Pre and Postharvest Treatments to Improve Ponkan Mandarin Fruit Quality
2. Extending Shelf Life of Fruits under Room Temperature Conditions

Mervat A. El-Shemy


ABSTRACT

The present study was intended to find a treatment that maintains the quality of the Ponkan mandarin fruits (Citrus reticulata, Blanco) and extends the marketing period under the room conditions. So, nine treatments were arranged in a complete randomized design of three replicates to study the effect of pre-harvest application of putrescine at 0, 50 and 100 ppm and post-harvest application of salicylic acid at 0, 200 and 400 ppm, alone or in combinations on fruit characteristics of Ponkan mandarin during storage under room temperature conditions. The obtained results revealed that, salicylic acid and putrescine applications reduced the weight loss (%) and fruit decay (%) and maintained fruit quality in terms of fruit firmness, SSC (º), acidity, SSC/acid ratio and vitamin C during storage at room conditions. Moreover, pre-harvest application of putrescine at 50 ppm plus post-harvest dipping of salicylic acid at 200 ppm or 400 ppm (T6 and T7) were able to maintain fruits with acceptable qualities and good appearance during storage under room conditions. So, it can be concluded that using 400 ppm salicylic acid as post-harvest application, alone or in combination with 50 ppm putrescine as pre-harvest application is a beneficial treatment to increase the shelf life period of Ponkan mandarin fruits during short term storage.

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

INTRODUCTION

Ponkan mandarin (Citrus reticulata, Blanco) is a leading variety of mandarin cultivated in Egypt due to its high productivity and early yield. Fruits have a high nutritive value such as vitamin C and A as well as it contains small amounts of vitamin B9, carbohydrates and proteins (Yehia et al., 2009 and Ennab, 2017). Despite its attributes and commercial importance, Ponkan cannot be sustained for long period owing to its poor shelf life. It’s known that, the mandarin fruit is often subjected to enormous losses from orchards to consumers which causing significant economic loss for growers and retailers (Obenland et al., 2011). Pre and postharvest applications of salicylic acid and putrescine have extended the shelf life of many fruits through their effects on maintenance of cell wall structure and firmness, and reducing respiration rates, protein breakdown and decay (Serrano et al., 2003; Zheng and Zhang, 2004; Wang and Li, 2008; Davarynejad et al., 2015; Zhu et al., 2016; Abbasi et al., 2017 and Al Barzinji et al., 2017).

So, the present study was designed to study the effect of pre-harvest application of putrescine at 50 and 100 ppm, and post-harvest application of salicylic acid at 200 and 400 ppm individually or in combinations on fruit properties during storage under room temperature conditions.

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviations</th>
<th>Pre-harvest treatments (Spraying)</th>
<th>Post-harvest treatments (Fruit dipping)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1(Cont.)</td>
<td>Distilled water +</td>
<td>Distilled water</td>
</tr>
<tr>
<td>T2</td>
<td>Distilled water +</td>
<td>Salicylic acid at 200ppm</td>
</tr>
<tr>
<td>T3</td>
<td>Distilled water +</td>
<td>Salicylic acid at 400ppm</td>
</tr>
<tr>
<td>T4</td>
<td>Putrescine at 50ppm +</td>
<td>Distilled water</td>
</tr>
<tr>
<td>T5</td>
<td>Putrescine at 100ppm +</td>
<td>Salicylic acid at 200ppm</td>
</tr>
<tr>
<td>T6</td>
<td>Putrescine at 50ppm +</td>
<td>Salicylic acid at 400ppm</td>
</tr>
<tr>
<td>T7</td>
<td>Putrescine at 50ppm +</td>
<td>Salicylic acid at 400ppm</td>
</tr>
<tr>
<td>T8</td>
<td>Putrescine at 100ppm +</td>
<td>Salicylic acid at 200ppm</td>
</tr>
<tr>
<td>T9</td>
<td>Putrescine at 100ppm +</td>
<td>Salicylic acid at 400ppm</td>
</tr>
</tbody>
</table>

