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Berry Physicochemical Properties of Crimson Seedless Grapevine as Affected by Potassium and Boron Foliar Application

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Abstract: The current study was carried out during two consecutive seasons of 2023 and 2024, by using thirty uniforms in vigor, nine years old own rooted 'Crimson Seedless' grapevines. The chosen vines were grown in private vineyard located at Beni Mazar district, El-Minia Governorate – Egypt. The soil texture was sandy loam and it irrigated by using drip irrigation system. Ten treatments from Potassium citrate (at 0.5%, 1.0%, and 1.5%) and Boric acid (at 50, 100, and 150 ppm) as well as their combination were examined. The obtained results showed that foliar spraying of Potassium and Boron play an essential role in improving cluster physical properties and berry physicochemical characters of 'Crimson Seedless' grape. The individual treatments with Potassium showed noticeable superiority over Boron treatments. Moreover, the combined application with Potassium and Boron surpassed the individual application of each one. In order to improve the physicochemical properties of Crimson Seedless cluster physical properties and berry physicochemical properties it is recommended to spray Potassium in form of potassium citrate at 1.5% and Boron in form of boric acid at 150 ppm three times yearly.

Key words: Crimson Seedless' grapevines, Potassium citrate, Boric acid, Berry quality.

1. Introduction

Grapevine (*Vitis vinifera L.*) conceded as one of the most widely cultivated fruit crops worldwide. However, the mineral nutrition of grapevines plays a crucial role in determining in berry physicochemical quality (**Reynier, 2000**). Egypt is considered as one of the leading grape-producing countries in the Arab world and the Middle East countries. Egyptian grape exports exceeded 181 thousand tons in 2024. El-Minia Governorate is one of the leader rejoin of table grape cultivation (FAO-stat 2024). 'Crimson Seedless' grapevine (*Vitis vinifera L.*) is one of the most important seedless table grape cultivars grown worldwide due to its excellent fruit quality and high market value. It is characterized by its attractive bright-red berries, oval shape, crisp texture, and sweet flavor, marking it highly preferred by consumers (**Dokoozlian and Peacock, 2001**). This cultivar is also known for its good storage and transport ability, which helps maintain fruit quality during marketing and export. It is considered a late ripening cultivar (**Peacock *et al.,* 2000**). It was developed through the breeding program of the USAD and then it spread in many grape producing countries (**Dokoozlian *et al., 1994***). Therefore, Crimson seedless has received considerable attentions in viticulture research aimed to improving productivity and fruit quality (**Ibrahim, 2026**).

Potassium (K) considered a key element influencing both physiological and biochemical processes in grapevines (**Villette *et al.,* 2020**). It is the most abundant cation in plant cells and is involved in numerous physiological functions, including enzyme activation, osmoregulation inside plant cell (**Hu *et al.,* 2023**). According to **Singh *et al.,* (2024)**, potassium can improve plant tolerance to abiotic stresses such as drought and hot, which are becoming more frequent in grape-growing regions (**Wang *et al.,* 2024**). Foliar potassium application can improve the cluster and berry physicochemical properties (**Reynier 2000**). Boron plays a pivotal role in improving the berry physical and chemical characteristics. In grapevines, boron has been shown to exert a significant indirect influence on pigment synthesis, stability, and functionality through its effects on cellular integrity and metabolic regulation (**Marschner, 2012)**. In sandy soil Boron deficiency resulted in a significant decline in chlorophyll a, chlorophyll b, and total chlorophyll content in grapevine leaves (**Wei *et al.,* 2022**). Additionally, boron has been linked to the regulation of enzymatic activities involved in photosynthesis (**Khan *et al.,* 2021**).

The main objective of this study was to investigate the potential for improving the physicochemical quality characteristics of 'Crimson Seedless' table grape through foliar application of Potassium and Boron.

2. Material and Methods

This investigation was achieved during 2023 and 2024 seasons, using thirty uniforms in vigor, nine years old 'Crimson Seedless' grapevines. The chosen vines were grown in private vineyard orchard located at Beni Mazar district, El-Minia Governorate – Egypt. The soil texture was sandy loam (Table 1). The farm has been irrigated by using drip irrigation system feeding from underground well water.

2.1. Soil and water analysis

A composite soil and irrigation water samples were collected and subjected to Physical and chemical analysis according **Chapman & Partt (1961)** and **Walsh & Beaton (1986)**. The obtained data are illustrated in Table (1).

