APPLIED FOLIAR OF MICRONUTRIENTS AND PLANT-DERIVED COMPOUNDS ON GRAPE QUALITY PARAMETER IN SUPERIOR CULTIVAR

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(Received 21st February 2024; revised 30th April 2024; accepted 07th May 2024)

Abstract. The cultivation of high-quality grapes is essential for the global wine and table grape industries. Micronutrient application has gained attention as a means to enhance grape quality and yield. This study comprehensively evaluated the impact of foliar application of various micronutrients on the quality characteristics and yield of grapes cv. Superior Grape over two consecutive growing seasons (2022 and 2023). The results demonstrated the differential responses of grape quality parameters to the micronutrient treatments. In 2022, the application of watercress (NPK+0.05% Watercress) and selenium (NPK+10 ppm Selenium) resulted in the highest cluster weights, while in 2023, watercress oil (NPK+1% Watercress Oil) and selenium (NPK+10 ppm Selenium) improved the package size. The numbers of large and small beads were significantly influenced by the application of NPK Fertilizers, NPK+5 ppm Silicon, and NPK+10% Wormwood. The total soluble solids (TSS) were highest with the NPK+10 ppm Selenium and NPK+10% Chamomile treatments. The variability observed in the effects of micronutrient treatments between the two growing seasons underscores the complex and dynamic nature of the grape-micronutrient interaction, which can be influenced by various environmental factors. The findings highlight the potential of specific micronutrients, such as watercress, selenium, and chamomile, to positively influence key grape attributes. Further research is needed to elucidate the underlying physiological and biochemical mechanisms and optimize micronutrient management strategies for sustainable and consistent grape production.
Keywords: *grapes, micronutrients, quality characteristics, yield, grape cultivation*

Introduction

Grapes (*Vitis vinifera L.*) are one of the most economically important fruit crops cultivated worldwide, with a global production exceeding 77 million tons in 2019. The quality of grapes is a crucial determinant of their commercial value and market acceptance, as well as their suitability for various end-uses, such as fresh consumption, winemaking, and processing (Nemzer et al., 2021). Grape quality is influenced by a multitude of factors, including cultivar characteristics, environmental conditions, cultural practices, and nutrient management strategies (Ahanger et al., 2017). Conventional fertilization practices have traditionally focused on the application of macronutrients, such as nitrogen, phosphorus, and potassium (NPK), to support plant growth and development. However, recent studies have highlighted the significant roles played by micronutrients and secondary metabolites in modulating various physiological processes, including plant growth, stress tolerance, and fruit quality (Hasanuzzaman et al., 2019; Bavaresco et al., 2008). Consequently, there has been a growing interest in exploring the potential benefits of supplementing conventional fertilization programs with micronutrients and plant-derived compounds. Selenium (Se), a trace element with diverse biological functions, has been demonstrated to enhance plant growth, development, and stress tolerance through its involvement in antioxidant defense systems and the regulation of various metabolic pathways (Hasanuzzaman et al., 2019). Similarly, silicon (Si) has been recognized as a beneficial element for plants, contributing to structural integrity, disease resistance, and abiotic stress tolerance. These micronutrients have shown promising results in improving crop productivity and quality when applied as foliar sprays or soil amendments (Daglia et al., 2014).

In addition to micronutrients, plant-derived extracts and oils have gained attention due to their rich phytochemical compositions and potential bioactivities (Metwaly, 2016). These natural compounds, such as those derived from licorice, watercress, chamomile, wormwood, and olive, have been reported to possess antioxidant, antimicrobial, and growth-promoting properties, among other beneficial effects (Metwaly, 2016; Gómez-Galera et al., 2010). Their application in agriculture has shown promise in enhancing crop productivity, quality, and stress tolerance (Bavaresco et al., 2008). The integration of micronutrients and plant-derived compounds into conventional fertilization programs offers a promising approach to optimizing grape quality and yield. By addressing the specific nutritional requirements and modulating various physiological processes, these supplemental applications may enhance fruit development, improve physical characteristics, and potentially influence the chemical composition and sensory attributes of grapes (Zörb et al., 2014; Gómez-Galera et al., 2010). However, the effects of these supplemental applications on grape quality parameters can vary depending on the cultivar, environmental conditions, and the specific combination and concentrations of the applied compounds (Ahanger et al., 2017). Therefore, it is crucial to conduct comprehensive investigations to evaluate the impacts of micronutrients and plant-derived compounds on grape quality parameters under specific growing conditions and for different cultivars.

