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Effect of Calcium, Magnesium Fertigation and Molybdenum Foliar Sprays on Yield and Fruit Quality of Flame Seedless Table Grape Cultivar

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Abstract: This investigation was performed during the 2018 and 2019 seasons in a private vineyard to study the effect of calcium, magnesium fertigation and molybdenum foliar sprays on the yield and fruit quality of Flame seedless table grape cultivar. The experimental layout was arranged in a split-plot design. All treatments were applied on three dates: after the bud burst stage, at the fruit set stage and veraison stage. The results showed that the combined application of 30 Kg calcium with 20 Kg magnesium fertigation and foliar spraying of 30 ppm molybdenum was the most effective among all treatments in terms of enhancing vegetative growth characteristics, increasing leaf content of total chlorophylls and mineral elements as well as improving yield and fruit quality attributes.

1 Introduction

The area cultivated in grapes reached 85240 hectares producing 1435000 tons (FAO 2023). In Egypt, grape is one of the most significant and advantageous fruit crops; it is ranked second to citrus in terms of production. Grape production was enhanced due to the introduction of new cultivars and improved cultural practices. Flame seedless grape is a promising variety around Egypt and has gradually developed over the last few years. In the recently reclaimed land along the desert roads in North and Middle Egypt, a sizable area of Flame seedless grapevine is being raised. An appropriate supply of macro- and microelements is required for all plants to perform their regular physiological and biochemical processes (Aly et al 2020). Optimum production and fruit quality depend on a balanced supply of nutrients (Ilyas et al 2014). Calcium (Ca) is crucial for plant growth, development, maintenance and modulation of numerous cell processes. It is important to keep the membrane stable and is an essential component of the cell wall and its rigidity (Thor 2019). Additionally, it is essential for signaling specific enzymes to become active and coordinate proper cellular processes (White and Broadley 2003). Magnesium (Mg) is essential for the enzyme activation that takes part in photosynthesis, respiration and the production of nucleic acids (Kleczkowski and Igamberdiev 2021). In the light-absorbing chloroplast complex, the central atom of the chlorophyll molecule is magnesium, which aids in the photosynthesis of carbon dioxide in plants making its role most important (Cakmak and Kirkby 2008). Molybdenum (Mo) is a crucial trace element for plant growth, nitrate reductase and other nitrogen metabolism enzymes, that play a direct or indirect role in nitrogen metabolism (Kaiser et al 2005). Sufficient Mo is required for the synthesis of molybdenum-containing enzymes in plants, that play roles in sulfide detoxification, nitrate assimilation, phytohormone production and purine metabolism (Tejada-Jiménez et al 2013).

This study aimed to find suitable levels of Ca and Mg fertilization and foliar spraying of molybdenum for improving yield and fruit quality attributes of 01the Flame seedless table grape cultivar.

2 Materials and Methods

This investigation was performed during the 2018 and 2019 seasons in a private vineyard located at Badr Center, Beheira Governorate. The vines were eight years old, grown in sandy soil **Table 1**, irrigated by the drip irrigation system, spaced at 2 X 3 meters apart, trellised by Gable system, and cane pruned during the first week of January. The bud load was seventy-two eyes/vine; whereas, after cultural and pruning practices, thirty-five clusters were left per vine. The experimental layout was arranged in a split-plot design. The main plot was allocated by applying (Ca + Mg) fertilization including three doses of Ca (0, 20 and 30kg /Fed) as actual calcium oxide (CaO) combined with three doses of Mg (0, 10 and 20kg /Fed) as actual magnesium oxide (MgO), while, three doses of Mo foliar spray (0, 20 and 30ppm) as actual molybdenum were occupied in the subplot. Thus, the experiment consisted of fifteen treatments with three replicates and each replicate was represented by three vines. All treatments were applied at three stages: after the bud burst stage, at the fruit set stage and veraison stage. Calcium nitrate 26.5% as a source of calcium, magnesium sulfate 15% as a source of magnesium, and molybdenum ammonium 52% as a source of molybdenum.

The following criteria were used. for the conducted treatments:

2.1 Morphological characteristics of vegetative growth

At growth cessation, the morphological characteristics were evaluated on ten fruitful shoots at the considered vine: shoot length, and the number of leaves per shoot. The leaf area (cm^2) of the apical 6th and 7th leaves was recorded using a CI-203-Laser Area-meter made by CID, Inc., Vancouver, USA. Also, the average weight of annual pruning (Kg/vine) was recorded at the pruning time in the first week of January.

2.2 Leaf total chlorophyll and mineral elements content

Total chlorophyll was measured by using a nondestructive Minolta chlorophyll meter SPAD-502 MINOLTA (Loh et al 2002). Leaf N, P and K were determined by Micro-Kjeldahl method, spectrophotometer and flame photometer, respectively (Jackson 1973). Ca, Mg, Fe, Zn and Mn were measured by atomic absorption (De Ruig and Collaborators 1986). Molybdenum was determined according to Eivazi et al (1982).

