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Pre and Post-Harvest Treatments to Improve Ponkan Mandarin Fruits Quality
1. Maintaining Fruit Quality during Cold Storage

Cross Mark

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ABSTRACT

Ponkan mandarin (*Citrus reticulata*, Blanco) occupies a prime position among the mandarin species cultivated in Egypt, owing to its high productivity and early yields as well as fruits have a high nutritive value. Despite its attributes and commercial importance, Ponkan mandarin fruits cannot be sustained for a long period due to its poor shelf life. So, the present study was conducted during 2017 and 2018 seasons on 10 years old trees, grown in clay soil at the experimental farm of Faculty of Agriculture, Kafr El-Sheikh University, Egypt, to evaluate the effect of putrescine at 0, 50 and 100 ppm as pre-harvest treatments individually or combinations with salicylic acid at 0, 200 and 400 ppm as post-harvest treatment on fruit properties during cold storage at 5±1 °C and 90 - 95 % RH for 90 days.The obtained results revealed that pre and postharvest treatments of putrescine and salicylic acid enhanced achievment fruits with acceptable qualities during cold storage period as compared to control. The combination treatment of putrescine pre-harvest spraying at 50 ppm plus salicylic acid post-harvest dipping at 400 ppm (T7) was more effective on fruit quality such as fruit weight loss, decay, firmness, SSC%, acidity, SSC/acid ratio and vitamin C during cold storage. Therefore, putrescine and salicylic acid treatments have capability to avoid post-harvest and storage losses along with enhancing quality of the stored fruits.

Keywords: Putrescine, salicylic acid Ponkan, mandarin, fruit quality.

INTRODUCTION

Ponkan mandarin (*Citrus reticulata*, Blanco) became one of the main mandarin varieties produced in Egypt, with great consumers acceptance due to its sweet taste, easy peeling and big size when compared with other mandarin varieties found in the market. Ponkan mandarin is marketing as Chinese mandarin. The Ponkan tree has high productivity and early yield (Yehia *et al.*, 2009 and Putnik *et al.*, 2017). It's known that, the mandarin fruit is often subjected to high losses during harvest, transportation and storage. Mechanical damage, pathogen diseases and physiological disorders are found to be the most important reasons causing significant economic losses at harvest time and during storage (Obenland *et al.*, 2011). Many pre- and post-harvest treatments had been used to reduce weight loss, decay rate and maintaining fruit quality during storage and transport for fetching highly prices and increasing economic values. In this respect, salicylic acid and putrescine application became more important to maintain fruit quality during pre- and post-harvest storage (Zheng and Zhang, 2004; Davarynejad *et al.*, 2015 and Zhu *et al.*, 2016).

Salicylic acid (SA) belongs to a group of phenolic compounds wildly distributes in plants and is considered as a plant hormone. It showes an important role in plant growth regulating, development and enhancing plant growth under different stresses (Hayat *et al.*, 2010; El Shazly *et al.*, 2015 and Ennab and El-Sayed, 2016). Moreover, salicylic acid improves plant resistance to pathogens via inducing the production proteins that related to a pathogen (Wang and Li, 2008). Pre- and post-harvest applications of salicylic acid showed a great advantage on fruit quality and storability such as size, weight and firmness (Ahmad *et al.*, 2013 and Al Barzinji *et al.*, 2017).

Additionally, salicylic acid applications showed a positive effect on reducing weight loss, decay incidence and softening rate of citrus fruits by reducing the activation of cell wall degrading enzymes as cellulase, xylanase and polygalacturonase during storage (Srivastava and Dwivedi, 2000 and Huang *et al.*, 2008).

With regard to this subject, putrescine belongs to polyamines which found in every plant cell to regulate plant development, affect synthesis and degradation of DNA and RNA, reduce activities of some enzymes (protease, peroxidase and polygalacturonase), improve ribosomal formation moreover and maintain cell membrane (Abbasi *et al.*, 2017). Also, putrescine has a regulatory role in promoting productivity of citrus (Bons *et al.*, 2015). Moreover, Khosroshahi and Esna-Ashari (2008) showed that foliar application of polyamines enhanced fruit quality throughout various changes in fruit firmness, weight loss, soluble solids content and titratable acidity of strawberry, apricot, peach and sweet cherry fruits. Also, Serrano *et al.*, (2003) showed that polyamines play an important role as anti-senescence, where the treated plum fruits with putrescine showed a reduction in color changes, respiration rate and chilling symptoms, and increased fruit firmness during cold storage. In this respect Valero *et al.*, 1998 indicated that, the treated lemon fruits with putrescine

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showed a delay and reduction of ethylene production that was associated with enhancing fruit firmness, reducing of weight loss, delaying of color changes, and extending storage period.

The aim of the present investigation was to evaluate the effect of pre-harvest putrescine spraying either alone or with post-harvest salicylic acid immersion on quality characteristics of Ponkan mandarin fruits during cold storage.

MATERIALS AND METHODS

This study was conducted during 2017 and 2018 seasons on 10 years old Ponkan mandarin (*Citrus reticulata,* Blanco) trees, budded on Volkamer lemon (*Citrus volkameriana* Ten & Pasq) rootstock, planted at 3.5 × 3.5 meters apart in the experimental farm of Faculty of Agriculture, Kafr El-Sheikh University, Kafr El-Sheikh governorate, Egypt. Trees were grown in clay soil under flood irrigation system. Fifteen vigorous and uniform in growth trees were selected, and divided into three groups. Each group was sprayed ten days before harvest date with one of the following solutions: distill water (control), putrescine at 50 and 100 ppm.

