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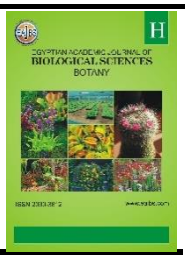

Effect of some Pre-Harvest Treatments on Quality of ″Crimson Seedless″ Grapes During Cold Storage and Shelf Life

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ABSTRACT

This work was carried out during two successive seasons (2017 and 2018) to examine the response of ″Crimson Seedless″ grapes to some pre-harvest treatments i.e. jasmonic acid (JA) at (4 and 8) mM/L and grapefruit seed extract (GSE) at (0.5 and 1) mM/L on some berries quality parameters under cold storage and shelf-life conditions. Vines were sprayed in two application times at (25^{th} and 30^{th} August) during 2017 and 2018, respectively. The non-ionic surfactant Tween-20 at 0.05% (v/v) was added to all treatments to reduce the surface tension and increase the contact angle of sprayed droplets. Results showed that both jasmonic acid and grapefruit seed extract treatments at different concentrations were significantly effective in reducing weight loss, berry decay, berry shatter, and total loss in cluster weight percentages during the cold storage period and shelf life as compared to the control. Also, the previous treatments significantly increased berry firmness, soluble solid content (SSC%), SSC/acid ratio, and total anthocyanin contents, where it was caused a significant decrease in total acidity percentage during the cold storage period and shelf life in comparison with control.

Furthermore, the lowest values of weight loss, berry shatter, berry decay and total loss in cluster weight were founded by JA at 8 mM and GSE at 1 mM at the end of shelf life in comparison with other treatments. It could be concluded that JA at 8 mM and GSE at 1 mM as preharvest treatments are applicable for improving the storability of ″Crimson Seedless″ grapes and maintaining their quality during cold storage and shelf life.

INTRODUCTION

Grapevine (*Vitis vinifera*, L) is one of the most important fruit crops grown in the world. The cultivated area of grapevine in Egypt recently increased since it reached about 77895 hectares producing 218678 tons according to FAO (2017). "Crimson Seedless" cultivar is a late-season, attractive, red seedless grape cultivar with firm berries. ″Crimson Seedless″ grape, also, has superior eating characteristics, berry texture firm and crisp, and its flavor is excellent (Dokoozlian and Peacock, 2001).

Table grape is one of the moderately susceptible fruits to decay and subject to serious water loss during postharvest handling, rachis browning, which occurs as a consequence of water loss (Crisosto *et al.*, 2001). However, postharvest life of table grapes is relatively short due to water loss, skin browning, rachis dehydration and browning, berry shatter, and fungal

decay. In this respect, gray mold (*Botrytis cinerea*) is the most postharvest disease of table grapes, especially in late season. Previously, using SO_2 during cold storage as a fumigant or generator is the most universal method to control fungal decay and also to maintain the table grape quality (Gao *et al.,* 2003). Although SO_2 excellently controls fungal decay and prevents rachis browning, its residues are toxic and dangerous to human health. Recently, grapefruit seed extract (GSE) is a commercial product derived from the seeds and pulp of grapefruit (*Citrus paradisi* Macf. Rutaceae). GSE is an effective broad-spectrum bactericide (Coombe, 1989; Reagor *et al.,* 2002; Lee *et al.,* 2005), fungicide (Heggers *et al.,* 2002), and antiviral and antiparasitic (Ionescu *et al.,* 1990; Tirillini, 2000) natural extract. GSE is also, environmentally safe without toxicity to humans or animals at effective concentrations. Ionescu *et al.* (1990) demonstrated that GSE performed as well as other antimicrobial agents tested on 770 strains of bacteria, and 93 strains of fungus. Inhibitory activity of GSE on yeast and some yeast-like fungi showed different efficacy depending on the strains and was generally weaker than that on bacteria and fungi (Ionescu *et al.,* 1990). The safety of GSE has been tested in several areas, with Heggers *et al.* (2002) showing that GSE was not detrimental to human fibroblast skin cells in vitro, while still retaining high antimicrobial activity.

Furthermore, jasmonic acid and its volatile methyl ester, methyl jasmonate (MeJA), are a class of cyclopentanone compounds regarded as endogenous regulators that play an important role in regulating the stress response, plant growth, and development (Creelman and Mullet, 1997). Furthermore, MeJA has been applied to reduce the development of chilling injury symptoms on mango (Gonzalez-Aguilar *et al.,* 2000). Moreover, MeJA has been shown to reduce decay and maintain the postharvest quality of papayas (Gonzalez-Aguilar *et al.,* 2003). In raspberry, Wang and lin (2000) demonstrated that MJ increased the resistance of tissues against decay by enhancing their antioxidant system and their free radical scavenging capability and there is a positive correlation between antioxidant activity and total phenolic or anthocyanin content.