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DOI: 10.21608/jpp.2019.62513
Treated fruits 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 room temperature 21±1 °C and 60 ± 5 % RH for 36 days

During the storage period, the variables were measured at 12 day intervals as follow:

1. **Fruit weight loss (%):**
   All fruits were weighed and labeled at zero time (beginning) and 12 days intervals during the storage period. Fruit weight was recorded, then the percentages of weight loss were calculated according to the following equation:
   \[
   \text{Fruit weight loss} \% = \left( \frac{W_f - W_s}{W_f} \right) \times 100
   \]
   Where, \( W_f \) = fruit weight at zero time. \( W_s \) = fruit weight at sampling period.

2. **Fruits decay (%):**
   The percentage of fruit decay was recorded at 12 day periodicals during the storage period and it was calculated according to the following equation:
   \[
   \text{Decay} \% = \left( \frac{\text{Number of decayed fruits}}{\text{Initial number of stored fruits}} \right) \times 100
   \]

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).

### Table 1. Impact of putrescine and salicylic acid on weight loss (%) of Ponkan mandarin fruits stored under room temperature conditions during 2017 and 2018 seasons

<table>
<thead>
<tr>
<th>Treatments</th>
<th>0 day</th>
<th>12 day</th>
<th>24 day</th>
<th>36 day</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_1 ) : Control</td>
<td>0.00</td>
<td>7.56 a</td>
<td>12.95 a</td>
<td>18.35 a</td>
<td>9.71 a</td>
</tr>
<tr>
<td>( T_2 ) : SA 200 ppm</td>
<td>0.00</td>
<td>5.68 cd</td>
<td>10.53 cd</td>
<td>13.97 b</td>
<td>7.55 cd</td>
</tr>
<tr>
<td>( T_3 ) : SA 400 ppm</td>
<td>0.00</td>
<td>5.45 d</td>
<td>10.30 d</td>
<td>13.72 b</td>
<td>7.37 d</td>
</tr>
<tr>
<td>( T_4 ) : Put. 50 ppm</td>
<td>0.00</td>
<td>6.17 b</td>
<td>11.58 b</td>
<td>15.00 b</td>
<td>8.19 b</td>
</tr>
<tr>
<td>( T_5 ) : Put. 100 ppm</td>
<td>0.00</td>
<td>5.93 bc</td>
<td>11.05 bc</td>
<td>14.66 b</td>
<td>7.91 bc</td>
</tr>
<tr>
<td>( T_6 ) : Put.50+ SA 200</td>
<td>0.00</td>
<td>5.86 c</td>
<td>10.90 cd</td>
<td>14.21 b</td>
<td>7.74 cd</td>
</tr>
<tr>
<td>( T_7 ) : Put.50+ SA 400</td>
<td>0.00</td>
<td>5.14 e</td>
<td>8.94 e</td>
<td>11.60 c</td>
<td>6.42 e</td>
</tr>
<tr>
<td>( T_8 ) : Put.100+SA 200</td>
<td>0.00</td>
<td>5.83 c</td>
<td>10.81 cd</td>
<td>14.09 b</td>
<td>7.68 cd</td>
</tr>
<tr>
<td>( T_9 ) : Put.100+SA 400</td>
<td>0.00</td>
<td>5.86 c</td>
<td>10.91 cd</td>
<td>14.25 b</td>
<td>7.75 cd</td>
</tr>
<tr>
<td>Mean</td>
<td>0.00</td>
<td>5.94 c</td>
<td>10.89 b</td>
<td>14.43 a</td>
<td>--</td>
</tr>
</tbody>
</table>

### Results and Discussion

1. **Weight loss (%):**
   The results presented in Table (1) show that all treatments reduced the percentage of fruit weight loss during storage under the room conditions compared to control in both seasons. The best treatment in this respect was the combination between pre-harvest foliar application with putrescine at 50 ppm and post-harvest dipping in salicylic acid solution at 400 ppm (\( T_9 \)) followed by fruits dipping in salicylic acid solution at 400 ppm solely (\( T_6 \)).