2.2. Experimental work

For achieving the main objectives of this investigation, ten treatments from the two elements (Potassium in form of potassium citrate and Boron in form of Boric acid) as well as their combinations) were implemented as the following: Control treatment (untreated vines); spraying Potassium citrate at 0.5 %; spraying Potassium citrate at 1.0 %, spraying Potassium citrate at 1.5 %, spraying Boric acid at 50 ppm, spraying Boric acid at 100 ppm, spraying Boric acid at 150 ppm, Spraying potassium citrate at 0.5% + Boric acid at 50 ppm, spraying potassium citrate at 1.0% + Boric acid at 100 ppm; and spraying potassium citrate at 1.5% + Boric acid at 150 ppm. Three replications were done by each treatment, one vine per each replicate. All potassium and boron as well as their combinations treatments were sprayed three times yearly (after burst bud "1st week of April", after berry setting "2nd week of May" and one month later.

Table (1). Physical and chemical analysis of orchard soil and irrigation water

Soil analysis		Water analysis	
Constituents	**Values**	**Constituents**	**Values**
Sand %	81.1	**E.C (mmhos/cm/25C)**	1.8
Silt %	14.1	**Hardness**	16.7
Clay %	4.8	**pH**	7.74
Texture	Sandy loam	**Ca (mg/L)**	40.1
EC (1:2.5 extract) mmhos/cm/ 25 C	2.2	**Mg (mg/L)**	20.8
Organic matter %	0.07	**K (mg/L)**	5.27
pH (1 : 2.5 extract)	8.02	**Na (mg/L)**	71.6
Active lime ($CaCO_3$ %)	9.92%	**Sum of Cations (mg/L)**	9.16
Total N %	0.07	**Alkalinity (mg/L)**	152
Available Phosphorus (ppm)	2.04	**Chlorides (mg/L)**	102
Available Ca (meq/100g)	22.1	**Nitrate (mg/L)**	10.0
Available Mg (meq/100g)	2.14	**Sulphates (mg/L)**	41.9
Available K (meq/100g)	0.49	**Sum of anions (mg/L)**	7.09

2.3. Experimental design and statistical analysis

The present investigation was designed in Randomized Complete Block Design (RCBD) (**Gomez and Gomez, 1984**). At the end of each season, the obtained data tabulated and subjected to statistical analysis, using new LSD at 5% (**Snedecor and Cochran, 1990**).

2.4. Berry physicochemical parameters

Four clusters from each vine (two clusters from each side) were taken random for determination of the following physical and chemical characteristics:

- **Cluster longitudinal and diameter** at shoulders area (cm)
- Berry weight (g), was achieved by using an accurate digital balance
- **Berry dimensions** (longitudinal and equatorial 'cm'), were achieved by using vernier caliper Then, the shape index was calculated by divided the longitudinal of berry by its equatorial.
- **Berries coloration %** was estimated by counting the number of red berries and dividing by the total number of berries per cluster, and so multiple by 100.
- **Juice total soluble solids percentage (TSS%)** was achieved by using a hand refractometer.
- **Percentage of total acidity,** in form of tartaric acid in grams per 100 g of juice, was done by titration with NaOH 0.1N in existence of Ph-Th indicator (**A.O.A.C., 2000**).
- **The ratio between TSS and acidity** was calculated.
- Reducing sugars percentage: was done by using **Lane and Eynon, 1965**) volumetric method as described by **Rangana (1990**).
- **The total anthocyanins** of berry skin were extracted and determined according to **Fulcki and Frabcis (1968)**.
- **Berries coloration %:** At the harvesting stage, four cluster per vine were used in this process. The, number of successfully colored berries per cluster were counted, as well

as the number of uncolored berries was counted. Accordingly, the berries coloration percentage was calculated for each one of cluster separately. Then, the average percentage of berries coloration was calculated as following (**Ibrahim 2010**).

The total numbers of berries/cluster = number of colored berries + number of uncolored berries.

$$\textbf{Berries coloration \%} = \frac{\textbf{Number of colored berries/cluster}}{\textbf{The total numbers of berries/cluster}} \, \boldsymbol{X}\,\textbf{100}$$

3. Results and Discussion

3.1. Effect of potassium citrate and boric acid on cluster physical characteristics

The effect of spraying potassium citrate (at 0.5%, 1.0%, and 1.5%) and Boric acid (at 50, 100, 150 ppm) on the physical properties of ‘Crimson Seedless’ cluster under cultivation in sandy soil conditions, during 2023 and 2024 seasons were illustrated in Table (2). Data presented in this table showed that both individual and combined treatments with Potassium citrate and Boric acid significantly improved the physical properties of Crimson cluster (cluster longitudinal and diameter).