Therefore, the objectives of this study reported here were to study the effect of pre-harvest spraying of jasmonic acid and grapefruit seed extract on the quality of ″Crimson Seedless″ grapes during cold storage and shelf life.

MATERIALS AND METHODS

Plant Materials and Experimental Procedure:

The present experiment was conducted during the two successive seasons 2017 and 2018 on 7-year old ″Crimson Seedless″ grapevines grown in sandy soil, spaced at 4×4m and trained according to cane pruning system, under drip irrigation system in a private orchard at El-Nubaria region, El-Behira governorate, Egypt. All vines received the recommended regular fertilizer and other horticulture practices. Forty-five vines of nearly similar vigor and bud load were chosen for the spraying applications according to a completely randomized block design with three replicates each one was represented by three vines.

Preparing of Grapefruit Seed Extract:

Self-made ethanolic extract of Citrus paradisi Mecf. (Rutaceae) was prepared from commercially available grapefruits. Air-dried powdered plant material (juiceless pulp and seeds, in quantitative ratio 4:1) was extracted with 70% ethanol in a Soxhlet apparatus for 6 h. After cooling, the solvent was removed using a rotary evaporator and dry residue was chemically analysed. For microbiological test, 33% (m/v) extract was prepared using 70% ethanol.

Treatment of Table Grape Clusters:

Treatments included water as the control, jasmonic acid (JA) at (4 and 8) mM/L, grapefruit seed extract (GSE) at (0.5 and 1) mM/L. Vines were sprayed in two application times at (25th and 30th August) during 2017 and 2018, respectively. The non-ionic surfactant Tween-20 at 0.05% (v/v) was added to all treatments to reduce the surface tension and increase the contact angle of sprayed droplets.

Harvest date was carried out on the 15th of September during 2017 and 2018 seasons when berries reached full colour and soluble solids content in berry juice were about 16-18%, from vines received common horticultural practices, undamaged berries, free from any obvious pathogen infection and the existence of healthy greenish rachis, then transported to the laboratory. Clusters were sorted to remove any infected and damaged berries.

Storage Conditions:

At the beginning of the experiment, samples of 12 clusters per treatment were taken to determine the initial berry and cluster properties, then 60 clusters were randomly divided into five groups, and then each cluster packed using ventilated bags. All bags with clusters were weighted and every four bags were put in a ventilated box (50x30x12) cm. After treatments, carton boxes were taken and stored under cold storage at 0°C and 90-95% relative humidity (R.H.) for 60 days followed by 3 days shelf life at (20°C and 75% RH). The treated clusters were evaluated in each treatment at 0, 30, 60, and 60+3 days of treatment.

Determination of Physical and Chemical Properties:

1. Cluster weight loss (%): It was calculated according to the following equation:

$$\text{Cluster weight loss \%} = \frac{\text{Initial weight} - \text{Weight at sampling date}}{\text{Initial weight}} \times 100$$

2.Berry Shatter (%): It was determined according to the following equation:

$$\text{Berry shatter \%} = \frac{\text{Weight of berry shatter}}{\text{Initial weight}} \times 100$$

3. Berry Decay (%): It was calculated according to the following equation:

$$\text{Berry decay \%} = \frac{\text{Weight of decayed berries}}{\text{Initial weight}} \times 100$$

4. Total Loss (%): It was calculated according to the following equation:

Total loss % = Cluster weight loss (%) + Berry shatter (%) + Berry decay (%)

5. Berry Firmness (Newton):

Berry firmness was measured on 10 berries for each replicate were taken randomly for each treatment to determine berry firmness and the results were expressed as Newton's units. Berry firmness was determined by using PHSH-Pull (Dynamometer Model DT 101(with 3/16 inch plunger).

6. Soluble Solids Content (SSC%), Titratable Acidity (TA%) and SSC/Acid Ratio:

Soluble solids content in berry juice was measured as Brix% by using a digital refractometer (Model BX-1 and Brix 0-32%). Ten ml of berry juice was titrated against 0.1 N sodium hydroxide solution using phenolphthalein as an indicator. Total acidity was expressed as gram tartaric acid/100 ml juice according to (A.O.A.C., 1980). SSC/acid ratio was calculated from the results recorded from juice SSC and titratable acidity.