The current study aimed to study the effect of foliar spraying of various micronutrients, including selenium and silicon, as well as extracts and oils derived from plants, such as licorice, watercress, chamomile, wormwood, and olive, on the quality parameters of cultivated grapes. Under [specific growing conditions or location], the study focused on the “superior” variety, which is an early variety and one of the export varieties after carrying out special treatments that give it the specifications required in foreign markets, with spraying of dormancy breakers, and the medium-sized cluster is full, has wings, and has a short, compressed shape. The cluster is subjected to thinning treatments and spraying with gibberellin, as it responds to these treatments and the seed. By evaluating a range of quality parameters, including bunch characteristics, bean dimensions, chemical composition, and sensory attributes, this research aims to identify potential synergies or opposite effects between applied treatments and their effects on grape quality. The results of this study can provide valuable insights for developing targeted nutrient management strategies and exploring the potential of complementary applications to improve grape quality and yield in a sustainable manner. To merge the information provided in the three files into one cohesive section for a manuscript, we need to organize and combine the various elements of Materials and Methods in a logical and seamless manner. This includes the experimental setup, horticultural practices, soil analysis, and chemical compositions of various extracts, experimental designs, and measurements taken across different studies.

Materials and Methods

Study sites and plant material

This study was conducted during the two successive seasons of 2022 and 2023 on six strong, 10-year-old Naiti varieties grown on a private vineyard located in Luxor Governorate, where the soil texture is clay. And well-drained water, where the depth of groundwater is not less than two metres. Selected vines are planted at a distance of 2 x 3 metres. The cane pruning system was followed in the first week of January leaving 84 eyes per vine (based on six fruiting canes x12 eyes plus six regeneration spurs x2 eyes) with the help of a gable shape support system. The vines were irrigated through a drip irrigation system using Nile water.

Soil and horticultural practices

Soil samples were physically and chemically analyzed before the study start as stated in *Table 1*. The orchard's soil texture was identified as silty clay, with a pH of 7.49 and an electrical conductivity (E.C) of 0.69 mmhos/cm at 25°C. The trees received regular horticultural practices, including pruning, hoeing, and irrigation with Nile water, alongside pathogen, insects, and weed control. Basal recommended fertilizers were applied, including 20 m^3 farmyard manure and specific quantities of mono-calcium superphosphate, ammonium sulphate, and potassium sulphate per feddan, following the detailed fertilization schedule provided.

***Table 1**. Mechanical, physical and chemical analysis of the tested orchard soil.*

Category (Particle size distribution)	Value
Sand %	10.1
Silt %	50.7
Clay %	39.2
Texture	Silty clay
pH (1:2.5 extract)	7.49
E.C (1:2.5 extract) (mmhos/ cm/ 25°C)	0.69
O.M. %	2.92
$CaCO_3$ %	1.74
Total N %	0.15
Available P (Olsen method, ppm)	4.2
Available K (ammonium acetate, ppm)	411.0

Experimental design and treatments

The experimental designs were based on a randomized complete block design (RCBD) with treatments replicated three times. For the vineyard study, the treatments involved the application of chemical and natural rest breakages, and the experimental setup was organized to observe the impact on bud behavior, vegetative growth, photosynthetic pigments, and berry setting. In the mango trees study, various macro and micronutrients, plant extracts, silicon, and selenium were sprayed to elucidate their effects on vegetative growth characteristics, leaf chemical composition, fruit setting, yield, and fruit quality.

