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Enhancing the Shelf Life and Storage Ability of Flame Seedless Grapevine by Agrochemicals Preharvest Foliar Applications

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Abstract: The present investigation was carried out during 2009 and 2010 seasons at the Research and Agricultural Experimental Station, King Saud University, Riyadh, Saudi, Arabia in order to study the effect of cytofex (CPPU), putrescine (Put), gibberellic acid (GA_3), Ascorbic acid (AA), Ethephon (Eth), calcium chloride($CaCl_2$) and salicylic acid (SA) at two stages of berry development, pea stage (5-7 mm fruitlet diameter) and veraison stage (when approximately 20% of the berries on 50% of the clusters had softened and red color) on berry quality either after held at ambient temperature for 7 days and 80-85% RH or after 15 and 30 days of cold storage at 0°C and 80-85% RH of Flame seedless grapevine. The data obtained indicated enhancement in fruit shelf life and storage ability as follows, the Put, GA_3, CPPU, SA and $CaCl_2$ maintained the berry quality grade after keeping fruits for 7 days at ambient temperature and after 15 or 30 days of cold storage by spraying Put, GA_3, SA and CPPU while, the Eth maintained the berries quality grade after 15 and 30 days of cold storage. In general, all sprayed substances except Ethephon had a positive influence in increasing fruit firmness, TSS, rachis condition and berry adherence strength and decreasing the percentages of berry shattering and weight loss compared to the control. On the other hand, Ethephon decreased berry adherence strength and increased the percentage of weight loss after 15or 30 days of cold storage.

Key words: Growth regulators · Foliar sprays · Grape · Grade quality · Shelf life · Storage ability

INTRODUCTION

Grapevines (*Vitis vinifera* L.) occupy more land in the world than any other single fruit and account for almost half of the total world production of all fruits. Flame seedless grapes, as non-climacteric fruits with a relatively low rate of physiological activity, are exposed to serious water loss during marketability and storage, which result in stem drying and browning, berry shatter (loss of berries from the cap stem) and shrivelling or water loss. Grapes quality deterioration in clusters is expressed in terms of weight loss, rachis senescence or necrosis, berry shatter, fruit softening, undesirable color changes in the berries or rachis and the development of fungal rots. The severity of these quality changes vary according to cultivar and to practices in the vineyard and in the postharvest storage facility [1]. The maintenance of postharvest grape quality is becoming increasingly significant as the supply of high quality commodities constantly exceed demand, not only for marketing at harvest time but also after storage [2]. Therefore, focus should be done on the methods and strategies for improving fruit quality characteristics, as well as for maintaining fruit with high quality for longer periods. This will allow grape clusters to have better marketability, storability and to be more capable to tolerant exportation to distant markets without facing quality deterioration and any disease infections.

Preharvest foliar sprays of different agrochemicals is one of several tools which when properly used might lead to maintain grape berries with high quality for longer time under different conditions, either consumed directly in local markets or after storage for a certain period. Exogenous sprays of many growth regulators such as gibberellic acid, putrescine, salicylic acid and others were proven effective in retarding quality disorders as well as, in decreasing fungal infection, either by delaying ripening and senescence or preventing fungal infection in many fruit species [3-8]. Enormous work has demonstrated that exogenously applied polyamines have effects on fruit quality with emphasis on fruit firmness, weight loss,

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ethylene evolution, soluble solutions and titratable acids [9]. In another report, putrescine treatment resulted in reduce or slow color change, ethylene emission and respiration in kiwifruit, which resulted in reducing senescence rate after harvest [10]. Furthermore, salicylic acid, phenolic compounds are a group of important secondary metabolites in grape berries and play an essential role in determining grape berry quality as well as berries characteristics such as color, flavor, astringency and bitterness [11] and improved fruit quality during cold storage of pomegranate [12]. Fruit anthocyanine, flesh firmness acidity and stem freshness were significantly increased with application of SA, but ethylene production, pH and fungal infection were reduced as well as the stem green color was prolonged [13]. The cytofex (N-(2-chloro-4-pyridinyl)-N'-phenyl urea) has been tried successfully to enhance grape fruits quality and delay fruit aging at harvest day or during cold storage [14]. Another compound which is reported to play an important role in improving fruit quality is the ascorbic acid, a natural organic antioxidant [15]. In addition, calcium compounds as preharvest treatments has been used as firming agent to extend postharvest shelf life of several fruits [16,17]. Also, the GA_3 treatment significantly delayed fruit ripening and decreased ethylene production, flesh softening, weight loss, stem browning, pH and fungal rot, but the anthocyanine content, firmness and acidity increased [13]. Dal Ri *et al*. [18] reported that even though grape berries are classified as non-climacteric fruit, they respond to exogenous ethylene treatments performed in the field at veraison stage were shown to influence the onset of ripening and some of the related processes such as anthocyanine accumulation.