Pre-harvest spray with putrascine was carried out at ten days before harvest. Harvesting of fruits was done 14th and 20th October in the two seasons, respectively. A fruits sample similar in size, color and free from physical injuries and insect attack was randomly taken from each treatment and directly transported to the laboratory of Sakha Horticulture Research Station. The fruit of each group were divided into three sub group. Fruits were cleaned and dipped for 5 minutes in the different concentrations of salicylic acid solution or distilled water (control).

The experiment was layout in randomized complete block design with nine treatments as follows:

Abbreviations	Pre-harvest treatments (Spraying)		Post-harvest treatments(Fruit dipping)
T_1(Cont.)	Distilled water	+	Distilled water
T_2	Distilled water	+	Salicylic acid at 200ppm
T_3	Distilled water	+	Salicylic acid at 400ppm
T_4	Putrascine at 50ppm	+	Distilled water
T_5	Putrascine at 100ppm	+	Distilled water
T_6	Putrascine at 50ppm	+	Salicylic acid at 200ppm
T_7	Putrascine at 50ppm	+	Salicylic acid at 400ppm
T_8	Putrascine at 100ppm	+	Salicylic acid at 200ppm
T_9	Putrascine at 100ppm	+	Salicylic acid at 400ppm

Salicylic acid (SA) was prepared, by dissolving SA powder in ethanol alcohol 1% (v/v).

The treated fruits for each sub group were divided into two groups; the first one was used to achieve the initial quality parameters at the picking date. However, the second one was packed in 40 x25 x15 cm dimensions carton boxes. Each treatment was represented by three carton boxes for each date. Each carton box contains 2kg of mandarin fruits. All boxes were stored at 5±1 °C and 90 - 95 % RH for 90 days.

During the storage period, the variables were measured at 15 day intervals as follow:

1. **Fruit weight loss (%):**

All fruits were weighed and labeled at zero time (beginning) and 15 day intervals during the storage period. Fruit weight was recorded, then the percentages of weight loss were calculated according to the following equation:

Fruit weight loss %= $(W_I - W_S) / W_I \times 100$

Where, W_I = fruit weight at zero time. **Ws** = fruit weight at sampling period.

2. **Fruits decay (%):**

The percentage of fruit decay was recorded at 15 day periodicals during cold storage period and it was calculated according to the following equation:

$$\textbf{Decay}\ \% = \frac{\textbf{Number of decayed fruits}}{\textbf{Initial number of stored fruits}}\ x\,\mathbf{100}$$

3. **Fruit firmness:**

Fruit firmness was examined in two sides of the fruit using a pressure tester (Model FT 011 USA) and expressed as force Newton according to Reyes and Paull, (1995).

4. **Soluble solids content (SSC%):** It was determined using a hand refractometer according to A.O.A.C. (1995).
5. **Titratable acidity (%):**

It was estimated by titrating against standard alkali solution (0.1N NaOH) using the phenolphthalein indicator and expressed as percentage of citric acid/100 ml of juice according to (Ranganna, 1986).

6. **SSC/acid ratio:** SSC/acid ratio was estimated.
7. **Ascorbic acid content:**

Ascorbic acid concentration (Vitamin C) in fruit juice was determined by using 2,6- dichlorophenol indophenol solution as described by (A.O.A.C., 1995). Vitamin C content was calculated as mg / 100 ml juice.

8. **Pectin methylesterase activity (PME):**

It was determined as described by Anthon and Barrett (2006).

9. **Statistical analysis:**

The experiment treatments were arranged in randomized complete block design with three replicates, and the data were analyzed of variance according to Snedecor and Cochran (1980). The treatment means were compared using Duncan's multiple range test DMRT (Duncan, 1955).

RESULTS AND DISCUSSION

1. **Weight loss (%):**

The results presented in Table (1) cleare that, the percentage of fruit weight loss increased with the progress of the storage period. All treatments were effective in reducing weight loss (%) as compared to control in both seasons. It also cleared that, the superiority in this respect was obtained with the pe-harvest application of putrescine at 50 ppm and post- harvest application of salicylic acid solution at 400 ppm (T_7) during all storage period. Otherwise, the control treatment (T_1) tabulated the highest periodical readings among the tested treatments during cold storage period. These results once more proved that the main effective factor on reducing weight loss (%) in cold stored Ponkan fruits was related to post-harvest dipping fruits before storage in salicylic acid solution at 400 ppm for 5 min. These results are in harmony with those of Lu *et al.*, (2011) and Tareen *et al.*, (2012) where they concluded that, salicylic acid applications reduced the weight loss of pineapple and peach fruits during storage and maintained fruit quality. Moreover, putrescine applications were effective in decreasing weight loss of Ponkan mandarin fruits (Zheng and Zhang 2004).