A. Cluster longitudinal (cm)

It is clear from this table that spraying Potassium and Boron at different concentrations were very effective in improve the cluster length (cm) of Crimson Seedless cultivar. Regarding the effect of individual treatments, it is clear from this table that all individual Potassium citrate treatments were capable to enhancing ‘Crimson Seedless’ cluster longitudinal (cm) during the two experimental seasons. Except the case of the lowest concentration (0.5%), during the first season only. However, spraying Boric acid at 50 ppm and 100 ppm during the first seasons, as well as spraying Boric acid at 50 ppm in the second season failed to improve the length of cluster (cm) significantly. Contrary, spraying the higher concentration of Boric acid (150 ppm in the first seasons and 100 ppm & 150 ppm in the second season) was capable to enhancing cluster longitudinal significantly. Concerning the combined application of Potassium citrate and Boric acid, the obtained data showed that all combined treatments was successful increase the cluster longitudinal significantly, in both two experimental seasons. As shown in table 2, it is worth to mention that the improvement in cluster longitudinal was parallel to increasing the concentrations of both examined compounds. Moreover, the vines received the highest Potassium and Boron concentrations produced the clusters with the higher longitudinal. On the opposite side, untreated vines produced the lowest cluster longitudinal. These findings were true during the two experimental seasons respectively.

B. Cluster diameter at shoulder (cm)

The obtained data confirmed that spraying both potassium and Boron individually or in combination was capable to enhancing the cluster diameter significantly, during the two experimental seasons. Concerning the individual treatments, the lowest concentrations of Potassium citrate (0.5%) and Boric acid (50 and 100 ppm) failed to improve the cluster diameter significantly, neither in the first season nor in the second one. Contrary, spraying the high concentrations of Potassium citrate (1.0% & 1.5%) and Boric acid (150 ppm) was very effective in improve the cluster diameter. These findings were true during the two experimental seasons. With regard to studying the response of Crimson Seedless *Cv.* cluster diameter to spraying both Potassium citrate and Boric acid in combination at different concentration, the obtained data confirming that all combined treatments were capable to increase the cluster diameter (cm), in both experimental seasons. This increment was positively related to the concentration used. Furthermore, the vines received the highest combined potassium citrate and Boric acid concentrations produced the clusters with higher diameter. Contrary, untreated vines present the lowest cluster diameter. These findings were true during the two experimental seasons.

Table (2). Effect of spraying potassium citrate and Boron at different concentrations on cluster physical properties of Crimson Seedless grapevines, during 2024 and 2025 seasons

Treatments	Cluster length (cm)		Cluster shoulder (cm)	
	2023	**2024**	**2023**	**2024**
Control	18.4	18.2	13.6	13.5
K Citrate 0.5 %	19.3	19.9	13.9	14.2
K Citrate 1.0 %	20.2	21.1	14.8	14.9
K Citrate 1.5 %	21.4	22.0	15.3	15.9
B 50 ppm	18.9	19.2	13.7	13.9
B 100 ppm	19.4	20.2	14.1	14.4
B 150 ppm	20.3	21.1	14.9	15.2
K Citrate 0.5% + B 50 ppm	20.2	21.4	15.1	15.5
K Citrate 1.0% + B 100 ppm	22.7	23.8	15.9	16.2
K Citrate 1.5% + B 150 ppm	24.2	24.8	16.3	16.6
Mean	**20.5**	**21.0**	**14.8**	**15.0**
New LSD at 5%	**1.4**	**1.2**	**1.1**	**1.2**

3.2. Effect of spraying potassium citrate and boric acid on beery physical properties

Data concerning the effect of foliar spraying of Potassium citrate and Boric acid at different concentrations on berry physical characteristics of ‘Crimson Seedless’ grape during the two experimental seasons are illustrated in Tables (3). It is clear from this table that spraying potassium and boron caused a significant promotion in all berry physical properties.