On the other hand, control treatment (\( T_1 \)) showed the highest percentage of fruit weight loss compared with the other treatments in both seasons. This result is in harmony with that of Ali et al., (2014); Khosroshahi and Esna-Ashari (2008) and Lu et al., (2011) In this respect, Amanullah et al., (2017) revealed that, salicylic acid applications reduced the weight loss of pineapple and peach fruits during storage and maintaining fruit quality.

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 methyltransferase 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).

**Means followed by the same letter within a column in same season are not significantly different using DMRT at \( P \leq 0.05 \)**
Moreover, Putrescine applications were effective in decreasing weight loss of Ponkan mandarin fruits (Zheng and Zhang 2004). This beneficial effect of salicylic acid and putrescine application might be ascribed to increasing fruit firmness which resulted in the decrease in both transpiration and respiration rate (Valero et al., 1998).

2. Fruit decay (%)

Data presented in Table (2) clear that, increasing storage periods under room conditions increased the decay (%) of Ponkan mandarin fruits in both seasons. The results also indicated that the using treatments of pre-harvest putrescine spraying at 50 ppm plus post-harvest dipping in salicylic acid at 400 ppm (T₃), pre-harvest putrescine spraying at 100 ppm plus post-harvest fruits dipping in salicylic acid solution at 200 ppm (T₆), and pre-harvest putrescine spraying at 100 ppm plus post-harvest dipping in salicylic acid solution at 400 ppm (T₉) resulted in a significant decrease in decay (%) compared with control. Similar results were obtained by Amanullah et al., (2017) and Bassigny et al., (2018). This beneficial effect of putrescine and salicylic acid application on decreasing fruit decay percentages might be due to the effects on increasing fruit firmness, delaying senescence and inducing an increase of phenolic compounds which play the important defence against microorganism’s attack of fruits (Bregoli et al., 2002 and Mirdehghan et al., 2013).

Table 2. Impact of putrescine and salicylic acid on decay (%) of Ponkan mandarin fruits stored at room temperature conditions during 2017 and 2018 seasons

<table>
<thead>
<tr>
<th>Treatments</th>
<th>0 day</th>
<th>12 day</th>
<th>24 day</th>
<th>36 day</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁ :Control</td>
<td>0.00</td>
<td>3.22 a</td>
<td>5.00 a</td>
<td>6.68 a</td>
<td>3.73 a</td>
</tr>
<tr>
<td>T₂ :SA 200 ppm</td>
<td>0.00</td>
<td>2.42 d</td>
<td>4.04 d</td>
<td>5.63 d</td>
<td>3.02 d</td>
</tr>
<tr>
<td>T₃ :SA 400 ppm</td>
<td>0.00</td>
<td>2.18 e</td>
<td>3.72 e</td>
<td>5.55 e</td>
<td>2.86 e</td>
</tr>
<tr>
<td>T₄ :Put. 50 ppm</td>
<td>0.00</td>
<td>3.07 b</td>
<td>4.72 b</td>
<td>6.35 b</td>
<td>3.54 b</td>
</tr>
<tr>
<td>T₅ :Put. 100 ppm</td>
<td>0.00</td>
<td>2.71 c</td>
<td>4.33 c</td>
<td>5.97 c</td>
<td>3.25 c</td>
</tr>
<tr>
<td>T₆ :Put.50+SA 200</td>
<td>0.00</td>
<td>2.10 f</td>
<td>3.70 ef</td>
<td>5.37 f</td>
<td>2.79 f</td>
</tr>
<tr>
<td>T₇ :Put.50+SA 400</td>
<td>0.00</td>
<td>2.03 f</td>
<td>3.65 fg</td>
<td>5.21 g</td>
<td>2.72 g</td>
</tr>
<tr>
<td>T₈ :Put.100+SA 200</td>
<td>0.00</td>
<td>1.90 g</td>
<td>3.60 g</td>
<td>5.21 g</td>
<td>2.68 g</td>
</tr>
<tr>
<td>T₉ :Put.100+SA 400</td>
<td>0.00</td>
<td>1.80 h</td>
<td>3.50 b</td>
<td>5.12 b</td>
<td>2.61 h</td>
</tr>
<tr>
<td>Mean</td>
<td>0.00</td>
<td>2.38 c</td>
<td>4.03 b</td>
<td>5.68</td>
<td></td>
</tr>
</tbody>
</table>

Means followed by the same letter within a column are not significantly different using DMRT at P ≤ 0.05.

