JSAES
Journal of Sustainable Agricultural and Environmental Sciences

Print ISSN : 2735-4377
Online ISSN : 2785-9878
Homepage: https://jsaes.journals.ekb.eg/

Research Article

Morphological and Biochemical Characteristics of ʽCrimson Seedless' Grape in Response to Basal Defoliation with Foliar Spraying of Potassium Silicate and Methionine

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Article info: -

- **Received:** 7 April 2025
- **Revised:** 23 April 2025
- **Accepted:** 6 May 2025
- **Published:** 13 May 2025

Keywords:
Crimson Seedless, leaf basal defoliation, potassium silicate, methionine, anthocyanins

Abstract:

The current study was conducted during two consecutive seasons (2022 and 2023) on ʽCrimson Seedless' grapevines to improve the vegetative growth traits, yield and fruit quality. The grapevines are grown in the experimental farm at El-Baramon station, Horticulture Research Institute, Mansoura, Dakahlia Governorate, Egypt. In both seasons the grapevines were subjected to T1) Control (sprayed with distilled water), T2) Leaf basal defoliation (LBD) after the berry set, T3) Foliar spray of methionine (M) at 500 ppm, T4) foliar spray of potassium silicate (PS) at 3%, T5) LBD + 500 ppm M, T6) LBD + 3% PS, T7) 500 ppm M + 3% PS and T8) LBD + 500 ppm M + 3% PS. Results indicated that, either individually or combined had a significant effect on morphological and biochemical characteristics as compared to the control in both seasons. Also, the combined applications were the most effective than the individual applications, especially the application of LBD + 3% PS + 500 ppm M, which significantly improved the vegetative growth aspects, physical properties of clusters, yield and enhancing SSC and total anthocyanins.

1. Introduction

Grapes (*Vitis vinifera* L.) belong to the Vitaceae family and are one of the top fruit crops worldwide, (Al-Rawi and Al-Rawi, 2000). Red grape varieties, such as ʽRed Globe', ʽFlame Seedless' and ʽCrimson seedless' are popular in the market. The ʽCrimson Seedless' cultivar, known for its sweet taste and high nutritional value, faces challenges with berry color intensity and uneven pigmentation, often due to factors like genetics, phytohormones, and climate change. (Ramming et al., 1995 and El-Boray et al. 2019). To address these issues, farmers use some practices like basal defoliation, which improves sunlight exposure and reduces disease risk. The effectiveness of defoliation depends on some factors like timing, grape variety, and climate (Poni et al., 2006 and Sabbatini et al., 2010).

Methionine is an essential amino acid crucial for growth and body functions in mammals. It also plays a key role in plants, supporting systemic defenses, growth, and adaptation to environmental conditions. Methionine aids in ethylene synthesis and contributes to various metabolic processes, including chlorophyll and cell wall biosynthesis (Goyer et al., 2007 and Mira et al., 2024).

Potassium silicate, a source of potassium and silicon, enhances fruit size, color, shelf life, and overall quality in horticultural crops. It improves plant processes such as photosynthesis, protein synthesis, and nutrient movement, while being environmentally safe with no harmful by-products (Kanai et al., 2007).

The goal of this study is to improve the growth and fruit quality of ʽCrimson Seedless' grapevines through the application of safe and environmentally friendly techniques, including leaf removal, potassium silicate, and methionine treatments, individually and in combination.

2. Materials and Methods

2.1. Plant material

This investigation was carried out during two successive seasons (2022 & 2023) 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 7-years-old 'Crimson Seedless' grafted on freedom rootstocks in clay soil with no artificial drainage system and a groundwater table of 1.5 m, 15 m elevation above sea level). Soil samples were randomly collected from the root zone (0–90 cm) for analysis, according to the methodology adopted in the study of Wilde et al. (1985) as shown in Table 1.

Seventy–two uniform grapevines planted at 2 m × 3 m spacing, free from any sign of physiological disorders or nutrient deficiencies, were chosen for this experiment. Grapevines were grown in a Spanish baron trellis with a quadrilateral cordon training system of long canes. Winter pruning was carried out by mid-February in both seasons by reducing the number of canes on each vine to six canes of 12 buds each, and six renewal spurs of 2 buds each, with a total number of 84 buds per vine. All selected grapevines received the same common agricultural practices, as did the entire 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.