2.3 Yield and physical characteristics of clusters

Nine clusters per vine were taken as representative random samples when the TSS reached maturity, which was at 16–17%. The following characteristics were determined:

Yield per vine (kg) and its components were estimated as the number of clusters/vine X average cluster weight (g). Length (cm) and width (cm) were estimated.

2.4 Physical properties of berries

Average berry weight (g), size (cm^3), length (cm), diameter (cm), firmness (g/cm^2), adherence strength (g) and berry stem necrosis (%) were estimated.

2.5 Chemical properties of berries

Total soluble solids in berry juice (TSS) was established by hand refractometer (HR-110.) and total titratable acidity as tartaric acid was determined as g tartaric acid / 100 ml juice (AOAC 2019). Hence TSS /acid ratio was calculated. Total sugars were determined according to the method described by Shanmugavelan et al (2013). The total anthocyanin of the berry skin was determined as mg/100g fresh weight (Hsia et al 1965).

2.6 Experimental design and statistical analysis

The experimental layout was arranged in a split-plot design. The main plot was allocated by applying (Ca + Mg) fertilization, while Mo foliar spray was occupied in the subplot. The statistical analysis was carried out according to Snedecor and Cochran (1980). Means were compared using the LSD values at a 5% level (Steel and Torrie 1960).

Table 1. Physical and chemical characteristics of the experimental soil

Parameter	Unit	Value
pH		8.63
EC	$ds.m^{-1}$	0.64
TDS	Mg/l	304.48
Na^+	Meq l^{-1}	1.71
K^+		0.93
Ca^{2+}		2.82
Mg^{2+}		1.41
Cl^-		2.01
CO_3^{2-}		n.d
HCO_3^-		1.83
SO_4^{2-}		3.07
Organic matter O.M	%	0.34
Total carbonate		4.02
CEC	Meq $100g^{-1}$ soil	7.92
Saturation Percent		32.52
Field Capacity		24.51
Wilting point		6.00
Sand	%	86.50
Silt		3.00
Clay		12.50
Texture		Sandy Loam
Bulk Density	g cm^{-3}	1.55
Porosity	%	42.02

3 Results and Discussion

3.1 Morphological characteristics of vegetative growth

It is apparent in **Table 2** that vegetative growth traits i.e., shoot length, number of leaves, average leaf area and pruning weights were significantly affected by the fertigation of calcium plus magnesium and the foliar spraying of molybdenum in comparison to control in both seasons.

Regards to the influence of the fertigation of calcium and magnesium, it was shown that significantly highest values of these parameters were obtained from the combining application of calcium and magnesium at 30 Kg/Fed and 20 Kg/Fed followed, in descending order, by 20+20 kg/Fed, while control treatment recorded the lowest values of vegetative growth in both seasons.

Concerning the influence of foliar spraying of molybdenum, it is obvious that the foliar spraying of molybdenum at a high dose (30ppm) significantly enhanced the vegetative growth traits followed, in descending order, by the low dose (20ppm), whereas control treatment recorded the least values in both seasons.

A significant interaction was noticed between the fertigation application of calcium plus magnesium and the foliar spraying of molybdenum. It is clear that the fertigation of calcium plus magnesium at 30+20 kg/Fed and the foliar spraying of molybdenum at a high dose (30ppm) significantly resulted in the highest values for these traits followed by the combined application of calcium plus magnesium at 20+20 kg/Fed and the foliar spraying of molybdenum at high dose (30ppm). On the other hand, the control treatment recorded the lowest values in both seasons.

The improvement in vegetative growth parameters might be attributed to the importance of Ca and Mg in cell division and carbohydrate metabolism (Ilyas et al 2014). Moreover, in vines growing in nutrient-poor circumstances, a lack of Mg and K severely reduces photosynthesis (Rogiers et al 2020). it is necessary for N2-fixing activity and prevents plants from growing properly (Hernandez et al 2009). The above results line up with those by Morsi et al (2009), El-Badawy (2019), and Abo El-Ezz et al (2022), who found that calcium, magnesium and molybdenum application enhanced the vegetative growth traits of grape cultivars.

3.2 Leaf content of total chlorophylls and mineral elements

Data presented in **Tables 3 and 4** showed that the fertigation of calcium plus magnesium and the foliar spraying of molybdenum had a positive influence on the leaf total chlorophylls and mineral elements content expressed in N, P, K, Ca and Mg as macro-elements as well as Fe, Zn, Mn and Mo as micro-elements as compared to control.

Regarding the influence of the fertigation of calcium and magnesium, it was found that the highest values for these determinations were obtained from the application of calcium plus magnesium at 30+20 kg/Fed significantly followed, in descending order, by 20+20 kg/Fed, while control treatment recorded the least values in both seasons.

