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Effect of Different Levels of Cluster Tipping On Quality Characteristics and Phenolic Composition in Crimson Seedless Grape Variety

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Abstract

In table grapes, berry size, homogeneous colour, and medium-dense cluster structure are desirable characteristics. However, the Crimson Seedless grape variety has late maturity small berry size, and poor colour. The study aimed to apply different levels of technical applications to the vines to achieve the desired quality of this table grape variety and it was used completely randomized block design with three replicates for each treatment, and six vines in each replication. Treatments were made as control (C), 1/5 (A1), 1/3 (A2), and 1/2 (A3) cluster tipping (CT). As a result, the grape variety was affected by both vintage averages effect of different rates of CT applied in both years on some quality characteristics and the phenolic composition of the Crimson Seedless grape variety was found to be statistically significant ($p<0.05$). According to the findings, treatments A1 and A2 for CT were more efficient than the control in enhancing cluster features, berry diameter, and berry quality. Organic acids in both years, the highest values of tartaric acid and malic acid were found in the control and A1 treatments, while the lowest values were found in the A2 and A3 treatments. On the other hand, CT treatments increased as the average peonidin-3-glucoside by 48.58%, malvidin-3-glucoside by 20.54%, cyanidin-3-glucoside content by 15.98 %, delphinidin-3-glucoside by 7.85%, and petunidin-3-glucoside by 7.48 % in both years.

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1. Introduction

Turkiye's most important viticulture region in cultivating table grapes is the Gediz basin, which covers Sarıgöl/Manisa zone. Grape production in Turkiye is realized in an area of 400,778 ha. with 5.65% of the world's grape production area. Turkiye ranks 5th in the world in grape production area. Manisa ranks first in Türkiye with 28% of the total vineyard area and 45% of the grape production, and Sarıgöl is one of the districts where table grape production and trade is widespread. Sarıgöl has 11,590 hectares of vineyard area and produces 125,415 tons of fresh grapes (Anonymous, 2022). In general, Sultana Seedless, Red Globe, Mevlana, Superior Seedless, Trakya Ilkeren, and Antep Karası varieties are dominant in the region, and the cultivation of the Crimson Seedless grape variety has been increasing rapidly in recent years. When it comes to table grapes, consumers are primarily influenced by the variety and their appearance. Özer et al. (2012), according to the findings of the research on the influence of cluster thinning applications on Reçel grapes, found that applications increased the size of the berry and the attractiveness of the clusters, the density of the clusters, and the colour homogeneity of the berry. Piernas et al. (2022) and Choi et al. (2023) explained that for table grapes to be of good quality, they should have medium-sized clusters with characteristic colours and pleasant flavours, equal size, and excellent berries.

Various cultural practices and technical procedures such as canopy management, cluster tipping, berry thinning, girdling, and the use of growth regulators are applied to develop grape features in table grape cultivation. Thinning is a technical treatment that doesn't require specialized skills to improve the quality of vines and regulate their yield. This involves manually eliminating flowers or berries from clusters after the fruit set, which can increase the size and weight of the remaining fruit, leading to better quality. Asmaa et al. (2020), in their study on the Ruby Seedless grape variety, reported that they obtained large-berry and homogeneous clusters by removing some clusters and explained the reason for this as an increase in the amount of leaf area per unit yield. Thinning clusters is a technique to achieve larger berries, higher berry weight, and faster ripening. This means that reducing the number of grape clusters on a vine directly affects the balance between yield and quality. As a result, the production of assimilates is improved and leads to an increase in grape superiority (Nan et al., 2023). Numerous studies have been conducted on the quality of table grapes. These studies have explored different factors such as colour characteristics (Lutzt et al., 2011), cultural practices (Jayasana et al., 2008), chemical parameters, and phenolic composition (Sing Brar et al., 2008; Baiano et al., 2011; Lutz et al., 2011), protein content and enzymatic activities (López-Miranda et al., 2011), post-harvest storage conditions, and packaging atmosphere and materials (Rolle et al., 2011). Crimson seedless grape variety has late maturity and small berry size and red colour. However, there is not enough research on Crimson Seedless, which has been used as a late variety in recent years and its production is increasing day by day.

The study aimed to examine how varying degrees of clusters tipping (1/5, 1/3, and 1/2 cm) impact the phenolic composition, cluster, and berry characteristics of the Crimson Seedless grape variety.