In accordance to the previous mentioned, the present study was conducted in order to investigate the effect of spraying putrescine (Put), gibberellic acid (GA_3), cytofex (CPPU) salicylic acid (SA), calcium chloride ($CaCl_2$), ascorbic acid (AA) and Ethephon (Eth) at two stages of berry development, pea stage (5-7 mm fruitlet diameter) and veraison stage (when approximately 10% of the berries on 50% of the clusters had softened and red color) on improving shelf life and storability of Flame seedless grape.

MATERIALS AND METHODS

Plant Materials, Experimental Site and Treatments: This study was carried out during the two successive seasons, 2009 and 2010 in the Research and Agricultural Experimental Station in Dirab, Riyadh, Saudi Arabia on ten years old, uniform, Flame seedless grape (*Vitis vinifera* L.) grown in sandy loam soil under aird environmental conditions and irrigated with treated domestic wastewater by flooding irrigation system. Grapevines were planted at 1.5 × 3 m spacing and pruned by retaining a maximum of 35-40 nodes/vine. Vines were trained to the cordon system (Trellised on four stories cross arm system, pruned to approximate 3-5 nodes fruiting spure in a telephone trellis system). In November of both years vines were fertilized with organic manure (2.5% N) and calcium super phosphate (15 % P_2O_2) at a rate of 10 and 1.5 kg per vine respectively. Also, one kg of ammonium sulphate (20.6 % N) and 1.5 kg potassium sulphate (48% K_2O) per vine were added in three equal doses, at the beginning of March, April and May.

The experiment was designed as randomized complete design (RCD) and the following eight foliar spray treatments were obtained with three replicates for each treatment (1 replicate = 2 vines):

- Control (water only).
- 8 mM putrescine (Put).
- 25 ppm gibberellic acid (GA_3)
- 5 ppm cytofex (CPPU)
- 100 ppm salicylic acid (SA).
- 1 g/L calcium chloride ($CaCl_2$).
- 500 ppm ascorbic acid (AA).
- Ethephon (Eth) at 150 ppm.

All chemicals were sprayed at two stages of berry development, pea stage (4-5 mm fruitlet diameter) and at veraison stage (when approximately 20% of the berries on 50% of the clusters had softened). The surfactant Nourfilm (produced by Alam Chemica) was added at the rate of 40 cm/100 L water to all sprayed chemicals in order to obtain best penetration results. The chemicals were applied directly to the clusters with a handheld sprayer until runoff, once in the early morning. Plastic shields prevented overspray or runoff from contacting other clusters. In both seasons, clusters from each vine were harvested after most (60%) of the fruits were considered to have exceeded the minimum market requirements of 16.5-18 % total soluble solids, 22:1 total soluble solids:titratable acidity ratio and full red berry colour. Only commercially acceptable clusters were harvested on any date and each treatment was harvested two or three times during the harvest season. At harvest, all the harvested clusters were inspected and berries that were coloured green or had other quality defects (decayed or wilted berries) were removed with a shear. After that clusters of each replicate were packed in boxes that included liners and transported immediately to the laboratory to investigate the effect of the different treatments on the grapes storage ability and shelf life, 12 clusters from each replicate were taken, three of them were held at ambient temperature (20-25°C and 80-85 % RH) for 7 days to estimate the shelf life and the other nine cluster were cold stored at 0ºC and 80-85 % relative humidity for one month to estimate fruit quality after the shelf life time and after 15 and 30 days from cold storage.

Berry Texture Analyzer: The berries of each sample were weighed and subjected to tests with a fruit texture analyzer instrument (Fruit Hardness Tester, No. 510-1) as a small cylinder used a flat plate traveling at a speed of $5mms^{-1}$ to compress each whole berry by 3 mm. Peak force expressed in (g/cm^2) was recorded and considered to be an indicator of fruit firmness. These berries were then discarded and a second sample of 20 randomly selected berries per box was subjected to berry adherence strength measurements (retention force) using a digital force gauge (g).