Table 1. Effect of putrescine and salicylic acid on weight loss (%) of Ponkan mandarin fruits under cold storage conditions during 2017 and 2018 seasons

Treatments	2017 season							
	0	15	30	45	60	75	90	Mean
T_1 :Control	0.00	3.95 a	5.48 a	8.77 a	9.97 a	11.23 a	13.80 a	٧.٦٠a
T_2 :SA 200 ppm	0.00	3.09 b	3.81 b	5.45 bc	5.94 bcd	6.45 cd	7.79bcd	٤.٦٥c
T_3 :SA 400 ppm	0.00	2.90 b	3.69 b	5.08 c	5.65 bcd	6.30 cd	7.54cd	٤.٤٥cd
T_4: Put. 50 ppm	0.00	3.28 b	4.26 b	6.61 b	7.00 bc	7.91 b	8.85 b	٥.٤٢b
T_5: Put. 100 ppm	0.00	3.48 ab	4.17 b	6.57 b	7.08 b	7.55 b	8.10 bc	٥.٢٨b
T_6 : Put.50+ SA 200	0.00	2.18 c	3.5 b	5.05 c	6.52 bcd	6.73 c	7.29cd	٤.٤٧cd
T_7 : Put.50+SA 400	0.00	1.99 c	3.21 b	4.63 c	5.05 d	5.77 d	6.78d	٣.٩١e
T_8 : Put.100+ SA 200	0.00	2.13 c	3.24 b	4.66 c	5.24 cd	6.10 cd	6.83d	٤.٠٣e
T_9 : Put.100+ SA 400	0.00	2.15 c	3.39 b	4.97 c	5.51 bcd	6.13 cd	7.00cd	٤.١٦de
Mean	0.00g	2.79f	3.86e	5.75d	6.44c	7.13b	8.22 a	--
	2018 season							
T_1 :Control	0.00	3.87a	5.19a	9.00a	10.16a	11.63a	13.43a	٧.٦١a
T_2 :SA 200 ppm	0.00	3.00bc	3.78b	5.29c	5.72bc	6.50c	7.38cd	٤.٥٢c
T_3 :SA 400 ppm	0.00	2.78c	3.46bc	5.26c	5.63bc	6.33c	7.65bcd	٤.٤٥c
T_4: Put. 50 ppm	0.00	3.15b	3.90b	7.10b	7.43bc	8.10b	9.12b	٥.٥٤b
T_5: Put. 100 ppm	0.00	3.00bc	3.69b	7.13b	7.47b	7.91b	8.32bc	٥.٣٦b
T_6 : Put.50+ SA 200	0.00	2.10d	3.31bcd	4.95c	5.34bc	5.75c	6.94cd	٤.٠٦d
T_7 : Put.50+SA 400	0.00	1.95d	2.19d	4.75c	5.29c	5.58c	6.22d	٣.٧١d
T_8 : Put.100+ SA 200	0.00	1.99d	2.28d	4.88c	5.43bc	6.17c	7.11cd	٣.٩٨d
T_9 : Put.100+ SA 400	0.00	1.99d	2.40cd	4.76c	5.54bc	6.30c	7.18cd	4.03d
Mean	0.00 g	2.64 f	3.35 e	5.90 d	6.44 c	7.14 b	8.15 a	--

Means followed by the same letter within a column in same season are not significantly different using DMRT at $P \leq 0.05$

2. Fruit decay %

Data presented in Table (2) cleared that, all pre- and post-harvest treatments individually or in combinations reduced fruit decay (%) during all storage period as compared with control in both seasons. Salicylic acid at 200 and 400 ppm (T_2 and T_3) and their combinations with putrescine at 50 and 100 ppm, (T_6, T_7, T_8 and T_9) did not show any fruit decay until 30 days storage in both seasons. Moreover, treatment of pre-harvest spraying with putrescine solution at 100 ppm and post-harvest dipping in salicylic acid solution at 400 ppm (T_9) recorded the lowest significant percent of fruit decay at the end of storage period, however control treatment showed the highest percentages in both seasons. This reduction in decay incidence may due to the effect of salicylic acid in increasing the accumulation of phenolic compounds, induced term of numerous defense genes and improved resistance of fruits against fungal attack by increasing activities of anti-oxidant enzymes (Wang and Li, 2008). Also, polyamines application was thought to delay fruit senescence by inhibiting the formation of enzymes that are necessary for ethylene synthesis (Malik *et al.*, 2005).

Table 2. Effect of putrescine and salicylic acid on decay (%) of Ponkan mandarin fruits under cold storage conditions during 2017 and 2018 seasons