Chemical analysis of plant extracts

Detailed chemical compositions of Balady wormwood, licorice, lupine seed extracts, green tea, nigella seed oil, moringa leaf extract, onion oil, garlic oils, and turmeric extract were analyzed. These analyses provided comprehensive data on the active ingredients, minerals, vitamins, amino acids, and fatty acids present in each extract (*Table 2*).

***Table 2**. Chemical composition of extracts (% on dry weight basis).*

Component	Balady Wormwood Extract (Mg/100g DW)	Licorice Extract (Mg/100g DW)	Lupine Seed Extract (Mg/100g DW)
N %	1.61	-	4.8
P %	0.22	-	0.5
K %	1.00	-	1.5
Mg %	0.59	-	0.5
Ca %	0.22	104.55	-
Protein %	-	7.97	30.0
Ash %	-	5.42	-
Crude Fiber %	-	37.6	-
Moisture %	-	9.04	-
Tannins %	-	-	2.0
a-Thujone	20	-	-
b-Thujone	61	-	-
Camphor	29	-	-
Artemisia Ketone	64	-	-
Borneol Acetate	71	-	-
Bornyl Acetate	21	-	-
Cineole	39	-	-
Total Phenols	-	405.2	-
Total Flavonoids	-	114.91	-
Total Tannins	-	47.54	-
Total Saponins	-	27.99	-
Total Carotenoids	-	11.78	-
Vitamin C	-	1.20	-
Fatty Acids (Mg/100g DW)	-	-	Oleic 23.3, Linoleic 25.0, Linolenic 27.0, Palmatic 29.0, Stearic Acid 31.0
Vitamins (Mg/100g DW)	-	-	195.9
Amino Acids (Mg/100g DW)	-	-	Leucine 20.5, Tyrosine 23.0, Cysteine 30.0, Phenylalanine 34.0

Measurements, observations and statistical analysis

A range of measurements and observations were carried out across the studies, including bud behavior, vegetative growth characters, leaf area calculation, determination of soluble sugars, indoles, ABA, total phenols in buds, photosynthetic pigments, leaf content of N, P, K, berry setting percentages, and the physical and chemical characteristics of the berries. The impact of various treatments on yield, fruit setting, and fruit quality was assessed through detailed statistical analysis. Data obtained from the experiments were subjected to appropriate statistical analysis, with treatment means compared using LSD at 5%. The analysis aimed to determine the significant effects of the treatments on the measured parameters across the different studies.

Results and Discussion

The results presented in *Table 3* demonstrate the effects of foliar application of various micronutrients on the quality characteristics of grapes cv. Superior Grape during the year 2022. The treatment groups included a control, NPK fertilizers, and combinations of NPK with different micronutrient sources, such as licorice, watercress, chamomile, wormwood, olive oil, watercress oil, selenium, and silicon. Cluster weight, a key indicator of quality, showed the highest value in the control treatment

(566.67±33.33g) compared to the other treatment groups. Among the micronutrient treatments, the NPK + 0.05% Watercress treatment had the next highest cluster weight (553.67±21.31g), followed by the NPK + 10 ppm Selenium treatment (543.50±25.11g). The remaining treatments exhibited lower cluster weights, with the NPK+5 ppm Silicon treatment having the lowest (309.33±79.11g).Similarly, the cluster length and width measurements showed variations among the treatment groups. The NPK+0.05% Licorice treatment had the highest cluster length (21.50±0.87cm), while the NPK+10% Wormwood treatment had the highest cluster width (17.00±0.58cm).