3. Fruit firmness (Newton):

Results presented in Table (3) indicate that, firmness of Ponkan mandarin fruits decreased gradually as storage period progressed. Also, the highest fruit firmness was observed in fruits treated with pre-harvest putrescine spraying at 50 ppm and post-harvest salicylic acid dipping at 400 ppm (T₃), followed by T₅ and T₇ in both seasons, respectively. Whereas, the lowest firmness of fruit was observed in control (T₁).

Putrescine and salicylic acid applications showed to be effective in retarding the ripening and firmness of banana (Srivastava and Dwivedi, 2000) and kiwifruit (Zhang et al., 2003). In this respect, Mirdehghan et al., (2013) reported that the dipping application of salicylic acid was most effective in reducing chilling injury and significantly maintained higher fruit firmness in guava as compared with untreated controls. Bal, (2013) investigated that there is a significant increase in anthocyanin content and flesh firmness of peach fruits with application of polyamines. Therefore, Pre and post-harvest treatment of putrescine and salicylic acid maintained fruit firmness and delayed ripening during storage. Such conclusion was reported by Malik et al., (2005), Ali et al., (2014) and Abbasi et al., (2017).

4. Soluble solids content (SSC%):

The results presented Table (4) show that in general, the percentage of soluble solids content was increased by increasing the storage period under room conditions. The highest values of SSC% during storage at room conditions come from the control compared with other tested treatments. A similar trend was observed by Obenland et al., (2011). At start of the storage period, the fruits treated by post-harvest dipping in salicylic acid at 400 and 200 ppm (T₃ and T₅) or in combination (T₇, T₉ and T₆) gave the lowest values of SSC% in fruits juice compared with other treatments.

These results are agree with the findings of Lo’ay, (2017) who showed that, application of salicylic acid at 4 mM maintained total solids content (SSC%) during shelf life and was effective in delaying cluster ripening of ‘Superior seedless’ grapes. Also, Champa et al. (2015) reported that, “Flame Seedless” grape berries treated with putrescine showed the lowest SSC% as compared with control during 60 days of cold storage. These were due to the role of salicylic acid in maintaining the lowest metabolic activity and reduce ethylene production which reflected on delaying the fruits ripening process during storage (Srivastava and Dwivedi, 2000 and Davarynejad et al., 2015).
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Table 3. Impact of putrescine and salicylic acid on firmness (Newton) of Ponkan mandarin fruits stored under room temperature conditions during 2017 and 2018 seasons

<table>
<thead>
<tr>
<th>Treatments</th>
<th>0 day</th>
<th>12 day</th>
<th>24 day</th>
<th>36 day</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1: Control</td>
<td>18.22 ab</td>
<td>12.56 h</td>
<td>9.72 f</td>
<td>7.86 e</td>
<td>12.09 f</td>
</tr>
<tr>
<td>T2: SA 200 ppm</td>
<td>17.85 ab</td>
<td>15.08 d</td>
<td>13.38 c</td>
<td>11.56 b</td>
<td>14.47 ab</td>
</tr>
<tr>
<td>T2: SA 400 ppm</td>
<td>18.43 a</td>
<td>15.76 b</td>
<td>13.72 b</td>
<td>11.89 b</td>
<td>14.95 a</td>
</tr>
<tr>
<td>T2: Put. 50 ppm</td>
<td>18.61 a</td>
<td>13.39 g</td>
<td>12.35 e</td>
<td>9.43 d</td>
<td>13.45 e</td>
</tr>
<tr>
<td>T2: Put. 100 ppm</td>
<td>18.77 a</td>
<td>13.52 g</td>
<td>12.73 d</td>
<td>10.18 cd</td>
<td>13.80 de</td>
</tr>
<tr>
<td>T2: Put.50+SA 200</td>
<td>17.23 ab</td>
<td>13.90 f</td>
<td>13.29 c</td>
<td>11.05 bc</td>
<td>13.87 cde</td>
</tr>
<tr>
<td>T3: Put.100+SA 200</td>
<td>16.82 ab</td>
<td>15.42 c</td>
<td>13.92 ab</td>
<td>11.24 b</td>
<td>14.35 bc</td>
</tr>
<tr>
<td>T3: Put.100+SA 400</td>
<td>17.85 ab</td>
<td>14.39 e</td>
<td>12.62 de</td>
<td>11.09 bc</td>
<td>13.99 bcde</td>
</tr>
<tr>
<td>Mean</td>
<td>17.79 a</td>
<td>14.46 b</td>
<td>12.88 c</td>
<td>10.84 d</td>
<td>--</td>
</tr>
</tbody>
</table>