Treatments	2017 season							
	0	15	30	45	60	75	90	Mean
T_1 :Control	0.00	0.00	0.82 a	1.38 a	1.78 a	2.28 a	2.44 a	1.24 a
T_2 :SA 200 ppm	0.00	0.00	0.00 d	0.57 d	0.74 d	0.83 d	0.90 d	0.43 d
T_3 :SA 400 ppm	0.00	0.00	0.00 d	0.33 e	0.42 e	0.70 e	0.85 d	0.33 e
T_4: Put. 50 ppm	0.00	0.00	0.47 b	1.22 b	1.42 b	1.57 b	1.65 b	0.90 b
T_5: Put. 100 ppm	0.00	0.00	0.35 c	0.87 c	1.03 c	1.21 c	1.36 c	0.69 c
T_6 : Put.50+ SA 200	0.00	0.00	0.00 d	0.25 f	0.40 f	0.57 f	0.70 e	0.27 f
T_7 : Put.50+SA 400	0.00	0.00	0.00 d	0.18 g	0.35 g	0.41 g	0.68 e	0.23 g
T_8 : Put.100+ SA 200	0.00	0.00	0.00 d	0.05 h	0.30 h	0.40 g	0.53 f	0.18 h
T_9 : Put.100+ SA 400	0.00	0.00	0.00 d	0.00 i	0.20 i	0.32 h	0.40 g	0.13 i
Mean	0.00 e	0.00e	0.18 e	0.54 d	0.74 c	0.92 b	1.06 a	--
	2018 season							
T_1 :Control	0.00	0.00	0.97 a	1.45 a	1.82 a	2.21 a	2.56 a	1.29 a
T_2 :SA 200 ppm	0.00	0.00	0.00 d	0.64 d	0.87 d	0.97 d	1.06 d	0.51 d
T_3 :SA 400 ppm	0.00	0.00	0.00 d	0.17 e	0.55 e	0.72 e	0.81 e	0.32 e
T_4: Put. 50 ppm	0.00	0.00	0.55 b	0.87 b	1.22 b	1.48 b	1.53 b	0.81 b
T_5: Put. 100 ppm	0.00	0.00	0.32 c	0.70 c	1.00 c	1.15 c	1.32 c	0.64 c
T_6 : Put.50+ SA 200	0.00	0.00	0.00 d	0.00 f	0.33 f	0.58 f	0.70 f	0.23 f
T_7 : Put.50+SA 400	0.00	0.00	0.00 d	0.00 f	0.12 h	0.38 g	0.60 g	0.16 g
T_8 : Put.100+ SA 200	0.00	0.00	0.00 d	0.00 f	0.21 g	0.30 h	0.41 h	0.13 h
T_9 : Put.100+ SA 400	0.00	0.00	0.00 d	0.00 f	0.05 i	0.17 i	0.30 i	0.07 i
Mean	0.00 f	0.00 f	0.20 e	0.43 d	0.69 c	0.88 b	1.03 a	--

Means followed by the same letter within a column in same season are not significantly different using DMRT at $P \leq 0.05$

3. Fruit firmness (Newton):

Results presented in Table (3) show a decrease in fruit firmness values as the cold storage period advanced. All tested treatments were significantly enhanced the fruit firmness during storage period compared to control in both seasons. The treated fruits with pre-harvest putrescine at 100 ppm plus post-harvest salicylic acid at 200 ppm (T_8) showed the best fruit firmness till 90 days cold storage in the first season. However, by the second one, treatment of pre-harvest putrescine at 50 ppm plus post-harvest salicylic acid at 400 ppm (T_7) gave the best fruit firmness. On the contrary, losing control fruits firmness occurred progressively during storage period in both seasons. The positive effect of putrescine and salicylic acid in maintaining firmness might due to decreasing the activity of cell wall degrading enzymes as xylanase, cellulose and polygalacturonase. This explanation came true with our data in figure 1 which showed that the combination between putrescine and salicylic acid at different concentrations especially treatments of T_7, T_8 and T_9 gave the lowest level of pectin methyl esterase activity during storage period. In addition, it had a close relation with physiological water loss from fruits during storage as showed in Table (1). These results are supported by both Kassem *et al.,* (2011) and Ponce *et al.,* (2002) where they summarized that putrescine spray delayed maturation and ripening of grape and reduced berry softening. Moreover, it was effective in decreasing respiration rate which maintained the firmness of peach fruits during cold storage (Bal, 2012).

4. SSC (%)

Data presented in Table (4) clear that, soluble solid content (SSC %) in fruit juice under all the tested treatments increased compared with control under cold storage. Among the tested treatment of pre-harvest spraying with putrescine at 50 ppm plus post-harvest dipping in salicylic acid at 400 ppm (T_7) was the best one to store the harvested fruits till the end of cold storage period having the highest significantly SSC(%) in juice. On the other hand, the least values were found in fruit juice of the control in both seasons. These results agree with those of Kazemi *et al.*, (2011) and Khosroshahi and Esna-Ashari (2008). So, the above results proved that the treatments of pre-harvest putrescine at 50 ppm plus post-harvest salicylic acid at 400 ppm was considered the most effective ones to reduce the decreasing rate in juice SSC (%) during the storage period.

5. Titratable acidity (%):

The results presented in Table (5) showed that, titratable acidity values were significantly decreased with advancing of storage period. Moreover, all tested treatments and their combinations were considered effective to maintain the juice acidity during storage period compared to control. In this respect, the treatments of T_7 and T_3 slowly maintain acidity of fruits at higher levels till 90 days of storage as compared with control and other treatments. On the other hand, the titratable acidity loss progressively occurred with control during storage period in both seasons. These findings are accordance with those of Bal, (2012) who summarized that putrescine and salicylic acid applications were effective in suppressing degradation of SSC% and acidity during cold storage of Sweet cherries. In addition, Zheng and Zhang (2004) reported that application of putrescine and salicylic acid led to improve Ponkan mandarin fruit quality such SSC and acidity%.

Table 3. Effect of putrescine and salicylic acid on firmness (Newton) of Ponkan mandarin fruits under cold storage conditions during 2017 and 2018 seasons

