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Research Article

Improving Yield and Bunch Quality of 'Crimson Seedless' Grapevines Through the Use of Some Elicitors and Shoot-Topping Under Semi-Arid Conditions

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Abstract:

The current study was carried out on "Crimson Seedless" grapevines in the experimental farm at El-Baramon station, Horticulture Research Institute, Mansoura, Dakahlia Governorate, Egypt, for two consecutive seasons (2023 and 2024). The application of shoot-topping treatment (vegetative apex removal before the berry color stage) with foliar of spraying proline at 500 mg/L, melatonin at 500 µL/L, and methyl jasmonate at 500 µL/L. The whole grapevines were sprayed until dripping at three different times; after berry set, at the beginning of berry coloring (veraison stage) and seven days after veraison stage. While, control was sprayed with distilled water and without soot-topping. The combination with proline at 500 mg/L + shoot topping was effective in improving wood ripening and pruning weight as well as enhancing yield per vine, bunch weight, length and width, berry weight, and berry firmness. While a combination of 500 µL/L methyl jasmonate + shoot topping was the best treatment for increasing soluble solids content, anthocyanin accumulation, and total sugars and reducing titratable acidity.

1. Introduction

Grape is the third leading fruit crop worldwide, with a harvested area of 7.194.665 million hectares producing 67.2 million tons (FAO, 2023). In Egypt, it ranks fourth after citrus, mango and olive fruit crops concerning the production area and consumption rates. In the last decade, Grape acreage exhibited a remarkable increase in Egypt, reaching a harvested area of 85024 hectares, producing 1.582 million (FAO, 2023).

Red grape varieties hold a strong market position in Egypt due to high consumer acceptance (Mohamed and Sayed, 2021). Crimson Seedless grape is a popular late-season red seedless cultivar, ripening in first -September with crisp, sweet berries and high export value (Ramming et al., 1995; El-Boray et al., 2019). However, its production faces key challenges, including poor and uneven berry coloration, limiting its market and export potential (Cameron, 2005). This issue is linked to suboptimal conditions for anthocyanin biosynthesis, influenced by factors like genetics, phytohormones, and climate change (Ferrara et al., 2014).

Proline is a nonpolar amino acid with a unique cyclic structure, providing conformational stability to proteins (MacArthur and Thornton, 1991). It plays critical roles in osmotic adjustment, ROS scavenging, and enhancing activities of antioxidant enzyme (Kiyosue et al., 1996; Ozden et al., 2008). In grapevines, exogenous proline alleviates oxidative stress, enhances proline metabolism across organelles, and improves fruit yield and quality, including increased cluster weight, sugar content, anthocyanins, and total soluble solids (Viehweger, 2014).

Methyl jasmonate (MeJA) is a plant hormone involved in stress responses, fruit ripening, and color development (Wang et al 2021). MeJA improves grape quality by enhancing TSS and anthocyanin biosynthesis (García-Pastor et al., 2019), and it upregulates genes related to pigment and sugar metabolism in fruits like peaches and strawberries. It also boosts defense mechanisms against biotic and abiotic stresses (Han et al., 2019).

Melatonin (MT) is a natural antioxidant hormone that protects plants from various stresses (drought, salinity, heavy metals) (Liangjie et al., 2022) and enhances fruit ripening and quality (EL-Bauome et al., 2022). Exogenous melatonin increases antioxidant capacity, polyphenol, flavonoid, and anthocyanin levels in crops like grapes, tomatoes, and litchi. Although promising, melatonin's role in grape development needs further study (Xu et al., 2017; Ze et al., 2021). Shoot topping (vegetative apex removal) is a summer pruning practice that reduces apical dominance, promoting lateral shoot growth, carbohydrate redistribution, and improved ventilation and light exposure (Abd El-Wahab et al., 2009). This technique influences fruit quality, yield, and bud fertility by managing vegetative growth and carbohydrate balance in grapevines (Reynolds et al., 2005; Mota et al., 2010). The purpose of this research is to examine the influence of shoot-topping treatment with spraying some elicitors (foliar spray of Proline, melatonin, and methyl jasmonate) to enhance the physio-biochemical, morphological, and color development of 'Crimson Seedless' grapevines.