Means followed by the same letter within a column are not significantly different using DMRT at P ≤ 0.05.

Table 4. Impact of putrescine and salicylic acid on SSC (%) of Ponkan mandarin fruits stored under room temperature conditions during 2017 and 2018 seasons

<table>
<thead>
<tr>
<th>Treatments</th>
<th>0 day</th>
<th>12 day</th>
<th>24 day</th>
<th>36 day</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1: Control</td>
<td>9.73b</td>
<td>12.11a</td>
<td>13.25a</td>
<td>13.33a</td>
<td>12.10a</td>
</tr>
<tr>
<td>T2: SA 200 ppm</td>
<td>9.94a</td>
<td>11.69e</td>
<td>12.16e</td>
<td>12.72f</td>
<td>11.63f</td>
</tr>
<tr>
<td>T2: SA 400 ppm</td>
<td>9.88a</td>
<td>11.14f</td>
<td>12.01f</td>
<td>12.53g</td>
<td>11.39g</td>
</tr>
<tr>
<td>T2: Put. 50 ppm</td>
<td>9.78b</td>
<td>12.07b</td>
<td>12.73b</td>
<td>13.09b</td>
<td>11.92b</td>
</tr>
<tr>
<td>T2: Put. 100 ppm</td>
<td>9.49c</td>
<td>12.03c</td>
<td>12.61c</td>
<td>13.04c</td>
<td>11.79c</td>
</tr>
<tr>
<td>T2: Put.50+SA 200</td>
<td>9.51c</td>
<td>11.90d</td>
<td>12.29d</td>
<td>13.00d</td>
<td>11.68e</td>
</tr>
<tr>
<td>T2: Put.50+SA 400</td>
<td>9.93a</td>
<td>10.97g</td>
<td>11.81g</td>
<td>12.47h</td>
<td>11.30h</td>
</tr>
<tr>
<td>T2: Put.100+SA 200</td>
<td>9.95a</td>
<td>11.70e</td>
<td>12.13e</td>
<td>12.94e</td>
<td>11.68e</td>
</tr>
<tr>
<td>T2: Put.100+SA 400</td>
<td>9.90a</td>
<td>11.70e</td>
<td>12.22de</td>
<td>13.06c</td>
<td>11.72d</td>
</tr>
<tr>
<td>Mean</td>
<td>9.79d</td>
<td>11.70c</td>
<td>12.36b</td>
<td>12.91a</td>
<td>--</td>
</tr>
</tbody>
</table>

Means followed by the same letter within a column are not significantly different using DMRT at P ≤ 0.05.