1-Control (sprayed with distilled water).
2-Leaf basal defoliation (LBD) after berry set.
3- Foliar spray of methionine (M) at 500 ppm.
4- Foliar spray of potassium silicate (PS) at 3%.
5- LBD after berry set + M at 500 ppm.
6- LBD after berry set + PS at 3%.
7- Foliar spray of M at 500 ppm + PS at 3%.
8- LBD after berry set + foliar spray of PS at 3% + foliar spray of M at 500 ppm.

Basal defoliation was performed by removing the first four leaves at the shoot base, after berry set, crop load for all treatments was adjusted to 20 clusters per vine. Foliar application of distilled water, Potassium Silicate or methionine (Sigma Aldrich, St. Louis, MO, USA) as a surfactant, was carried out using a 25 L knapsack power sprayer (Model HT-767; Taizhou Tianyi Agricultural and Forestry Machinery Co., Zhejiang, China). The whole vine was sprayed until dripping at three different times; at vegetative growth start stage when shoot length reached about 20– 30 cm in length, after berry set and beginning of berry coloring (veraison stage). All chemicals used in this research were imported from Sigma Aldrich (St. Louis, MO, USA).

Table 1. Soil analysis

Depth (cm)	0–30	30–60	60–90
Clay (%)	49.25	50.55	51.15
Silt (%)	27.69	26.72	26.11
Sand (%)	23.06	22.66	21.55
Texture	Clay	Clay	Clay
Field capacity (%)	15.3	15.7	15.8
Permanent wilting point (%)	7.4	7.6	7.7
pH (1:2.5 extract)	7.7	7.11	7.11
Organic material (%)	2.3	0.55	0.35
E.C. (dS/m) [1:5 extract]	0.61	0.61	0.61
$CaCO_3$ (%)	1.83	1.41	1.88
HCO_3^- (meq/100 g)	0.30	0.37	0.40
CO_3^{2-} (meq/100 g)	0.0	0.0	0.0
SO_4^{2-} (meq/100 g)	3.17	4.04	4.13
Cl^- (meq/100 g)	0.96	0.98	1.08
Na^+ (meq/100 g)	0.48	0.66	1.42
Ca^{2+} (meq/100 g)	0.80	0.20	1.25
Mg^{2+} (meq/100 g)	0.33	0.97	1.16
N (mg/kg)	32	24	18
P (mg/kg)	13	22	13
K (mg/kg)	271	240	230
Fe (mg/kg)	2.48	2.21	2.11
Mn (mg/kg)	4.10	3.50	3.21
Zn (mg/kg)	1.18	0.61	0.51
Cu (mg/kg)	4.24	2.10	0.75

The recorded measurements during the two experimental seasons:

2.2. Vegetative growth

2.2.1. Average shoot length (cm)

It was calculated by measuring the average length of five shoots/ vine.

2.2.2. Number of leaves/shoot

It was calculated by counting the leaves per shoot /vine.

2.2.3. Average leaf surface area (cm^2)

This was calculated according to the method described by Montero et al. (2000).

Leaf surface area (cm^2 / leaf) = 0.587 (L × W).

Where, L= Length of the leaf blade. W= Width of leaf blade. And total leaf area per vine (m2) was determined by multiplying the average leaf surface area by the average number of leaves/shoots by the number of shoots per vine.

2.2.4. Chlorophyll content in leaves

Eight leaves used to determine leaf area, were used for chlorophyll analysis, according to the protocol of Lichtenthaler and Wellburn (1985). The absorbance of the extract was measured at 663 nm for chlorophyll a and 646 nm for chlorophyll b using a UV/Vis spectrophotometer, Model UV-9100-B (LabTech Inc., Hopkinton, MA, USA), and chlorophyll contents (µg/ml) were calculated using the following equations:

Chlorophyll a = (12.21 E663 - 2.81 E646)
Chlorophyll b = (20.13 E646 - 5.03 E663)

Where E is the optical density at the indicated wavelength. Accordingly, total chlorophyll content (mg/g f.w) was calculated, as follows:

Total chlorophyll = [((chlorophyll a + chlorophyll b) × extract volume)/(1000×f.w)].