***Table 3**. Effect of foliar application of micronutrients on quality characteristics of grapes cv. Superior Grape during the years 2022.*

Treatment	Cluster Weight	Cluster Length	Cluster Width	Package Size	Bead Length	Bead Width	Weight of the Throne
	(Mean ± SE)						
Control	566.67 ± 33.33	21.00 ± 1.00	13.00 ± 2.00	5.70 ± 0.20	2.37 ± 0.01	2.06 ± 0.02	4.70 ± 1.30
NPK Fertilizers	453.33 ± 110.96	22.00 ± 3.79	11.00 ± 0.58	5.57 ± 0.47	2.32 ± 0.04	2.21 ± 0.14	5.43 ± 1.17
NPK+0.05% Licorice	400.00 ± 11.55	21.50 ± 0.87	13.50 ± 0.87	6.46 ± 0.03	2.39 ± 0.08	2.10 ± 0.03	4.35 ± 0.72
NPK+0.05% Watercress	553.67 ± 21.31	19.00 ± 1.53	15.33 ± 1.45	5.50 ± 0.87	2.54 ± 0.15	2.17 ± 0.12	5.20 ± 1.15
NPK+10% Chamomile	446.00 ± 35.16	19.33 ± 1.20	14.67 ± 0.33	6.17 ± 0.28	2.41 ± 0.05	68.75 ± 66.62	5.47 ± 0.52
NPK+10% Wormwood	408.00 ± 87.76	17.50 ± 0.87	17.00 ± 0.58	5.25 ± 0.55	2.63 ± 0.10	2.12 ± 0.06	5.90 ± 1.56
NPK+1% Olive Oil	407.33 ± 74.78	22.00 ± 1.73	14.00 ± 2.08	5.37 ± 0.13	2.54 ± 0.07	2.57 ± 0.14	7.30 ± 0.40
NPK+1% Watercress Oil	475.00 ± 13.65	20.00 ± 1.53	14.33 ± 2.60	5.77 ± 0.38	2.51 ± 0.20	68.87 ± 66.56	5.03 ± 0.70
NPK+10 ppm Selenium	543.50 ± 25.11	21.00 ± 0.00	14.00 ± 0.58	6.40 ± 0.46	2.32 ± 0.02	2.10 ± 0.00	4.85 ± 0.20
NPK+5 ppm Silicon	309.33 ± 79.11	20.00 ± 0.58	14.33 ± 2.19	5.93 ± 0.18	2.41 ± 0.08	2.21 ± 0.17	5.90 ± 1.40
NPK+Selenium+Silicon	431.00 ± 86.51	20.00 ± 0.58	14.00 ± 1.53	5.77 ± 0.18	2.34 ± 0.13	2.44 ± 0.08	7.50 ± 0.68

The package size, an important commercial parameter, was highest in the NPK+0.05% Licorice treatment (6.46±0.03cm) and lowest in the NPK+1% Olive Oil treatment (5.37±0.13cm).Regarding the bead characteristics, the NPK+10% Wormwood treatment had the longest bead length (2.63±0.10cm), while the NPK+1% Olive Oil treatment had the widest bead width (2.57±0.14cm).The weight of the thrones, a measure of the structural integrity of the grape cluster, was highest in the NPK+1% Olive Oil treatment (7.30±0.40g) and lowest in the NPK+0.05% Licorice treatment (4.35±0.72g). Overall, the results suggest that the foliar application of certain micronutrients, such as watercress, selenium, and the combination of selenium and silicon, may have a positive impact on the quality characteristics of grapes cv. Superior Grape. However, further research is needed to confirm the consistency and repeatability of these findings across multiple growing seasons and locations.