2. Materials and methods

2.1. Plant Material, Vineyard Site and treatments

This investigation was carried out during two successive seasons (2023 and 2024) in the vineyard of EL-Baramon experimental farm Horticulture Research Institute, Agricultural Research Center, Al-Baramon, Mansoura, Dakahlia, (31°11′98″ N, 31°45′13″ E, 15 m elevation above sea level) Egypt on 8-years-old 'Crimson Seedless' grafted on freedom rootstocks in a clay soil

1-Control (sprayed with distilled water).
2- Foliar spray proline at 500 mg/L
3- Foliar spray melatonin at 500 µL/L
4- Foliar spray methyl jasmonate (MeJ) at 500 µL/L
5- Shoot topping (vegetative apex removal before berry color stage).
6- Foliar spray proline at 500 mg/L + shoot topping
7- Foliar spray at melatonin at 500 µL/L + shoot topping
8- Foliar spray MeJ at 500 µL/L + shoot topping.

Treatments were arranged in a randomized complete block design (RCBD) system with three replicates each, and three vines represented each replicate. The same nine vines were subjected to the same treatment in both seasons. All chemicals used in this research were imported from Sigma Aldrich (St. Louis, MO, USA). The whole grapevines were sprayed until dripping at three different times; after berry set, beginning of berry coloring (veraison stage) and seven days after veraison stage, while the application of shoot-topping treatment (vegetative apex removal) was done before the berry color stage. The crop load for each treatment was set at 25 clusters per vine.

2.2. The recorded measurements

2.2.1. Yield

At harvested time when SSC of berries juice reached 16–17° Brix. Soluble solids content was determined using a hand-held refractometer 0-32%, Model N-1E (Atago Co., Ltd., Tokyo, Japan). 25 bunches of each vine in a replicate were weighted using a regular field digital scale [200 kg capacity] (VEVOR Equipment and Tools, Rancho Cucamonga, CA, USA), and then average yield/vine per each treatment was calculated (kg/vine).

2.2.2. Physical properties of bunch and berries

At harvest, ten clusters per vine were randomly selected, and individually weighted using a bench-top digital scale Model PC-500 (Doran scales, Batavia, IL, USA), and average bunch weight (g) was calculated and recorded. Bunch length and width (cm) was also measured using a regular 40 cm stainless steel ruler (Apuxon, Shenzhen, Guangdong, China) from the uppermost berry to the most bottom berry also, average of 50 berry weight (g) berry length (cm), diameter (cm), and berry firmness were measured.

2.2.3. Chemical properties of berries

A. Soluble solids content (SSC)

It was determined in berry juice extract and recorded as °Brix.

B. Titratable acidity (TA)

It was determined as a percentage of tartaric acid in 10 ml juice using NaOH (0.1 N), and phenolphthalein as indicator AOAC (2005).

C. SSC/TA ratio was calculated

D. Total sugars (%)

It was determined by the method described by Sadasivam and Manickam (1996), the absorbance was measured at 490 nm using the spectrophotometer and the concentration of total sugars was calculated as g glucose per 100 g fw, and expressed as a percentage.

Total anthocyanin of berries skin (mg/100g^{-1} fresh weight) was calculated according to Husia et al. (1965).

2.3. Statistical analysis

Data were first examined utilizing the Shapiro-Wilk and Levene testing for numerical normality and homogeneity of variance, respectively. Before doing the analysis of variance (ANOVA), the percentage data were first converted to the values of the Arcsine square root. The outcomes were then shown as back-transformed means. The Co-stat software packaging, version 6.311 (Co-Hort software, Monterey, CA, USA), was used for carrying out the ANOVA. Tukey's honestly significant difference (HSD) test was used to conduct mean comparisons at probability (p) < 0.05 (Snedecor and Cochran, 1990).

3. Results and Discussion

3.1. Yield and physical properties of bunches

Data from Table 1 revealed that shoot-topping treatment with spray of Methyl jasmonate (MeJA) proline, and melatonin on Crimson seedless grapes increased yield and physical properties of bunches. This appears for spray proline at 500 ppm and shoot topping, which had the highest level in bunch weight, yield per vine and per feddan, followed by shoot topping and spraying with melatonin at 500 µL/L, the least being shoot topping and MeJ at 500 µL/L, which was done in the two seasons of study. In this context, when treated with proline, melatonin, and jasmonic acid, each individually, without shoot topping, proline at 500 ppm showed results nearly identical to melatonin at 500 µL/L, with significant differences between proline, Methyl jasmonate

(MeJA) at 500 µL/L, and the control. Increasing cluster weight owing to an increase on total yield for the vine becomes clear on treated vines by proline at 500 ppm and shoot topping that releases an increased yield per feddan. These results agree with Shehata (2025), indicated that using proline on grapevines due to upgrade yield components, overall raises a highest number of bunches per vine and bunch weight.