2.2.5. Internode thickness

It was calculated by measuring the average diameter of five shoots per vine by using a digital Vernier caliper during dormant season.

2.2.6. Pruning weight (kg)

Pruning weight is an indicator of vegetative growth and vigor in grapevine, and traditionally, it is manually determined, according to Sabry et al. (2020)

2.2.7. Wood ripening (%)

Samples of five ripe canes were taken in the 1st week of November; the coefficient of wood ripening (%) was calculated by dividing the length of the ripened part of the branch (changing from greenish to brownish color) by the total length of the branch and multiplied in 100 according to the methods.

2.3. Yield

All clusters were harvested when SSC reached 16–17 °Brix. Soluble solid contents were determined using a hand-held refractometer 0-32 %, Model N-1E (Atago Co., Ltd., Tokyo, Japan). 20 clusters of each vine in a replicate were weighted using a regular field digital scale and then the average yield/vine (bunch weight was multiplied by number of bunches/vine) per each treatment was calculated (kg/vine).

2.4. Chemical properties of berries

2.4.1. Juice soluble solids content (SSC %)

20 berries were used to evaluate SSC (°Brix) using a hand-held refractometer 0-32 %, Model N-1E (Atago Co., Ltd., Tokyo, Japan).

2.4.2. Titratable acidity

It was determined as a percentage of tartaric acid ($C_4H_6O_6$) in 10 ml juice using NaOH (0.1 N) and phenolphthalein as indicator (AOAC, 2005)

2.4.3. Total anthocyanin

It was determined in skin berry according to Husia et al. (1965) and was calculated as mg/100g fresh weight.

3.5. Statistical analysis

Data were first examined utilizing the Shapiro-Wilk and Levene testing for numerical normality and homogeneity of variance, respectively. Before analyzing 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 CoStat software packaging, version 6.311 (CoHort 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. Shoot length, number of leaves per shoot, leaf area and total chlorophyll in leaves

Data in Table 2 presents the impact of the three applied treatments leaf basal defoliation (LBD), foliar spray methionine (M) and potassium silicate (PS), either separately or in combination, on the vegetative growth characteristics of ‘Crimson Seedless’ grapevines in two seasons. These characteristics include shoot length, number of leaves per shoot, leaf area, and total chlorophyll in leaves. Firstly, the data show that, in the 2022 and 2023 seasons, all applied treatments either separately or in combination significantly improved the morphological traits of vegetative development as compared to the control. As for individual treatments, as can be observed, in both seasons, the M application employed in this study was the most beneficial in terms of shoot length, number of leaves/shoot, and leaf area. The descending order was as follows: foliar spray of M > PS > LBD.

Regarding total chlorophyll in leaves, it is obvious that, in both seasons, the potassium silicate application used for this study was the most effective of the others. The decreasing order was as follows: foliar spray: PS > M > LBD. Referring to the combination treatments, the findings revealed that when compared to the individual treatments, the combined treatments significantly increased the stimulation of morphological vegetative development features. The dual treatment with foliar spray of M + PS was shown to be the most effective compared to the other dual treatments in both seasons. The descending order of the dual treatments was as follows: foliar spray M + PS > LBD + M > LBD + PS. Non-significant differences between using M, and PS in leaf area in the first season of the study. Furthermore, there were no significant differences in shoot length and number of leaves/shoot between LBD + M and M + PS in the two seasons of the study. A closer look at the results revealed that the number of combined treatments also had an important effect, with the effect growing with the number of combined treatments. Accordingly, when compared to all treatments in seasons, the highest significant values for these traits are shoot length (168.0 and 175.3 cm), number of leaves/shoot (24.0 and 25.4), leaf area (163.3 and 171.6 cm2), and total chlorophyll in leaves (14.6 and 15.1 mg/g F.W.) were obtained by triple application (LBD + M + PS). While, the control recorded the lowest values of shoot length (146.0 and 150 cm), number of leaves/shoot (20.8 and 21.8), leaf area (119.6 and 125.3 cm2) and total chlorophyll in leaves (10.6 and 10.8 mg/g F.W) in 2022 and 2023, respectively.

Leaf removal has been shown to enhance the flow of water, nutrients, and hormones to other growing leaves, which supports overall plant growth (Tardaguila et al., 2010; Palliotti et al., 2011). Chlorophyll in leaves is essential for photosynthesis, helping convert CO_2 into glucose for growth (Creasy and Creasy, 2018).