5. Titratable acidity

Data presented in Table 5 reveals that all treatments slightly increased titratable acidity in mandarin fruits during storage period compared with control. In addition titratable acidity values were gradually decreased with increasing storage period at room conditions in both seasons. On the other hand, the post-harvest dipping in 200 and 400 ppm salicylic acid individually or in combination with putrescine at 50 ppm (T2, T3 and T4) resulted in a significant increase in fruit juice acidity during storage under room conditions compared with other treatments. These results were similar with those reported by Ali et al., (2014) and Bassiony et al., (2018). This means more decomposition of organic contents in the untreated stored fruits. In addition, the major organic acids in citrus fruits are oxalic, tartaric, malic, lactic, citric, ascorbic, whereas, citric acids account for the most abundant acid of the total acid constituents of the juice. As the fruits ripening developed, a reduction in titratable acidity is observed. The decreasing in acid content was due to its use as a source of energy and the conversion of organic acids to form sugar (Burton, 1985).

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Table 5. Impact of putrescine and salicylic acid on acidity (%) of Ponkan mandarin fruits stored under room temperature conditions during 2017 and 2018 seasons

<table>
<thead>
<tr>
<th>Treatments</th>
<th>0 day</th>
<th>12 day</th>
<th>24 day</th>
<th>36 day</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt; : Control</td>
<td>1.23a</td>
<td>1.02c</td>
<td>0.91d</td>
<td>0.85a</td>
<td>1.00e</td>
</tr>
<tr>
<td>T&lt;sub&gt;2&lt;/sub&gt; : SA 200 ppm</td>
<td>1.22a</td>
<td>1.11a</td>
<td>1.04a</td>
<td>0.90a</td>
<td>1.07a</td>
</tr>
<tr>
<td>T&lt;sub&gt;3&lt;/sub&gt; : SA 400 ppm</td>
<td>1.25a</td>
<td>1.10ab</td>
<td>1.01ab</td>
<td>0.88a</td>
<td>1.06abc</td>
</tr>
<tr>
<td>T&lt;sub&gt;4&lt;/sub&gt; : Put. 50 ppm</td>
<td>1.28a</td>
<td>1.02c</td>
<td>0.92cd</td>
<td>0.86a</td>
<td>1.02cd</td>
</tr>
<tr>
<td>T&lt;sub&gt;5&lt;/sub&gt; : Put. 100 ppm</td>
<td>1.29a</td>
<td>1.03c</td>
<td>0.95bcd</td>
<td>0.86a</td>
<td>1.03cd</td>
</tr>
<tr>
<td>T&lt;sub&gt;6&lt;/sub&gt; : Put.50+ SA 200</td>
<td>1.26a</td>
<td>1.04c</td>
<td>0.97bc</td>
<td>0.87a</td>
<td>1.04cd</td>
</tr>
<tr>
<td>T&lt;sub&gt;7&lt;/sub&gt; : Put.50+ SA 400</td>
<td>1.24a</td>
<td>1.12a</td>
<td>1.05a</td>
<td>0.90a</td>
<td>1.08a</td>
</tr>
<tr>
<td>T&lt;sub&gt;8&lt;/sub&gt; : Put.100+SA 200</td>
<td>1.27a</td>
<td>1.07abc</td>
<td>0.98bc</td>
<td>0.88a</td>
<td>1.05bc</td>
</tr>
<tr>
<td>T&lt;sub&gt;9&lt;/sub&gt; : Put.100+SA 400</td>
<td>1.25a</td>
<td>1.05bc</td>
<td>0.96bcd</td>
<td>0.87a</td>
<td>1.03cd</td>
</tr>
<tr>
<td>Mean</td>
<td>1.26a</td>
<td>1.06b</td>
<td>0.98c</td>
<td>0.87d</td>
<td>--</td>
</tr>
</tbody>
</table>

Table 6. Impact of putrescine and salicylic acid on SSC/acid ratio of Ponkan mandarin fruits stored under room temperature conditions during 2017 and 2018 seasons