Treatments	2017 season							
	0	**15**	**30**	**45**	**60**	**75**	**90**	**Mean**
T_1 :Control	18.22 a	16.27b	13.25d	13.09cd	11.85c	11.24f	11.19ef	13.59e
T_2 :SA 200 ppm	17.85 a	16.22b	14.09bc	13.12cd	12.61e	12.05e	12.01c	13.99cd
T_3 :SA 400 ppm	18.43 a	16.45b	14.34bc	14.15b	13.64b	13.08c	12.40b	14.73b
T_4: Put. 50 ppm	18.61 a	16.24b	13.92c	12.73d	12.17f	11.21f	11.05fg	13.70de
T_5: Put. 100 ppm	18.76 a	16.45b	14.22bc	13.25cd	12.87d	11.18f	10.95g	13.96cd
T_6 : Put.50+ SA 200	17.86 a	17.23a	14.54b	13.37c	13.11c	12.49d	11.38de	14.19c
T_7 : Put.50+SA 400	18.76 a	17.68a	15.67a	14.50b	13.67b	13.53b	12.86a	14.89b
T_8 : Put.100+ SA 200	17.63 a	17.51a	15.75a	15.64a	14.96a	14.37a	13.02a	15.35a
T_9 : Put.100+ SA 400	18.85 a	17.84a	16.13a	14.53b	12.68de	11.96e	11.48d	14.64b
Mean	17.79a	16.88b	14.66c	13.82d	13.06e	12.35f	11.82g	--
	2018 season							
T_1 :Control	17.88ab	15.45c	13.24e	12.14g	11.69g	11.45f	11.00d	13.26f
T_2 :SA 200 ppm	17.09ab	16.74a	14.70c	14.24c	13.83c	12.82c	12.15b	14.51c
T_3 :SA 400 ppm	17.00ab	16.82a	15.41b	14.76b	14.25b	13.20b	12.17b	14.80b
T_4: Put. 50 ppm	18.27ab	16.20b	13.31e	13.00e	12.33f	12.00e	11.48c	13.80e
T_5: Put. 100 ppm	18.38a	16.28b	13.90d	12.61f	12.13f	11.96e	11.57c	13.83e
T_6 : Put.50+ SA 200	16.63b	16.25b	14.29cd	13.31d	12.85e	12.32d	11.98b	13.95e
T_7 : Put.50+SA 400	17.57ab	16.86a	16.00a	15.40a	14.52a	14.00a	13.24a	15.37a
T_8 : Put.100+ SA 200	16.81ab	16.10b	14.38c	13.99c	13.29d	12.66c	12.11b	14.19d
T_9 : Put.100+ SA 400	17.75ab	16.21b	14.33c	13.37d	13.39d	12.33d	11.98b	14.19d
Mean	17.49a	16.32b	14.40c	13.65d	13.14e	12.53f	11.96g	--

Means followed by the same letter within a column in same season are not significantly different using DMRT at $P \leq 0.05$

Table 4. Effect of putrescine and salicylic acid on SSC (%) of Ponkan mandarin fruits under cold storage during conditions 2017 and 2018 seasons

Treatments	2017 season							
	0	15	30	45	60	75	90	Mean
T_1 :Control	9.73b	9.93e	9.95g	10.16c	10.85e	10.67f	9.75f	10.15g
T_2 :SA 200 ppm	9.94a	10.36b	10.79bc	10.81ab	11.91bc	11.21b	10.88c	10.84b
T_3 :SA 400 ppm	9.88a	10.83a	10.85ab	10.84ab	11.97b	11.06c	11.00b	10.92b
T_4: Put. 50 ppm	9.78b	9.95de	10.00g	10.24bc	10.94e	10.70f	10.09e	10.24f
T_5: Put. 100 ppm	9.49c	10.02d	10.32f	10.26bc	11.09d	10.79e	10.55d	10.36e
T_6 : Put.50+ SA 200	9.51c	10.11c	10.45e	10.51abc	11.13d	10.96d	10.61d	10.47d
T_7 : Put.50+SA 400	9.90a	10.89a	10.91a	11.00a	12.29a	12.00a	11.51a	11.22a
T_8 : Put.100+ SA 200	9.95a	10.32b	10.72c	10.76abc	11.83bc	10.84e	10.80c	10.75c
T_9 : Put.100+ SA 400	9.90a	10.16c	10.53d	10.73abc	11.80c	11.00cd	10.80c	10.70c
Mean	9.79g	10.29f	10.50e	10.59d	11.53a	11.03b	10.67c	--
	2018 season							
T_1 :Control	9.14b	9.39h	9.52h	9.70i	9.92h	10.08g	10.35h	9.73i
T_2 :SA 200 ppm	9.15b	9.94c	10.26d	10.53f	11.34c	11.61c	11.93d	10.68d
T_3 :SA 400 ppm	9.29a	10.24b	10.48b	10.69b	11.44b	11.73b	12.17b	10.86b
T_4: Put. 50 ppm	9.12b	9.49g	9.97g	10.17h	10.62g	10.81f	11.10g	10.18h
T_5: Put. 100 ppm	9.16b	9.55g	10.13f	10.45g	10.70f	10.92e	11.29f	10.31g
T_6 : Put.50+ SA 200	9.17b	9.62f	10.19e	10.57e	10.85e	10.96e	11.45e	10.40f
T_7 : Put.50+SA 400	9.28a	10.34a	10.75a	10.92a	11.51a	11.89a	12.36a	11.01a
T_8 : Put.100+ SA 200	9.28a	9.82d	10.25de	10.66c	11.23d	11.66c	12.19b	10.73c
T_9 : Put.100+ SA 400	9.15b	9.71e	10.37c	10.60d	11.17d	11.55d	12.07c	10.66e
Mean	9.19g	9.79f	10.21e	10.48d	10.98c	11.24b	11.66a	--

Means followed by the same letter within a column in same season are not significantly different using DMRT at $P \leq 0.05$

Table 5. Influence of putrescine and salicylic acid on acidity (%) of Ponkan mandarin fruits under cold storage conditions during 2017 and 2018 seasons