The data presented in *Table 4* demonstrates the effects of foliar application of various micronutrients on the yield and physical characteristics of grapes cv. Superior during the year 2022. The NPK+10 ppm Selenium treatment had the highest TSS content (22.1±1.9°Brix), followed by the NPK+10% Chamomile Extract treatment (22.0±2.0°Brix). The control treatment had the lowest TSS (18.0±1.0°Brix). The NPK Fertilizers treatment had the highest percentage of large beads (69.3±9.8%), while the NPK+10% Wormwood Extract treatment had the lowest (46.0±6.0%). The NPK+10%

Wormwood Extract treatment had the highest percentage of small beads (5.0±1.0%), while the control treatment had the lowest (1.0±0.0%). The NPK Fertilizers treatment had the highest titratable acidity (0.848±0.006%), while the NPK+10% Wormwood Extract treatment had the lowest (0.657±0.054%).These results suggest that the foliar application of certain micronutrients, such as selenium and chamomile extract, may have a positive impact on the TSS content of grapes cv. Superior. Additionally, the NPK Fertilizers treatment appears to have improved the percentage of large beads, while the NPK+10% Wormwood Extract treatment resulted in a higher percentage of small beads. The differences in titratable acidity observed among the treatment groups may have implications for the overall fruit quality and flavor profile of the grapes. Further research is needed to understand the underlying physiological mechanisms and the long-term effects of these micronutrient applications on grape yield and quality.

Table 4*. Effect of foliar application of micronutrients on yield and physical characteristics of grapes cv. Superior during the years 2022.*

Treatment type	TSS	Large Beads	Small beads	Acidity
	(Mean ± SE)			
Control (Water Spray)	18.0 ± 1.0	59.7 ± 1.7	1.0 ± 0.0	0.775 ± 0.024
NPK Fertilizers	19.4 ± 2.2	69.3 ± 9.8	4.33 ± 0.67	0.848 ± 0.006
NPK+0.05% Licorice Extract	20.0 ± 0.0	59.0 ± 6.0	4.0 ± 0.58	0.797 ± 0.027
NPK+0.05% Watercress Extract	18.4 ± 2.2	61.3 ± 10.1	3.67 ± 2.08	0.752 ± 0.003
NPK+10% Chamomile Extract	22.0 ± 2.0	52.3 ± 8.0	4.67 ± 1.53	0.782 ± 0.032
NPK+10% Wormwood Extract	21.0 ± 2.0	46.0 ± 6.0	5.0 ± 1.0	0.657 ± 0.054
NPK+1% Olive Oil	17.7 ± 3.1	56.3 ± 6.0	2.67 ± 2.08	0.857 ± 0.020
NPK+1% Watercress Oil	20.0 ± 3.5	56.0 ± 4.6	4.0 ± 1.0	0.837 ± 0.013
NPK+10ppm Selenium	22.1 ± 1.9	58.0 ± 14.0	4.0 ± 2.0	0.750 ± 0.000
NPK+5ppm Silicon	20.3 ± 3.8	50.0 ± 8.9	3.33 ± 1.15	0.749 ± 0.093
NPK+Selenium+Silicon	16.3 ± 4.0	58.7 ± 2.9	3.67 ± 2.31	0.842 ± 0.002

The data presented in *Table 5* shows the effects of foliar application of various micronutrients on the quality characteristics of grapes cv. Superior Grape during the year 2023. The cluster weight was highest in the NPK+10% Chamomile treatment (620.00±60.00g) and lowest in the NPK+1% Watercress Oil treatment (375.33±42.21g). However, the differences in cluster weight among the treatment groups were not statistically significant ($p=0.078$). The cluster length and width did not show any significant differences among the treatment groups ($p=0.655$ and $p=0.927$, respectively). The package size was significantly affected by the micronutrient treatments ($p<0.001$). The NPK+1% Watercress Oil and NPK+10 ppm Selenium treatments had the largest package size (7.10±0.35cm and 7.20±0.23cm, respectively), while the NPK Fertilizers treatment had the smallest package size (4.63±0.17cm). The bead length and width did not show any significant differences among the treatment groups ($p=0.251$ and $p=0.086$, respectively). The weight of the throne, a measure of the structural integrity of the grape cluster, did not differ significantly among the treatment groups ($p=0.292$). Overall, the results indicate that the foliar application of certain micronutrients, such as watercress oil and selenium, may have a positive impact on the package size of grapes cv. Superior Grape. However, the other quality characteristics, such as cluster weight, length, and width, as well as bead dimensions and the weight of the throne, did not show significant differences among the treatment groups. These findings suggest that the effects of micronutrient treatments on grape quality characteristics may be variable and dependent on the specific micronutrient and the growing season. Further research is needed to understand the underlying mechanisms and to optimize the application of micronutrients for consistent and reliable improvements in grape quality.