A. Berry weight (g)

Data concerning the effect of foliar spraying with different potassium citrate concentrations (0.5%, 1.0%, and 1.5%) as well as Boric acid (at 50, 100, and 150 ppm) each compound alone or in combination on the average berry weight of ‘Crimson Seedless’ table grape, during 2023 and 2024 seasons, showed that, it is clear from Table (3) that treating ‘Crimson Seedless’ grapevines with potassium citrate at 0.5% and 1.0% individually was associated with slight and non-significant increase, during the two experimental seasons. While, spraying the highest concentration (1.5%) of potassium citrate individually was associated with sharp and significant increase in berry weight (g), during the two experimental seasons. On the other side, whatever the concentration used of Boric acid non-significant differences were observed between untreated vines and those sprayed with Boric acid individually. These findings were true during the two experimental seasons. Concerning the combined application of Potassium citrate and Boric acid, it is clear from the obtained data that all combined treatments were capable to enhancing the berry weight significantly, in both experimental seasons. Additionally, the vines received the highest concentration of potassium citrate and boric acid in combination produced the highest berry weight. On the opposite side, untreated vines produced the lowest weight of berries. These data were true during the two seasons respectively.

B. Berry longitudinal (cm)

The Data tabulated in Table (3) illustrates the effect of spraying Potassium citrate and Boric acid at deferent concentration each one individual or both in combination on the longitudinal (cm) of ‘Crimson Seedless’ table grape, grown in sandy soil under El-Minia Governorate conditions, during 2023 and 2024 seasons. Regarding the individual treatments of K and B, the results clearly demonstrated that, al individual treatments was capable to improve significantly the berry longitudinal of ‘Crimson Seedless’ in both experimental seasons. Overcoming, berry longitudinal increment was parallel to increasing the concentration used of each compound. However, the vines received the highest concentration present the highest berry longitudinal (cm). These findings were true during the two experimental seasons. Regarding the combined application of Potassium citrate and Boric acid, it was more effective on berry longitudinal. Additionally, the results in Table (3) confirmed that, the vines received the highest combined Potassium and Boron concentration produced the berries with longitudinal. On the opposite side, untreated vines produced the berries with the lowest longitudinal. These findings were true during the two experimental seasons respectively.

Table (3). Effect of spraying potassium citrate and Boron at different concentrations on berry physical properties of ‘Crimson Seedless’ grapevines, during 2024 and 2025 seasons

Treatments	Berry weight (g)		Berry longitudinal (cm)		Berry diameter (cm)		Shape index	
	2023	2024	202.23	2024	202.23	2024	202.23	2024
Control	2.42	2.44	2.11	2.19	1.98	1.89	1.03	1.17
K Citrate 0.5 %	2.65	2.71	2.50	2.51	2.07	2.19	1.21	1.15
K Citrate 1.0 %	2.72	2.79	2.54	2.53	2.20	2.21	1.15	1.14
K Citrate 1.5 %	2.85	2.90	3.11	3.21	2.22	2.25	1.43	1.43
B 50 ppm	2.55	2.54	2.88	2.89	2.02	2.07	1.43	1.40
B 100 ppm	2.61	2.66	2.90	2.95	2.11	2.13	1.37	1.38
B 150 ppm	2.65	2.71	2.98	3.01	2.20	2.22	1.35	1.36
K Citrate 0.5% + B 50 ppm	2.89	2.91	3.12	3.19	2.22	2.28	1.41	1.40
K Citrate 1.0% + B 100 ppm	2.99	3.21	3.25	3.46	2.35	2.45	1.38	1.41
K Citrate 1.5% + B 150 ppm	3.24	3.53	3.45	3.53	2.45	2.56	1.41	1.39
Mean	**2.76**	**2.84**	**2.90**	**2.95**	**2.18**	**2.22**	**1.31**	**1.32**
New LSD at 5%	**0.27**	**0.30**	**0.21**	**0.25**	**0.21**	**0.28**	**0.12**	**0.17**

C. Berry diameter (cm)

The obtained results showed that the individual treatments, the obtained data showed that spraying the lowest concentrations of Potassium citrate (0.5%) in both seasons and Boric acid (at 50 ppm) in both seasons and (100 ppm) in the first season only, each one individual, were failed to enhancing the diameter of ‘Crimson Seedless’ berries (cm). Contrary, spraying the highest concentrations of Potassium citrate and Boric acid was very effective in enhancing the diameters of ‘Crimson Seedless’ berries. Regarding the combined application of Potassium citrate and Boric acid at deferent concentrations, it is clearly shown that all K and B combination was capable to significantly increased berry diameter rather than control treatment. These findings were true during the two experimental seasons. Berry diameter increment was parallel to increasing the concentration used from each compound. However, the vines received the highest Potassium citrate 1.5% and boric acid at 150 ppm in combination produced the highest berry diameter. On the opposite side, untreated ‘Crimson Seedless’ vines produced the lowest berry diameter. These results were true during the two experimental seasons respectively.

