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Controlling Berry Dryness Phenomenon by Using Some Mineral Fertilizers in "Flame Seedless cv." (*Vitis vinifera* L.)

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Abstract: Lately some symptoms of berry dryness (BD) began to appear on the clusters around veraison stage or later. The occurrence of these symptoms is associated to the berry death, and they may or may not drop off. As a result, supply of water and nutrients are limited, leading to grape berries with less sugar, remain sour and eventually dryness. Thus, the present investigation was carried out at Behaira governorate during two successive seasons (2021and 2022) with a preliminary season 2020 to control the berry dryness (BD) of "Flame Seedless cv." (*Vitis vinifera* L.) by using some mineral compound fertilizers in order to detect the cause of this phenomenon. Fifteen year-old vines, planted in a sandy soil, spaced 2×3 meters apart and irrigated by drip system, cane pruned and trellised by Gable system. The vines were pruned during the last week of December with bud load (96 buds/vine). The experiment included 6 foliar spray treatments; the control and five combined mineral treatments for calcium, magnesium, phosphorous and potassium. Obtained results revealed that treating the vines by a combination of Ca 26% + K 7% + Mg 10% + P 44% recorded the highest values for both vegetative and reproductive growth and reduced the berry dryness phenomenon.

Key words: Flame seedless cv., Grapevines, Mineral fertilizers, Berry dryness phenomenon.

INTRODUCTION

Flame Seedless (*Vitis vinifera* L.), is a vigorous, heavy-bearing table grape cultivar .It is a hybrid of Thompson Seedless, Cardinal, and several other *Vitis vinifera* cultivars. It produces large clusters of medium-large red grapes with a sweet flavor **(Brooks and Olmo, 1997).**

Berry dryness (BD) is a ripening physiological disorder affecting grape berry with visible symptoms appearing after veraison. Berry dryness leads to shrinking berries with a reduced weight and a lower content of sugars and anthocyanins. Stress causes the plant's xylem to shut down in the cluster during ripening. With a dead xylem, water cannot be transported to the rest of the cluster as a result, the bunch stems dry, and then the berries dry up. Dried berries in grapes (Vitis spp.), often appear in vineyards all over the world and it can occur due to late season dehydration, sunburn, or ripening disorders (BD) which is also known as sour dryness or sugar accumulation disorder **(Keller *et al.*, 2016).**

Thus most researches has concentrated on the berry breakdown in table grapes that it may be a form of berry dryness **(Tilbrook and Tyerman, 2008 and Singh, 2010).** Among these disorders, berry dryness, which affects many cultivars, is not particularly well understood. Typical syndrome causing the stopping of sugar accumulation and berry growth followed by wilting due to water loss, low pH and decreased color development in dark-skinned grapes due to impaired anthocyanin biosynthesis **(Griesser *et al*., 2020).**

In contrast, organic acid metabolism continues in affected berries **(Keller *et al.*, 2016)** whereas the onset of the disorder is thought to occur near the beginning of berry ripening, with changes in the berries composition first occurring around 2-3 weeks before drying symptoms appear.

No specific cause of berry dryness has been identified, despite many years of research. In some cases, diverse differences in susceptibility have been linked to xylem structure, namely a decrease in the xylem area distal to the branching points of the peduncle. Its occurrence is also associated with the concentration or ratios of various mineral nutrients, including Ca, Mg, K and N **(Morrison and Lodi, 1990).**

There are conflicting reports regarding the association of essential nutrients with dryness (berry dryness) and an increase in its incidence has been reported with the addition of a large amount of nitrogen. In addition to increasing the ratio of K to Mg and/or Ca in the affected tissues, and BD in Europe **(Boselli and Frogoni, 1986).**

Therefore, purpose of this study is first to determine whether the imbalance of mineral nutrition is related to the phenomenon of berry dryness in grapevines farms. Second, the aim is to determine the optimal rates in tissues in different forms with berry dryness occurrence and also to explore the possibility that P, K, Ca, and Mg are involved in the disorder.