Concerning the influence of foliar spraying of molybdenum, it revealed that the foliar spraying of molybdenum at a high dose (30ppm) markedly increased leaf total chlorophylls and mineral elements content followed by the low dose (20ppm), whereas control treatment recorded the least values in both seasons.

Table 2. Effect of calcium, magnesium fertigation and molybdenum foliar sprays on morphological characteristics of vegetative growth of Flame seedless during 2018 and 2019 seasons

	Average shoots length (cm)		Average number of leaves/shoot		Average leaf area (cm^2)		Average pruning weight (Kg/vine)	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Ca + Mg (kg/Fed.)								
A1 (control)	163.9	167.1	25.82	28.68	149.4	155.7	2.12	2.19
A2 (30 + 20)	196.2	197.3	31.44	33.68	176.3	184.5	2.49	2.59
A3 (30 + 10)	181.3	183.2	28.72	31.41	163.8	171.1	2.33	2.40
A4 (20 + 20)	190.5	191.9	30.25	32.81	171.2	179.5	2.43	2.51
A5 (20 + 10)	170.9	173.7	26.98	29.78	155.1	161.9	2.20	2.28
L.S.D. (A)=	1.7	1.4	0.19	0.23	1.8	1.3	0.02	0.03
Mo (ppm)								
B1 (control)	177.7	180.0	28.11	30.81	160.8	167.9	2.28	2.36
B2 (20)	180.4	182.3	28.65	31.25	162.9	170.4	2.31	2.39
B3 (30)	183.6	185.5	29.16	31.76	165.8	173.3	2.35	2.44
L.S.D. (B)=	1.5	1.2	0.17	0.20	1.6	1.1	0.01	0.02
Interaction								
A1 B1	161.2	164.7	25.37	28.19	147.2	153.3	2.09	2.16
A1 B2	163.3	166.3	25.71	28.63	148.9	155.2	2.12	2.18
A1 B3	167.2	170.2	26.37	29.21	152.1	158.7	2.16	2.23
A2 B1	194.6	195.7	30.93	33.45	174.8	183.3	2.46	2.56
A2 B2	195.3	196.2	31.49	33.52	175.2	183.5	2.48	2.57
A2 B3	198.7	199.9	31.91	34.08	178.8	186.7	2.52	2.63
A3 B1	176.5	178.9	27.92	30.65	159.8	166.4	2.28	2.34
A3 B2	180.8	182.5	28.64	31.32	163.4	170.8	2.32	2.40
A3 B3	186.5	188.2	29.59	32.27	168.1	175.9	2.38	2.47
A4 B1	187.4	189.1	29.74	32.34	168.9	176.8	2.39	2.48
A4 B2	191.2	192.5	30.36	32.92	171.3	180.1	2.44	2.52
A4 B3	192.9	194.1	30.65	33.18	173.4	181.6	2.46	2.54
A5 B1	168.7	171.6	26.61	29.44	153.3	159.9	2.18	2.25
A5 B2	171.3	174.2	27.06	29.85	155.6	162.4	2.21	2.28
A5 B3	172.6	175.3	27.27	30.05	156.3	163.5	2.22	2.31
L.S.D. (AXB)=	3.3	2.7	0.37	0.45	3.5	2.5	0.03	0.05

Table 3. Effect of calcium, magnesium fertigation and molybdenum foliar sprays on leaf content of total chlorophylls and macro-elements of Flame seedless during 2018 and 2019 seasons