D. Berry shape index (cm)

Data illustrated in Table (3) showed that the potassium and boron treatments succeeded to increase the shape index of 'Crimson Seedless' berries. Concerning the individual treatments of Potassium citrate and Boric acid, it is clearly shown that during the first season all individual Potassium citrate and Boric acid treatments was capable to increase the berry shape index. During the second season spraying Potassium citrate at law concentrations (0.5% and 1.0%) were failed to varied the shape index of berries. While, in the same season spraying Potassium citrate at highest concentration (1.5%) caused a significant promotion in berry shape index. On the other side, spraying any concentration of Boric acid was capable to enhancing the shape index during the second season. Concerning the combined treatments with Potassium and Boron, the obtained data showed that all complained treatments significantly increase the berry shape index in both experimental seasons. This increment can explain by the higher increasing in berry longitudinal compared to increasing of berry diameter, these findings were true during the two experimental seasons.

E. Berry coloration %

The data pertaining to the effect of Potassium citrate and boric acid at different concentrations on berries colorations of 'Crimson Seedless' grape during 2023 and 2024 seasons are presented in Figure (1). It is clear from this figure that all potassium and Boron treatments were capable to improve the coloration of Crimson berries significantly during the two seasons. Regarding the individually application of Potassium citrate and Boric acid, it is clear that all Potassium and Boron treatments were succeeded to significantly enhancing the percentage of berries colored during the two experimental seasons. This increment was clear in the case of Potassium treatments rather than those of Boron treatments. However, the vines sprayed with Potassium citrate at 1.5% individually presented the highest berries coloration compared to untreated vines or those received other Potassium and Boron treatments individually, these data were true during the two experimental seasons. Concerning the combined application of Potassium and Boron, it is clear from the same figure that all Potassium and Boron combined application were capable to improve the percentage of berries coloration during the two experimental seasons (2023 and 2024). It is remarkable that increasing the concentrations of the two examined compounds was associated with significant increment in berry coloration %. However, spraying the 'Crimson Seedless' vines with the highest concentration of Potassium citrate (at 1.5%) and Boric acid (at 150 ppm) in combination produced the highest percentage of berries coloration, contrary the control vines presented the lowest percentage of berries coloration. These findings were true during the two experimental seasons respectively.

Several studies demonstrated that foliar application of potassium significantly increased berry weight and berry dimensions in grapevines cultivars. It is well known that, Potassium improves photosynthetic efficiency and enhances the movement of assimilates from leaves to berries, leading to larger and heave berries (**Marschner 2012**). On Thompson Seedless grapevines, foliar spraying with potassium citrate and potassium thiosulfate significantly increased berry weight, and berry dimensions compared with untreated vines. It may be concluded that potassium treatments improved the physical quality of berries and grape clusters as well as enhancing berry development during ripening stages (**Kumar *et al.*, 2006**). Potassium also contributes to improving cluster and berry physical parameters during harvesting. This enhancement may be attributed to the role of potassium in regulating osmotic pressure and maintaining cell turgidity within berry tissues (**Mengel and Kirkby (2001)**. Additionally, investigations on 'Flame Seedless' indicated that foliar application of potassium phosphate significantly increased berry firmness, berry width, berry length, and 100-berry weight compared with control vines. The improvement in physical berry attributes was associated with enhanced nutrient translocation and better physiological performance of vines (**Singha *et al.*, 2024**).

Concerning Boron effect on berry physical properties on table grape, treated the clusters with Boron improved grape structural properties, enhanced berry texture and improved cell wall integrity, which contributed to better berry firmness and resistance to mechanical damage. Such improvements are very important for table grapes intended for export and long-distance transportation (**Taiz and Zeiger 2015**). Foliar application of Boron on local grape cultivars significantly improved and berry physical quality, such as increases in berry size, berry weight, and berry uniformity after boron spraying. Boron enhances calcium mobility and strengthens cell wall components, which subsequently improves berry firmness and reduces cracking incidence. These physiological responses contribute to the production of attractive grape clusters with higher commercial value (**Mpelasoka *et al.*, 2003**).

