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Effects of Foliar Macro and Micro Nutrient Sprays on Growth and Leaf Quality of Flame Seedless Grapevines

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Abstract: Field examination spanning two years (2022-2023) have been done in the vine region of Minia Governorate, West of Samalout Center, to investigates the effects of foliar application of different concentrations of macronutrients (NPK) and micronutrients (Zn, B, Fe) on vegetative growth, leaf pigment content, and nutritional status of Flame Seedless grapevines. Treatments included various levels of NPK or micronutrients alone, and their combinations applied three times during the growing season. Results showed that combined foliar sprays of macro and micro -nutreints significantly enhanced shoot length, leaf number, leaf area, cane thickness, and pruning wood weight compared to untreated controls. Leaf chlorophyll and carotenoid as well as nutritional analysis contents were also highest in vines receiving combined macro- and micronutrients, indicating improved nutrient uptake and metabolic activity. The optimal treatment was foliar spraying with 0.75% NPK plus 100 ppm Zn/B and 150 ppm Fe, which maximized vegetative vigor and leaf pigment content while ensuring better economic returns for growers under local conditions. This integrated nutrient management approach supports sustainable viticulture by balancing growth and quality in Flame Seedless grapevines.

Key words: macro, micronutrients, vegetative growth, pigments and Flame seedless.

1. Introduction

The grapevine (*Vitis vinifera* L.) is a major fruit cultivated worldwide, employed for both direct consumption and raisin manufacture. It occupies a larger global area than any other fruit crop and constitutes around fifty percent of total worldwide consumption. Grapes are the third most farmed fruit in Egypt, after mangoes and citrus (**Mostafa *et al.*, 2023**). The grape growing area in Egypt is 186735 feddans, with a productive zone of 175245 feddans, yielding a total production of 1715410 tons. The arable land in Minia Governorate was 21098 feddans, with a productive area of 20852 feddans, yielding a total of 205244 tons (**MALR, 2023**).

Achieving a balance between productivity and fruit quality is a fundamental goal in viticulture, especially complicated by the effects of climate change and weather variability (**James *et al.*, 2022**). The advancement of grapevines and, subsequently, the yield of superior grapes can be profoundly affected by the implementation of contemporary agro-technical practices, particularly regarding nutrition. This entails the application of optimal dosages and varieties of fertilizers at the proper time (**Stojanova, 2023**).

Effective management of vineyard nutritional requirements requires a visual assessment of grapevines, their growth patterns, and the nutrient status of plant tissues and soil to develop an appropriate fertilization strategy. Vineyards display unique combinations of soil type, grapevine age, canopy architecture, and cultivars, resulting in variability in nutritional requirements across different vineyards and within specific areas of a single vineyard (**Arrobas *et al.*, 2014**).

Nutrition must be aligned with the phenophases of plant development, as the grapevine, a perennial crop, necessitates significant amounts of nutrients that are utilized differently across distinct phenophases. The lack of nutrient availability for plants often leads to the application of soil nutrients not producing the expected outcomes. The successful cultivation of grapevines and the production of high-quality grapes depend on the absorption of physiologically active substances via the leaves (**Stojanova *et al.*, 2024**). Foliar feeding of grapevines, characterized by the provision of adequate macro and microelements in active forms at specific concentrations, stimulates hydrolytic processes in reproductive organs, accelerates photosynthetic processes, and enhances the influx and migration of nutrients into growth and fruiting organs (**Stojanova, 2018**).

Plant roots absorb naturally occurring nutrients present in the soil. Excessive nutrient levels lead to rapid vine growth, resulting in a dense canopy that can overshadow the fruit or display varying degrees of toxicity. Over time, soil nutrients deplete and require replenishment through mineral fertilizers to enhance grape yield and quality. Chlorosis, characterized by the yellowing of leaves rather than their typical purple coloration, is a common indicator of nutrient deficiency. This leads to restricted photosynthesis, hindering proper grape development and subsequently reducing both quality and yield. Utilizing appropriate fertilizers, particularly a blended formulation that provides both macro and micronutrients, can address the issue (**Gur *et al.*, 2022**). NPK levels exert a significant immediate effect, enhancing both the yield and quality of berries (**Michopoulos and Solomou 2019 and Fiaz *et al.*, 2021**).