Defoliation at berry set can stimulate compensatory growth, increasing leaf area, shoot length, and chlorophyll content, possibly through the development of lateral shoots (Poni et al., 2006). Later in the season, the loss of leaf area is compensated by the increased photosynthetic efficiency of the remaining leaves (Petrie et al., 2003; Palliotti et al., 2011). Basal defoliation has also been shown to enhance vegetative growth and chlorophyll content (Abd El-Khalek et al., 2023b and Abd El-Khalek et al., 2024). Methionine has a positive effect on plant growth, improving shoot length, number of leaves, leaf area, and chlorophyll content. This is due to its role in regulating proteins and initiating mRNA translation in plant cells (Hesse et al., 2004). El-Kenawy and Abo-ELwafa (2021) showed that methionine also enhances vegetative growth and amino acid levels in leaves. Potassium silicate is important for plant growth by enhancing root efficiency in nutrient absorption (Adrees et al., 2015). Foliar spraying with potassium silicate has been shown to significantly improve vegetative growth (Shehata et al., 2018).

3.2. Internode thickness, wood ripening (%) and pruning weight

Results for the three applied treatments of LBD, foliar spray of M and PS as well as their effects on internode thickness, wood ripening, and pruning weight of ‘Crimson Seedless’ grapevines throughout two seasons are shown in Table 3. Primarily, according to the data, all applied treatments either singly or in combination significantly enhanced the morphological characteristics of wood ripening (%), pruning weight, and internode thickness in the 2022 and 2023 seasons when compared to the control.

Methionine, an application used in this investigation was the most effective individual treatment in terms of internode thickness, wood ripening %, and pruning weight, as can be shown in both seasons. The following was the descending order: PS foliar spray > M > LBD of leaves of wood ripening %, and pruning weight.

Table 2. Effect of leaf basal defoliation (LBD), foliar spray methionine (M) and potassium silicate (PS) on shoot length, number of leaves/shoot, leaf area and total chlorophyll in leaves of 'Crimson Seedless' grapevines

Treatments		Shoot length (cm)		Number of leaves/ Shoot		Leaf area (cm^2)		Total chlorophyll (mg/g fw)	
		2022	2023	2022	2023	2022	2023		
T1	Control (distilled water)	146.0 g	150.0 f	20.8 g	21.8 f	119.6 h	125.3 f	10.6 e	10.8 h
T2	Leaf basal defoliation (LBD)	152.0 f	155.3 e	21.6 f	22.6 e	130.6 g	139.0 e	10.8 e	11.3 g
T3	Foliar spray of methionine (M)	159.6 d	163.6 cd	22.7 d	23.8cd	138.3 e	148.6 d	12.6 d	13.0 f
T4	Foliar spray of potassium silicate (PS)	156.3 e	160.6 d	22.3 e	23.3 d	134.3 f	143.0 e	12.9 d	13.2 e
T5	LBD + M	163.0 bc	169.3 b	23.2bc	24.6 b	155.3 c	162.0 b	13.7 c	13.7 d
T6	LBD + PS	162.0 cd	165.3 c	23.1cd	24.0 c	148.3 d	153.6 c	14.0 bc	14.0 c
T7	M + PS	164.6 b	171.6 b	23.4 b	24.9 b	159.3 b	165.0 b	14.3 b	14.4 b
T8	LBD + M + PS	168.0 a	175.3 a	24.0 a	25.4 a	163.3 a	171.6 a	14.6 a	15.1 a

Means followed by the same letter (s) in the same column don't significantly differ at 0.05 of probability according to Tukey's HSD Test.

Regarding the combination treatments, data show that the combined treatments significantly enhanced the stimulation of wood ripening (%), internode thickness, and pruning weight characteristics when compared to the individual treatments. In both seasons, it was found that the dual treatment with foliar spray of M + PS was the most effective in terms of internode thickness, wood ripening (%) and pruning weight when compared to the other dual treatments. The dual treatments were arranged in the following descending order: foliar spray M + PS > LBD + PS > LBD + M of wood ripening % and pruning weight.