Combined application of potassium and boron often produces synergistic effects on grape cluster and berry physical properties. Potassium enhances carbohydrate synthesis and transport, while boron facilitates sugar movement and improves reproductive growth. Consequently, the interaction between both nutrients improves berry enlargement, berry weight, cluster weight, and overall cluster appearance more effectively than individual applications (**Abdel-Rahman *et al.*, 2018**). Several viticulture studies confirmed that combined nutrient sprays improved berry physical properties such as length, diameter, firmness, as well as improved cluster compactness in table grape cultivars (**Mehta, 2012**). This discussion can declare the positive role of Potassium and Born on enhancing the physical properties of Crimson berries which obtained in the current study.

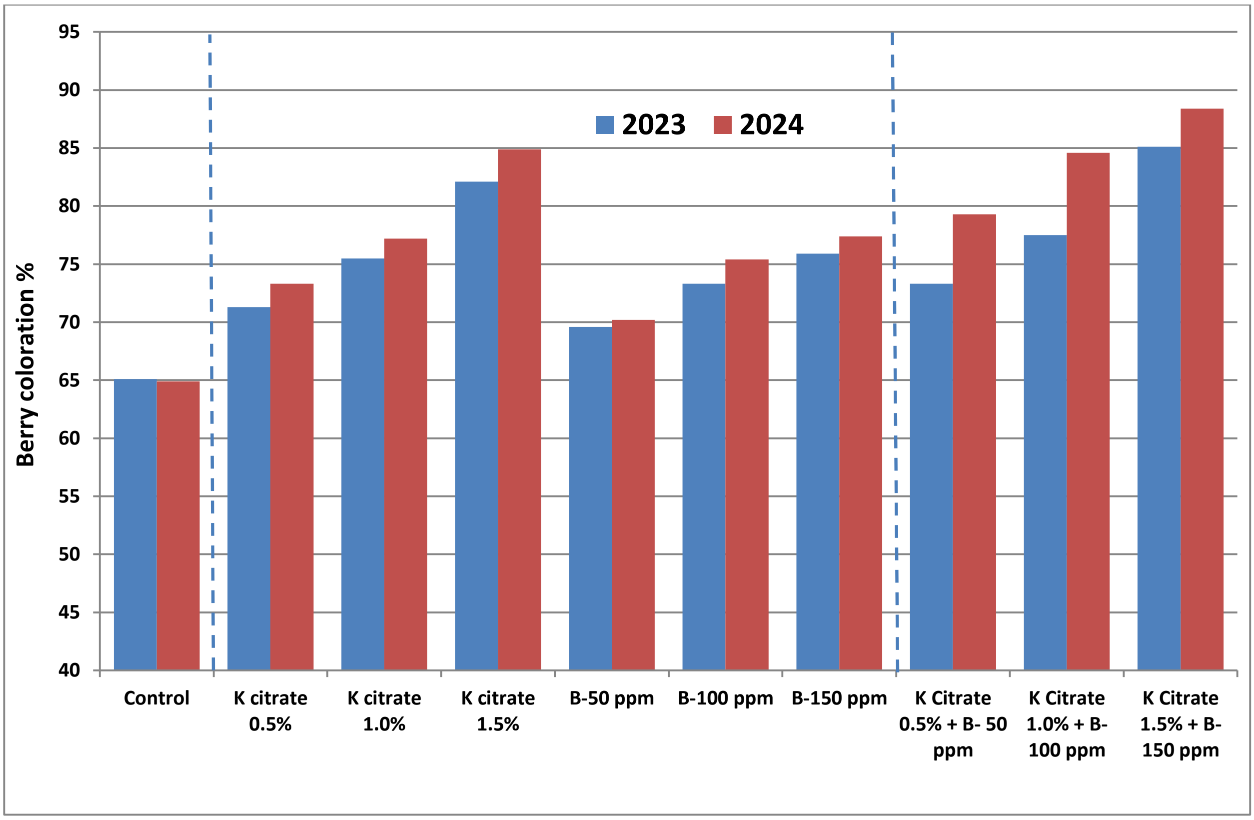

Fig. (1). Effect of spraying Potassium citrate and Boric acid on fruit coloration % of Crimson Seedless grapevines, during 2023 and 2024 seasons

3.3. Effect of spraying potassium citrate and boric acid on beery chemical properties

Data concerning the effect of foliar spraying of different concentrations of Potassium in form of potassium citrate (at 0.5%. 1.0%, & 1.5%) and Boron in form of boric acid (at 50, 100, and 150 ppm) on berry chemical properties of 'Crimson Seedless' grape during the two experimental seasons are illustrated in Tables (4). It is clear from this table that spraying potassium and boron caused a significant promotion in berry chemical properties, during the two experimental seasons.