MATERIALS AND METHODS

Plant material and study site

This study was conducted in two successive seasons (2021and 2022) with a preliminary season 2020 in a commercial vineyard of own-rooted (*Vitis vinifera* L.) cv. Flame seedless, located at "Markaz Badr", Behaira governorate (30.8481° N, 30.3436° E), North Egypt. The vines were planted in 2005 with 3 m between rows and 2 m within rows in a sandy soil, trellised by Gable system and cane-pruned during the last week of December with a vine load of 96 buds (12 canes x 8 buds) and irrigated through drip irrigation system. Seventy-two vines (6 treatments x 3 replicates x 4 vines / replicate) uniform in vigor and receiving common horticultural practices were chosen for this study.

All treatments were applied thrice as a foliar application at the concentration of 3 cm^3 / L starting from before bloom, at berry set (at berry diameter 8 mm) and two weeks later. To maintain the sufficient nutrient status of the soil, N, P, K, Ca and Mg soil fertilizers were applied for all treatments, based on previous recommendations as follow:

(T_0) Control (soil addition only)

(T_1) Ca 26% + K 51%

(T_2) Ca 26% + Mg 10%

(T_3) Ca 4%+ P 31%

(T_4) Ca 5% + K 5% + Mg 20%

(T_5) Ca 26% + K 7% + Mg 10% + P 44%

A randomized complete block design was used in this experiment.

Data taken on the vegetative and reproductive growth

1. Concentration of Nutrients in pedicels affected and unaffected by berry dryness

The percentage of N, Ca, K, Mg and P: they were collected and calculated in the pedicel of the chosen vines at veraison in the preliminary season of 2020 before applying the treatments to determine the correlation between them. The samples were analyzed for the concentration of nutrients N, P, K, Ca and Mg by adopting standard analytical methods **(AOAC, 2000).** Total N was estimated by Kjedahl method, P % was measured referring to the method of **Schouwenburg and Walinga (1967)** and K % was determined using a flame photometer **(Jackson, 1973).** Ca % and Mg % were determined using atomic absorption spectrophotometer "Perkin Elmer 3300" according to **Cottenie *et al.* (1982).**

2. Yield

a. Yield/vine (Kg)

b. Average cluster weight (g).

c. Average berry weight (g).

d. Average berry size (cm^3).

3- Morphological measurements

a. Percentage of dried berries/cluster: it was calculated by dividing the number of dried berries/cluster by the total number of berries/cluster x 100.

b. Berry firmness (g/cm^2) by using PHSH-PULL (Dynamometer Model DT101).

c. Leaf area: Samples of leaves from each treatment were randomly collected from the 5th, 6th and 7th basal leaves of three shoots from different sides of the vine for leaf area determination at harvest using leaf area meter, Model (CI 203, U.S.A.).

4. Chemical characteristics of berries and leaves

Representative random samples of 15 clusters /treatment (5 clusters from each replicate) were collected when clusters reached their full color and total soluble solids reached about 16-18%, according to **Badr and Ramming (1994).**

The following determinations were carried out:

a. Refractometric total soluble solids (TSS %) and titratable acidity as gram of tartaric acid per 100 ml of juice **(AOAC, 2000)** and TSS / acid ratio.

b. Total anthocyanin in berry skin (mg/100g) using spectrocolourimeter at 250 µm according to **Yilidz and Dikmen (1990).**

c. Leaf pigments content (chlorophyll) were measured in the mature leaves of the sixth and seventh positions from the apex at full boom by using the nondestructive Minolta chlorophyll meter model SPAD 502 (SPAD) is an acronym for soil plant analysis development **(Wood *et al*., 1992).**

d. The percentage of N, P, K, Ca and Mg in leaf petioles was estimated in the leaf opposite to the cluster, Total N was estimated by Kjedahl method, P % was measured referring to the method of **Schouwenburg and Walinga (1967)** and K % was determined using a flame photometer **(Jackson, 1973).** Ca % and Mg % were determined using atomic absorption spectrophotometer "Perkin Elmer 3300" according to **Cottenie *et al.* (1982).**

Statistical analysis

Means representing the effect of the tested treatments were compared by the New L.S.D. method at 0.05 according to **Snedecor and Cochran (1980).**

RESULTS AND DISCUSSION

Data taken on the vegetative and reproductive growth

Concentration of Nutrients in pedicel affected and unaffected by berry dryness

The percentage of N, Ca, K, Mg and P

The correlation between N, Ca, K, Mg and P and the dryness phenomenon was studied and displayed in Table 1. A significant increase in potassium and nitrogen and a decrease in calcium and magnesium content are observed in the affected pedicels. Whereas there is no significant difference in phosphorus content between the affected and unaffected pedicels. Similarly, in a trial done by **Cicala and Catara, (1994)** he reported that there was a significant negative correlation between potassium and berry pedicels content. In addition, a significant correlation was observed between potassium concentration and BD where a high K/Mg ratio was observed in affected pedicels. A similar trend of observations between Ca and Mg was recorded by **Mungare *et al.* (2013)** who reported that the balance between Ca / Mg effectively reduces the severity of berry dryness in grapes.