	Total chloro-phylls (SPAD)		**Total nitrogen (%)**		**Phosphorus (%)**		**Potassium (%)**		**Calcium (%)**		**Magnesium (%)**	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Ca + Mg (kg/Fed.)												
A1 (control)	32.3	35.7	1.81	1.85	0.19	0.23	1.31	1.34	1.72	1.77	0.63	0.68
A2 (30 + 20)	35.6	38.9	2.23	2.25	0.40	0.46	1.49	1.53	1.93	1.97	0.79	0.83
A3 (30 + 10)	33.7	36.8	2.02	2.04	0.33	0.35	1.39	1.43	1.81	1.86	0.71	0.75
A4 (20 + 20)	34.5	37.8	2.13	2.15	0.37	0.39	1.43	1.47	1.87	1.91	0.75	0.78
A5 (20 + 10)	33.1	36.3	1.92	1.95	0.27	0.29	1.36	1.39	1.76	1.82	0.67	0.71
L.S.D. (A)=	0.5	0.3	0.02	0.01	0.02	0.01	0.03	0.02	0.02	0.01	0.03	0.02
Mo (ppm)												
B1 (control)	33.5	36.8	1.98	2.02	0.29	0.33	1.38	1.42	1.80	1.85	0.69	0.74
B2 (20)	33.8	37.1	2.02	2.05	0.31	0.34	1.39	1.43	1.82	1.87	0.71	0.75
B3 (30)	34.2	37.4	2.06	2.08	0.33	0.37	1.42	1.45	1.83	1.88	0.72	0.77
L.S.D. (B)=	0.4	0.2	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01
Interaction												
A1 B1	32.2	35.5	1.76	1.83	0.17	0.21	1.29	1.32	1.71	1.75	0.61	0.67
A1 B2	32.3	35.6	1.81	1.84	0.19	0.24	1.31	1.33	1.73	1.78	0.63	0.68
A1 B3	32.5	35.9	1.85	1.87	0.21	0.24	1.33	1.36	1.73	1.79	0.64	0.70
A2 B1	34.8	38.6	2.19	2.22	0.38	0.44	1.46	1.51	1.91	1.95	0.77	0.82
A2 B2	35.3	38.9	2.23	2.25	0.39	0.46	1.48	1.53	1.93	1.97	0.79	0.83
A2 B3	36.8	39.3	2.26	2.27	0.43	0.49	1.52	1.56	1.96	1.99	0.82	0.85
A3 B1	33.4	36.5	1.99	2.01	0.33	0.34	1.37	1.42	1.79	1.85	0.69	0.74
A3 B2	33.7	36.8	2.02	2.04	0.33	0.35	1.39	1.43	1.81	1.86	0.71	0.75
A3 B3	33.9	37.1	2.06	2.08	0.34	0.37	1.41	1.44	1.82	1.88	0.72	0.75
A4 B1	34.2	37.4	2.09	2.11	0.35	0.38	1.42	1.46	1.85	1.90	0.74	0.76
A4 B2	34.5	37.8	2.13	2.15	0.37	0.38	1.43	1.47	1.87	1.91	0.75	0.78
A4 B3	34.7	38.2	2.16	2.18	0.38	0.41	1.45	1.49	1.88	1.93	0.77	0.81
A5 B1	32.9	36.2	1.89	1.91	0.24	0.26	1.34	1.37	1.75	1.81	0.66	0.71
A5 B2	33.1	36.4	1.92	1.95	0.27	0.29	1.36	1.39	1.76	1.82	0.67	0.71
A5 B3	33.2	36.4	1.96	1.98	0.31	0.32	1.37	1.40	1.78	1.82	0.67	0.72
L.S.D. (AXB)=	0.9	0.5	0.03	0.02	0.03	0.02	0.05	0.03	0.03	0.02	0.05	0.03

Table 4. Effect of calcium, magnesium fertigation and molybdenum foliar sprays on leaf content of micro-elements of Flame seedless during 2018 and 2019 seasons

	Iron (ppm)		Zinc (ppm)		Manganese (ppm)		Molybdenum (ppm)	
	2018	2019	2018	2019	2018	2019	2018	2019
Ca + Mg (kg/Fed.)								
A1 (control)	52.6	53.6	39.4	41.4	69.8	73.3	0.06	0.05
A2 (30 + 20)	64.6	65.4	42.9	44.1	75.1	78.3	0.12	0.11
A3 (30 + 10)	58.4	59.5	41.2	42.8	72.3	75.9	0.08	0.08
A4 (20 + 20)	61.4	62.4	42.0	43.3	73.9	77.0	0.09	0.09
A5 (20 + 10)	55.6	56.6	40.1	42.0	70.9	74.7	0.07	0.06
L.S.D. (A)=	0.4	0.3	0.5	0.4	0.3	0.2	0.02	0.01
Mo (ppm)								
B1 (control)	57.5	58.6	40.8	42.5	71.9	75.4	0.08	0.07
B2 (20)	58.5	59.5	41.1	42.7	72.4	75.9	0.08	0.08
B3 (30)	59.6	60.4	41.4	42.9	72.8	76.3	0.09	0.09
L.S.D. (B)=	0.3	0.2	0.4	0.3	0.2	0.1	0.01	0.01
Interaction								
A1 B1	51.8	53.3	39.2	41.1	69.3	72.6	0.05	0.03
A1 B2	52.5	53.4	39.3	41.5	69.8	73.5	0.06	0.05
A1 B3	53.7	54.2	39.6	41.7	70.2	73.9	0.06	0.06
A2 B1	63.5	64.6	42.5	43.8	74.6	77.9	0.11	0.10
A2 B2	64.7	65.5	42.9	44.1	75.1	78.3	0.11	0.11
A2 B3	65.5	66.2	43.2	44.3	75.7	78.8	0.14	0.13
A3 B1	57.7	58.5	40.7	42.7	71.8	75.6	0.08	0.07
A3 B2	58.1	59.4	41.3	42.9	72.3	75.9	0.08	0.08
A3 B3	59.4	60.5	41.5	43.0	72.7	76.2	0.09	0.08
A4 B1	60.2	61.3	41.7	43.1	73.5	76.6	0.09	0.08
A4 B2	61.8	62.6	42.0	43.4	73.9	77.1	0.09	0.09
A4 B3	62.3	63.4	42.2	43.5	74.2	77.4	0.10	0.09
A5 B1	54.3	55.6	39.9	41.9	70.5	74.2	0.07	0.06
A5 B2	55.6	56.7	40.2	41.9	70.9	74.7	0.07	0.06
A5 B3	56.9	57.6	40.4	42.2	71.4	75.1	0.07	0.07
L.S.D. (AXB)=	0.7	0.5	0.9	0.7	0.5	0.3	0.03	0.02