Table 1. Effect of some elicitors and shoot topping applications on bunch properties and yield/vine of 'Crimson Seedless' grapevine.

Treatments		Bunch weight (g)		Bunch length (cm)		Bunch width (cm)		Yield/vine (Kg)	
		2023	2024	2023	2024	2023	2024	2023	2024
T1	Control (distilled water)	481.30 g	505.00 g	19.33 d	20.33 c	10.95 f	11.86 e	12.03 g	12.62 g
T2	Proline at 500 mg/L	516.60 d	541.60 d	21.00 bc	22.66 b	12.48 d	13.56 c	12.91 d	13.54 d
T3	Melatonin at 500 µL/L	513.00 de	538.00 de	21.33 bc	22.33 b	12.24 de	13.26 cd	12.82 de	13.45 de
T4	Methyl jasmonate at 500 µL/L	505.00 ef	530.00 ef	21.33 bc	22.33 b	12.12 de	13.10 cd	12.62 ef	13.25 ef
T5	Shoot topping (vegetative apex removal)	495.60 f	520.00 f	20.00 cd	21.66 bc	11.88 e	12.92 d	12.39 f	13.00 f
T6	Proline at 500 mg/L + shoot topping	571.00 a	599.00 a	24.33 a	26.00 a	14.52 a	15.79 a	14.27 a	14.97 a
T7	Melatonin at 500 µL/L + shoot topping	547.60 b	574.30 b	22.00 b	23.00 b	14.04 b	15.29 a	13.69 b	14.35 b
T8	Methyl jasmonate at 500 µL/L + shoot topping	527.30 c	553.00 c	22.00 b	23.33 b	13.38 c	14.56 b	13.18 c	13.82 c

Means in each column followed by the same letter (s) are not significantly different at 5 % level according to Tukey's HSD Test.

Measuring bunch length and bunch width as shown in Table 1 found there were no significant differences between proline at 500 ppm, melatonin at 500 µL/L, and Methyl jasmonate (MeJA) at 500 µL/L, when each was sprayed individually. While comparing treated vines by the same treatments with shoot topping found a great difference between those treated with shoot topping with the individual treatments or shoot topping alone and the control. Vines sprayed proline at 500 ppm and shoot topping had a big value in bunch length and bunch width compared to vines that were sprayed with melatonin 500 µL/L or Methyl jasmonate (MeJA) at 500 µL/L and shoot topping or sprayed with each treatment alone without topping. Proline does as the molecular chaperons it is can protect the protein softly and improvement the activities of various enzymes. Many studies have mentioned proline level increased at of the ripening process Pandy et al. (1974). El-Kenawy. (2022) showed that foliar application with proline at 200 ppm recorded the highest yield and physical properties of clusters of Red Roumy grapevines. The beneficial effects of amino acids on yield and physical properties of clusters are in harmony with those obtained by Faissal et al. (2015) and AbdElkader et al. (2020). Also, Abd El-Wadoud (2015) reported that, all summer pruning treatments as lick pinching and shoot topping resulted in significantly increase in bunch length and width of "Melissa" grapevines. These data are agreed to the mentioned by (Morris et al. 2004; Ghada, 2015 and El-Boray et al. 2018).

3.2. Physical properties of berries

Data from Table 2 revealed that shoot-topping treatment with spray of Methyl jasmonate (MeJA), proline, and melatonin on Crimson seedless grapes increased physical properties of berries. This appears for spray proline at 500 ppm and shoots topping, which had the highest level in berry weight (232.66 and 238.66 g for 50 berries) in two seasons. Berry length and width improved when vines treated beside proline at 500 ppm with shoot topping or sprayed by melatonin 500 µL/L with shoot topping followed by spraying with Methyl jasmonate (MeJA) at 500 µL/L with shoot topping. The same treatments without shoot topping found that sprayed melatonin 500 µL/L alone had big value in berry length when compared with sprayed proline 500 ppm or sprayed Methyl jasmonate (MeJA) at 500 µL/L. These results were rationalized because tipping due to the apical control is freed as a result; it boosts lateral shoot grow at the nodes nearer to the excised tip owing to significant number of clusters/vines, number of berries/cluster, berry length, diameter and yield. Proline results in stable and effective photosynthetic efficacy by preserving the structural integrity of chloroplasts and prevention the breakdown of the photosystem complex Abdul-Qader (2006).