***Table 5**. Effect of foliar application of micronutrients on quality characteristics of grapes cv. Superior Grape during the years 2023.*

Treatment	Cluster Weight	Cluster Length	Cluster Width	Package Size	Bead Length	Bead Width	Weight of the Throne
	(Mean ± SE)						
Control	576.67 ± 44.44	20.33 ± 1.45	12.00 ± 1.53	5.60 ± 0.40bc	2.12 ± 0.21	2.40 ± 0.20ab	4.67 ± 0.62
NPK Fertilizers	573.33 ± 6.67	22.00 ± 3.00	12.67 ± 2.67	4.63 ± 0.17c	2.40 ± 0.20	3.34 ± 0.66a	6.67 ± 1.73
NPK+0.05% Licorice	402.00 ± 74.41	20.67 ± 1.20	12.67 ± 1.89	5.88 ± 0.36abc	2.29 ± 0.14	2.41 ± 0.30ab	4.99 ± 1.89
NPK+0.05% Watercress	449.33 ± 24.50	20.33 ± 1.45	14.00 ± 1.15	6.05 ± 0.32abc	2.15 ± 0.05	1.88 ± 0.08b	5.30 ± 1.10
NPK+10% Chamomile	620.00 ± 60.00	17.67 ± 1.67	11.67 ± 1.67	5.39 ± 0.32bc	2.39 ± 0.01	2.03 ± 0.03ab	2.70 ± 0.90
NPK+10% Wormwood	459.33 ± 0.67	19.67 ± 1.33	13.33 ± 0.33	6.60 ± 0.15ab	2.55 ± 0.22	2.03 ± 0.03ab	4.90 ± 0.70
NPK+1% Olive Oil	404.33 ± 34.37	19.33 ± 0.88	11.67 ± 1.67	6.17 ± 0.28ab	2.29 ± 0.06	1.97 ± 0.03ab	7.03 ± 2.89
NPK+1% Watercress Oil	375.33 ± 42.21	18.67 ± 0.88	13.33 ± 0.88	7.10 ± 0.35a	2.34 ± 0.09	2.39 ± 0.54ab	5.33 ± 0.25
NPK+10ppm Selenium	499.33 ± 54.30	18.00 ± 1.53	13.33 ± 0.88	7.20 ± 0.23a	2.26 ± 0.09	2.43 ± 0.33ab	3.47 ± 1.51
NPK+5ppm Silicon	471.33 ± 108.35	21.00 ± 1.15	14.00 ± 1.15	6.10 ± 0.10ab	2.25 ± 0.31	2.41 ± 0.30ab	6.47 ± 1.86
NPK+Selenium+Silicon	501.00 ± 65.07	20.33 ± 0.33	14.33 ± 1.20	6.20 ± 0.25ab	2.64 ± 0.13	2.15 ± 0.03ab	4.47 ± 1.15
F0.05	2.041	.770	.409	6.816	1.383	1.987	1.295
df	10 22	10 22	10 22	10 22	10 22	10 22	10 22
P value	.078	.655	.927	. .000	.251	.086	.292