A significant interaction was observed between the fertigation application of calcium plus magnesium and the foliar spraying of molybdenum. It is noticed that the fertigation of calcium plus magnesium at 30+20 kg/Fed and the foliar spraying of molybdenum at a high dose (30ppm) significantly had the highest values for these determinations followed by the combined application of calcium plus magnesium at 20+20 kg/Fed and the foliar spraying of molybdenum at high dose (30ppm), whereas, the control treatment recorded the least values in both seasons.

The enhancing influence of magnesium on the overall chlorophyll of the leaf can be attributed to the fact that magnesium is an essential element in the structure of the chlorophyll molecule that increases the production of chlorophyll and chlorophyll-binding proteins and hence photosynthesis level was increased (Papadakis et al 2023). For calcium effect, it had remarkable effects on delaying the degradation of chlorophyll and maintaining a relatively high level of photosynthesis efficiency. The role of molybdenum in the increase in leaf chlorophyll may be its stimulus effect on the process of photosynthesis (Oliveira et al 2022). Similar to calcium, magnesium and molybdenum, there was continued accumulation of other macro- and microelements in the leaves as a result of Ca, Mg and Mo applications. The foliar application of these nutrients balances the vine nutritional status by increasing the amount of Ca and Mg than their values before spray (James et al 2023).

3.3 Yield and physical characteristics of clusters

Data presented in **Table 5** showed that the fertigation of calcium plus magnesium and the foliar spraying of molybdenum had a positive influence on yield and cluster physical characteristics *i.e.* cluster weight and dimensions in comparison with control.

Regarding the influence of the fertigation of calcium and magnesium, it was found that the greatest values for these parameters were acquired from the application of calcium plus magnesium at 30+20 kg/Fed significantly followed by 20+20 kg/Fed. Control treatment recorded the lowest values in both seasons.

The foliar spraying of molybdenum at a high dose (30ppm) significantly increased yield and cluster physical characteristics followed in descending order by the low dose (20ppm) whereas the control treatment showed as usual the lowest values.

A significant interaction was observed between the fertigation application of calcium plus magnesium and the foliar spraying of molybdenum. It is noticed that the fertigation of calcium plus magnesium at 30+20kg/Fed and the foliar spraying of molybdenum at a high dose (30ppm) significantly had the greatest values for these parameters followed by the combined application of calcium plus magnesium at 20+20 kg/Fed and the foliar spraying of molybdenum at high dose (30ppm). On the other hand, the control treatment recorded the lowest.

The cluster weight increased with Mg + Ca applications (Capps and Wolf, 2000). Williams et al (2005) also found that the application of Mo increased crop output, as evidenced by the number and weight of bunches**.** Large berries were produced when K, Mg and Ca were applied in the proper amounts. This may be related to the use of Mg and occasionally Ca fertilizers, which frequently decreased the prevalence of Berry dryness (BD). Additionally, under this treatment, cluster and berry weight were highest. Contrarily, BD was increased by increasing the nitrogen content of berry pedicels whereas it was decreased by applications of Ca and Mg alone.

3.4 Physical properties of berries

Table 6 clearly shows that berry physical properties i.e., average berry weight, size, length, diameter, firmness, adherence strength and berry stem necrosis were significantly affected by the fertigation of calcium plus magnesium and the foliar spraying of molybdenum in comparison with control in both seasons.

The fertigation of calcium and magnesium gave the highest values for these attributes. The application of calcium plus magnesium at 30+20 kg/Fed gave the best attributes followed by 20+20 kg/Fed, while the control treatment showed the lowest values.

The foliar spraying of molybdenum at a high dose (30ppm) significantly improved berry physical properties followed by the low dose (20ppm), while control treatment still recorded the lowest values in both seasons.

A significant interaction was noticed between the fertigation application of calcium plus magnesium and the foliar spraying of molybdenum. The fertigation of calcium plus magnesium at 30+20 kg/Fed and the foliar spraying of molybdenum at high dose (30ppm) significantly recorded the highest values of berry weight, size, length, diameter, firmness and adherence strength and the least values of berry stem necrosis followed by the combined application of calcium plus magnesium at 20+20 kg/Fed and the foliar spraying of molybdenum at high dose (30ppm).

The positive influence of Ca on berry physical properties especially berry firmness and adherence strength might be lowering the sensitivity of the cell wall towards the enzymatic hydrolysis by inhibiting the activity of the enzymes polygalacturonase and pectin methyl esterase, as well as by binding to cellular polymers, as well as prevents cell collapse and disintegration (Kittemann et al 2010).