2. Materials and Methods

2.1. Location and plant material

The study was conducted in 2021 and 2022 in a producer vineyard where the Crimson Seedless grape variety was grown in Sarıgöl district, Manisa /Turkiye [38°10' 24.2" N 28°38' 42.6" E]. The research vineyard is ten years old, the implanting spaces were 3.0 m between the rows and 2.0 m on the row and trained onto a big "Y" trellis system. During winter pruning (mid-February) the vines were cane pruned and 6 canes with 15 buds each were left for cv. Crimson Seedless.

2.2. Field treatments

The experimental design was planned as completely randomized block with three replicates for each treatment. There were six vines in each replication. Cluster tipping (CT) processes applied to grapes at the berry-set stage (when the berry diameter is 2-3 cm). The treatments with scissors were made as follows,

1. C, control (no treatment)

2. A1, 1/5 cluster tipping (berry thinning, 20% of berries removed per cluster)

3. A2, 1/3 cluster tipping

4. A3, 1/2 cluster tipping

2.3. Morphological traits

On September 21st, the grapes were harvested when the berry colour turned red and was evenly distributed in 90-95% of the clusters in two consecutive years. Six vines were randomly selected, and from each, ten clusters were taken and weighed. The average weight (g), length (cm), and width (cm) of the clusters were measured using a digit-meter instrument. For each cluster, 12 berries were randomly picked from the top, center, and tip. The weight (g), length (mm), and diameter (mm) of each berry were determined using digital calliper with in 0.01 accuracy using the fresh berries.

2.4. Extraction

At harvest, the following extracts were prepared and analyzed by extracting the must of berries collected randomly from the clusters of six vines in each replicate. The soluble solid content (SSC) of juices was measured using a handheld refractometer (Atago, Japan) and expressed as ^{o}Brix. The titratable acidity (TA) was measured by titrating 10 mL juice with 0.1N NaOH to pH 8.1 and expressed as tartaric acid g L^{-1}. The pH of grape juices was found using a pH meter (MP220, Switzerland). Berry firmness was determined using a digital penetrometer with a 2 mm needle FM200 (Rolle et al., 2011). The compactness of the clusters was observed on a scale of 1 (very loose) to 5 (very compact) according to Çelik (1998).

2.5. Organic acid

To prepare for high-performance liquid chromatography (HPLC), we followed a modified method by Bevilacqua and Califano (1989) to extract organic acids from 100g of berries. First, we crushed the berries with a Heidolph SilentCrusher M (Germany), then homogenized 7g of the skin and pulp with 50mL of 0.009N H2SO4 using an A-10 Analytical Mill (Tekmar Ohio, USA). Next, we shook the samples using a Heidolph Unimax 1010 (Germany) for an hour before centrifuging them at 7000 g for 5 minutes with a Hettich Zentrifugen Universal 32 R (Germany). Afterward, we passed the supernatant through a filter once and then twice through a 0.45 μm membrane filter (Millipore Millex-HV Hydrophilic PVDF, USA). The standard solutions were prepared individually in different concentrations with double distilled water. Organic acids (l-tartaric, l-malic, citric, fumaric, and succinic) were obtained from Sigma (St. Louis, USA).

2.5.1. HPLC conditions

The modified method (Bevilacqua et al., 1983; Perez-Ruiz et al., 2004) was used to extract organic acids. The system was controlled with the Agilent package program and a column of Aminex HPX - 87 H, 300 mm × 7.8 mm (Bio-Rad Laboratories, Richmond, USA) was used. The Photodiode array detector was set to 214 and 280 nm wavelength. A mobile phase of 0.009 N H2SO4 was filtered through a 0.45 μm membrane at a flow rate of 1 mL min^{-1} to analyze organic acids. The acid amounts were determined by measuring peak areas with external standards and expressed as mg g^{-1}. For the analysis, a high-performance liquid chromatography system (LC-10Avp; Shimadzu, Kyoto, Japan) was used.

2.6. Phenolic composition

A modified version of the Di Stefano and Cravero (1991) method was used to analyzed the phenolic composition of berry skin. The skins were peeled and ground into a fine powder with liquid nitrogen. Then, skin powders (0.1g) were extracted in 30 mL of HCl-methanol (1:99, v:v) solution for 24 hours in the dark. The extraction solution (1 mL) was added to 3 mL of potassium chloride buffer (0.025 mmol L^{-1}, pH 1.0) and 3 mL of sodium acetate buffer (0.4 mmol L^{-1}, pH 4.5), respectively. The solutions were then macerated at room temperature for 20 minutes. Absorbance was measured at 520 and 680 nm using a spectrophotometer (UV1901P, Phenix, China). The data collected were analyzed using SPSS software (version 20.0; SPSS Inc., USA). The means were compared using ANOVA variance analysis and evaluated with Tukey's Test to determine any differences.