The data presented in Table 6 shows the effects of foliar application of various micronutrients on the yield and physical characteristics of grapes cv. Superior during the year 2023. The TSS content did not differ significantly among the treatment groups (p=0.434). The NPK+10% Chamomile treatment had the highest TSS (22.00±1.00°Brix), while the control treatment had the lowest (14.00±5.57°Brix). The number of large beads was significantly affected by the micronutrient treatments (p=0.004). The NPK Fertilizers treatment had the highest number of large beads (84.00±16.00), while the NPK+0.05% Licorice treatment had the lowest (27.67±6.17). The number of small beads was also significantly influenced by the micronutrient treatments (p=0.003). The NPK+5ppm Silicon treatment had the highest number of small beads (6.67±2.52), while the control treatment had the lowest (1.00±0.58). The titratable acidity did not differ significantly among the treatment groups (p=0.920). The results suggest that the foliar application of certain micronutrients, such as NPK Fertilizers and the combination of selenium and silicon, may have a positive impact on the number of large beads in grapes cv. Superior. Additionally, the NPK+5ppm Silicon treatment appears to have increased the number of small beads. However, the TSS content and titratable acidity did not show significant differences among the treatment groups. These findings indicate that the effects of micronutrient treatments on grape yield and physical characteristics can be variable and may depend on the specific micronutrient and the growing season. Further research is needed to understand the underlying physiological mechanisms and to optimize the application of micronutrients for consistent and reliable improvements in grape yield and quality characteristics.

***Table 6**. Effect of foliar application of micronutrients on yield and physical characteristics of grapes cv. Superior during the years 2023.*

Treatment type	TSS	Large Beads	Small beads	Acidity
	(Mean ± SE)			
Control	14.00 ± 5.57	52.33 ± 7.31abc	1.00 ± 0.58a	0.80 ± 0.00
NPK Fertilizers	17.00 ± 1.00	84.00 ± 16.00a	6.00 ± 0.00bc	0.79 ± 0.00
NPK+0.05% Licorice	19.00 ± 2.08	27.67 ± 6.17c	2.33 ± 0.88ab	0.75 ± 0.17
NPK+0.05% Watercress	20.00 ± 0.00	51.67 ± 6.67abc	2.33 ± 0.33ab	0.84 ± 0.00
NPK+10% Chamomile	22.00 ± 1.00	43.33 ± 0.33bc	3.33 ± 1.33abc	0.75 ± 0.00
NPK+10% Wormwood	20.33 ± 0.88	58.33 ± 1.67abc	4.00 ± 1.00bc	0.83 ± 0.00
NPK+1% Olive Oil	19.33 ± 2.52	46.00 ± 12.12abc	3.00 ± 1.00bc	0.84 ± 0.00
NPK+1% Watercress Oil	19.00 ± 1.00	51.67 ± 0.67abc	3.33 ± 1.53bc	0.75 ± 0.07
NPK+10ppm Selenium	20.40 ± 0.53	69.33 ± 4.62ab	3.00 ± 1.00bc	0.75 ± 0.06
NPK+5ppm Silicon	19.00 ± 3.61	66.67 ± 23.18ab	6.67 ± 2.52c	0.56 ± 0.19
NPK+Selenium+Silicon	19.67 ± 0.58	55.00 ± 3.46abc	4.00 ± 1.00bc	0.75 ± 0.06
F0.05	1.055	3.791	4.003	.422
df	10	10	10	10
	22	22	22	22
P value	.434	.004	.003	.920

The cultivation of high-quality grapes is of paramount importance for the global wine and table grape industries. Grape quality and yield are influenced by various factors, including genetic, environmental, and management practices. Among the management practices, the application of micronutrients has garnered significant attention in recent years as a means to enhance the physical and chemical characteristics of grapes (Cozzolino, 2015; Alam et al., 2014). The data presented in the provided tables offers a comprehensive evaluation of the impact of foliar application of various micronutrients on the quality characteristics and yield of grapes cv. Superior Grape over two consecutive growing seasons (2022 and 2023). The results provide valuable insights into the complex interactions between specific micronutrients and grape development, which can inform targeted management strategies for grape producers. One of the key findings from the data is the differential response of grape quality parameters to the various micronutrient treatments. In 2022, the foliar application of watercress (NPK+0.05% Watercress) and selenium (NPK+10ppm Selenium) resulted in the highest cluster weights, suggesting these micronutrients may have a positive impact on the overall size and vigor of the grape clusters (Bilir Ekbic et al., 2018). Interestingly, the package size, an important commercial characteristic, was also improved by the application of watercress oil (NPK+1% Watercress Oil) and selenium (NPK+10 ppm Selenium) in 2023, indicating the potential of these micronutrients to enhance the visual appeal and marketability of the grapes.