Nitrogen, phosphorus, and potassium are the essential macronutrients that significantly affect plant growth and the formation of diverse plant structures. Nutrients like nitrogen and potassium demonstrate considerable mobility, facilitating swift translocation from older to younger leaves when the demand in the younger leaves or fruiting bodies surpasses the soil supply. This may result in chlorosis and necrosis (**Michopoulos and Solomou, 2019 and Jegadeeswari *et al.*, 2020**). In contrast, micronutrients are generally applied directly to the vegetative parts via foliar sprays and are required in minimal amounts. These nutrients interact to influence various pathways within the plant (**Kumar *et al.*, 2021**). An effective fertilizer management program relies on the selection of the appropriate fertilizer to address specific deficiencies identified in the vineyard, the accurate rate of nutrient demand, and the timing of fertilizer application (**Rahaman *et al.*, 2019**). The benefits encompass soil and environmental conservation, alongside enhanced grape quality and production.

This systematic approach aims to establish the appropriate concentrations for managing macro and micronutrients in relation to vegetative growth, leaf pigments, and biochemical properties of Flame Seedless grapevines, while addressing existing gaps in the synergistic interactions between these nutrients under Minia Governorate field conditions.

2. Materials and Methods

2.1. Description of the experimental site

Field examination spanning two years (2022-2023) have been done in the vine region of Minia Governorate, West of Samalout Center, which possesses agro-ecologically advantageous circumstances for cultivating Flame Seedless grapevine. Clay soils are the soil type in the experimental site (Table A), as determined by **Wilde *et al.* (1985)**. In both seasons, a cane pruning system was implemented during the second week of December, resulting in 80 eyes per vine (8 canes × 8 eyes per cane + 8 renewal spurs × 2 eyes) with a row spacing of 2 x 3 m.

With regular fertilization, the thirty vines that were selected were consistently robust and vigorous, exhibiting no visible signs of nutrient shortages. Water from the Nile Rivier was used to irrigate the vineyard using a surface irrigation system.

Table (A). Examined soil properties

Soil characters		2022/2023
Particle size distribution (%)	**Sand**	2.10
	Silt	34.85
	Clay	63.05
	Texture class	Clay
EC ppm (1:2.5 extract)		291
pH (1:2.5 extract)		7.82
Organic matter %		2.23
$CaCO_3$ %		2.51
Soil nutrients	**Total N (%)**	0.15
	Available P (ppm)	5.08
	Available K (ppm)	491.0
	Zn (ppm)	2.3
	Fe (ppm)	2.5
	Mn (ppm)	3.1
	Cu (ppm)	0.11

2.2. Treatments and design of the experimental

The experiment has been conducted according the method of complete randomized block design with one vine/treatment and three repetitions. The treatments were organized in the following manner:

1- T1 (control spray with tap water).
2- T2: Zn (50 ppm) + B (50 ppm) + Fe (100 ppm).
3- T3: Zn (75 ppm) + B (75 ppm) + Fe (150 ppm).
4- T4: Zn (100 ppm) + B (100 ppm) + Fe (200 ppm).
5- T5: N (0.5%) + P (0.5%) + K (0.5%).
6- T6: N (0.75%) + P (0.75%) + K (0.75%).
7- T7: N (1.0%) + P (1.0%) + K (1.0%).
8- T8: T2 + T5.
9- T9: T3 + T6.
10- T10: T4+ T7.

At three distinct intervals: at the onset of growth, immediately following berry set, and one month thereafter, each treatment was administered with the studied dosages of macronutrients, including nitrogen in the form of ammonia (46.0% N), P in the form of phosphoric (85.0%), and K in the form of potassium sulfate (50.0%), and micronutrients, including Fe in the form of ferrous sulfate (19.7%), Zn in the form of zinc sulfate (21.0%) and B in the form of borax (11.5%). The applying of macro and micro applications was separated by a week in early morning hours.