Treatments	2017 season							
	0	15	30	45	60	75	90	Mean
T_1 :Control	1.23a	1.17f	1.08c	0.98f	0.91d	0.76f	0.68d	0.97f
T_2 :SA 200 ppm	1.22a	1.19de	1.16ab	1.12b	1.09ab	0.95bc	0.91b	1.09b
T_3 :SA 400 ppm	1.25a	1.22b	1.19a	1.15a	1.11a	1.00ab	0.96ab	1.13a
T_4: Put. 50 ppm	1.28a	1.18ef	1.10c	1.04e	1.00c	0.78f	0.68d	1.01e
T_5: Put. 100 ppm	1.29a	1.19de	1.12bc	1.08d	1.04bc	0.80ef	0.75c	1.04d
T_6 : Put.50+ SA 200	1.26a	1.18ef	1.10c	1.09cd	1.06ab	0.83def	0.76c	1.04d
T_7 : Put.50+SA 400	1.24a	1.24a	1.20a	1.16a	1.12a	1.07a	0.97a	1.14a
T_8 : Put.100+ SA 200	1.27a	1.21bc	1.19a	1.13b	1.09ab	0.87cde	0.79c	1.08bc
T_9 : Put.100+ SA 400	1.25a	1.20cd	1.14abc	1.10c	1.06ab	0.91cd	0.76c	1.06c
Mean	1.25a	1.20b	1.14c	1.09d	1.05e	0.89f	0.81g	--
	2018 season							
T_1 :Control	1.26a	1.19f	1.16e	1.09d	0.96c	0.80d	0.70g	1.02f
T_2 :SA 200 ppm	1.27a	1.24cd	1.20c	1.16abc	1.10ab	0.97bc	0.92b	1.12b
T_3 :SA 400 ppm	1.29a	1.27a	1.23a	1.18ab	1.13a	1.02ab	0.97a	1.16a
T_4: Put. 50 ppm	1.32a	1.23d	1.18d	1.11cd	1.04b	0.82d	0.72f	1.06e
T_5: Put. 100 ppm	1.33a	1.24cd	1.20c	1.15a-d	1.09ab	0.84d	0.75e	1.09cd
T_6 : Put.50+ SA 200	1.30a	1.23d	1.18d	1.13bcd	1.09ab	0.85d	0.77d	1.08de
T_7 : Put.50+SA 400	1.28a	1.21e	1.21bc	1.20a	1.12a	1.05a	0.98a	1.15a
T_8 : Put.100+ SA 200	1.31a	1.26ab	1.22ab	1.18ab	1.08ab	0.86d	0.80c	1.10c
T_9 : Put.100+ SA 400	1.29a	1.25bc	1.20c	1.15a-d	1.05b	0.93c	0.78d	1.09cd
Mean	1.29a	1.24b	1.20c	1.15d	1.07e	0.90f	0.82g	--

Means followed by the same letter within a column in same season are not significantly different using DMRT at $P \leq 0.05$

6. SSC/acid ratio:

Data obtainable in Table (6) indicate a gradual increasing in SSC/acid ratio as storage period advanced. All tested treatments have approximately the same values of SSC/acid ratio without significant differences among them in most cases in the same time. These results are in agreement with those of *Malik et al.,* (2005) on strawberry and *Ezzat et al.,* (2017) on apricot, they concluded that, polyamines applications were effective delaying maturity and fruits ripening.

7. Ascorbic acid:

The levels of ascorbic acid in Ponkan fruits followed a declining trend commensurate with advancement of storage period (Table 7) where the content of ascorbic acid at the initial of storage period was higher than the end ones. These results came true with those of Ishaq *et al.,* (2009) who reported that the ascorbic acid content in apricot fruits was reduced as affected by putrescine and salicylic acid treatments during storage.

Table 6. Effect of putrescine and salicylic acid on SSC/acid ratio of Ponkan mandarin fruits under cold storage conditions during 22017 and 2018 seasons

Treatments	2018 season							
	0	**15**	**30**	**45**	**60**	**75**	**90**	**Mean**
T_1 :Control	7.91ab	8.51d	9.21ab	10.37a	11.94a	14.04a	14.36ab	10.91a
T_2 :SA 200 ppm	8.15a	8.71bc	9.30ab	9.62bc	10.93b	11.81cde	11.97c	10.07cd
T_3 :SA 400 ppm	7.92ab	8.88a	9.12ab	9.43bc	10.78b	11.06e	11.46c	9.81e
T_4: Put. 50 ppm	7.64ab	8.43d	9.09ab	9.83b	11.29ab	13.73a	14.86a	10.70a
T_5: Put. 100 ppm	7.34b	8.42d	9.21ab	9.50bc	10.67b	13.51a	14.12ab	10.40b
T_6 : Put.50+ SA 200	7.59ab	8.57cd	9.50a	9.64bc	10.51b	13.23ab	14.00ab	10.43b
T_7 : Put.50+SA 400	8.01a	8.78ab	9.07b	9.17c	10.97b	11.24be	11.88c	9.88de
T_8 : Put.100+ SA 200	7.85ab	8.53d	9.02b	9.52bc	10.86b	12.47bc	13.67b	10.27bc
T_9 : Put.100+ SA 400	7.92ab	8.47d	9.24ab	9.66bc	11.24ab	12.10cd	14.21ab	10.41b
Mean	7.81g	8.59f	9.20e	9.64d	11.02c	12.58b	13.39a	--
	2019 season							
T_1 :Control	7.25a	7.89cd	8.21c	8.90a	10.34abc	12.61abc	14.78a	10.00b
T_2 :SA 200 ppm	7.20a	8.01bc	8.56b	9.08a	10.31abc	11.98cde	12.96b	9.73c
T_3 :SA 400 ppm	7.20a	8.06b	8.52b	9.07a	10.13abc	11.50de	12.55b	9.58c
T_4: Put. 50 ppm	6.93a	7.72e	8.45bc	9.16a	10.22abc	13.19ab	15.43a	10.16ab
T_5: Put. 100 ppm	6.91a	7.70e	8.44bc	9.09a	9.83c	12.96abc	15.06a	10.00b
T_6 : Put.50+ SA 200	7.05a	7.82de	8.64b	9.36a	9.96bbc	12.90abc	14.88a	10.09ab
T_7 : Put.50+SA 400	7.25a	8.55a	8.89a	9.38a	10.27abc	11.34e	12.62b	9.76c
T_8 : Put.100+ SA 200	7.12a	7.79de	8.40bc	9.03a	10.39ab	13.60a	15.24a	10.22a
T_9 : Put.100+ SA 400	7.13a	7.77de	8.64b	9.22a	10.64a	12.43bcd	15.49a	10.19ab
Mean	7.12g	7.92f	8.53e	9.14d	10.23c	12.50b	14.33a	--