7. Total Anthocyanin Content:

Total anthocyanin content was measured according to (Mazumdar and Majumder, 2003) by extracting half a gram of fresh berry skin in 10 mL of ethanolic hydrochloric acid 1.5 N. Samples put overnight at 40oC then centrifuged for 3 min and filtered through filter paper (Whatman No.1). The filtered aliquot was maintained in darkness for about 2 h with

the cover of the container. The optical density (OD) value of the solution was measured through 535 nm wavelength in a spectrophotometer against blank. The amount of total anthocyanin in berry skin was calculated using the following equations:

$$\textbf{Total absorbance value for the berry skin (per 100g)} = \frac{e.\ b.\ a}{d.\ a}$$

Where:
a= Weight of sample
b= Volume made for color measurement
c= Total volume made
d= Volume of aliquot taken for estimation
e= Specific OD value at 535 nm wavelength.
The 1 mg mL^{-1} of the solution is equivalent to the absorbance of 98.2. Therefore, the amount of total anthocyanin present in the sample (mg/100g) = Total absorbance for the sample /98.2.

Experimental Design and Statistical Analysis:

Data of the present study were subjected to the analysis of variance test (ANOVA) as Randomized Complete Block Design (RCBD). Where the first factor was for the five treatments mentioned before, the second factor was for the storage period. The least significant differences (LSD) at the 5% level of probability were calculated using a computer program SAS according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Cluster Weight Loss, Berry Shatter, Berry Decay, and Total Loss Percentage:

Results of the present investigation, presented in Tables (1, 2, 3 and 4) showed the effect of preharvest spraying of jasmonic acid and grapefruit seed extract during cold storage on cluster weight loss, berry shatter, berry decay and total loss percentages of ″Crimson Seedless″ grape in 2017 and 2018 seasons. Data showed that previous parameters increased with increasing storage periods, and the differences among all tested storage periods were statistically significant compared with the initial date in the two seasons of study.

In addition, jasmonic acid and grapefruit seed extract treatments at all concentrations significantly decreased cluster weight loss, berry shatter, berry decay, and total loss percentages during cold storage periods as compared to the control, except for cluster weight loss parameter, where, JA at 4 mM/L and GSE at 0.5 mM/L in the second season and the differences were not big enough to be significant. Furthermore, the treatments of jasmonic acid at 8 mM/L and grapefruit seed extract at 1 mM/L were more effective on decreasing cluster weight loss, berry shatter, berry decay, and total loss percentages during cold storage periods as compared with other treatments. The antifungal action of GSE might largely rely on its effect on the fungal membranes, probably as a result of the ability of antifungal compounds in GSE to act as surfactants (physical disruption of the membrane). In another study, Ding *et al.* (2001) reported that methyl jasmonate induced the synthesis and expression of some stress proteins such as heat shock proteins which lead to increase the resistance of the pathogens and decreased incidence of decay. It is observed in strawberry that the suppression of fungus decay may be inducing the chemical defense mechanisms of plant tissues by low concentration jasmonate (Ayala-zavala *et al.,* 2005). These results are in harmony with those obtained by Wang and lin (2000) reported that jasmonic acid increased the resistance of tissues against decay by enhancing their antioxidant system and their free radical scavenging capability and there is a positive correlation between antioxidant activity and total phenolic or anthocyanin content. Jasmonates also, are

contributed in many important functions, including defense against insects and pathogens by inducing phytoalex in production, impunity, and plant growth, suggesting that they have critical roles in plant physiology (Avanci *et al.*, 2010).

Table 1: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on cluster weight loss percentage of ″Crimson Seedless″ grapes during cold storage in 2017 and 2018 seasons.

Treatments	1st Season				2nd Season			
	Storage Periods (Days)				Storage Periods (Days)			
	0	30	60	Mean	0	30	60	Mean
Control	0.00	2.98	5.03	**2.67**	0.00	3.18	5.20	**2.79**
JA at 4 mM/L	0.00	2.71	4.60	**2.44**	0.00	2.73	5.23	**2.65**
JA at 8 mM/L	0.00	2.50	4.37	**2.29**	0.00	2.48	4.37	**2.2**
GSE at 0.5 mM/L	0.00	2.89	4.68	**2.52**	0.00	2.83	5.29	**2.7**
GSE at 1 mM/L	0.00	2.58	4.55	**2.37**	0.00	2.57	4.48	**2.3**
Mean	**0.00**	**2.73**	**4.65**		**0.00**	**2.76**	**4.19**	
LSD at 0.05	**Treatments (T) = 0.06** **Storage Periods (D) = 0.05** **Interaction (T×D) = 0.10**				**Treatments (T) = 0.21** **Storage Periods (D) = 0.16** **Interaction (T×D) = 0.11**			

Table 2: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on berry shatter percentage of ″Crimson Seedless″ grapes during cold storage in 2017 and 2018 seasons.