Moreover, a composite pedicel tissue analysis showed that BD affected clusters had significantly higher total N levels in the pedicels as compared with the unaffected clusters and was closely related to the BD incidence. Same findings are also reported by **Capps and Wolf (2000)** that nitrogen fertilizers have occasionally increased the occurrence of BD, where the symptoms are observed in heavily NO3 applied vines but only when there was Ca deficient and vines fed with NH4 as the sole N source. A possible reason for these results is that glutamine synthetase, which is responsible for reassimilation of NH4 into glutamine under natural condition is activated by relatively high concentration of divalent cations as Mg, where Mg is almost five times more efficient than Ca.

Table 1. Percentages of Nutrients (N, P, K, Ca and Mg) in the pedicels affected and unaffected by berry dryness phenomenon of Flame Seedless grapevines for the preliminary season 2020

Treatments	N %	P %	K %	Ca %	Mg %	K/ Ca	K/ Mg
Affected	1.32	0.26	3.02	2.10	0.37	1.43	8.16
Unaffected	1.18	0.24	2.81	2.30	0.56	1.22	5.01
New L.S.D at 5%	0.04	0.29	0.18	0.16	0.12	0.16	2.05

2. Yield and Morphological measurements

Yield/vine (Kg), average cluster weight (g), berry size (cm^3) and berry weight (g)

Data in Table 2 shows the average yield per vine as affected by all treatments. Generally, increases in yield tend to result from increases in cluster weight. It is obvious that in the case of spraying the vines with a combination of the four elements Ca 26% + K 7% + Mg 10% + P 44% resulted in highest yield followed by Ca 26% + Mg 10%. This detection is being linearly related to those of **Capps and Wolf (2000)** who found that cluster weight was lower on control vines but increased when applying Mg + Ca as there was a significant negative correlation between leaf potassium and yield **(Cicala and Catara,**

1994). Typically, **El-Badawy (2019)** mentioned that when data derived from vineyard fertilizer trials, indicates that some occurrences of BD result from nutrient imbalances, in particular a high ratio of potassium (K) to magnesium (Mg) and/or calcium (Ca), and when these nutrients were applied with the adequate amount, this tend to produce large berries, which might be related to the application of Mg and occasionally Ca fertilizers which often reduced the incidence of BD. In addition, cluster weight, berry weight and berry size, were the greatest under this treatment. progressively decreased by eliminated the other minerals.

In contrast, BD was reduced by applications of Ca and Mg alone, but increased by increasing the amount of nitrogen (N) in berry pedicels as shown in Table 1. Additionally, phosphorus application has a great impact on yield as stated by **Bedrech and Farroh (2020)** that P fertilizer can potentially enhance agronomical yield.

Table 2. Effect of using some mineral fertilizers in controlling berry dryness phenomenon on yield and its attributes of Flame Seedless grapevines for both growing seasons 2021-2022

Treatments	Average Yield/vine (Kg)		Average cluster weight (g)		Average berry weight (g)		Average berry size (cm^3)	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
T_0	15.9	16.7	495.6	501.8	3.50	3.62	3.01	3.33
T_1	18.9	20.7	630.8	655.8	3.85	4.06	3.55	3.73
T_2	20.1	22.9	699.5	745.0	4.50	4.59	4.08	4.17
T_3	17.6	19.9	585.3	595.8	3.80	3.85	3.50	3.60
T_4	19.4	21.8	645.4	741.0	4.40	4.36	3.95	4.00
T_5	21.6	23.4	748.5	780.0	4.67	4.81	4.20	4.53
New LSD at 0.05	**0.7**	**0.3**	**16.3**	**14.7**	**0.12**	**0.11**	**0.09**	**0.10**

Percentage of dried berries/cluster

Both total number of berries and number of dried berries per cluster were counted at harvest and the severity of dryness % was calculated as shown in Figure (1). Results indicated that there were significant differences among treatments and the control in both seasons. However, applying Ca 26% + K 7% + Mg 10% + P 44% gave the lowest percentage of dried berries which may ascribed to the balance of these nutrients. Similar finding was mentioned by **El-Badawy (2019)** who stated that some occurrences of BD result from nutrient imbalances, in particular a high ratio of (K^+) to magnesium (Mg^{++}) and/or calcium (Ca^{++}). Ca deficiency induces physiological disorders in berries, such as dehydration (dryness), and it delays ripening (**Venios *et al.*, 2020)**.