Means followed by the same letter within a column in same season are not significantly different using DMRT at $P \leq 0.05$

Table 7. Effect of putrescine and salicylic acid on vitamin C content of Ponkan mandarin fruits under cold storage conditions during 22017 and 2018 seasons

Treatments	2017 season							
	0	**15**	**30**	**45**	**60**	**75**	**90**	**Mean**
T_1 :Control	34.73i	32.20g	30.16i	27.33h	24.40i	21.33i	20.16i	27.19i
T_2 :SA 200 ppm	37.62c	36.80b	35.12c	32.28c	31.27c	30.38c	29.10c	33.22c
T_3 :SA 400 ppm	37.83b	37.00ab	35.65b	32.63b	31.42b	30.65b	29.34b	33.50b
T_4: Put. 50 ppm	36.44h	34.20f	31.75h	29.55g	26.32h	26.05h	25.89h	30.03h
T_5: Put. 100 ppm	36.65g	35.00e	32.63g	30.50f	28.20g	27.45g	27.05g	31.07g
T_6 : Put.50+ SA 200	36.70f	35.12de	33.85e	31.71e	29.08e	27.56f	27.13f	31.59f
T_7 : Put.50+SA 400	38.08a	37.17a	36.20a	32.91a	31.70a	31.15a	29.87a	33.87a
T_8 : Put.100+ SA 200	36.99d	35.65c	34.35d	32.29c	29.34d	28.75d	28.17d	32.22d
T_9 : Put.100+ SA 400	36.73e	35.38cd	33.37f	32.15d	28.87f	28.35e	28.02e	31.84e
Mean	36.86a	35.39b	33.67c	31.26d	28.96e	27.96f	27.19g	--
	2018 season							
T_1 :Control	35.20i	32.16i	30.16i	23.65g	20.18i	19.62g	19.02f	25.71i
T_2 :SA 200 ppm	38.10c	35.91c	32.85c	30.07b	26.97c	26.22c	25.31b	30.78c
T_3 :SA 400 ppm	38.42b	36.21b	33.57b	30.40a	27.13b	26.45b	25.35b	31.08b
T_4: Put. 50 ppm	35.70h	32.40h	30.71h	26.80f	22.75h	21.06f	20.40e	27.12h
T_5: Put. 100 ppm	36.00g	33.60g	31.16g	28.25e	23.18g	22.15e	21.55d	27.98g
T_6 : Put.50+ SA 200	36.77f	34.82f	31.41f	29.57d	26.45f	26.08d	25.22c	30.05f
T_7 : Put.50+SA 400	38.76a	36.63a	34.50a	30.43a	27.95a	27.22a	26.42a	31.70a
T_8 : Put.100+ SA 200	37.18d	35.70d	32.64d	30.00c	26.95d	26.16c	25.30bc	30.56d
T_9 : Put.100+ SA 400	37.00e	35.25e	31.50e	29.60d	26.77e	26.18c	25.27bc	30.22e
Mean	37.01a	34.74b	32.05c	28.75d	25.37e	24.57f	23.76g	--

Means followed by the same letter within a column in same season are not significantly different using DMRT at $P \leq 0.05$

With regards to the effect of treatments, data in Table (7) indicated that the significant best treatments that had the lowest decreasing rates were those of pre-harvest putrescine at 50 ppm plus post-harvest salicylic acid at 400 ppm (T_7) followed by salicylic acid at 400 (T_3) and 200 ppm (T_2) . On contrary, the highest reduction was observed by control. Similar results were obtained by Ishaq *et al.,* (2009) and Kazemi *et al.,* (2011). The effective role of putrescine and salicylic acid in that respect might be explained as its activation on many carbohydrate metabolic processes that lead to an increase of glucose, fructose and sucrose during storage (Bubba, *et al.,* 2009 and Asensi and Bosch, 2010). So, putrescine and salicylic acid treatments effect on maintaining high level of ascorbic acid might be due to decreasing or delaying ascorbate oxidase activity.