A. Total soluble solids %

The obtained Data concerning the effect of foliar spraying of potassium citrate concentrations and Boric acid each compound alone or both in combination on the berry TSS% of ‘Crimson Seedless’ grape showed that, ‘Crimson Seedless’ berry juice TSS% significantly varied according to individual or combined application of Potassium citrate and Boric acid, during the two experimental seasons. Regarding the individual treatments, the obtained data (Table 4) showed that spraying the lowest concentrations of potassium citrate (0.5%) and Boric acid (50 ppm) failed to enhance the juice TSS% during the two experimental seasons. On the other side, spraying the higher concentrations of Potassium citrate (1.0% & 1.5%) and Boric acid (100 & 150 ppm) significantly improved the juice TSS% rather than control or lower concentrations. In addition, the vines received the highest potassium citrate concentration (1.5%) produced the best TSS% in compared to control or other individual treatments. Concerning the combined treatments with Potassium citrate (at 0.5%, 1.0% and 1.5%) and Boric acid (at 50, 100, and 150 ppm), the obtained data showed that all combined treatments were capable to increase the TSS% in ‘Crimson Seedless’ grape berries significantly. These data were true during the two experimental seasons. Furthermore, the vines received the highest Potassium and Boron concentrations produced the highest TSS% in their berries (18.4% and 18.5%). On the contrary, untreated vines present the lowest TSS% (16.2% and 16.5%). These results were true during the two experimental seasons respectively.

B. Reducing sugars %

The obtained results presented in Table (4) showed that treating the ‘Crimson Seedless’ grape with Potassium citrate and Boric acid at different concentrations (individually or both in combination) resulted in significant increment in the reducing sugars percentage. This increment was parallel related to increasing the Potassium and Boron concentrations. Regarding the individual treatments, all individual treatments with Potassium citrate and Boric acid was capable to increasing the reducing sugars of ‘Crimson Seedless’ berries juice. These findings were true during the two experimental seasons. However, spraying Potassium citrate at 1.5% produced the highest reducing sugars percentage on comparison to control or other individual treatments. Concerning the effect of combined application of Potassium citrate and Boric acid, all combined treatments was capable to improve the percentage of reducing sugars of ‘Crimson Seedless’ berries, during the two experimental seasons. This increment was significant and parallel to increasing the concentration used. Moreover, the vines received the highest Potassium citrate and Boric acid in combination produced the highest reducing sugars percentage in their berries (16.4 % and 16.9 %). While, untreated vines produced the lowest reducing sugars percentage (14.1% and 14.2%). These findings were true during the two experimental seasons respectively.

C. Total acidity %

It is clear from the obtained data (Table 4) that individually or combination treatments with Potassium citrate and Boric acid significantly decrease the total acidity percentage, in both experimental seasons. This decrement was negatively parallel related to increasing the Potassium and Boron concentrations, in both experimental seasons. All individual treatments were capable to decreasing the total acid percentage of ‘Crimson Seedless’ berries juice. Except, the lowest concentration of Boric acid (50 ppm), which failed to vary the total acidity significantly. However, spraying Potassium citrate at 1.5% produced the lowest total acidity percentage (0.588% and 0.579%) on comparison to control or other individual treatments, during the two experimental seasons. Concerning the effect of combined application of Potassium and Boron, all combined treatments were capable to decrease the percentage of total acidity percentage of ‘Crimson Seedless’ berries in both experimental seasons. This decrement was negatively correlated to the concentration used. Moreover, the vines received the highest concentrations of Potassium citrate and Boric acid in combination produced the lowest total acidity percentage in their berries. While, untreated vines produced the highest total acidity percentage. These findings were true during the two experimental seasons respectively.