In a similar fashion, it was stated that the foliar application of solution containing Mg and / or Ca are effective in the control of BD **(Mungare *et al.*, 2013)**. A foliar spray with magnesium helps correct the imbalance of too much Potassium-uptake leading to preventing berry dryness **(Zlámalová *et al.*, 2015).**

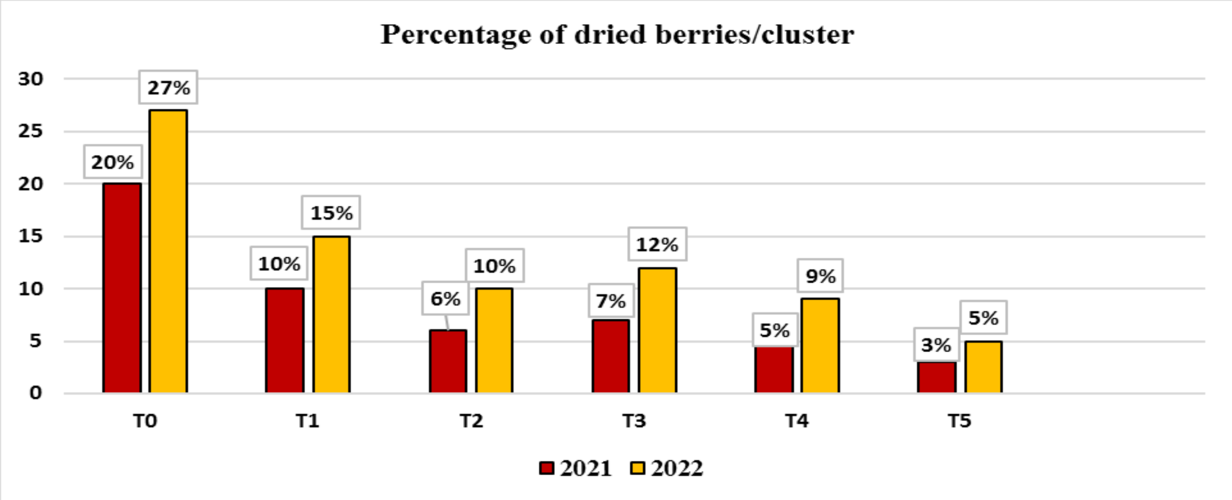

Figure 1. Percentage of dried berries/cluster as affected by the applied treatments of Nutrients (Ca, K, Mg and P) on berry dryness phenomenon of Flame Seedless grapevines for both seasons 2021 and 2022.

Berry firmness (g/cm^2)

In both years of the study, it was observed an improving in berry firmness, due to spraying Ca 26% + K 7% + Mg 10% + P 44% over all other treatments and the control (Figure 2). Generally, treating the vine with the higher concentrations of Ca and Mg than K are more effective as mentioned by **El-Badawy (2019)**. This result may be ascribed to calcium effect on berry firmness as stated by **Bedrech and Farroh (2020)** who mentioned that berry firmness was significantly influenced positively by Ca sprays. However, it is obvious that all Ca treatments especially in significantly increased the firmness of berries over the control which recorded the lowest firmness.

Additionally, Magnesium treatments came next in this respect. Anyhow, control berries were more soft and had the least values of firmness. Similar results were obtained by **Kilany *et al.* (2000)** who confirmed the beneficial effect of the foliar spray using Ca and Mg in increasing the berry firmness. Likewise, **Mungare *et al.* (2013),** reported that, foliar spray with nutrient solution including Mg is effective in controlling Berry dryness.