Treatments	1st Season				2nd Season			
	Storage Periods (Days)				Storage Periods (Days)			
	0	30	60	Mean	0	30	60	Mean
Control	0.00	2.17	4.14	**2.10**	0.00	2.30	4.39	**2.23**
JA at 4 mM/L	0.00	0.79	2.13	**0.97**	0.00	0.82	2.19	**1.00**
JA at 8 mM/L	0.00	0.44	1.60	**0.68**	0.00	0.48	1.57	**0.68**
GSE at 0.5 mM/L	0.00	0.71	2.02	**0.91**	0.00	0.80	2.04	**0.95**
GSE at 1 mM/L	0.00	0.40	1.52	**0.64**	0.00	0.45	1.54	**0.66**
Mean	**0.00**	**0.90**	**2.28**		**0.00**	**0.97**	**2.35**	
LSD at 0.05	**Treatments (T) = 0.08** **Storage Periods (D) = 0.06** **Interaction (T×D) = 0.14**				**Treatments (T) = 0.05** **Storage Periods (D) = 0.04** **Interaction (T×D) = 0.09**			

In agreement with these results are those obtained by Bassem (2015) investigated the impact of postharvest on the quality of ″Crimson Seedless″ grapes by dipping in jasmonic acid (JA) solutions at 5, 10 mM for 5 minutes at 22°C during cold storage. The results showed that JA treatments at different concentrations were significantly effective in reducing weight loss, berry decay, berry shatter, and total loss in cluster weight percentages during cold storage period as compared to the control. Also, the previous treatments significantly reduced rachis browning during cold storage period in comparison with control. Furthermore, the lowest values of weight loss, berry shatter, berry decay, the total loss in cluster weight percentages, and rachis browning were presented by JA at 10 mM at the end of the storage period in comparison with other treatments.

Table 3: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on berry decay percentage of ″Crimson Seedless″ grapes during cold storage in 2017 and 2018 seasons.

Treatments	1st Season				2nd Season			
	Storage Periods (Days)				Storage Periods (Days)			
	0	30	60	Mean	0	30	60	Mean
Control	0.00	1.32	4.12	**1.81**	0.00	1.28	3.97	**1.75**
JA at 4 mM/L	0.00	0.71	2.45	**1.05**	0.00	0.68	2.43	**1.04**
JA at 8 mM/L	0.00	0.63	2.40	**1.01**	0.00	0.61	2.37	**0.99**
GSE at 0.5 mM/L	0.00	0.67	2.41	**1.03**	0.00	0.63	2.36	**1.00**
GSE at 1 mM/L	0.00	0.59	2.35	**0.98**	0.00	0.56	2.31	**0.96**
Mean	**0.00**	**0.79**	**2.74**		**0.00**	**0.75**	**2.69**	
LSD at 0.05	**Treatments (T) = 0.03** **Storage Periods (D) = 0.02** **Interaction (T×D) = 0.06**				**Treatments (T) = 0.01** **Storage Periods (D) = 0.01** **Interaction (T×D) = 0.02**			

Table 4: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on total loss percentage of ″Crimson Seedless″ grapes during cold storage in 2017 and 2018 seasons.

Treatments	1st Season				2nd Season			
	Storage Periods (Days)				Storage Periods (Days)			
	0	30	60	Mean	0	30	60	Mean
Control	0.00	6.47	13.29	**6.59**	0.00	6.76	13.55	**6.77**
JA at 4 mM/L	0.00	4.21	9.19	**4.47**	0.00	4.23	9.86	**4.36**
JA at 8 mM/L	0.00	3.57	8.37	**3.98**	0.00	3.57	8.31	**3.96**
GSE at 0.5 mM/L	0.00	4.27	9.10	**4.46**	0.00	4.26	9.69	**4.65**
GSE at 1 mM/L	0.00	3.57	8.42	**3.99**	0.00	3.59	8.33	**3.97**
Mean	**0.00**	**4.42**	**9.67**		**0.00**	**4.48**	**9.75**	
LSD at 0.05	**Treatments (T) = 0.09** **Storage Periods (D) = 0.07** **Interaction (T×D) = 0.16**				**Treatments (T) = 0.56** **Storage Periods (D) = 0.43** **Interaction (T×D) = 0.95**			