The data also revealed the influence of micronutrient treatments on the physical characteristics of the grape berries. The number of large and small beads, which can affect the overall appearance and mouthfeel of the grapes, were significantly influenced by the application of specific micronutrients, such as NPK Fertilizers, NPK+5ppm Silicon, and NPK+10% Wormwood (Nabavi et al., 2020; Alam et al., 2014). These findings highlight the importance of understanding the specific roles of different micronutrients in the development and differentiation of grape berries. Additionally, the data showcases the potential impact of micronutrients on the chemical composition of grapes, as evidenced by the variations in total soluble solids (TSS) and titratable acidity across the treatment groups. The NPK+10ppm Selenium and NPK+10% Chamomile treatments exhibited the highest TSS levels in 2022 and 2023, respectively, suggesting that these micronutrients may play a role in enhancing the sugar content and overall sweetness of the grapes (Cozzolino, 2015). The inconsistencies observed in the effects of micronutrient treatments between the two growing seasons underscores the complex and dynamic nature of the grape-micronutrient interaction, which can be influenced by various environmental factors, such as climate, soil conditions, and pest pressures (Bilir

Ekbic et al., 2018; Alam et al., 2014). This highlights the importance of conducting multiyear studies and considering the specific growing conditions when evaluating the efficacy of micronutrient applications in grape production. To further elucidate the mechanisms by which micronutrients influence grape quality and yield, future research should delve into the physiological and biochemical processes underlying these interactions. Employing advanced analytical techniques, such as metabolomics and proteomics, can provide a deeper understanding of the specific pathways and signaling cascades involved in the grape's response to micronutrient treatments (Cozzolino, 2015). Additionally, investigating the interplay between different micronutrients and their synergistic or antagonistic effects could help optimize the application of these essential elements for enhanced grape production.

Conclusion

The comprehensive analysis of the data presented in the tables demonstrates the complex and multifaceted role of micronutrients in shaping the quality characteristics and yield of grapes cv. Superior Grape. The findings highlight the potential of specific micronutrients, such as watercress, selenium, and chamomile, to positively influence key grape attributes, including cluster weight, package size, and total soluble solids. However, the variability observed across growing seasons underscores the need for continued research and the development of tailored micronutrient management strategies that account for the unique growing conditions and cultivar-specific responses. By integrating these insights, grape growers and producers can optimize their management practices to deliver high-quality, marketable grapes that cater to the evolving demands of the global wine and table grape industries.

Based on the findings of this study, the following recommendations are proposed for optimizing micronutrient management strategies in grape cultivation: (1) investigate the synergistic effects of micronutrient combinations to further enhance grape quality and yield; (2) evaluate the influence of environmental factors, such as climate and soil conditions, on the grape's response to micronutrient applications; (3) develop cultivar-specific micronutrient application protocols to account for the unique nutritional requirements and physiological responses of different grape varieties; (4) explore the integration of micronutrient applications with other sustainable practices, such as organic amendments and precision farming techniques, for a holistic approach to grape production; and (5) conduct long-term, multi-year studies to better understand the consistency and repeatability of the observed micronutrient effects on grape quality and yield.

Acknowledgement

The authors would like to acknowledge the financial support provided by [funding agency name] and the technical assistance offered by the [collaborating institution/organization name] during the course of this study. We also express our gratitude to the grape growers and industry stakeholders who contributed their valuable insights and expertise throughout the project.

Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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