D. Total anthocyanins contents

Data concerning the effect of foliar spraying of potassium citrate concentrations (0.5%, 1.0%, and 1.5%) and Boric acid (at 50, 100, and 150 ppm), each compound alone or both in combination, on the berry skin total anthocyanins (mg/100g F.W.) of ‘Crimson Seedless’ grape showed that, ‘Crimson Seedless’ berry juice total anthocyanins (mg/100g F.W.) significantly varied according to individual and combined application of Potassium citrate and Boric acid, during the two experimental seasons. Regarding the individual treatments with, the obtained data (Table 4) showed that, all potassium citrate and Boric acid individual treatments were capable to enhancing the skin total anthocyanins contents, during the two experimental seasons. It is clear from this table that increasing the individual concentration of Potassium and Boron was parallel with significant increment in berry total anthocyanins contents. In addition, the vine received the highest Potassium citrate concentration (1.5%) produced higher and significant total anthocyanins contents rather than control or those received other individual treatments. These results were true during the two experimental seasons. Concerning the combined treatments, all combined Potassium and Boron treatments were capable to increase the total anthocyanins in ‘Crimson Seedless’ berries significantly, during the two experimental seasons. Furthermore, the vines received the highest Potassium and Boron concentrations produced the highest total anthocyanins in their berries (146.5 and 152.6 mg/100 g F.W.). On the contrary, untreated vines present the lowest total anthocyanins in their berry (97.9 and 99.2 mg/100g F.W.). These findings were true during the two experimental seasons respectively.

Table (4). Effect of spraying potassium citrate and Boron at different concentrations on berry chemical properties of ‘Crimson Seedless’ grapevines, during 2024 and 2025 seasons

Treatments	TSS (%)		Reducing sugars (%)		Total acidity (%)		Total anthocyanins Mg/100 g F.W.	
	2023	2024	2023	2024	2023	2024	2023	2024
Control	16.2	16.5	14.1	14.2	0.713	0.721	97.9	99.2
K Citrate 0.5 %	16.6	16.9	14.7	14.9	0.680	0.674	115.3	122.3
K Citrate 1.0 %	17.0	17.2	15.4	15.7	0.612	0.601	127.7	130.1
K Citrate 1.5 %	17.4	17.6	15.8	16.2	0.588	0.579	132.7	139.4
B 50 ppm	16.4	16.4	14.3	14.4	0.689	0.685	107.2	111.5
B 100 ppm	16.8	16.9	14.8	14.9	0.622	0.614	117.3	119.2
B 150 ppm	17.1	17.2	15.2	15.6	0.611	0.601	121.5	126.3
K Citrate 0.5% + B 50 ppm	17.8	17.9	15.9	16.4	0.556	0.543	123.3	128.4
K Citrate 1.0% + B 100 ppm	18.2	18.4	16.3	16.8	0.542	0.529	138.3	141.1
K Citrate 1.5% + B 150 ppm	18.4	18.6	16.4	16.9	0.529	0.521	146.5	152.6
Mean	**17.2**	**17.4**	**15.3**	**15.6**	**0.614**	**0.607**	**122.3**	**126.7**
New LSD at 5%	**0..3**	**0.4**	**0.2**	**0.4**	**0.043**	**0.051**	**6.5**	**7.1**

Spraying Potassium has been reported to accelerate berry maturation, and increase total soluble solids concentration as well as improve berry coloration, in colored cultivars. **Khayyat *et al.* (2007)** reported that spraying potassium enhanced soluble solids concentration and improved berry color in several table grape cultivars. Although berry weight slightly decreased in some treatments due to enhanced water loss, the overall cluster quality and marketability were significantly improved

(**Wallingford, 1990**). In grapevines, potassium accumulation is especially important during berry ripening (**Reynier, 2000)**. Adequate potassium nutrition improves berry size, sugar accumulation, color development, and acidity balance (**Keller, 2015**). Potassium plays a vital role in determining the chemical composition of grape berries. **Zhang *et al.* (2023)** reported that potassium application significantly increased total soluble solids and sugar accumulation by enhancing carbohydrate metabolism. Potassium fertilization affects juice pH and acidity levels (**Marcuzzo *et al.*, 2021**). While, potassium reduces titratable acidity, excessive levels may increase juice pH, which can negatively impact wine quality. Potassium improves the balance between sugars and organic acids, resulting in better flavor and fruit quality (**Hu *et al.*, 2023**). **Villette *et al.* (2020)** highlighted that potassium influences secondary metabolites such as phenolic compounds, which contribute to flavor, color, and antioxidant properties of grape berries.

4. Conclusion

The obtained results indicated that foliar spraying of Potassium and Boron played a vital role in improving berries physical and chemical properties of Crimson Seedless grape. Moreover, the combined application with Potassium and Boron surpassed the individual application of each one. In order to improve the berry physicochemical properties, it is recommended to spray potassium citrate at 1.5% and Boric acid at 150 ppm in combination, three times yearly,

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