2.3. Data recorded

The subsequent parameters were analyzed to ascertain the effects of the aforementioned treatments:

2.3.1. Vegetative growth aspects

The morphological characteristics of five productive branches were documented during the first week of June: Main shoots height, leaf number/shoot, the leaf area (cm²) of the apical sixth and seventh leaves was documented according to **Ahmed and Morsy (1999**).

$$\text{Leaf area} = 0.56\ (0.79 \times w^2) + 20.01$$

where, W = the maximum leaf width

The average pruning wood weight (Kg/vine) was determined by measuring the mass of one-year-old wood removed after pruning at the end of the growing season and Cane thickness (cm).

2.3.2. Leaf pigments

The method developed by **Von Wettstein (1957**) was employed to ascertain the quantity of chlorophyll a and b, as well as total carotenoids in leaves.

2.3.4. Leaves nutritional status

Leaf petioles from 20 basal leaf clusters were examined for nitrogen, phosphorus, and potassium percentage utilizing the Micro-Kjeldahl method, spectrophotometry, and flame photometry, respectively, after berry set during the first week of July. The concentrations of zinc, iron, and manganese (ppm) were quantified by atomic absorption, following the methodologies developed by **Cottenie *et al.* (1982)** and **Balo *et al.* (1988**).

2.4. Data Analysis

The new LSD technique was employed to analyze the data at a significance level of 5%, as described by **Mead *et al.* (1993).**

3. Results and Discussion

3.1. Features of the growth vegetation

The information shown in Table (1) demonstrates that the growth parameters included main shoot length (cm), number of leaves per plant, leaf area (cm²), cane thickness (mm), and pruning wood weight per vine (kg) of Flame Seedless grapevines was significantly greater than that of the untreated control when treated with various concentrations of macro and micro nutrients. Additionally, the increase in traits were largely dependent on the nutrient concentration for each treatment across both growing seasons. The most pronounced improvement was observed with the application of macro nutrients (NPK), particularly at the highest concentration (1.0% for N, P, and K), corresponding to treatment T7. However, increasing the concentration from medium to high levels did not further enhance these traits. The vines receiving three applications of both macro and micro nutrients combined (T10) showed the tallest main shoots (123.7 cm and 126.0 cm), number of leaves per plant (23.2 and 25.3), leaf area (112.7 and 114.0 cm²), cane thickness (1.16 cm), and pruning wood weight per vine (2.26 and 2.39 kg) in 2022 and 2023, respectively. This was closely followed by the medium concentration treatments for both nutrients, with no significant difference between them. In contrast, the untreated vines consistently exhibited the lowest mean values of vegetative aspects throughout both seasons.

Table (1). Impact of applying some macro and micro nutrients on vegetative growth aspects of Flame Seedless grapevines across 2022 and 2023 seasons

Characteristics / Treatments	Main shoots length (cm)		Number of leaves/ shoot		Leaf area (cm^2)		Pruning wood weight (kg)/vine		Cane thickness (cm)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T1	110.1	113.3	15.5	16.8	105.5	107.1	1.75	1.85	0.94	0.96
T2	115.2	117.9	18.6	19.9	107.6	109.0	1.93	2.4	1.00	1.01
T3	117.5	120.1	20.0	21.5	109.0	110.3	2.03	.2.15	1.05	1.06
T4	119.3	121.9	21.0	22.8	109.9	111.4	2.10	2.21	1.08	1.09
T5	117.4	120.1	19.8	21.4	109.1	110.4	2.02	2.13	1.04	1.05
T6	119.5	122.4	21.1	22.8	110.5	111.7	2.11	2.22	1.09	1.11
T7	122.2	124.3	22.0	24.1	111.5	112.8	2.17	2.29	1.11	1.13
T8	119.7	122.2	21.0	22.8	110.2	111.6	2.10	2.23	1.09	1.11
T9	121.9	124.2	22.2	24.3	111.8	112.9	2.19	2.32	1.13	1.17
T10	123.7	126.0	23.2	25.3	112.7	114.0	2.26	2.39	1.16	1.16
New LSD at 5%	**1.9**	**2.0**	**1.1**	**1.4**	**1.1**	**1.2**	**0.08**	**0.08**	**0.04**	**0.04**

Grapevine vegetative growth is heavily controlled by the availability and balance of macronutrients and micronutrients, which play unique but complimentary functions in vine development. The combined application of macro- and micronutrients frequently creates synergistic effects, resulting in superior vegetative development as compared to individual nutrient treatments. In the current study, foliar sprays containing NPK, Zn, B, and Fe were found to dramatically enhance leaf number, leaf area, and pruning wood weight in grapevines, indicating improved vine vigor and canopy development. This synergy is likely due to the complementary activities of these nutrients in metabolic pathways and structural functions, which optimize nutrient uptake and use.