In previous results, ‘Redglobe’ table grapes (*Vitis vinifera* cv. Redglobe), undergoing deterioration were selected as model fruit with, *Botrytis cinerea*, to test the antifungal activity of grapefruit seed extract (GSE) in vitro and in vivo by Xu *et al.* (2007). The results of inhibition of spore germination and radial growth of *B. cinerea* in vitro indicated that GSE could efficiently inhibit the growth of the tested fungi. The effectiveness of GSE control postharvest decay and quality of ‘Redglobe’ grape berries stored at 0–1ºC was also investigated. GSE treatment significantly reduced postharvest fungal rot of the fruit compared with controls challenged with *B. cinerea*. Differences in weight loss and microorganism index between grapes treated with GSE and control fruit suggested that GSE had both antifungal and antioxidative activity. Moreover, the sensory analyses revealed beneficial effects in terms of delaying rachis browning and dehydration and maintenance of the visual aspect of the berry without detrimental effects on taste, or flavour. GSE and might have a synergistic effect in reducing postharvest fungal rot and maintaining the keeping quality of ‘Redglobe’ grapes. Moreover, the antifungal action of GSE might largely rely on its effect on the fungal membranes, probably as a result of the ability of antifungal compounds in GSE to act as surfactants (physical disruption of the membrane).

Berry Firmness:

The response of berry firmness of ″Crimson Seedless″ grape during cold storage to preharvest spraying of jasmonic acid and grapefruit seed extract in 2017 and 2018 seasons were reported in Table (5). The data indicated that there was a significant decrease in berry firmness as the storage period prolonged. Moreover, the present data reveal that the highest values of berry firmness were recorded for grapes treated with preharvest treatments of jasmonic acid in descending order grapefruit seed extract compared with untreated fruits which had the lowest significant means of berry firmness at the end of storage periods in both seasons of study.

Table 5: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on berry firmness (Newton) of ″Crimson Seedless″ grapes during cold storage in 2017 and 2018 seasons**.**

Treatments	1st Season				2nd Season			
	Storage Periods (Days)				Storage Periods (Days)			
	0	30	60	Mean	0	30	60	Mean
Control	841.00	758.00	671.33	**756.78**	836.00	753.00	665.00	**751.33**
JA at 4 mM/L	841.00	780.33	701.67	**774.33**	836.00	776.67	694.67	**769.11**
JA at 8 mM/L	841.00	806.33	714.00	**787.11**	836.00	803.00	706.33	**781.78**
GSE at 0.5 mM/L	841.00	776.67	693.67	**770.44**	836.00	777.33	688.00	**765.11**
GSE at 1 mM/L	841.00	794.67	705.00	**780.22**	836.00	795.00	696.00	**775.67**
Mean	**841.00**	**783.20**	**697.13**		**836.00**	**779.80**	**690.00**	
LSD at $_{0.05}$	**Treatments (T)** = **3.68** **Storage Periods (D)** = **2.85** **Interaction (T×D)** = **6.22**				**Treatments (T)** = **2.64** **Storage Periods (D)** = **2.05** **Interaction (T×D)** = **4.47**			

In harmony with these results are those obtained by Bassem (2015) investigated the impact of postharvest on quality of ″Crimson Seedless″ grapes by dipping in jasmonic acid (JA) solutions at 5, 10 mM for 5 minutes at 22°C during cold storage. The results showed that JA treatments at different concentrations were significantly increased berry firmness during cold storage period in comparison with control. Lolaei (2013) also, reported that the application of (Methyl Jasmonate) MJ had higher effects on delayed fruit repining and increased firmness of strawberry fruit. On the other hand, contrary to these results those obtained by Shafiq *et al.* (2013) reported that preharvest spray applications of MeJA did not significantly affect the fruit firmness in Cripps Pink apples.

Soluble Solids Content, Titratable Acidity, and SSC/Acid Ratio:

Data on studying the effect of preharvest spraying of jasmonic acid and grapefruit seed extract during cold storage on soluble solids content, titratable acidity, and SSC/acid ratio of ″Crimson Seedless″ grape in 2017 and 2018 seasons were reported in Tables (6, 7 and 8). Data showed that soluble solids content and SSC/acid ratio increased with increasing storage periods, and the soluble solids content differences among all tested storage periods were statistically significant compared with the initial date in the two seasons of study. However, SSC/acid ratio differences decreased gradually and significantly at sampling three (after 60 days) compared with first and second dates prolonging storage period.

Table 6: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on soluble solids content (Brix %) of ″Crimson Seedless″ grapes during cold storage in 2017 and 2018 seasons.