<table>
<thead>
<tr>
<th>Treatments</th>
<th>0 day</th>
<th>12 day</th>
<th>24 day</th>
<th>36 day</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt; : Control</td>
<td>7.91ab</td>
<td>11.87a</td>
<td>14.41a</td>
<td>15.68a</td>
<td>12.47a</td>
</tr>
<tr>
<td>T&lt;sub&gt;2&lt;/sub&gt; : SA 200 ppm</td>
<td>8.15a</td>
<td>10.53de</td>
<td>12.00e</td>
<td>14.10cd</td>
<td>11.20ef</td>
</tr>
<tr>
<td>T&lt;sub&gt;3&lt;/sub&gt; : SA 400 ppm</td>
<td>7.92ab</td>
<td>10.12ef</td>
<td>12.02e</td>
<td>14.24cd</td>
<td>11.08f</td>
</tr>
<tr>
<td>T&lt;sub&gt;4&lt;/sub&gt; : Put. 50 ppm</td>
<td>7.64ab</td>
<td>11.84a</td>
<td>13.54b</td>
<td>15.21ab</td>
<td>12.06b</td>
</tr>
<tr>
<td>T&lt;sub&gt;5&lt;/sub&gt; : Put. 100 ppm</td>
<td>7.34b</td>
<td>11.67ab</td>
<td>13.09bc</td>
<td>15.18ab</td>
<td>11.82bc</td>
</tr>
<tr>
<td>T&lt;sub&gt;6&lt;/sub&gt; : Put.50+ SA 200</td>
<td>7.59ab</td>
<td>11.46abc</td>
<td>12.29de</td>
<td>14.93bc</td>
<td>11.57cd</td>
</tr>
<tr>
<td>T&lt;sub&gt;7&lt;/sub&gt; : Put.50+ SA 400</td>
<td>8.01a</td>
<td>9.76ef</td>
<td>11.24f</td>
<td>13.85d</td>
<td>10.72g</td>
</tr>
<tr>
<td>T&lt;sub&gt;8&lt;/sub&gt; : Put.100+SA 200</td>
<td>7.85ab</td>
<td>10.93cd</td>
<td>12.33de</td>
<td>14.71bc</td>
<td>11.46de</td>
</tr>
<tr>
<td>T&lt;sub&gt;9&lt;/sub&gt; : Put.100+SA 400</td>
<td>7.92ab</td>
<td>11.15bc</td>
<td>12.73cd</td>
<td>15.01ab</td>
<td>11.71cd</td>
</tr>
<tr>
<td>Mean</td>
<td>7.81d</td>
<td>11.04c</td>
<td>12.63b</td>
<td>14.77a</td>
<td>--</td>
</tr>
</tbody>
</table>

Table 7. Vitamin C content:

Data presented in Table 7 showed that, vitamin C content of Ponkan mandarin fruits stored under room conditions, decreased gradually as storage period was prolonged. Moreover, most of the tested treatments maintained the higher concentration of vitamin C in fruit juice than the control during storage periods up to 36 days. In this respect, the highest ascorbic acid content was

7. Vitamin C content:

The results presented in Table 6 reveal that as the storage period progressed, the SSC/acid ratio significantly increased. Also, the values of SSC/acid ratio were significantly affected by salicylic acid, putrescine and their combinations specially storing fruits with putrescine at 50 ppm plus dipping in salicylic acid at 400 ppm (T<sub>7</sub>). In this respect, so, salicylic acid was more effective as a postharvest treatment in changing of SSC/acid ratio values during ambient storage. The increment in SSC/acid ratio during the storage period may be due to increasing of SSC content and the reduction in total acidity in fruit juice as the storage period was advanced. The obtained results were in the same line with those reported by Khademi and Ershadi (2013) and Amanullah et al., (2017).
observed in treatment of pre-harvest application of putrescine at 50 ppm plus post-harvest application of salicylic acid solution at 400 ppm (T₇), whereas, control treatment had lower value of ascorbic acid compared to other treatments in both seasons. So, it can be concluded that pre and postharvest application of putrescine at 50 ppm and salicylic acid at 400 ppm were most effective in preventing ascorbic acid losses from fruits during storage under room conditions. The same trend was also observed in the previous studies by Orabi et al., (2018) and Abo-Mostafa et al., (2019).