3. Results and Discussion

3.1. Influence of different CT levels on cluster and berry features

The effect of various CT levels on the characteristics of clusters and berries in the Crimson Seedless grape variety was analyzed and found to be significant (Table 1). The highest cluster weight value was observed in A2-treated vines (744.10 g vine^{-1}, group a), while the lowest weight value was observed in untreated control vines (700 g vine^{-1}, group b). The increase in weight between the two vintages was found to be 5.83%. These results are consistent with previous studies by Özer et al. (2012) and Asmaa et al. (2020), which found that removing a portion of the cluster resulted in a slight increase in weight. Furthermore, in our study, treated vines consistently had clusters with a higher average weight than the control.

Table 1. Effect of different cluster tipping levels on characteristics of clusters

	Cluster weight (g)			Cluster length (cm)			Cluster width (cm)			Num. berries of cluster			Cluster Compactness		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
C	703.00b	710.20b	706.6b	25.30a	28.90a	27.1a	13.80c	12.35b	13.0b	152.82a	186.89a	169.85a	4.04a	4.46a	4.25a
A1	713.10b	743.70a	728.4a	22.45b	26.30b	24.3b	14.60b	11.90b	13.2b	141.76a	170.21a	155.98b	3.46b	3.46b	3.46b
A2	730.80a	758.30a	744.1a	21.10bc	22.25c	21.6c	15.40b	14.71a	15.0a	110.51b	115.32b	112.91c	3.23b	3.18b	3.20b
A3	715.50a	705.70a	710.1ab	19.85c	21.10c	20.4c	19.10a	14.35a	16.7a	100.40b	98.50b	99.45d	4.05a	4.66a	4.68a

a, b, c: Mean values followed by the same letter in each column are not significantly different (P>0.05)
C, control A1, 1/5 cluster tipping (berry thinning) A2, 1/3 cluster tipping A3, 1/2 cluster tipping

Table 1 shows that the control vines had the longest cluster length and the highest number of berries per cluster on average. However, the CT treatments at different levels (A1, A2, A3) significantly decreased the number of berries per cluster compared to the control, with the greatest reduction observed in CT treatments at A2 and A3. For two years, the number of berries per cluster was reduced by approximately 15.76 - 39.13% compared to the control. These results are consistent with previous studies on the effects of cluster-tipping practices in various grape varieties, such as those conducted by Dardeniz (2014), Fallahi et al. (2018) and Nan et al. (2023). Moreover, CT may have caused a decrease in the amount of berries in each cluster, but it has resulted in a slight increase in the average weight of each cluster per vine. These results are in line with the study conducted by Belal et al. (2016), who noted that the thinning of grape clusters tended to lead to a higher average weight of clusters for Merlot and Cabernet Sauvignon grapes.

The effect of CT treatments on cluster compactness is significant. Specifically, treatments A2, A3, and cluster tipping resulted in a lower number of grape berries per cluster compared to the control group. This suggests a slight decrease in cluster compactness and a medium-density homogeneous cluster structure, which ultimately leads to an increase in the number of marketable grapes. Several other researchers have supported these findings in their studies, citing how CT treatments remove the living parts of the vine and concentrate their activities on the remaining parts, thereby preventing cluster compactness (Çelik, 1998; Han et al., 2019; Xi et al., 2020). Dardeniz (2014) reported similar results, noting that removing the tip of the cluster during berry thinning reduces the number of berries in the cluster and subsequently decreases its compactness.

The results of Table 2 showed that all CT treatments resulted in higher berry weight and diameter values than the control. Specifically, A1, A2, and A3 treatments had a more significant effect, increasing average berry weight, diameter, length, and firmness compared to A3 or untreated vines. These treatments increased the average berry weight by approximately 19.26-22.36% compared to the control. The mean berry diameter, length, and firmness were similarly affected. It was observed that CT treatments caused an increase in average berry diameter and length compared to the control. A2 CT treatment had the highest impact, producing the highest berry diameter, length, and firmness in both seasons of the study, with an increase of about 4.39-6.43%, 5.14-5.08%, and 3.05-13.88%, respectively, compared to the control.