Postharvest Quality Evaluation: After 15 and 30 days of cold storage (0°C, 80-85% RH) and after shelf boxed grapes from each replicate were removed from storage and shelf life and fruit quality was evaluated. Juice berries was extracted with a hand press and filtered through cheesecloth. The TSS of the filtered juices were measured with a refractometer and the titratable acidities were determined by titration of 5mL of juice with 0.1N sodium hydroxide (NaOH) to an end point of pH 8.2 and expressed as mg 100 m^{-1} juice. The cluster grapes quality grade (overall visual appearance of the cluster grapes) was rated according to the following scale: (1) excellent, (2) acceptable, or (3) commercially unacceptable.

Rachis condition (rachis browning) was rated according to Crisosto *et al.* [1], as follows: (1) healthy = entire rachis including the pedicels green and healthy, (2) slight = rachis in good condition, but noticeable browning of pedicels, (3) moderate = browning of pedicels and secondary rachis, or (4) severe = pedicels, secondary and primary rachis completely brown. Berry shatter was evaluated for each box at the end of the storage (shelf, 15 and 30 days) by subtracting the weight of free berries from the total boxed grape weight and expressed as percentage of shatter in each box. Cluster weight loss percentage was also calculated.

$$\text{Berries shattering \%} = \frac{\text{Weight of free berries inside each box}}{\text{Total clusters weight}} \times 100$$

$$\text{Cluster weight loss\%} = \frac{\text{Initial cluster weight-final cluster weight}}{\text{Initial clusters weight}} \times 100$$

In berries juice, the percentage of total soluble solids (TSS) was measured by a hand refractometer AOAC [19]. (A.S.T., Japan). Also, the juice pH (at 20°C) was determined by a pH meter.

Statistical Analysis: All data were tested for treatments effects on analyzed parameters by the one-way analysis of variance (ANOVA) technique. Treatments means were separated and compared using the honest significant differences (HSD) at 0.05 level of significance according to Snedecor and Cochran [20]. The statistical analysis was performed using Statistical Analysis System [21].

RESULTS

Berries Characters after 7 Days at Ambient Temperature: The effect of the different sprayed compounds on berry characters after keeping clusters for 7 days at 20-25° C is presented in Tables 1and 2. Data of both seasons showed a significant increase in berry firmness by GA_3, CPPU, put, SA and $CaCl_2$ sprays, while the other compounds (AA and Eth) did not differ from the control. Ascorbic acid and ethrel sprays by the lowest firmness values as compared to all other sprayed compounds. The CPPU treatment gave the highest firmness value as compared to Put, SA and $CaCl_2$ during both seasons. Similarly, GA_3 had the highest berry firmness value as compared to SA and Ca Cl_2. No significant differences between CPPU and GA_3 and between Put and GA_3. Berries adherence strength (retention force) decreased in storage, as expected, but again there was an increase by all sprayed compounds except the control, Ethephon and ascorbic acid, which did not significantly differ from each other. The SA had the lowest berries adherence strength by GA_3, CPPU, Put and $CaCl_2$, which did not significantly differ from each other during both seasons, but again there was increased by all sprayed compounds except the control. In the mean time, all sprayed compounds by lower berry shattering percent than the control, a finding agrees with the lack of differences in fruit retention force discussed earlier. GA_3, Put, SA, CPPU and $CaCl_2$ were similar and significantly higher than the Eth and AA, which did not significantly differ from each other during both seasons. In addition, a significant increase in the quality grade (visual appearance quality of the grapes) was obtained in both seasons, by spraying Put, GA_3, SA and CPPU as compared to the control during both seasons,

Table 1: Effect of foliar application of some substances on berry firmness, unmarketable and adherence strength of Flame seedless grape after 7 days at 20°C during 2009 and 2010 seasons

	Firmness (gm/cm^2)		Berry adherence strength (g)		Berries shatter (%)		Quality grade	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010
Control	152	168	236	220	39.9	36.9	1.4	1.7
Putrescine	198	212	300	322	10.3	12.9	2.6	2.7
Gibberellic acid	218	230	297	303	8.7	6.9	2.8	2.6
Cytofex	230	240	323	312	9.2	8.9	2.8	2.7
Salicylic acid	188	192	268	270	15.3	14.6	2.5	2.7
Calcium chloride	190	206	297	308	11.6	12.8	2.0	2.2
Ascorbic acid	160	172	240	246	25.0	26.8	1.6	1.8
Ethephon	150	166	218	218	28.8	24.6	2.0	1.9
H.S.D.0.05	21	19	27	32	9.4	8.9	1.1	0.8