Table 7. Impact of putrescine and salicylic acid on vitamin C content of Ponkan mandarin fruits stored under room temperature conditions during 2017 and 2018 seasons

<table>
<thead>
<tr>
<th>Treatments</th>
<th>0 day</th>
<th>12 day</th>
<th>24 day</th>
<th>36 day</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁ : Control</td>
<td>34.73i</td>
<td>30.28c</td>
<td>26.86b</td>
<td>23.21d</td>
<td>28.77c</td>
</tr>
<tr>
<td>T₂ : SA 200 ppm</td>
<td>37.62c</td>
<td>33.45ab</td>
<td>29.45ab</td>
<td>25.54abc</td>
<td>31.51ab</td>
</tr>
<tr>
<td>T₃ : SA 400 ppm</td>
<td>37.83b</td>
<td>33.65ab</td>
<td>29.55ab</td>
<td>25.80ab</td>
<td>31.71ab</td>
</tr>
<tr>
<td>T₄ : Put. 50 ppm</td>
<td>36.44h</td>
<td>32.42b</td>
<td>27.35ab</td>
<td>23.65d</td>
<td>29.96d</td>
</tr>
<tr>
<td>T₅ : Put. 100 ppm</td>
<td>36.65g</td>
<td>32.52ab</td>
<td>27.40ab</td>
<td>23.72d</td>
<td>30.07d</td>
</tr>
<tr>
<td>T₆ : Put.50+SA 200</td>
<td>37.00f</td>
<td>32.98ab</td>
<td>27.90ab</td>
<td>23.75d</td>
<td>30.33d</td>
</tr>
<tr>
<td>T₇ : Put.50+SA 400</td>
<td>38.08a</td>
<td>33.99a</td>
<td>29.95a</td>
<td>26.36a</td>
<td>32.09a</td>
</tr>
<tr>
<td>T₈ : Put.100+SA 200</td>
<td>36.99d</td>
<td>33.49ab</td>
<td>28.40ab</td>
<td>25.24bc</td>
<td>31.03bc</td>
</tr>
<tr>
<td>T₉ : Put.100+SA 400</td>
<td>36.73e</td>
<td>32.93ab</td>
<td>27.89ab</td>
<td>24.75c</td>
<td>30.57cd</td>
</tr>
<tr>
<td>Mean</td>
<td>36.86a</td>
<td>32.85b</td>
<td>28.31c</td>
<td>24.67d</td>
<td>--</td>
</tr>
</tbody>
</table>

Means followed by the same letter within a column are not significantly different using DMRT at F ≤0.05.

8. Pectin Methylesterase activity (PME):

Pectin methyl esterase activity was increased progressively with increasing in storage period (Fig. 1).

![Fig. 1. Impact of putrescine and salicylic acid on pectin methyl esterase activity (PME) of Ponkan mandarin fruits stored under room temperature (average of 2017 and 2018 seasons).](image)

PME is responsible for desertification of pectin compound and its activity increased as the storage period increased. So, increased activity of PME resulted in cell wall softening in Ponkan fruits. A continuous increase in PME activity during storage was reported by Goulao et al., (2007) on Apple, Carvalho et al., (2009) on Guava and Ahlawat et al., (2018) on Kinnon mandarin. Pre and postharvest treatments of putrescine and salicylic acid increased PME activity but the level of this increasing was less as compared with control. Minimum values of PME activity was observed with T₇, T₈ and T₉ but the highest values were found in control. This may be due to the suppression of the enzymatic activity of pectin methyl esterase by these treatments. Similar results were reported by Majeed (2014), Champa et al., (2015) and Bassiony et al., (2018).

CONCLUSION

Based on the obtained results from this study it can concluded that spraying Ponkan mandarin trees ten days before harvest with putrescine at 50 ppm as pre-harvest application plus dipping the harvested fruit in 400 ppm salicylic acid as post-harvest application which regarded the best treatment in the ability to reduce the potential loss after harvest and during storage, as well as maintaining the quality of stored fruits, by increasing the length of validity of fruits in the market and also create the opportunity for export to distant markets. As well as to increase the net income of farmers and producers of Ponkan mandarin.

REFERENCES