Analyzing the data more closely show that the number of combined treatments also had a significant impact, and that the impact increased with the number of combined treatments. As a result, triple application (LBD + M + PS) produced the greatest significant values for these traits internode thickness (1.43 and 1.52 cm), wood ripening (%) (92 and 93.3%), and pruning weight (3.3 and 3.4 kg) when compared to all treatments in seasons. In contrast, the control group saw the lowest levels of wood ripening (%) (72.6 and 76.6%), internode thickness (1.11 and 1.22 cm), and pruning weight (2.65 and 2.87 kg) in 2022 and 2023, respectively. Non-significant differences between using M + PS and LBD + M + PS on pruning weight in two seasons of study.

Defoliation at the berry set likely triggers a compensatory response, resulting in increased internode thickness, wood ripening (%), and pruning weight, possibly through lateral shoots that enhance leaf area (Poni et al., 2006 and Pastore et al., 2013). By the end of the season, leaf removal boosts chlorophyll and carbohydrate content, compensating for leaf loss with enhanced photosynthesis and respiration in the remaining leaves (Petrie et al., 2003). Palliotti et al. (2011) observed that while vine size, cane diameter, and main leaf area decreased after one year of defoliation, carbohydrate storage was unaffected, likely due to increased lateral leaf area and higher photosynthetic capacity in the remaining leaves.

Amino acids play a crucial role in promoting growth and fruiting by protecting against oxidative stress and enhancing protein synthesis, as well as the production of growth hormones like GA3, IAA and cytokinin (Rachel & Hacahm, 1998). Methionine has been shown to improve growth parameters compared to controls (Belal et al., 2016 and Mekawy, 2019). Silicon and potassium contribute to photosynthesis, respiration, energy production, and root activation, leading to improved growth and chlorophyll content (Al-Saeedi, 2000). These findings were also observed in 'Crimson Seedless' (Abdel Aal et al., 2017) and Thompson Seedless grapes (Eisa et al., 2023).

Table 3. Effect of leaf basal defoliation (LBD), foliar spray methionine (M) and potassium silicate (PS) on internode thickness, wood ripening and pruning weight of 'Crimson Seedless' grapevines

Treatments		Internode thickness (cm)		Wood ripening (%)		Pruning weight (k g)	
		2022	2023	2022	2023	2022	2023
T1	Control (distilled water)	1.11 f	1.22 g	72.6 f	76.6 g	2.65 f	2.87 e
T2	Leaf basal defoliation (LBD)	1.18 e	1.26 f	76.3 e	80.3 f	2.73 f	2.98 de
T3	Foliar spray of methionine (M)	1.28 cd	1.33 de	78.6 e	82 ef	2.80 ef	3.13 cd
T4	Foliar spray of potassium silicate (PS)	1.22 de	1.32 e	82.3 d	85 de	2.92 de	3.14 cd
T5	LBD + M	1.33 bc	1.37 c	84.3 cd	86.3 cd	2.97 cd	3.13 cd
T6	LBD + PS	1.30 bc	1.34 d	86.3 bc	88.3 bc	3.11 bc	3.23 bc
T7	M + PS	1.35 b	1.43 b	88.3 b	89.6 b	3.18 ab	3.37 ab
T8	LBD + M + PS	1.43 a	1.52 a	92.0 a	93.3 a	3.33 A	3.49 a

Means followed by the same letter (s) in the same column don't significantly differ at 0.05 probability according to Tukey's HSD Test.

3.3. Yield and physical properties of bunches

Data on the influence of the three applied treatments of LBD, foliar spray of M and PS separately or in combination, on the yield and physical characteristics bunch of 'Crimson Seedless' grapevines in both seasons are shown in Table 4. Initially, the data show that, in the 2022 and 2023 seasons, all applied treatments either separately or in combination significantly improved yield per vine, bunch weight, bunch length, and bunch width as compared to the control. As for individual treatments, as can be observed, in both seasons, foliar spray potassium silicate employed in this study was the most beneficial in terms of yield per vine, bunch weight, bunch length, and bunch width. The descending order was as follows: foliar spray: potassium silicate > methionine > leaf basal defoliation.