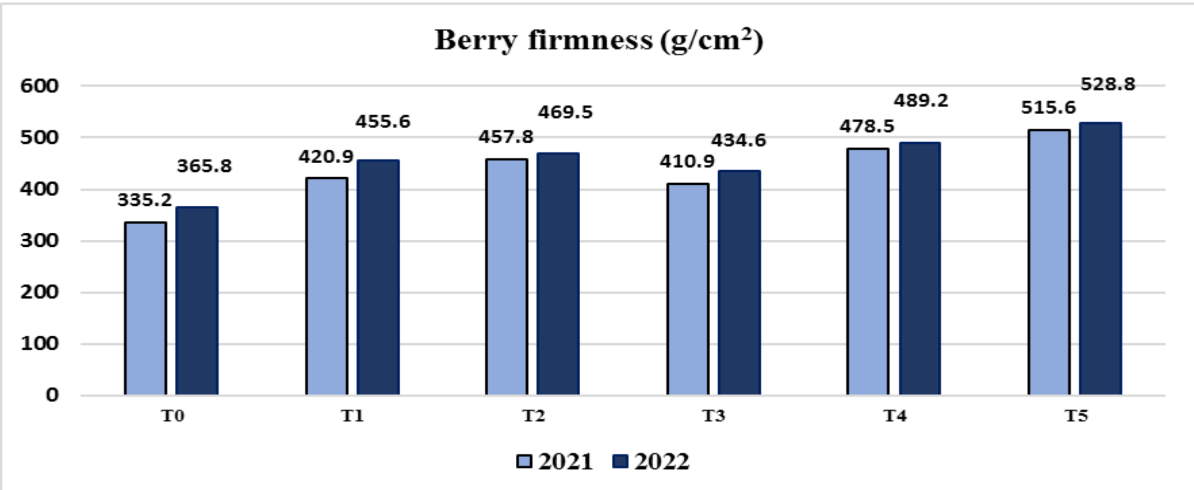

Figure 2. Berry firmness (g/cm^2) as affected by the applied treatments of Nutrients (Ca, K, Mg and P) on berry dryness phenomenon of Flame Seedless grapevines for both seasons 2021 and 2022.

Leaf area (cm²)

It is obvious in Figure 3 that there are significant differences among treatments in leaf area. The stimulation of growth was proportional to the increase of mineral combination where the highest values were recorded for vines that treated with the combined treatment of Ca 26% + K 7% + Mg 10% + P 44% followed by Ca 5% + K 5% + Mg 20% treatment in both seasons. Similarly, in another trial **El- Kenawy (2017)** found that the application of calcium was effective in increasing leaf surface area, in both seasons. Moreover, it was informed that calcium plays an important role in cell division, as well asin the growth and development of fruit trees **(Mahmoud *et al.*, 2020)** which led in turn to increasing leaf area

Concerning the effect of magnesium and potassium on leaf area, it was mentioned by **El- Badawy (2019)** that the highest values were obtained especially from the vines which receivedmagnesium at the higher rate of (300 ppm). Likewise, potassium has a great impact on leaf area where it could be interpreted on the basis of the physiological role of potassium where it considers as an activator of enzymes essential for photosynthesis, respiration process and enzymes that produce starch and proteins as well (**Cui and Tcherkez, 2021)**