Macronutrients, including nitrogen (N), phosphorus (P), and potassium (K), are critical for essential metabolic processes and structural development. Nitrogen plays a vital role in the synthesis of amino acids, proteins, and chlorophyll, thereby facilitating shoot growth, leaf development, and the postponement of leaf senescence. Adequate nitrogen availability promotes shoot elongation, leaf expansion, and overall biomass accumulation. Research on Flame Seedless grapevines indicates that nitrogen supplementation enhances both the quantity and surface area of leaves, leading to an improved photosynthetic system (**Bassiony *et al.*, 2018**). Phosphorus is crucial for energy transfer and the formation of genetic material, impacting early shoot growth and fruit set. It plays a vital role in energy transfer processes (ATP), nucleic acid synthesis, and maintaining membrane integrity. Phosphorus deficiency adversely affects root development and limits shoot growth, resulting in decreased leaf area and hindered vine establishment. Phosphorus application in grapevines is associated with improved root-to-shoot ratios and enhanced early-season vegetative growth, both of which are essential for establishing a productive canopy (**James *et al.*, 2022**). Potassium regulates stomatal function, protein synthesis, and carbohydrate metabolism, thereby influencing berry size and ripening. Adequate potassium nutrition enhances leaf turgor, expands leaf area, and aids in the transport of photosynthates to developing shoots and clusters (**Mpelasoka *et al.*, 2003**). Potassium deficiency results in marginal leaf chlorosis, diminished shoot growth, and compromised berry development. An adequate supply of these macronutrients typically leads to an increase in leaf number, leaf area, and pruning wood weight, indicating improved vegetative vigor (**Proffitt and Campbell-Clause, 2012 and Zhao *et al.*, 2025).**

Micronutrients including (Zn, B and Fe) that are needed in modest amounts but are very important for certain biochemical and physiological processes. Zinc helps make hormones, build chloroplasts, and break down carbohydrates, which helps cells grow longer and leaves grow bigger. Foliar application of zinc has been proven to make Flame Seedless grapevines stronger, increase the amount of chlorophyll in their leaves, and add more leaves to each shoot (**Bassiony *et al.*, 2018**). Boron is important for transporting sugar, forming cell walls, and reproductive activities including pollen germination. It indirectly supports vegetative growth by making sure that canes mature properly. When plants are growing, boron helps cells grow longer and divide, which helps shoots and roots grow. Adding boron has been linked to longer shoots and bigger leaves, as well as better fruit set since the pollen tubes grow faster (**Pereira *et al.*, 2021).** Iron is needed for making chlorophyll and for breathing. It keeps leaves from falling off too soon and keeps photosynthesis going strong (**Al-Atrushy, 2019 and Zhao *et al.*, 2025).**

3.2. Leaf pigments content mg/100 g F.W

Table 2 indicate that the application of both macro and micro nutrient fertilizers at different concentrations significantly influenced the levels of chlorophyll (a, b, and total) and total carotenoid when compared to the untreated control. The highest mean values in individual form were recorded for the macro nutrient NPK at 1.0% (T7), followed by 0.75% (T6), with no significant difference observed between these two concentrations. The increase in pigments content were contingent upon the concentration applied in each treatment. The findings indicated that the measured variables were influenced by varying concentrations of macro and micronutrients when applied in combination as a foliar spray. The control treatment exhibited the lowest values in both seasons, while the combination of macro NPK at T10 (1.0% for each) and micronutrients (100 ppm for Zn or B and 200 ppm for Fe) resulted in the highest values. The medium concentrations for both fertilizers (T9) were recorded in a descending order, showing no significant difference from the highest concentrations, while the other treatments displayed intermediate values throughout both seasons.