Treatments	1st Season				2nd Season			
	Storage Periods (Days)				Storage Periods (Days)			
	0	30	60	Mean	0	30	60	Mean
Control	18.30	18.51	18.80	**18.53**	17.80	18.02	18.17	**17.99**
JA at 4 mM/L	18.30	19.91	20.02	**19.41**	17.80	18.87	19.05	**18.57**
JA at 8 mM/L	18.30	19.97	10.09	**19.45**	17.80	19.22	19.29	**18.77**
GSE at 0.5 mM/L	18.30	19.65	19.90	**19.28**	17.80	18.73	18.92	**18.48**
GSE at 1 mM/L	18.30	19.90	19.96	**19.39**	17.80	18.73	19.01	**18.58**
Mean	**18.30**	**19.59**	**19.75**		**17.80**	**18.76**	**18.89**	
LSD at 0.05	**Treatments (T) = 0.03** **Storage Periods (D) = 0.03** **Interaction (T×D) = 0.05**				**Treatments (T) = 0.08** **Storage Periods (D) = 0.08** **Interaction (T×D) = 0.13**			

Table 7: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on acidity percentage of ″Crimson Seedless″ grapes during cold storage in 2017 and 2018 seasons.

Treatments	1st Season				2nd Season			
	Storage Periods (Days)				Storage Periods (Days)			
	0	30	60	Mean	0	30	60	Mean
Control	0.51	0.57	0.64	**0.57**	0.55	0.61	0.65	**0.60**
JA at 4 mM/L	0.51	0.55	0.61	**0.56**	0.55	0.58	0.62	**0.58**
JA at 8 mM/L	0.51	0.54	0.57	**0.54**	0.55	0.56	0.59	**0.57**
GSE at 0.5 mM/L	0.51	0.55	0.61	**0.56**	0.55	0.59	0.63	**0.59**
GSE at 1 mM/L	0.51	0.54	0.58	**0.54**	0.55	0.58	60	**0.58**
Mean	**0.51**	**0.55**	**0.60**		**0.55**	**0.58**	**0.62**	
LSD at 0.05	**Treatments (T) = 0.01** **Storage Periods (D) = 0.01** **Interaction (T×D) = 0.02**				**Treatments (T) = 0.01** **Storage Periods (D) = 0.01** **Interaction (T×D) = 0.02**			

Table 8: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on SSC/acid ratio of ″Crimson Seedless″ grapes during cold storage in 2017 and 2018 seasons.

Treatments	1st Season				2nd Season			
	Storage Periods (Days)				Storage Periods (Days)			
	0	30	60	Mean	0	30	60	Mean
Control	35.88	32.49	29.55	**32.64**	32.36	29.55	27.83	**29.91**
JA at 4 mM/L	35.88	36.21	32.84	**34.98**	32.36	32.72	30.73	**31.93**
JA at 8 mM/L	35.88	37.22	35.26	**36.12**	32.36	34.11	32.52	**32.99**
GSE at 0.5 mM/L	35.88	35.53	32.44	**34.62**	32.36	31.75	30.03	**31.93**
GSE at 1 mM/L	35.88	36.62	34.62	**35.71**	32.36	32.67	31.51	**32.18**
Mean	**35.88**	**35.61**	**32.94**		**32.36**	**32.16**	**30.52**	
LSD at 0.05	**Treatments (T) = 0.56** **Storage Periods (D) = 0.43** **Interaction (T×D) = 0.94**				**Treatments (T) = 0.44** **Storage Periods (D) = 0.34** **Interaction (T×D) = 0.75**			

In addition, jasmonic acid and grapefruit seed extract treatments at all concentrations significantly increased soluble solids content and SSC/acid ratio during cold storage periods as compared to the control. Moreover, the treatments of jasmonic acid at 8 mM/L and grapefruit seed extract at 1 mM/L were more effective in increasing soluble solids content as compared with other treatments.

Data also, revealed that there was a significant increase in acidity percentage as the storage period prolonged. Furthermore, the statistical analysis indicated that all treatments significantly decreased acidity percentage as compared with control. In addition, jasmnioc acid at 8 mM/L was more effective in decreasing acidity contents compared with other treatments. These results are in agreement with those obtained by Wang *et al.* (2008) found that preharvest application of 306 MeJA resulted in higher soluble solid content and lower titratable acidity of three blackberry 307 cultivars and similar findings were earlier reported by Wang and Zeng (2005) on raspberries.