Magnesium is an essential element for chlorophyll molecule structure that increases the production of chlorophyll and consequently, berry physical properties were improved by Mg application (Papadakis et al 2023). BSN is a physiological disorder that may appear

Table 5. Effect of calcium, magnesium fertigation and molybdenum foliar sprays on yield and cluster physical characteristics of Flame seedless during 2018 and 2019 seasons

	Yield/tree (kg)		Average cluster weight (g)		Average cluster length (cm)		Average cluster width (cm)	
	2018	2019	2018	2019	2018	2019	2018	2019
Ca + Mg (kg/Fed.)								
A1 (control)	10.23	11.03	363.18	380.96	18.42	19.41	13.27	14.52
A2 (30 + 20)	12.70	14.21	450.24	482.37	19.97	21.00	14.89	16.12
A3 (30 + 10)	11.47	12.75	407.92	435.48	19.10	20.22	13.95	15.23
A4 (20 + 20)	12.01	13.40	426.28	456.03	19.55	20.49	14.40	15.63
A5 (20 + 10)	11.04	12.23	393.11	419.82	18.75	19.82	13.54	14.96
L.S.D. (A)=	0.09	0.13	4.59	5.04	0.08	0.11	0.16	0.10
Mo (ppm)								
B1 (control)	11.32	12.41	401.42	424.73	19.05	20.05	13.88	15.17
B2 (20)	11.49	12.79	408.79	437.22	19.14	20.20	14.00	15.29
B3 (30)	11.65	12.97	414.24	442.85	19.28	20.32	14.15	15.42
L.S.D. (B)=	0.08	0.11	4.10	4.50	0.07	0.10	0.14	0.08
Interaction								
A1 B1	10.08	10.31	353.76	357.24	18.34	19.23	13.21	14.43
A1 B2	10.23	11.35	366.23	391.78	18.41	19.48	13.28	14.51
A1 B3	10.37	11.43	369.57	393.87	18.52	19.52	13.31	14.62
A2 B1	12.34	13.78	437.14	468.06	19.84	20.84	14.74	15.92
A2 B2	12.77	14.27	452.18	484.47	19.93	20.92	14.81	16.14
A2 B3	12.99	14.58	461.41	494.58	20.14	21.23	15.12	16.31
A3 B1	11.39	12.61	405.02	431.39	18.93	20.11	13.82	15.14
A3 B2	11.43	12.70	406.26	434.14	19.12	20.24	13.93	15.23
A3 B3	11.61	12.93	412.48	440.92	19.24	20.32	14.11	15.31
A4 B1	11.86	13.22	421.17	450.43	19.43	20.34	14.24	15.52
A4 B2	12.07	13.47	428.42	458.39	19.51	20.53	14.43	15.64
A4 B3	12.10	13.51	429.25	459.28	19.72	20.61	14.52	15.73
A5 B1	10.94	12.11	389.99	416.52	18.73	19.71	13.37	14.84
A5 B2	10.98	12.17	390.86	417.35	18.74	19.83	13.54	14.93
A5 B3	11.19	12.42	398.48	425.58	18.78	19.92	13.71	15.12
L.S.D. (AXB)=	0.17	0.25	9.17	10.07	0.15	0.22	0.31	0.19

Table 6. Effect of calcium, magnesium fertigation and molybdenum foliar sprays on berry physical properties of Flame seedless during 2018 and 2019 seasons