Foliar spraying ensures that nutrients are quickly absorbed by the leaves, hence correcting deficiencies and stimulating metabolic pathways that lead to increased pigment production. The foliar treatment of macronutrients (NPK) and micronutrients (Fe, B, Zn) is critical for increasing the chlorophyll and carotenoid content of grape leaves. Nitrogen, a fundamental element of the chlorophyll molecule, directly enhances chlorophyll biosynthesis, leading to improved photosynthetic efficiency and increased plant vigor (**Taiz and Zeiger, 2015**). Phosphorus and potassium enhance this process by promoting energy transfer, metabolic activity, and enzyme regulation, which are crucial for pigment stability and leaf health (**Marschner, 2012**).

Iron is essential for chlorophyll synthesis and serves as a cofactor for numerous photosynthetic enzymes, whereas zinc plays a role in activating enzymes that facilitate the biosynthesis of chlorophyll and carotenoids (**Alloway, 2008 and Marschner, 2012**). Boron plays a role in cell wall formation and sugar transport, thereby facilitating pigment accumulation and leaf development.

Table (2). Impact of applying some macro and micro nutrients on leaf pigment content of Flame Seedless grapevines across 2022 and 2023 seasons

Characteristics / Treatments	Chlorophyll a mg/100 g FW		Chlorophyll b mg/100 g FW		Total chlorophyll mg/100 g FW		Total carotenoid mg/100 g FW	
	2022	2023	2022	2023	2022	2023	2022	2023
T1	4.3	4.5	1.2	1.3	5.5	5.8	1.2	1.3
T2	4.9	5.1	1.7	1.8	6.6	6.9	1.7	1.8
T3	5.3	5.5	2.2	2.4	7.5	7.9	2.1	2.2
T4	5.5	5.8	2.5	2.7	8.0	8.5	2.4	2.5
T5	5.4	5.6	2.1	2.2	7.5	7.8	2.1	2.2
T6	5.7	6.0	2.5	2.7	8.2	8.7	2.6	2.7
T7	5.8	6.3	2.8	2.9	8.4	9.2	2.8	3.0
T8	5.7	6.1	2.5	2.6	8.2	8.7	2.6	2.7
T9	6.1	6.6	2.9	3.1	9.0	9.7	3.0	3.1
T10	6.2	6.9	3.2	3.4	9.4	10.3	3.3	3.4
New LSD at 5%	**0.3**	**0.4**	**0.4**	**0.4**	**0.6**	**0.7**	**0.4**	**0.4**

3.3. Nutritional status of leaves

Table 3 indicate that foliar application of macro- and micronutrient fertilizers, whether used individually or in combination at various concentrations, significantly affected the N, P, K%, Zn, Fe and Mn (ppm) in grape leaves. The results show that applying NPK, particularly at a concentration of 1.0% (T7), produced the highest nutrients concentration, with the 0.75% concentration (T6) yielding similar results and no significant difference between the two. Notably, a strong interactive effect was observed when macro- and micronutrients were applied together. The T10 treatment led to the highest recorded N (1.83 and 1.90%), P (0.31 and 0.35%), K (1.87 and 1.89%), Zn (58.9 and 61.2 ppm), Fe, 64.0 and 66.1 ppm) and Mn (64.9 and 66.0 ppm) for the two seasons, respectively. The T9 treatment also resulted in high nutrient concentrations, with no significant difference compared to T10. In contrast, the control vines, which received no foliar treatment, had the lowest concentration for studied nutrients across both years.

Applying macronutrients (NPK) and micronutrients like zinc (Zn), boron (B), and iron (Fe) to grapevine leaves has been proven to greatly increase the levels of both macronutrients and micronutrients in the leaves during the current study. For instance, studies on grapevines showed that applying zinc fertilizers (ZnO or $ZnSO_4$) to the leaves at higher concentrations led to larger levels of Zn in the leaves, with the highest levels seen at the highest treatment rates (**Daccak *et al.*, 2022**). Also, applying iron, zinc, and boron to the leaves of grapes was found to greatly increase the levels of micronutrient in the leaves and make the fruit more mineral-rich (**Saini *et al.*, 2019**).