In harmony with these results, also are those obtained by Sabry *et al.* (2011) found that treated grapevine with Jasmine oil at 0.2% increased juice SSC percentage, SSC/acid ratio, and reducing acidity content. Also, El-Kenawy (2018) worked on Crimson seedless grapevine cultivar to study the effects of jasmonic acid fruit quality of Crimson seedless grapevine. Jasmonic acid was used as a foliar application at a rate of (10, 20, 40 ppm). Results indicated that grapevines were treated with jasmonic acid were increased of SSC%, SSC /acid ratio, and decreased total acidity as compared with untreated in both seasons of the study. While, these results are in contrast with those obtained by Bassem (2015) investigated the impact of postharvest on quality of Crimson Seedless" grapes by dipping in jasmonic acid (JA) solutions at 5, 10 mM for 5 minutes at 22°C during cold storage. The results showed that soluble solid content (SSC%), titratable acidity (TA%), SSC/acid ratio were not significantly affected by JA treatments during the storage period.

Total Anthocyanin:

With respect to the effect of various applied treatments on total anthocyanin contents of ″Crimson Seedless″ grape, in both experimental seasons, the data demonstrated in Table (9) declared that total anthocyanin contents significantly decreased as the storage period extended till the end of storage period 60 days. Moreover, the statistical analysis showed that jasmnioc acid at (4 and 8) mM/L and grapefruit seed extract at 1 mM/L treatments significantly increased total anthocyanin compared with control. However, grapefruit seed extract at 0.5 mM/L had no effect in total anthocyanin in two seasons of this study. These results in agreement with Ribéreau- Gayon *et al.* (2000) who reported that there were five common anthocyanins found in grapes and their structure such as Malvidin purple-red, Delphinidin pink, Peonidin purple-blue, Cyanidin red, Petunidin purple. Induced senescence by jasmonic acid is characterized by a drastic loss of chlorophyll, the degradation of the inhibition of its biosynthesis, and increases in the respiratory rate and in protease and peroxidase activities. Moreover, Gonzalez-Neves *et al.* (2005) found that the amount of cyanidin- 3- glucoside, peonidin- 3-glucoside, and the acylated derivatives of these anthocyanins were higher in fresh grape skins than wines and crushed grapes. Jasmonic acid is biologically like to abscisic acid (ABA) and has been shown to exhibit a senescence-promoting activity in the leaves of many plant families (Yilmaz *et al.,* 2007). Furthermore, Xu *et al.* (2007) reported that the change in skin color of 'Redglobe' table grapes increase more slowly in GSE-treated berries than in the controls. Table grapes, such as 'Redglobe', also are rich in anthocyanin compounds, which account for their red color, and repining of berries has been correlated with the anthocyanin contents in 'Redglobe' table grapes (Cantos *et al.,* 2002). In addition, El-Kenawy (2018) worked on Crimson seedless grapevine cultivar to study the effects of jasmonic acid fruit quality of Crimson seedless grapevine. Jasmonic acid was used as a foliar application at a rate of (10, 20, 40 ppm). The Results showed that

applications of jasmonic acid were effective for improving total anthocyanin in berry skin as compared with the control during both seasons.

While, in contrast with these results are those obtained by Bassem (2015) investigated the impact of postharvest on quality of ″Crimson Seedless″ grapes by dipping in jasmonic acid (JA) solutions at 5, 10 mM for 5 minutes at 22°C during cold storage. The results showed that total anthocyanin in berry skin was not significantly affected by JA treatments during the storage period.

Table 9: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on total anthocyanin (mg/100g. *F.W.*) of ″Crimson Seedless″ grapes during cold storage in 2017 and 2018 seasons.

Treatments	1st Season				2nd Season			
	Storage Periods (Days)				Storage Periods (Days)			
	0	30	60	Mean	0	30	60	Mean
Control	0.87	0.82	0.75	**0.81**	0.84	0.78	0.71	**0.78**
JA at 4 mM/L	0.87	0.84	0.77	**0.83**	0.84	0.80	0.75	**0.80**
JA at 8 mM/L	0.87	0.87	0.81	**0.85**	0.84	0.82	0.78	**0.81**
GSE at 0.5 mM/L	0.87	0.82	0.76	**0.82**	0.84	0.79	0.73	**0.78**
GSE at 1 mM/L	0.87	0.86	0.79	**0.84**	0.84	0.80	0.76	**0.80**
Mean	**0.87**	**0.84**	**0.78**		**0.84**	**0.80**	**0.75**	
LSD at 0.05	**Treatments (T) = 0.01** **Storage Periods (D) = 0.01** **Interaction (T×D) = 0.02**				**Treatments (T) = 0.01** **Storage Periods (D) = 0.01** **Interaction (T×D) = 0.02**			

Marketing Life:

Concerning the effect of the market period for 3 days at (20° C and 75% RH) on ″Crimson Seedless″ grape parameters result presented in (Tables 10 and 11) showed a significant increase in parameters of cluster weight loss, berry shatter, berry decay and total loss percentages in control fruits as compared with various applied treatments. Meanwhile, berry firmness significantly decreased in control at room temperature in the two seasons. Statistical analysis of the present data also, indicated that all treatments caused a non-significant increase in SSC, except for jasmonic acid at (4 and 8) mM/L in the second season where the differences were big enough to be significant compared with control.