	Average berry weight (g)		Average berry size (cm3)		Average berry length (cm)		Average berry diameter (cm)		Average berry firmness (g/cm^2)		Average berry adherence strength (g)		Average berry stem necrosis (%)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Ca + Mg (kg/Fed.)														
A1 (control)	3.23	3.30	2.80	2.89	1.75	1.81	1.82	1.88	535.2	559.6	607.0	616.5	11.26	10.13
A2 (30 + 20)	3.61	3.74	3.10	3.25	1.94	2.04	2.02	2.12	618.9	641.0	704.9	707.0	5.56	4.30
A3 (30 + 10)	3.39	3.58	2.93	3.15	1.83	1.97	1.90	2.05	585.3	612.5	650.5	658.6	9.39	7.50
A4 (20 + 20)	3.47	3.66	2.99	3.20	1.87	2.01	1.94	2.08	604.0	628.8	675.2	682.3	8.36	6.19
A5 (20 + 10)	3.28	3.50	2.83	3.07	1.77	1.92	1.84	2.00	564.2	593.6	630.3	639.6	10.69	8.76
L.S.D. (A)=	0.02	0.01	0.02	0.01	0.02	0.03	0.02	0.01	2.7	1.9	4.3	3.8	0.21	0.27
Mo (ppm)														
B1 (control)	3.36	3.53	2.90	3.09	1.82	1.94	1.89	2.01	572.8	598.1	644.2	651.3	9.34	7.81
B2 (20)	3.40	3.55	2.92	3.11	1.83	1.95	1.90	2.02	583.4	608.1	653.9	661.6	9.15	7.36
B3 (30)	3.43	3.59	2.96	3.14	1.85	1.97	1.92	2.04	588.4	615.0	662.7	669.5	8.67	6.94
L.S.D. (B)=	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	2.4	1.7	3.8	3.4	0.18	0.24
Interaction														
A1 B1	3.21	3.27	2.78	2.86	1.74	1.79	1.81	1.86	524.6	543.2	596.4	604.7	11.43	10.34
A1 B2	3.23	3.29	2.79	2.88	1.75	1.80	1.82	1.87	537.4	558.7	606.9	617.4	11.21	10.11
A1 B3	3.25	3.36	2.81	2.95	1.76	1.85	1.83	1.92	543.5	576.8	617.7	627.3	11.14	9.93
A2 B1	3.53	3.71	3.04	3.24	1.91	2.03	1.98	2.10	614.8	636.2	695.4	697.2	5.92	4.93
A2 B2	3.62	3.73	3.11	3.25	1.94	2.04	2.02	2.12	618.2	641.9	703.2	705.6	5.63	4.22
A2 B3	3.67	3.78	3.15	3.27	1.97	2.05	2.05	2.13	623.7	644.7	716.1	718.3	5.14	3.74
A3 B1	3.36	3.56	2.90	3.13	1.81	1.96	1.89	2.03	577.1	607.1	641.5	649.2	9.43	7.83
A3 B2	3.39	3.58	2.92	3.15	1.83	1.97	1.90	2.05	587.3	613.5	652.8	662.1	9.41	7.54
A3 B3	3.43	3.60	2.96	3.16	1.85	1.98	1.92	2.06	591.6	616.9	657.3	664.5	9.32	7.12
A4 B1	3.44	3.63	2.97	3.18	1.86	1.99	1.93	2.07	597.1	622.4	664.2	670.8	9.11	6.71
A4 B2	3.48	3.66	2.99	3.21	1.87	2.01	1.95	2.09	605.5	630.6	675.6	683.4	8.74	6.24
A4 B3	3.49	3.68	3.01	3.22	1.88	2.02	1.96	2.09	609.3	633.2	685.8	692.7	7.23	5.61
A5 B1	3.27	3.47	2.82	3.05	1.76	1.91	1.83	1.99	550.2	581.6	623.4	634.5	10.81	9.24
A5 B2	3.27	3.49	2.81	3.07	1.76	1.92	1.83	2.00	568.6	595.5	630.9	639.3	10.74	8.71
A5 B3	3.31	3.52	2.85	3.09	1.79	1.94	1.86	2.01	573.7	603.6	636.7	644.9	10.53	8.32
L.S.D. (AXB)=	0.03	0.02	0.03	0.02	0.03	0.05	0.03	0.02	5.3	3.7	8.5	7.5	0.41	0.53

at any time during the early stage of berry ripening and interrupt the normal flow of sugar and other translocated to the cluster. During many years of research, the occurrence of BSN in *V. vinifara* has been associated with nutritional imbalance (Bondada 2016). The positive effect of calcium on reducing berry stem necrosis disorder might be attributed to stabilizing cell wall degradation through the development of proteins, activation of some enzymes, carbohydrate transport and nitrogen metabolism which is reflected in preventing physiological disorders attributed to calcium deficiency (White and Broadley 2003). Calcium markedly decreased fruit cracking, increased berry adherence strength and improved calcium storage (Jun et al 2020). Furthermore, magnesium is an activator of several enzymes that catalyze carbohydrate metabolism which is reflected in decreasing considerably in berry stem necrosis-affected clusters (Bondada 2016). In addition, Mo is crucial for the development of berries and nitrogen assimilation which is reflected in reducing berry physiological disorders (Williams et al 2005).

3.5 Chemical properties of berries

Data presented in **Table 7** revealed that fertigation of calcium plus magnesium and foliar spraying of molybdenum significantly affected the overall chemical properties of berries i.e., TSS, acidity, TSS/acid ratio, total sugars and total anthocyanin as compared to control in both seasons.

As regards the influence of the fertigation of calcium and magnesium, it was found that the highest values for these determinations were obtained from the application of calcium plus magnesium at 30+20 kg/Fed significantly followed in descending order by 20+20 kg/Fed while the lowest values were for the control treatment.