The reason for this impact is because nutrients are quickly absorbed through the leaf surface, which gets around problems with the soil, like nutrient fixation and low root uptake when the soil isn't in the best condition (**Ahmed *et al.*, 2021**). When NPK is applied to leaves, nitrogen helps make proteins and chlorophyll, phosphorus is important for moving energy, and potassium controls osmotic balance and enzyme activation. All of these things help the leaves get more nutrients and work better (**Zhao *et al.*, 2025**).

Table (3). Impact of applying some macro and micro nutrients on leaves nutritional status of Flame Seedless grapevines across 2022 and 2023 seasons

Characteristics / Treatments	Leaf N %		Leaf P %		Leaf K %		Leaf Zn ppm		Leaf Fe ppm		Leaf Mn ppm	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T1	1.53	1.59	0.12	0.13	1.62	1.67	50.4	51.8	54.0	55.6	51.9	52.4
T2	1.60	1.67	0.17	0.18	1.68	1.72	53.5	55.9	58.1	59.9	56.8	57.5
T3	1.67	1.73	0.21	0.23	1.73	1.76	55.5	57.3	59.7	61.5	58.9	59.7
T4	1.71	1.76	0.22	0.26	1.76	1.78	56.7	59.4	60.9	62.9	59.5	61.6
T5	1.66	1.74	0.22	0.23	1.73	1.77	55.0	57.3	59.7	61.6	59.1	59.9
T6	1.73	1.80	0.26	0.28	1.78	1.81	56.5	58.8	61.2	63.2	61.3	62.0
T7	1.76	1.84	0.28	0.30	1.80	1.84	57.6	60.0	62.5	64.5	63.1	63.9
T8	1.73	1.79	0.25	0.27	1.79	1.82	56.4	58.7	61.2	63.1	61.1	62.1
T9	1.79	1.86	0.29	0.32	1.84	1.86	57.7	60.0	62.7	64.7	63.1	64.2
T10	1.83	1.90	0.31	0.35	1.87	1.89	58.9	61.2	64.0	66.1	64.9	66.0
New LSD at 5%	**0.05**	**0.05**	**0.03**	**0.04**	**0.04**	**0.04**	**1.3**	**1.3**	**1.4**	**1.5**	**1.9**	**2.0**

4. Conclusion

Based on the current field trials, applying foliar sprays thrice through the growing; the onset of growth, immediately following berry set, and one months thereafter at rate of 0.75% NPK + 100 ppm Zn/B + 150 ppm Fe is superior to higher rates for Flame Seedless grapevines under Minia conditions. This approach achieves optimal vine health and productivity while ensuring better economic returns for growers.

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تأثر الرش الورقى بالعناصر الكبرى و الصغرى على نمو و جودة أوراق عنب فليم سيدلس

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الموجز

أجريت تجربه ميدانيه خلال عامى ٢٠٢٢ و ٢٠٢٣ بمزرعه خاصة فى غرب مركز سمالوط ، محافظة المنيا، لدراسة تأثير الرش الورقى بتركيزات مختلفه من العناصر الكبرى (نيتروجين، فوسفور و بوتاسيوم) و العناصر الصغرى (زنك، بورون و حديد) بصوره فرديه أو مجتمعه على النمو الخضرى و محتوى الأوراق من الصبغات و الحاله الغذائية لكروم عنب فليم سيدلس. أظهرت النتائج أن الرش الورقى للأسمده المدروسه عززبشكل كبير النمو الصفات التاليه: طول الفرع الرئيسي(سم)، عدد الأوراق / فرع، مساحة الورقه سم٢، سمك القصب سم ، وزن خشب التقليم/كرمة كجم، محتوى الأوراق من الصبغات و العناصر الغذائية مما يشير إلى تحسن فى النشاط الأيضى، حيث سجلت أفضل القيم عند الرش الورقى بمعدل ٠,٧٥% لكل من النيتروجين و الفوسفور و البوتاسيوم مع ٧٥ جزء فى المليون زنك او بورون مع ١٥٠ جزء فى المليون حديد مما أدى إلى تعظيم النمو الخضرى مع ضمان عائد إقتصادى أفضل من كروم عنب فليم سيدلس للمزراعين فى ظل ظروف محافظة المنيا.

الكلمات المفتاحيه: عناصر كبرى، عناصر صغرى، نمو خضرى، صبغات و عنب فليم سيدلس.