Table 10: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on marketing life of ″Crimson Seedless″ grapes cluster weight loss%, berry shatter%, berry decay%, total loss% and berry firmness (Newton) for 3 days at (20° C and 75% RH) in 2017 and 2018 seasons.

Treatments	Cluster weight loss%		Berry shatter%		Berry decay%		Total loss%		Berry firmness (Newton)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Control	7.31	7.38	8.20	8.06	8.50	8.49	24.01	23.93	600.00	597.00
JA at 4 mM/L	6.34	6.37	5.41	5.45	6.34	6.35	18.08	18.16	628.00	624.00
JA at 8 mM/L	5.62	5.58	4.52	4.51	5.48	5.47	15.43	15.56	636.00	640.33
GSE at 0.5 mM/L	6.93	6.92	5.09	5.25	6.04	5.87	18.05	18.06	609.33	601.00
GSE at 1 mM/L	6.20	6.31	4.27	4.34	5.24	5.26	15.70	15.91	622.00	613.67
LSD at 0.05	**0.30**	**0.31**	**0.25**	**0.19**	**0.27**	**0.20**	**1.43**	**0.35**	**5.93**	**2.65**

Table 11: Effect of jasmonic acid and grapefruit seed extract pre-harvest spraying on marketing life of ″Crimson Seedless″ grapes SSC (Brix%), acidity%, SSC/acid ratio and total anthocyanin (mg/100g. *F.W.*) for 3 days at (20° C and 75% RH) in 2017 and 2018 seasons.

Treatments	SSC (Brix%)		Acidity%		SSC/acid ratio		Total anthocyanin (mg/100g. *F.W.*)	
	2017	2018	2017	2018	2017	2018	2017	2018
Control	19.47	19.03	0.66	0.68	29.36	28.13	0.65	0.62
JA at 4 mM/L	20.11	19.25	0.64	0.65	31.58	29.77	0.67	0.66
JA at 8 mM/L	20.65	19.44	0.61	0.60	34.05	32.23	0.72	0.68
GSE at 0.5 mM/L	19.87	18.93	0.64a	0.66	30.73	28.69	0.66	0.64
GSE at 1 mM/L	20.29	19.24	0.62bc	0.63	32.92	30.54	0.69	0.66
LSD at $_{0.05}$	**0.82**	**0.16**	**0.02**	**0.02**	**1.63**	**0.69**	**0.02**	**0.03**

Furthermore, results showed that acidity percentage significantly decreased compared with control, except for JA at 4 mM/L and GSE at 0.5 mM/L treatments in the first season where the differences are big enough to be significant compared with control. However, SSC/acid ratio and total anthocyanin contents significantly increased, except for GSE at 0.5 mM/L in tow seasons of study, and the differences were not big enough to be significant compared with control. These results are in agreement with those obtained by Bassem (2015) investigated the impact of postharvest on the quality of ″Crimson Seedless″ grapes by dipping in jasmonic acid (JA) solutions at 5, 10 mM for 5 minutes at 22°C during shelf life. The results showed that JA treatments at different concentrations were significantly effective in reducing weight loss, berry decay, berry shatter, and total loss in cluster weight percentages during shelf life as compared to the control. Also, the previous treatments significantly reduced rachis browning and increased berry firmness during shelf life in comparison with control. On the other hand, soluble solid content (SSC%), titratable acidity (TA%), SSC/acid ratio, total anthocyanin in berry skin were not significantly affected by JA treatments during shelf life. Furthermore, the lowest values of weight loss, berry shatter, berry decay, the total loss in cluster weight percentages, and rachis browning were presented by JA at 10 mM at the end of shelf life in comparison with other treatments.

Conclusion

It might be concluded that jasmonic acid at 8 mM and grapefruit seed extract at 1 mM preharvest applications had a pronounced effect in reducing weight loss, berry decay, berry shatter, and total loss in cluster weight percentages and maintaining berry quality during the cold storage period and shelf life. Therefore, preharvest JA at 8 mM and GSE at 1 mM applications could be suggested for improving the storability of ″Crimson Seedless″ grapes and maintaining their quality characteristics during cold storage conditions and shelf life.

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