Table 7. Effect of calcium, magnesium fertigation and molybdenum foliar sprays on berry chemical properties of Flame seedless during 2018 and 2019 seasons

	TSS (%)		Total acidity (%)		TSS/acid ratio		Total sugars (%)		Total anthocyanin (mg/g FW)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Ca + Mg (kg/Fed.)										
A1 (control)	16.4	16.6	0.66	0.64	24.9	25.9	13.5	14.0	35.8	38.6
A2 (30 + 20)	17.2	17.4	0.54	0.54	32.0	32.4	15.9	16.1	39.8	42.9
A3 (30 + 10)	16.8	17.1	0.60	0.59	27.9	28.9	14.1	14.5	37.8	40.8
A4 (20 + 20)	17.0	17.2	0.58	0.57	29.1	30.2	15.0	15.2	38.7	41.8
A5 (20 + 10)	16.6	16.9	0.63	0.62	26.4	27.2	13.8	14.3	36.9	39.8
L.S.D. (A)=	0.2	0.1	0.03	0.02	1.1	0.9	0.3	0.2	0.4	0.3
Mo (ppm)										
B1 (control)	16.7	17.0	0.61	0.60	27.4	28.4	14.3	14.6	37.5	40.4
B2 (20)	16.8	17.0	0.60	0.59	28.0	28.9	14.4	14.8	37.8	40.8
B3 (30)	16.9	17.1	0.59	0.58	28.9	29.5	14.7	15.0	38.2	41.2
L.S.D. (B)=	0.1	0.1	0.02	0.01	0.9	0.8	0.2	0.1	0.3	0.2
Interaction										
A1 B1	16.2	16.5	0.67	0.65	24.2	25.4	13.4	13.8	35.3	38.1
A1 B2	16.4	16.6	0.65	0.64	25.2	25.9	13.5	13.9	35.8	38.7
A1 B3	16.5	16.7	0.65	0.63	25.4	26.5	13.6	14.1	36.3	39.0
A2 B1	17.1	17.3	0.56	0.55	30.5	31.5	15.5	15.7	39.4	42.6
A2 B2	17.2	17.4	0.55	0.54	31.3	32.3	15.8	16.1	39.7	42.7
A2 B3	17.4	17.5	0.51	0.52	34.1	33.6	16.3	16.5	40.3	43.5
A3 B1	16.8	17.0	0.61	0.60	27.5	28.3	13.9	14.3	37.4	40.5
A3 B2	16.8	17.1	0.61	0.59	27.6	28.9	14.1	14.4	37.8	40.7
A3 B3	16.9	17.1	0.59	0.58	28.7	29.5	14.3	14.8	38.1	41.2
A4 B1	16.9	17.2	0.59	0.57	28.7	30.1	14.7	15.1	38.5	41.5
A4 B2	17.0	17.2	0.58	0.57	29.3	30.2	14.9	15.2	38.6	41.8
A4 B3	17.1	17.3	0.58	0.57	29.5	30.3	15.3	15.4	38.9	42.0
A5 B1	16.6	16.8	0.64	0.63	25.9	26.7	13.7	14.2	36.6	39.5
A5 B2	16.6	16.9	0.63	0.62	26.4	27.2	13.7	14.3	36.8	39.9
A5 B3	16.7	16.9	0.62	0.61	27.0	27.8	13.8	14.3	37.2	40.1
L.S.D. (AXB)=	0.3	0.2	0.05	0.03	2.1	1.7	0.5	0.3	0.7	0.5

The influence of foliar spraying of molybdenum indicated that the foliar spraying of molybdenum at a high dose (30ppm) significantly improved the overall chemical properties of berries followed by the low dose (20ppm),

A significant interaction was observed between the fertigation application of calcium plus magnesium and the foliar spraying of molybdenum. It is noticed that the fertigation of calcium plus magnesium at 30+20 kg/Fed and the foliar spraying of molybdenum at a high dose (30ppm) significantly recorded the highest values of TSS, TSS/acid ratio, total sugars and total anthocyanin and the least values of acidity followed by the combined application of calcium plus magnesium at 20+20 kg/Fed and the foliar spraying of molybdenum at high dose (30ppm).

The increase in the berry chemical properties may be a result of the importance of calcium and magnesium in cell division and carbohydrate metabolism (Ilyas et al 2014).

These findings line up with those from Morsi et al (2009) who mentioned that Mo increased TSS and total sugars (%) and decreased acidity percentage in fruit juice. Masi and Boselli (2011) reported that Mo treatment caused noticeable changes in most soluble solids in the early flowering stage. On the other hand, acidity was not affected by Mo treatment. El-Badawy (2019) and Abo El-Ezz et al (2022), reported that since potassium and magnesium rates increase TSS% levels and lower acidity values, there is a positive association between these two variables. These outcomes are attributable to the beneficial effects of calcium and potassium, where a highly significant interaction existed between sugar buildup and the Ca/K level. Given the significance of both components, fresh information may help determine the ideal grape ripeness concerning the sugar content of the berries.

4 Conclusion

From the foregoing results, it can be concluded that the fruit quality attributes of Flame seedless grapevines might be easily enhanced by the considered treatments. The combined application of calcium plus magnesium fertigation at 30+20kg/Fed and the foliar spraying of molybdenum at a high dose (30ppm) achieved the best results in terms of increasing leaf content of total chlorophylls which produces carbohydrates through photosynthesis and thus promotes vegetative growth which reflected in improving yield and fruit quality attributes.

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