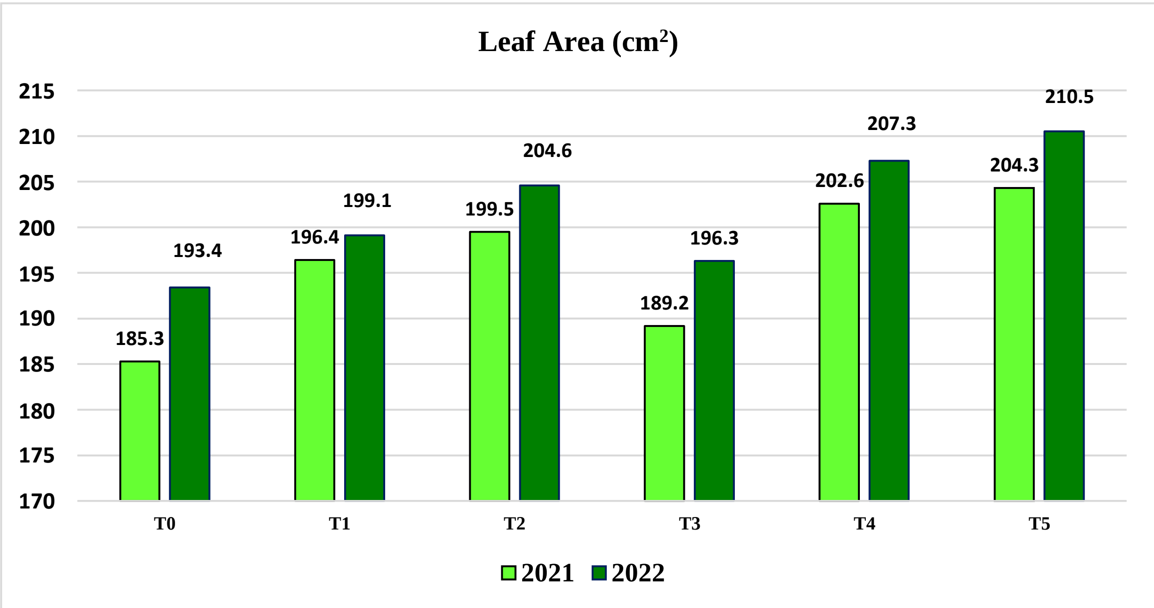

Figure 3. Leaf area (cm²) as affected by the applied treatments of Nutrients (Ca, K, Mg and P) on berry dryness phenomenon of Flame Seedless grapevines for both seasons 2021 and 2022.

3- Chemical characteristics of berries and leaves

Total soluble solids (TSS %), Titratable acidity and TSS / acid ratio

Data pertaining to the Chemical characteristics of berries and leaves are presented in Table (3). Results reveal that TSS, Titratable acidity and TSS / acid ratio were greatly influenced by all tested treatments. An increase in soluble solids and a decrease in acidity percentage were observed from Applying the combined treatment of Ca 26% + K 7% + Mg 10% + P 44% followed by the application of Ca 5% + K 5% + Mg 20%. These results are due to the positive effect of calcium and potassium where the interaction between sugar accumulation and the Ca/K content was highly significant. Given the importance of both elements, new data may contribute to establishing the optimum grape ripeness in relation to the sugar concentration in the berries **(Nistor *et al.*, 2022).**

In this regard, it worthy to note that there was a positive correlation between the values of TSS %

and the rates of potassium and magnesium, as they increase the values of TSS % and reduce the value of acidity in both seasons (**El-Badawy, 2019)**.

Table 3. Effect of using some mineral fertilizers in controlling berry dryness phenomenon on the chemical characteristics of berries and leaves of Flame Seedless grapevines for both growing seasons 2021-2022

Treatments	TSS %		Acidity %		TSS / acid ratio		Anthocyanin (mg/100g FW)		Total chlorophyll (SPAD)	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
T_0	14.5	15.0	0.69	0.67	21.0	22.3	25.4	29.5	34.5	37.4
T_1	17.8	17.9	0.60	0.58	29.6	30.8	37.9	39.4	40.7	42.8
T_2	16.2	16.5	0.64	0.63	25.3	26.1	35.6	37.4	36.4	38.1
T_3	15.2	16.4	0.67	0.65	22.7	25.2	31. 0	35.9	39.5	41.5
T_4	18.7	19.0	0.55	0.52	34.0	36.5	39.5	41.1	38.9	39.0
T_5	19.1	19.5	0.52	0.49	36.7	39.8	43.8	45.7	42.9	43.1
New LSD at 0.05	**0.2**	**0.1**	**0.01**	**0.01**	**2.0**	**1.0**	**1.4**	**1.2**	**0.3**	**0.2**

Anthocyanin content in berry skin (mg/100g FW)

Generally, data of anthocyanin content in berry skin displayed in Table (3) shows a high variability between treatments as the percentage of used minerals is different. As clear significantly the best results were obtained from vines treated by the combination of Ca 26% + K 7% + Mg 10% + P 44% followed by Ca 5% + K 5% + Mg 20% treatment in both seasons. Therefore, the color of berries might be more influenced by the fertilizer treatments more than the ripening process. Statistical analysis showed significant gradual increases in the concentration of anthocyanin in the treatments with lower berry dryness phenomenon. In these plots the balance between Ca, K, Mg and P level increased the concentration of anthocyanins. These results were assigned to the fact that berry dryness leads to shrinking berries with a reduced weight and a lower content of sugars and anthocyanins **(Keller *et al.*, 2016).**