8. Pectin Methylesterase activity (PME):

Results illustrated in Fig. (1) show that the values of PME activity were continuously increased with the progress of cold storage. The treatments of T_7, T_8 and T_9 recorded the lowest activity values as compared to the highest values obtained by control (T_1). The combination treatments (T_7, T_8 and T_9) cleared the lowest levels of PME activity through storage period at cold temperature. These results are in harmony with that of Bassiony *et al.,* (2018) who found that the activity of PME in grapevine fruits treated with the combination treatments of putrescine and salicylic acid during cold storage (0 – 2 ºC) was decreased compared with untreated ones. Also, Champa *et al.*, (2015) reported that putrescine application at 1.0 mM maintained the quality and extended the shelf life of Flame seedless grapevine up to 60 days under cold storage (3 - 4 ^{o}C and 90-95% RH) and it was effective in reducing the rate of berry softening and suppressed PME activity. In this line, Majeed (2014) reported that post-harvest treatment of salicylic acid at 3 mmol/l significantly lowered PME activity of plum fruits as compared to control fruits during cold storage period.

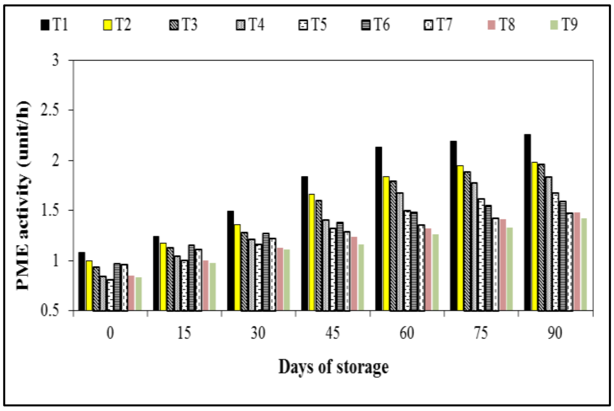

Figure 1. Effect of putrescine and salicylic acid on pectin methyl esterase activity (PME) of Ponkan mandarin fruits under cold storage (average of 2017 and 2018 seasons)

CONCLUSION

Pre-harvest application of putrescine at 50 ppm plus post-harvest salicylic acid dipping at 400 ppm before storage (T_7) was the most effective treatment in maintain fruit quality during cold storage. Therefore, it is recommended to use this treatment as pre-and post-harvest technology in Ponkan fruits, to avoid post-harvest and storage losses and enhancing quality of stored fruits.

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معاملات قبل وبعد الحصاد لتحسين صفات جودة ثمار اليوسفى بونكان أثناء التخزين
١. الحفاظ على جودة الثمار أثناء التخزين البارد

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يحتل اليوسفى صنف بونكان (اليوسفى الصينى) موقعًا متميزًا بين أصناف اليوسفى التي تزرع في مصر ، نظرًا للقيمة الغذائية العالية للثمار وارتفاع إنتاجيته ومحصوله المبكر. و على الرغم من الصفات الممتازة و الاهمية التجارية ، لا يمكن الاستمتاع باليوسفى البونكان لفترة طويلة بسبب قصر مدة صلاحية الثمار و عرضها فى الاسواق. لذا أجريت الدراسة الحالية خلال موسمى ٢٠١٧ و ٢٠١٨ على أشجار يوسفى صنف بونكان عمرها ١٠ سنوات منزرعة فى تربة طينية تحت نظام الرى بالغمر فى المزرعة البحثية لكلية الزراعة ، جامعة كفر الشيخ ، محافظة كفر الشيخ ، مصر ،حيث التربة طينية و الرى بالغمر و ذلك لدراسة تأثير رش الاشجار قبل الجمع بمحلول البوتريسين بتركيزات ٠ و ٥٠ و ١٠٠ جزء في المليون ثم معاملة الثمار بعد الجمع بغمرها لمدة ٥ دقائق فى حمض الساليسيليك بتركيزات ٠ و ٢٠٠ و ٤٠٠ جزء في المليون ، كمعاملات منفردة او فى توليفات فيما بينهما على بعض خصائص الثمار أثناء التخزين المبرد على درجة حرارة ٥ ± ١ و رطوبة نسبية ٩٠ - ٩٥ ٪ لمدة ٩٠ يوما. أظهرت النتائج التي تم الحصول عليها أن معاملات ما قبل الجمع بالبوترسين وما بعد بحمض الساليسيليك قادرة على إنتاج ثمار تتمتع بصفات جيدة خلال فترة التخزين المبرد مقارنةً بالكنترول. كانت المعاملة المركبة من رش الأشجار قبل الجمع بمحلول البوتريسين عند ٥٠ جزء في المليون بالإضافة إلى غمر الثمار بعد الجمع في محلول حمض الساليسيليك عند ٤٠٠ جزء في المليون (T7) أكثر فعالية في الحفاظ على جودة االثمار من حيث تقليل فقد وزن الثمار وتدهورها و الصلابة ، المواد الصلبة الذائبة الكلية (٪) ، الحموضة ، نسبة المواد الصلبة الذائبة الكلية / الحموضة وفيتامين ج أثناء التخزين المبرد عند درجة حرارة ٥ ± ١ °م و ٩٠-٩٥ ٪ رطوبة نسبية لمدة ٩٠ يومًا. لذلك ، اظهرت معاملات البوتريسين وحمض الساليسيليك القدرة على تقليل خسائر ما بعد الجمع والتخزين التي يمكن تجنبها مع الحفاظ على جودة ثمار اليوسفى بونكان المخزنة وتحسينها.