When measuring berry firmness for Crimson seedless vines treated with some elicitors in different growth stages, as on Table 2, it was found that berries treated with some elicitors with shoot topping had the highest berry firmness when compared with vines treated by distribution for each treatment or the control. The control had the lowest berry firmness, followed by vines that had shoot topping without any elicitors sprayed. Treated vines by proline at 500 ppm with shoot topping gave best berry firmness with significant differences with other treatments in descending with melatonin and MeJ. El-Kenawy. (2022) showed that foliar application with proline at 200 ppm recorded the highest physical properties of berries of Red Roumy grapevines.

Table 2. Effect of some elicitors and shoot topping applications on berry physical properties of 'Crimson Seedless' grapevine.

Treatments		Weight of 50 berry (g)		Berry length (mm)		Berry width (mm)		Berry firmness (N)	
		2023	2024	2023	2024	2023	2024	2023	2024
T1	Control (distilled water)	188.66 f	194.11 f	17.66 d	19.33 c	16.00 d	16.66 c	5.17 g	5.27 g
T2	Proline at 500 mg/L	212.66 c	218.25 c	19.66 bc	21.33 bc	17.33 abc	18.33 ab	6.71 cd	6.81 cd
T3	Melatonin at 500 µL/L	209.32 c	214.22 c	20.00 bc	22.00 b	16.66 cd	17.33 bc	6.59 de	6.72 de
T4	Methyl jasmonate at 500 µL/L	201.32 d	206.02 d	18.66 bcd	20.33 bc	17.30 abc	17.6 abc	6.45 e	6.57 e
T5	Shoot topping (vegetative apex removal)	195.32 e	200.12 e	18.33 cd	20.33 bc	16.33 cd	16.66 c	5.81 f	5.92 f
T6	Proline at 500 mg/L + shoot topping	232.66 a	238.10 a	22.33 a	24.33 a	18.46 a	19.00 a	7.28 a	7.42 a
T7	Melatonin at 500 µL/L + shoot topping	221.32 b	226.04 b	20.33 b	22.00 b	18.00 ab	18.66 ab	7.04 b	7.13 b
T8	Methyl jasmonate at 500 µL/L + shoot topping	218.00 b	224.16 b	19.66 bc	21.33 bc	17.16 bcd	17.60 abc	6.82 c	6.90 c

Means in each column followed by the same letter (s) are not significantly different at 5 % level according to Tukey's HSD Test.

The beneficial effects of amino acids on physical properties of berries are in harmony with those obtained by Faissal et al. (2015), Abd Elkader et al. (2020) and Mira et al. (2024). Shoot topping treatments enhanced photosynthetic activity and encourage translocation of assimilates from leaves towards berries (Elaidy et al., 2025). Abd El-Wahab et al. (1997) on "King Ruby" and Sabbatini et al. (2015) reported that, green pruning practices were effective in enhancing berries physical characters of "Niagara" grapevines.