Table 2. Effect of different cluster tipping levels on characteristics of berry weight

	Berry weight (g)			Berry length (mm)			Berry diameter (mm)			Firmness (g cm^{-2})		
	2021	2022	M*.	2021	2022	M	2021	2022	M	2021	2022	M
C	4.1±0.48	3.8±0.5 b	3.95c	13.5±0.9b	13.5±0.9 b	13.5bc	12.4a	12.7 b	12.4ab	360b	398b	379b
A1	4.7±0.3a	4.1±0.4 b	4.40b	13.8±0.9a	14.0±0.8a	13.9b	13.0a	13.0 a	13.0a	377b	401b	389b
A2	4.8±0.2 a	4.6±0.4 a	4.70a	14.1±1.1a	14.2±1.2 a	14.1a	13.2a	13.2 a	13.2a	410a	430a	420a
A3	4.8±0.4 a	4.4±0.3 a	4.60b	13.9±1.0a	14.0±0.9 a	13.9b	12.2b	13.0 a	12.6b	408a	412a	410a

a, b, c, d: Mean* (means ± SEM) values followed by the same letter in each column are not significantly different ($P>0.05$)
C, control A1, 1/5 cluster tipping (berry thinning) A2, 1/3 cluster tipping A3, 1/2 cluster tipping

The growth of berries can be attributed to the impact of CT treatments, which altered the ratio of leaves to fruit and lessened the competition among the remaining fruits for assimilates. As per Dardeniz (2014) and Uslu and Cardinal grape cultivars, the results of Asma et al. (2020) on Ruby seedless grape cultivars showed that there was an increase in fruit weight and diameter based on the rate of cluster thinning.

3.2. Influence of different CT levels on SSC (Brix), TA (g L^{-1}), pH, and ripeness index

The Crimson Seedless variety was subjected to different levels of CT, and the effect on SSC, TA, pH, and ripeness index was significant over two years, as shown in Table 3. However, pH was found to be insignificant in both years. The A2 and A3 treatments yielded the highest values for SSC, while the control had the lowest values. In other words, the CT treatments had a positive impact on SSC, resulting in higher values as compared to the untreated clusters, on average, over the two vintages. The data in the same table show that CT treatment has an opposite effect on TA compared to its effect on SSC in the juice. Specifically, CT treatment levels A2 and A3 resulted in lower TA values in the juice, while CT A1 treatment and the control group gave higher TA values (as shown in Table 3). This is consistent with the findings of Xi et al. (2020) in the local cultivar 'Jumeigui' and Nan et al. (2023) in two different cultivars, who reported that different levels of cluster tipping treatments significantly increased SSC value in grapes as the rate increased, while significantly reducing the TA of the cultivars when compared to untreated vines. Our study aligns with these findings.

Table 3. Effect of different cluster tipping levels on SSC (°Brix), TA (g L^{-1}), maturity index, and pH

	SSC (°Brix)			TA (g L^{-1})			maturity index			pH	
	2021	2022	mean	2021	2022	mean	2021	2022	mean	-21	-22
C	18.0±0.2b	19.2±0.1b	18.6 b	6.18±0.15a	5.98±0.18a	6.08 a	29.2±1.80b	32.1±0.95b	30.6 c	3.7	3.7
A1	18.1±0.6b	19.3±0.3a	18.6 b	5.75±0.11a	5.78±0.06a	5.75 b	31.5±1.15b	33.4±1.50b	32.4 b	3.8	3.8
A2	18.7±0.8a	19.5±0.5a	19.1 a	5.55±0.05b	5.40±0.50b	5.47 c	33.7±0.98a	34.0±1.24a	33.8 b	3.9	3.8
A3	18.9±0.4a	19.7±0.7a	19.3 a	5.40±0.13b	5.40±0.10b	5.40 c	35.0±1.50a	36.1±1.65a	35.5 a	3.9	3.8
$LSD_{0.05}$	-	-	-	-	-	-	-			ns	ns

a, b, c: Mean values (means ± SEM) followed by the same letter in each column are not significantly different (P>0.05) ns: non-significant
C, control A1, 1/5 cluster tipping (berry thinning) A2, 1/3 cluster tipping A3, 1/2 cluster tipping