Table 2: Effect of foliar application substances on berry TSS, anthocyanine and weight loss of Flame seedless grape after 7 days at 20°C during 2009 and 2010 seasons

	Rachis condition		Weight loss (%)		TSS (%)		pH	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010
Control	3.7	3.8	7.4	7.9	17.5	17.9	3.7	3.9
Putrescine	2.0	2.4	4.8	5.0	20.4	19.9	3.7	3.9
Gibberellic acid	1.8	2.2	5.0	4.6	20.7	20.5	3.6	3.6
Cytofex	1.8	1.4	4.2	4.4	20.6	21.1	3.6	3.7
Salicylic acid	2.0	2.4	5.1	5.4	20.1	19.3	3.7	3.5
Calcium chloride	3.0	3.4	6.1	5.8	19.5	19.4	3.6	3.7
Ascorbic acid	3.8	4.0	6.4	7.2	17.9	17.8	3.7	3.6
Ethephon	4.0	4.0	8.7	9.0	16.5	17.4	3.8	3.7
H.S.D.0.05	1.4	1.2	2.2	2.5	2.0	1.2	NS	NS

which did not significantly differ from each other. No significant differences were between AA, Eth and the control after 7 days at shelf life in their berry visual appearance quality.

As for the berries rachis condition (rachis browning), weight loss, TSS and pH after 7 days at the shelf life are presented in Table 2. Grapes treated with Put, GA_3, CPPU and SA had he lowest rachis browning score after 7 days at shelf (best berries condition) than other chemicals and the control during both seasons, which did not significantly differ from each other. No significant differences were between Put, GA_3, CPPU and SA, during both seasons and $CaCl_2$ in the first season. Fruit weight loss was not affected by the Eth, $CaCl_2$ and AA treatments as compared with the control, while that of Put, GA_3, CPPU and SA sprays decreased weight loss percentage compared with the control, Eth, $CaCl_2$ and AA treatments.

Furthermore, no significant influence was obtained on fruit TSS content by the AA and Eth treatments, while that of the Put, GA_3, CPPU, SA and $CaCl_2$ sprays increased the berry TSS, which did not significantly differ from each other. Fruit pH was not affected by any chemical treatments during both seasons as compared with the control.

Berries Characters after Cold Storage: The effect of different sprayed compounds on berry firmness, adherence strength shattering and quality grade after 15 or 30 days of cold storage at 0°C are presented in Tables 3 and 4. Data showed a significant increase in berry firmness by Put, GA_3, CPPU, SA and $CaCl_2$ sprays as compared with the control in both seasons, after 15 or 30 days at cold storage, which did not significantly differ from each other. Also, no significant differences were between AA and Eth sprays compared to the control during both seasons. The quality grade score (visual appearance quality of the grapes) of berries was increased in both seasons by putrescine, gibberellic acid, cytofex and salicylic acid sprays after 15 days of cold storage and by putrescine, gibberellic acid and cytofex after 30 days of

Table 3: Effect of foliar application substances on berry firmness, unmarketable and adherence strength of Flame seedless grape after 15 days from cold storage during 2009 and 2010 seasons

	Firmness (gm/cm^2)		Quality grade		Berry adherence strength (g)		Berries shatter (%)	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010
Control	172	188	1.5	1.3	260	248	21.6	26.8
Putrescine	218	239	2.9	2.5	298	289	16.2	15.3
Gibberellic acid	222	246	2.9	2.6	337	318	8.3	11.6
Cytofex	244	252	2.9	2.8	339	343	9.3	12.5
Salicylic acid	224	240	2.7	2.7	304	286	13.7	16.7
Calcium chloride	225	246	2.1	2.0	344	352	12.6	10.5
Ascorbic acid	182	200	2.0	1.2	270	256	22.6	23.7
Ethephon	186	192	1.8	1.3	214	220	24.6	21.4
H.S.D.0.05	28	37	1.2	1.0	31	26	5.2	7.4

Table 4: Effect of foliar application substances on berry TSS, anthocyanine and weight loss of Flame seedless grape after 15 days from cold storage during 2009 and 2010 seasons