3.3. Chemical properties of berries

Data in Table 3 revealed that all treatments used reduced the total acidity percentage and increased soluble solid content (SSC) in comparison with the control, which increased in acidity and reduced in SSC. Spraying of Methyl jasmonate (MeJA), proline, and melatonin are effective in raising SSC % and reducing total acidity. All previous treatments in the same order plus shoot topping arranged high concentration on soluble solid content (SSC) with reducing in acidity percentage. Spraying MeJ 500 µL/L + shoot topping is the best treatment for increasing SSC and minimizing total acidity, followed by proline at 500 ppm plus shoot topping and melatonin at 500 µL/L with shoot topping. On the other hand, from Table 3, the control had the lowest value for total sugars, while the highest value was recorded from vines treated by Methyl jasmonate (MeJA) 500 µL/L with shoot topping, followed by melatonin 500 µL/L with shoot topping, followed by proline at 500 ppm with shoot topping. This is true in two seasons of study and true also in individual treatments. Shoot topping alone or with elicitors (Methyl jasmonate (MeJA), proline, and melatonin) was effective on anthocyanin accumulation, as found in Table 3. Methyl jasmonate (MeJA) at 500 µL/L with shoot topping raises accumulation of anthocyanin, followed by proline 500 at ppm with shoot topping and melatonin at 500 µL/L. There were alert differences between the accumulation of anthocyanin on clusters from vines treated with elicitors and making shoot topping on them and clusters from vines treated by individual treatments. Individual treatments gave good results on anthocyanin accumulation when compared with the control, which could not concentrate sufficient anthocyanin. Methyl jasmonate (MeJA) is an endogenous plant regulator that acts as a signaling molecule upon biotic stress and is involved in plant defense mechanisms, triggering the synthesis of secondary compounds (Beckers and Spoel, 2006). Moreover, recent field studies have proved that the application of Methyl jasmonate (MeJA) to the grape bunches may exert a profound effect on the grape and wine phenolic content, particularly in anthocyanins and stilbenes (Ruiz-García et al., 2012 and Fernández-Marín et al., 2014 and Abd El-Khalek et al., 2023). Recent evidence suggests that Methyl jasmonate (MeJA) , when applied to the leaves, may enhance the grape and wine quality too by increasing the content of several phenolic compounds, including anthocyanins, stilbenes, and, to a lesser extent, flavanols (López-Giral et al., 2015).

Table 3. Effect of some elicitors and shoot topping applications on berry bio-chemical properties of 'Crimson Seedless' grapevine

Treatments		Soluble solids content (%)		Titratable acidity (%)		Total anthocyanins (mg/100g fw)		Total sugars (%)	
		2023	2024	2023	2024	2023	2024	2023	2024
T1	Control (distilled water)	17.20 e	17.70 e	0.77 a	0.74 a	23.84 h	25.74 g	12.93 e	13.96 d
T2	Proline at 500 mg/L	17.56 de	18.00 de	0.69 c	0.67 c	27.71 f	29.60 ef	13.09 de	14.26 cd
T3	Melatonin at 500 µL/L	17.40 de	17.86 de	0.72 b	0.70 b	26.59 g	28.72 f	13.20 de	14.25 cd
T4	Methyl jasmonate at 500 µL/L	18.13 c	18.63 c	0.64 d	0.62 d	29.87 d	32.22 d	13.36 cd	14.43 cd
T5	Shoot topping (vegetative apex removal before berry color stage)	17.80 cd	18.30 cd	0.66 d	0.64 d	28.62 e	30.50 e	13.59 c	14.67 bc
T6	Proline at 500 mg/L + shoot topping	18.66 b	19.16 b	0.56 f	0.55 f	33.84 b	36.50 b	13.65 bc	14.74 bc
T7	Melatonin at 500 µL/L + shoot topping	18.16 c	18.73 bc	0.60 e	0.58 e	31.84 c	34.35 c	13.99 b	15.11 ab
T8	Methyl jasmonate at 500 µL/L + shoot topping	19.36 a	19.86 a	0.55 f	0.53 f	35.25 a	38.05 a	14.55 a	15.48 a

Means in each column followed by the same letter (s) are not significantly different at 5 % level according to Tukey's HSD Test.

Liu et al. (2016) discovered that tomato fruits treated with melatonin likewise showed increases in TSS, glucose, and pigment accumulations. Debnath et al. (2018) found that melatonin triggers the carotenoids biosynthesis in tomato under stress conditions. Moreover, melatonin could have a critical role in intermediating the accumulation of pigment in fruits (total anthocyanins in berry skin). All of these effects could explain the positive effect of applied-melatonin on the yield of fruits and its quality attributes under the circumstances of this study. Pinching the main shoots, which led to the enhancement of photosynthetic activity of leaves, consequently increased carbohydrate accumulation, surely reflected on improving chemical properties in berries. These findings are in harmony with Ghada (2015) and El Boray et al. (2018) they ensured that some shoot removal improved chemical properties in the berries.

Conclusion

This study recommended that used applications of proline at 500 mg/L at three different times; after berry set, beginning of berry coloring (veraison stage) and seven days after veraison stage + shoot topping removal before berry color stage enhancing yield per vine, bunch weight, length and width, berry weight, and berry firmness. While a combination of 500 µL/L Methyl jasmonate (MeJA) + shoot topping is the best treatment for increasing SSC, anthocyanin accumulation, and total sugars and reducing total acidity of 'Crimson Seedless' vineyards under the Egyptian climatic.

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