The ratio of SSC/TA in fruit shows a similar pattern to that of grapes in both years studied. This is likely due to the cluster rotation increasing the SSC value in the grape juice while decreasing the TA levels, as shown in Table 3. Additionally, decreasing the amount of berries per cluster, without changing the number of leaves, reduces competition among the berries for essential materials. Therefore, it can be inferred that the cluster tipping treatments were successful in promoting carbohydrate accumulation, which activates growth and development, resulting in increased berry weight and faster ripening. Guadino et al. (2002) and Sabır et al. (2010) found that increasing cluster tipping in 'Nebbiolo' grape and five different grape cultivars, respectively, resulted in a higher ripeness index. This was attributed to the source/sink ratio. Our study supports these findings, as do studies by Da Mota et al. (2010), and Keskin et al. (2013). They also reported that cluster tipping can increase SSC and ripeness index while decreasing TA.

3.3. Influence of different CT levels on organic acids (mg g^{-1})

Table 4 presents the organic acid contents of grapevines that were grown organically and subjected to different levels of cluster tipping. The results show that the treatments had a significant effect ($p<0.05$) on the tartaric and malic acid of the Crimson Seedless variety at various CT levels in both years. However, citric acid, fumaric acid, and succinic acid showed no significance ($p>0.05$) in either year.

Table 4. Effect of different cluster tipping levels on Organic acids (mg g^{-1})

Organic acids (mg g^{-1})										
		2021	2022	Mean			2021	2022	Mean	$LSD_{0.05}$
Tartaric	**C**	4.98±0.90 a	5.10±0.92a	5.04±0.91a	Citric	**C**	0.44±0.10	0.40±0.10	0.42±0.05	ns
	A1	4.65±0.50 a	4.85±0.10a	4.75±0.75b		**A1**	0.39±0.00	0.37±0.05	0.38±0.10	
	A2	4.41±021 a	4.55±0.15a	4.48±0.17b		**A2**	0.39±0.10	0.36±0.10	0.37±0.15	
	A3	4.10±0.12a	4.15±0.13a	4.12±0.12c		**A3**	0.30±0.00	0.30±0.05	0.30±0.05	
Malik	**C**	2.10±0.20 a	1.98±0.05a	2.04±0.22a	Fumaric	**C**	0.25±0.05	0.26±0.05	0.25±0.00	ns
	A1	2.00±0.18 a	1.94±0.10a	1.97±1.86a		**A1**	0.17±0.00	0.22±0.10	0.19±0.00	
	A2	1.81±0.10 b	1.78±0.15b	1.79±0.12b		**A2**	0.22±0.00	0.19±0.00	0.19±0.00	
	A3	1.90±0.05 b	1.72±0.10b	1.81±0.75b		**A3**	0.27±0.05	0.25±0.05	0.26±0.10	
					Succinic	**C**	0.20±0.05	0.22±0.05	0.21±0.05	ns
						A1	0.22±0.05	0.19±0.05	0.20±0.05	
		-	-	-		**A2**	0.24±0.10	0.26±0.08	0.25±0.09	
						A3	0.25±0.10	0.28±0.10	0.26±0.10	

a, b, c: Mean values (means ± SEM) followed by the same letter in each column are not significantly different (P>0.05) ns: non-significant
C, control A1, 1/5 cluster tipping (berry thinning) A2, 1/3 cluster tipping A3, 1/2 cluster tipping

The organic acid content varied based on the treatments. Vines under A1 and control treatments had the highest levels of tartaric acid (4.65-4.98) and malic acid (1.95-2.01), respectively. However, the lowest values of tartaric and malic acid were found in A3 treatments (Table 4). Citric acid, fumaric acid, and succinic acid values ranged between (0.26-0.40; 0.22-0.27, and 0.21-0.26) in the CT treatments, respectively. Several studies, including those conducted by Lopez et al. (2011) and Keskin et al. (2013), have examined grapes grown using conventional cultivation methods. López-Tamames et al. (2011) discovered that citric and malic, acids were influenced by climate. Sabır et al. (2010) reported that ripe grape cultivars had significantly lower malic acid content compared to tartaric acid content. In contrast, Da Mota et al. (2010) found no effect on the tartaric, citric, and malic acids in 'Cabernet Sauvignon' from cluster thinning in the no-shoot trimmed vines. Previous research by Conte et al. (2012) and Melino et al. (2009) confirmed that malic acid, which serves as an energy source during the ripening stage, is present in lower quantities compared to tartaric acid. These studies also suggest that malic and tartaric acids constitute the majority of the total acidity in berries (Sweetman et al., 2009).