	Rachis condition		Weight loss (%)		TSS (%)		pH	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010
Control	3.4	3.6	6.0	6.3	18.0	17.8	3.7	3.7
Putrescine	1.7	1.6	3.4	4.0	21.4	20.6	3.6	3.8
Gibberellic acid	1.8	1.6	3.6	3.3	21.2	20.6	3.7	3.6
Cytofex	1.4	2.0	2.8	2.7	21.0	21.0	3.7	3.5
Salicylic acid	2.0	2.0	3.5	3.9	19.8	20.0	3.6	3.7
Calcium chloride	2.6	2.8	5.1	4.8	20.0	20.6	3.6	3.7
Ascorbic acid	3.8	3.4	5.1	5.7	18.8	18.4	3.6	3.6
Ethephon	3.8	4.0	7.5	7.2	17.8	17.2	3.7	3.6
H.S.D.0.05	1.4	1.3	1.1	1.9	1.8	2.0	NS	NS

cold storage at 0°C. No significant differences were between putrescine, gibberellic acid cytofex and salicylic acid sprays and between AA, Eth and the control after 15 days and $CaCl_2$ after 30 days of cold storage. In addition, berry adherence strength (retention force) increased by all sprayed compounds except ascorbic acid and Ethephon as compared with the control after 15 or 30 days of cold storage in both seasons. Ethephon spray had the lowest adherence strength value. After 15 days from cold storage the $CaCl_2$, GA_3 and CPPU sprays had similar and higher than the Put and SA sprays in their berry adherence strength during both seasons, whereas after 30 days the $CaCl_2$ and CPPU sprays had similar and higher than the Put, GA_3 and SA sprays in their berry adherence strength during both seasons. On the other side, berries shattering percent decreased by all treatments except Eth and AA sprays which did not differ than the control after 15 or 30 days of cold storage.

Regarding the effect of different treatments on berries rachis condition, weight loss percentage, TSS and pH after 15 or 30 days of cold storage are presented in Tables 5 and 6. Data of both seasons indicated that the berries rachis condition (rachis browning) in grapes treated with Put, GA_3, CPPU and SA had the lowest rachis browning score after 15 or 30 days at cold storage (best berries condition) than other chemicals and the control, during both seasons, which did not significantly differ from each other. No significant differences were between Put, GA_3, CPPU, SA and $CaCl_2$ during both seasons after 15 and 30 days of cold storage. Fruit weight loss percentage was decreased by Put, GA_3, CPPU and SA sprays as compared with the control, during both seasons, after 15 and 30 days at cold storage. No significant differences were between Put, GA_3, CPPU and SA, after 15 days of cold storage and $CaCl_2$ and AA, after 30 days, during both seasons. Furthermore, the Put, GA_3, CPPU, $CaCl_2$ and SA sprays increased the berry TSS as compared with the

Table 5: Effect of foliar application substances on berry firmness, unmarketable and adherence strength of Flame seedless grape after 30 days from cold storage during 2009 and 2010 seasons

	Firmness (gm/cm^2)		Quality grade		Berry adherence strength (g)		Berries shatter (%)	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010
Control	158	164	1.7	1.2	213	204	34.2	36.5
Putrescine	200	214	2.4	2.6	234	242	19.8	18.7
Gibberellic acid	218	229	2.3	2.7	242	258	10.8	14.9
Cytofex	236	232	2.6	2.7	288	276	11.3	14.5
Salicylic acid	200	218	2.1	2.0	241	232	16.3	18.9
Calcium chloride	211	229	2.1	2.3	294	310	16.6	13.7
Ascorbic acid	174	186	1.4	1.4	231	221	25.6	21.9
Ethephon	156	162	1.9	1.6	176	163	27.9	25.9
H.S.D.0.05	31	38	0.6	1.3	17	24	9.4	12.9

Table 6: Effect of foliar application substances on berry TSS, anthocyanine and weight loss of Flame seedless grape after 30 days from cold storage during 2008 and 2009 seasons

	Rachis condition		Weight loss (%)		TSS (%)		pH	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010
Control	3.9	3.8	10.8	11.3	17.0	17.3	3.6	3.7
Putrescine	2.2	2.0	6.2	6.6	19.0	19.5	3.5	3.7
Gibberellic acid	2.0	2.2	6.2	6.8	19.6	19.9	3.6	3.6
Cytofex	2.4	2.1	5.7	5.4	19.4	20.4	3.5	3.5
Salicylic acid	2.4	2.6	6.5	7.0	19.6	19.9	3.6	3.7
Calcium chloride	3.2	3.0	7.9	8.1	18.2	18.2	3.6	3.6
Ascorbic acid	4.0	4.0	9.2	8.3	17.7	17.0	3.6	3.6
Ethephon	4.0	4.0	11.4	12.8	16.6	16.4	3.6	3.6
H.S.D.0.05	1.4	1.1	4.1	3.0	1.6	2.0	NS	NS

control during both seasons after 15 days, whereas after 30 days the Put, GA_3, CPPU and SA only increased the TSS. Berry pH was not affected by any chemical treatments during both seasons as compared with the control either after 15 or 30 days of cold storage.

