the amount of chlorophyll in leaves, and the parameters of vegetative growth may all be greatly impacted by the foliar application of ZnNPs. This will subsequently have a positive effect on the yield per vine, the berries' physical attributes, and their chemical makeup in Thompson Seedless grapevines.

Yield components

The results for the Thompson Seedless grape cultivar's yield are shown in Table 1. The highest yield (kg/vine) and heaviest cluster weight were correlated with nano zinc oxide treatment at 2 ppm, followed by zinc sulfate at 100 ppm, chelated zinc at 100 ppm, and chelated zinc at 200 ppm, in that order. Ahmed and Abdelkader (2020), who stated that by making it simpler for plants to absorb nutrients, nanofertilizers speed up photosynthesis and the production of dry matter. Furthermore, applying nanofertilizers to agriculture has several advantages, including faster plant absorption, enhanced development, and greater harvests (Shareef *et al*., 2021). There were substantial changes in both study seasons when compared to other treatments. According to Song *et al*. (2016), Mohamed *et al*. (2017), Ibrahim *et al*. (2019), El-Said *et al*. (2019), and Abou El-Nasr *et al*. (2021), zinc was administered topically to enhance cluster number per vine, cluster weight, and yield per vine. These results are consistent with those of those studies.

Physical of cluster and berries parameters

Khan *et al*. (2019) claim that zinc (Zn) carries out several essential physiological functions that may enhance the berry quality. In plants, tryptophan has two primary purposes: first, it influences plant development; second, it aids in the synthesis of IAA (Castillo-Gonzalez *et al*., 2018). Zinc is necessary for plants to synthesize tryptophan. According to Nicolas *et al*. (2013), IAA activated the gene (VvCEB1) that regulates cell growth and changes the grape cell-wall network. Zn is also a structural element of the ribosome and contributes to the synthesis of proteins required for cell division, differentiation, and berry development (Barker and Eaton, 2015). Furthermore, Zn may be improving berry firmness by blocking many oxidative processes (Zhao *et al*., 2013). For these reasons, zinc may enhance berry quality, which would enhance cluster quality and raise Thompson Seedless grapevine output.

Chemical characteristics of berries

The berries' chemical properties are positively affected by the foliar application of several zinc treatments, particularly nano zinc oxide at a treatment dose of 2 ppm. Zn raises TSS%, reduces sugars, and lowers acidity% in leaf petioles via raising the K element content. Abul-Nasr *et al* (2021) they found that whereas N-ZnO treatments increased the accumulation of sugars and total soluble solids in fruit juice, they reduced the concentration of titratable acidity. Zinc's function in the translocation and synthesis of proteins and carbohydrates may be the cause of these effects (Belal-Basma *et al*, 2023). Furthermore, the following mechanisms have been proposed to explain how zinc influences antioxidant activity: a) zinc can form complexes with phospholipids and sulfhydryl groups, which shield lipids and membrane proteins from oxidative damage (Broadley *et al*., 2012); b) zinc can regulate the synthesis of antioxidant enzymes, such as ascorbate, peroxidase, catalase, and superoxide dismutase (Noreen *et al*., 2021). Zinc enhanced the antioxidant activity of grape berries as a result.

Conclusion

The results of this study showed that, when compared to the control treatment, spraying the clusters with various forms and concentrations of zinc enhanced the fruit quality and yield attributes of the Thompson Seedless grape cultivar. Following zinc sulfate at 100 ppm and chelated zinc at 100 ppm in that order, the nano zinc oxide therapy at 2 ppm was likewise the most successful. Therefore, it might be suggested to spray the clusters with nano zinc oxide at a concentration of 2 ppm or zinc sulfate at a concentration of 100 ppm for the best and highest-quality produce. As well as the importance of using zinc in the nanoform, as it is used in smaller quantities than the traditional image and thus reduces environmental pollution and the speed of its absorption by plants.

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تأثير اضافات الزنك على انتاجية كروم العنب طومسون سيدلس

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الملخص

أجريت هذه الدراسة بمزرعة الفاكهة - كلية الزراعة - جامعة أسيوط - مصر خلال موسمى النمو 2021 و 2022 بهدف دراسة تأثير الرش بمصادر مختلفة من سماد الزنك على المحصول وجودة حبات العنب الطومسون. كان تصميم التجربة قطاعات كاملة العشوائية تشمل 7 معاملات و 4 مكررات لكل معاملة وكانت المعاملات كالتالى الرش بنانو اوكسيد الزنك بتركيز 1و2 ppm وكبريتات الزنك بتركيز100 و 200 ppm والزنك المخلبى بتركيز 100 و200 ppm فى صورة فردية والكنترول وقد تم الرش عند بداية التفتح عندما وصل طول الفرخ إلى 10-15 سم وبعد العقد وبعد شهر من العقد.

ويمكن تلخيص النتائج كما يلى

- أدت جميع المعاملات المدروسة إلى زيادة معنوية فى مكونات المحصول مقارنة بالكنترول وكانت أفضل المعاملات هو الرش بنانو اوكسيد الزنك بتركيز 2 ppm.
- أظهرت جميع المعاملات قيد الدراسة تحسنا معنويا فى صفات الحبات مقارنة بالكنترول وكانت أفضل المعاملات هو الرش بنانو اوكسيد الزنك بتركيز 2 ppm .
- سببت المعاملات زيادة معنوية فى نسبة المواد الصلبة الذائبة والسكريات المختزلة ونقص معنوى فى الحموضة الكلية مقارنة بالكنترول وكانت أفضل المعاملات هى الرش بنانو اوكسيد الزنك بتركيز2 ppm يليها الرش بكبريتات الزنك بتركيز 100 ppm ثم الرش بالزنك المخلبى بتركيز 100 ppm.

من نتائج هذه الدراسة يمكن التوصية بأهمية الرش بنانو اوكسيد الزنك بتركيز 2 جزء فى المليون أوكبريتات الزنك بتركيز 100 ppm أوالزنك المخلبى بتركيز 100 ppm حيث يؤدى ذلك إلى إنتاج محصول عالى ذو خصائص عناقيد وحبات جيدة فضلا عن أهمية إستخدام الزنك فى الصورة النانونية حيث أنه يستخدم بكميات أقل من الصورة التقليدية وبالتالى يقلل من التلوث البيئى وسرعة امتصاصه بواسطة النبات.