Referring to the combination treatments, the findings revealed that when compared to the individual treatments, the combined treatments significantly increased the stimulation of yield and physical characteristics bunch. The dual treatment (foliar spray PS + M) was shown to be the most effective compared to the other dual treatments in both seasons. The descending order of the dual treatments was as follows: foliar spray M + PS > LBD + PS > LBD + M. Non-significant differences between using M, and PS, bunch weight, yield/vine in the two seasons of study. Furthermore, there were no significant differences in cluster weight and yield/vine, between LBD + PS and M + PS in the first season of the study.

After a thorough examination of the data, it was discovered that the number of combined therapies also had a significant impact, which increased with the number of combined treatments. Consequently, triple application (LBD + M + PS) produced the highest significant values for these traits when compared to all treatments in the two seasons: yield/vine (13.37 and 13.78 kg), bunch weight (668.6 and 689g), bunch length (23 and 24cm) and width (16.1and 16.1cm) in 2022 and 2023, respectively. On the other hand, in 2022 and 2023, the control recorded the lowest yield/vine (11.15 and 11.54 kg), bunch weight (558 and 577g), bunch length (19.0 and 20. 0cm), and bunch width (11.8 and 12.3 cm).

The beneficial effect of leaf basal defoliation on total yield and fruit characteristics could be due to the increased levels of photosynthesis and respiration in the remaining leaves to mitigate the impact of leaf removal (Petrie et al., 2003). These results are in agreement with those on ‘Chardonnay’ and ‘White Riesling’ grapevines (Zoecklein et al., 1992) and on ‘Pinot noir’ vines (Vasconcelos and Castagnoli, 2000). Abd El-Khalek et al. (2024) found that basal defoliation application improved total yield and physical characteristics of cluster grape. Also, El-Kenawy and Abo-ELwafa (2021) showed that spraying brassinosteroid and methionine improved yield per vine, cluster weight and cluster length.

The nutritional content is enhanced by potassium silicate, which leads to high amounts of gibberellic acid and indole acetic acid. Ali et al. (2024) clearly illustrated that, with increasing concentrations of 0.05, 0.1, and 0.2% of potassium silicate and/or seaweed extract, the cluster weight, length, and width were significantly increased. From the data it can be indicated that the vines were sprayed with 0.2% PS.

Table 4. Effect of leaf basal defoliation (LBD), foliar spray methionine (M) and potassium silicate (PS) cluster weight, yield/vine, cluster length and cluster width of ‘Crimson Seedless’ grapevines

Treatments		Bunch weight (g)		Yield/vine (Kg)		Bunch length (cm)		Bunch width (cm)	
		2022	2023	2022	2023	2022	2023	2022	2023
T1	Control (distilled water)	558 f	577 g	11.15 f	11.54 g	19 e	20 c	11.8 g	12. 3 f
T2	Leaf basal defoliation (LBD)	579 e	595 f	11.59 e	11.90 f	20 de	21 c	12.5 f	13.2 e
T3	Foliar spray of methionine (M)	591 de	607 ef	11.82 de	12.13 ef	20 cde	22 b	12.9 ef	13.67 de
T4	Foliar spray of potassium silicate (PS)	600 d	617 de	12.66 d	12.33 de	21 bcd	22 b	13.1 de	13.6 de
T5	LBD + M	614 c	621 d	12.28 c	12.42 d	21 bcd	22 b	13.5 d	13.9 d
T6	LBD + PS	628 b	634 c	12.56 b	12.68 c	21 abc	22 b	14.5 c	14.9 c
T7	M + PS	635b	660 b	12.70 b	13.20 b	22 ab	23 b	15.2 b	15.6 b
T8	LBD + M + PS	669 a	689 a	13.37 a	13.78 a	23 a	24 a	16.1 a	16.1 a

Means followed by the same letter (s) in the same column don't significantly differ at 0.05 probability according to Tukey’s HSD Test.

3.4. Chemical properties of berries

The information shown in Table 5 indicates that the three applied treatments leaf basal defoliation (LBD), foliar spray methionine (M), and potassium silicate (PS) affected the SSC%, acidity, and total anthocyanin of ‘Crimson Seedless’ grapevines throught both seasons, either alone or in combinations. After that, the data illustrate that, when compared to the control, all applied treatments, alone or in combination, greatly enhanced SSC%, total anthocyanin, and decreased acidity in the 2022 and 2023 seasons. The potassium silicate application used in this study was the most advantageous among the individual treatments, as can be seen, in terms of improved SSC%, total anthocyanin, and decreased acidity in both seasons. Following was the descending order: potassium silicate > methionine > leaf basal defoliation.