DISCUSSION

Short postharvest fruit life and lower storability may appear as a result of many factors such as, fruit softening, increase in ethylene biosynthesis as well as pathogenesis infection. Therefore, the increase in fruit shelf life and storability of the Flame seedless grapes by different spray compounds in the present study could be explained by their positive influence in increasing fruit firmness, reducing ethylene production as well as preventing fungal infection and inducing resistance to low temperature injury [7]. Calcium is known as stabilize cell membranes which prevent physiological disorders attributed to calcium deficiency [22]. It slows ripening and softening of fruit flesh by lowering respiration rates and reducing ethylene production [23]. In addition, a reduction in fruit weight loss by calcium and GA_3 sprays.

Furthermore, ethylene is the ripening hormone that influences the postharvest behaviour of the fruits and the inhibition of its biosynthesis by putrescine and gibberellic acid is previously indicated [24, 25, 26]. Also, in general grape berries after 15 and 30 days cold storage did not show loss in quality attributes by ascorbic and salicylic acids sprays. Ascorbic acid is an antioxidant and in association with other component of the antioxidant system, it protects plants against oxidative damage resulting from aerobic metabolism, photosynthesis and a range of pollutants. Shivashankara *et al.* [27] stated that the antioxidant capacity of mango fruits remained unchanged up to 20 days of cold storage and it was correlated to ascorbic acid. Similarly, salicylic acid is reported to maintain fruit antioxidant activity and its nutritional value, which allow the fruits to withstand oxidation injuries [28]. Exogenous applied salicylic acid has been reported to reduce decay, delay ripening and extend storage life of various fruits, bananas [29, 30], apples [31] and cherries [13]. Salicylic acid is a phenolic compound that regulates a number of processes in plants. It inhibits ethylene biosynthesis [30] and regulates expression of pathogenesis related protein genes and provides resistance against pathogen attack [29]. Mei-hua *et al.* [32] showed that SA can extend the shelf life with decrease oxygen free radicals and ACO. SA acid with increases the enzyme antioxidant activity cause delay the onset of hydrolysis of structural cell components, decrease oxygen free radicals production, ACO and sensitivity. SA acid decreased the permeability of plasma membrane of floret cells and improved the structure of chloroplasts which were badly damaged by ethylene.

The ripening response observed in this study by Ethephon applications therefore in agreement with literature to date. Ethephon, on the contrary in the present study, enhanced ripening response and fruit quality deterioration after harvest and cold storage. This result goes in line with previous findings reported by Amiri *et al.* [33] on grape. Accordingly, it is concluded that preharvest application of growth regulators such as GA_3, Put, AA and SA as well as calcium chloride could be used successfully to maintain Flame seedless berries quality after harvest or cold storage. The effects of Ethephon on fruit maturity and composition are well documented in literature but the results are variable. For numerous cultivars generally no changes in TSS or acidity have been noted and no or little change in pH has been found due to its application [34]. Ethylene enhanced fruit senescence and wilting, increased permeability of cells and accelerated the decrease in cell membrane fluidity. Ethylene production causes a sharp increase in production of oxygen free radicals which is responsible for stress dependent peroxidation of membrane lipids [35]. To scavenge oxygen free radicals, plants posses specific mechanisms, which include activation of antioxidant enzymes [36] and non enzymatic antioxidants such as, carotenoids, phenols component and ascorbic acid [37]. SA is well known as a phenol that can prevent ACC-oxidase activity that is the direct precursor of ethylene and decrease ROS with increase enzyme antioxidant activity SA is considered as a hormone-like substance, which plays an important role in regulating a number of physiological processes and provide protection against biotic and abiotic stresses in plant. The protective function of SA includes the regulation of oxygen free radicals and antioxidant enzymes [38].

CONCLUSION

From the obtained results obtained we may conclude that in general, all sprayed substances except Ethephon had a positive influence in increasing fruit firmness and berry adherence strength and decreasing the percentages of berry shattering and weight loss compared to the control. On the other hand, Ethephon decreased berry adherence strength and increased the percentage of weight loss after 30 days cold storage.

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