Likewise, as stated by **Amiri *et al.* (2009)** quality components including berry color, and appearance were significantly improved by Ca sprays. In addition, this foliar application treatment may be attributed to increase the uptake of phosphorus that affect in direct or indirect ways in increasing a variety of chemicals such as flavonoids, steroids, polyphenolic compounds and carbohydrates **(Amira *et al.*, 2016).**

Total chlorophyll (SPAD)

Leaf chlorophyll content of "Flame Seedless cv." grapevine as affected by foliar spray with nutrient solution (Ca, K, Mg and P) in different combinations are shown in Table (3). It is noticeable that Ca 26% + K 7% + Mg 10% + P 44% treatment recorded the highest content of chlorophyll. It can be deduced that Magnesium is an essential element for chlorophyll molecule structure that regulates photosynthesis process besides its several functions in the plant. It is the central component of the chlorophyll molecule - the green pigment responsible for photosynthesis in green plants - which was the reason for higher chlorophyll content under adequate Mg supply, which could be an enhanced production of chlorophyll. The application of K+Mg gave the highest leaf chlorophyll value followed by Mg treatment compared to K **(El-Sabrout and Kassem, 2002).** It is well documented that Mg deficiency leaves is associated with chlorophyll destruction due to photo-oxidation and accumulation of soluble sugar and starch in source leaves **(Cabanne and Donèche, 2003).**

Concerning the effect of Ca and P similar findings were mentioned by **Bedrech and Farroh (2020)** who stated that phosphorus as foliar fertilizer enhances total chlorophyll. With respect to Ca effect, it was noticed that it had remarkable effects on delaying the degradation of chlorophyll and maintaining relatively high level of photosynthesis efficiency.

The percentage of N, P, K, Ca and Mg in leaf petioles

Table 4 depicts statistical criteria for the nutritional status in leaf petioles (mineral content). It is clear that the maximum values of N, P, K, Ca, and Mg were 1.85, 0.31, 3.04, (for the control), 2.45 and 0.56 (for T5) respectively whereas the minimum values were 1.35, 0.27, 2.81 (for T5), 2.15 and 0.36 (for the control) respectively. The better results were obtained from T5 which created significantly a balance between these minerals. Furthermore, it is clear that the foliar application of these nutrients balances the vine nutritional status by increasing the amount of Ca and Mg than their values before spray as shown in Table 1, which led to decreasing the berry dryness phenomenon. Likewise, **Abdel-Sattar *et al.* (2022)** found that excessive N and K fertilization leads to deficiency of calcium (Ca) and magnesium (Mg) resulting in as shown in the control which are the main cause of berry dryness **(Boselli and Frogoni, 1986).**

Table 4. Effect of using some mineral fertilizers in controlling berry dryness phenomenon on the percentage of N, P, K, Ca and Mg in leaf petioles of Flame Seedless grapevines for both growing seasons 2021-2022

Treatments	N %		P %		K %		Ca %		Mg %	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
T_0	1.85	1.76	0.31	0.29	3.04	3.00	2.15	2.09	0.36	0.33
T_1	1.57	1.50	0.28	0.23	2.90	2.85	2.35	2.31	0.49	0.47
T_2	1.65	1.62	0.29	0.25	2.94	2.88	2.29	2.23	0.44	0.43
T_3	1.76	1.73	0.30	0.27	3.00	2.96	2.22	2.16	0.40	0.39
T_4	1.49	1.45	0.27	0.23	2.86	2.80	2.41	2.39	0.54	0.51
T_5	1.35	1.33	0.27	0.22	2.81	2.79	2.45	2.43	0.57	0.54
New LSD at 0.05	**0.2**	**0.1**	**NS.**	**NS.**	**0.02**	**0.01**	**0.02**	**0.03**	**0.01**	**0.01**

CONCLUSION

In conclusion, we can deduce that treating the vines with the foliar spray of the combination of Ca, K, Mg, and P, along with the soil application of NPK, affects positively the nutrients imbalance leading to diminishing the Berry Dryness Phenomenon as well as improving the efficiency of nutrients absorption. Results showed that in the case of coverage, best results were obtained when the fertilizers were sprayed at the rates of Ca 26% + K 7% + Mg 10% + P 44% reduce Berry Dryness phenomenon beside increasing all growth parameters.

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