About the combination treatments, the results show that the combinations treatments considerably enhanced SSC%, total anthocyanin, and decreased acidity in comparison to the individual treatments. In both seasons, the most effective dual treatment when compared to the other dual treatments was the foliar spray PS + M. The dual treatments were arranged in the following descending order: foliar spray M+ PS > LBD + PS > LBD + M. A detailed analysis of the data revealed that another important factor, which rose with the number of combinations treatments, was the number of combined therapies. As a result, SSC%, total anthocyanin, and acidity were all improved by triple application (LBD + M + PS), with M + PS coming next in 2022 and 2023, respectively. Conversely, the control demonstrated the lowest SSC%, total anthocyanin, and decreased acidity in 2022 and 2023.

Leaf removal affects photosynthesis by improving light access to leaves, increasing photosynthetic rates and TSS accumulation (Sun et al., 2011, Kok et al., 2013 and Abd El-Khalek et al., 2023a). While shading can raise acidity and NH4-N and K content in red berries (Perez and Kliewer, 1982), sun exposure enhances grape composition, including phenolic and flavonoid content. Leaf removal can increase soluble solids and anthocyanin, but excessive removal in warm climates may reduce anthocyanin levels and berry color (Abd El-Khalek et al., 2023b).

Table 5. Effect of leaf basal defoliation (LBD), foliar spray methionine (M) and potassium silicate (PS) alone or in combinations on soluble solids content (SSC), titratable acidity (TA) and total anthocyanin of 'Crimson Seedless' grapevines

Treatments		SSC (%)		TA (%)		Total anthocyanins (mg/100g F.W)	
		2022	2023	2022	2023	2022	2023
T1	Control (distilled water)	18.4 e	19.1 e	0.73 a	0.67 a	28.21 g	29.81 h
T2	Leaf basal defoliation (LBD)	18.7 de	19.4 de	0.73 a	0.66 a	31.68 f	33.23 g
T3	Foliar spray of methionine (M)	19 d	19.5 de	0.70 ab	0.63 a	32.6 ef	34.64 f
T4	Foliar spray of potassium silicate (PS)	19.2 d	19.8 cd	0.64 bc	0.61 ab	33.45 e	35.77 e
T5	LBD + M	19.7 c	20.1 c	0.59 cd	0.57 abc	36.25 d	37.34 d
T6	LBD + PS	20 bc	20.2 bc	0.59 cd	0.58 abc	37.81 c	39.81 c
T7	M + PS	20.3 b	20.7 b	0.56 d	0.5 c	41.06 b	42.31 b
T8	LBD + M + PS	21.2 a	21.5 a	0.54 d	0.51 bc	42.75 a	44.06 a

Means followed by the same letter (s) in the same column don't significantly differ at 0.05 probability according to Tukey's HSD Test.

Methionine promotes ethylene production, which plays a key role in fruit ripening. It also helps increase SSC percentage, and total anthocyanin, and reduce total acidity in grape berries (Khan et al., 2019). El-Kenawy and Abo-ELwafa (2021) showed that combining brassinosteroid and methionine lowered titratable acidity and significantly increased SSC% and total anthocyanins.

Potassium enhances fruit quality by regulating enzyme activity, improving photosynthesis, and speeding up nutrient movement in plants (Kumaran et al., 2019). Studies show that potassium spraying increases total anthocyanin products, juice content, fruit size, flavor, and color (Amiri & Fallahi, 2007 and Elaidy et al., 2023). Mohamed et al. (2024) showed that potassium silicate at 5% increased TSS% and anthocyanin content in King Roby grapes.

4. Conclusion

This study recommended that used applications of LBD, M and PS, either individually or in combinations among them, had a significant effect on all conducted traits compared to the control in both seasons. Also, the combined applications were more effective than the individual applications, especially the triple application (LBD + M + PS), which significantly improved the vegetative growth aspects, physical properties of clusters, yield, and enhanced SSC and total anthocyanin, which is recommended for application in 'Crimson Seedless' vineyards under the Egyptian climatic.

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