3.4. Influence of different CT levels on phenolic composition (mg kg^{-1})

Crimson Seedless Grape showed a significant difference ($p<0.05$) in anthocyanin content (mg kg^{-1}) when treated at varying CT levels in both 2021 and 2022. The highest levels of total anthocyanins and 3-mono glucoside anthocyanins were found in treatments A2, A1, and A3, respectively, while the lowest levels were observed in the control group for both years (Table 5). This means that untreated clusters had lower levels of total anthocyanins and 3-monoglucoside anthocyanins compared to those treated with CT, on average across both vintages. The treatments A3, A1, and A2 produced the highest levels of delphinidin, cyanidin, petunidin, and malvidin (free anthocyanins), while the lowest levels were found in the control group for both years. Peonidin content was highest in treatments A2, A1, and A3 in 2021, and A2, A3, and A1 in 2022.

Table 5. Effect of different cluster tipping levels on the anthocyanin composition (mg kg^{-1})

	2021				2022			
	C	A1	A2	A3	C	A1	A2	A3
Total anthocyanins mg kg^{-1}	1610.2 c	1820.5 b	2010.3 a	1805.2 b	1640.2 c	1805.1 b	1950.1 a	1780.5 b
3-monoglucoside anthocyanins mg kg-^{1}	1095.2 c	1630.1 b	1760.1 a	1450.5 bc	1245.3 d	1605.3 b	1720.5 a	1420.1 c
Delphinidin	86.23 b	84.25 b	77.85 c	90.23 a	87.35 b	82.42 c	75.23 d	91.42 a
Cyanidin	175.34 c	185.65 b	184.30 b	190.30 a	174.12 c	182.31 bc	187.15 b	191.42 a
Petunidin	82.54 b	84.45 b	79.43 c	90.25 a	80.50 b	84.00 b	77.27 c	92.15 a
Peonidin	532.75 c	650.86 b	780.25 a	624.65 b	535.34 c	649.10 b	784.45 a	623.40 b
Malvidin	225.24 b	205.34 b	220.21 b	250.10 a	234.18 bc	250.25 b	285.00 a	235.32 b

a, b, c, d: Values followed by the same letter in each line are not significantly different (P>0.05)
C, control A1, 1/5 cluster tipping (berry thinning) A2, 1/3 cluster tipping A3, 1/2 cluster tipping

In both years, the grapes from the control vines had the lowest peonidin content, as shown in Table 5. The data indicates that applying CT at A1, A2, and A3 resulted in higher total sugar and anthocyanin levels compared to vines without treatment. This difference can be attributed to various climatic factors, including the CT ratio, application time, and temperature during the vegetation period. Sugars are the primary source of anthocyanin synthesis, which is why these findings are in line with previous studies conducted by Guidoni et al. (2002), and Kök (2016) who also presented similar views in their research. The study found that reducing the number of berries in a cluster led to an increase in sugar and a decrease in acid content in the berries. It was also determined that clusters with larger berries had a more compact structure when at medium density. These findings are consistent with previous studies conducted on different types of grapes, such as the research by Guidini et al. (2002) and Xi et al. (2020) which showed that sugar content can affect flavonoid accumulation in grape berries. Additionally, Colombo et al. (2019) found that regulating the source/sink ratio with CT is a common method for increasing the accumulation of secondary metabolites.

In the Crimson Seedless table grape variety, the primary anthocyanins formed are cyanidin-based, particularly the methoxylated forms of peonidin-3-mono glucoside and malvidin-3-mono glucoside. These anthocyanin levels were observed to increase with different levels of CT treatments. Additionally, CT treatments were found to enhance the accumulation of peonidin-3-glucoside and malvidin-3-glucoside in the berry skin during ripening. These findings align with previous studies conducted by Profio et al. (2011), Xi et al. (2020), and Nan et al. (2023).

4. Conclusion

Based on the findings of the study, it has been concluded that various treatments employed in the research have a significant impact on the physical and chemical characteristics of grapes. Specifically, the practice of cluster tipping has been proven to be effective for table grape growers who aim to produce visually appealing, moderately dense, and large-berried clusters, resulting in a profitable production with high market value. This technique is particularly important for organic table grape cultivation. Overall, the research indicates that A2 is the optimal method for achieving the desired outcomes. A2 treatment can be recommended for producers of Crimson Seedless Table grapes.

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