Pre-Harvest Application of Aminoethoxyvinylglycine, Salicylic Acid and Plant Growth Promoting Rhizobacteria on Fruit Quality of ‘Sweetheart’ Sweet Cherry

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A B S T R A C T
Sweet cherry, which affects consumers’ preferences with its aroma, taste and sensory properties, is a significant fruit species for human health with its bioactive compounds such as organic acids, vitamins and anthocyanins. However, its post-harvest shelf life is very short due to its sensitive fruit structure. Thus, the significant economic losses occur. In the study, effects of pre-harvest Aminoethoxyvinylglycine (AVG), Salicylic acid (SA) and plant growth promoting rhizobacteria (PGPR) applications on fruit quality characteristics and biochemical content in sweet cherry were determined. SA and PGPR treatments increased fruit size, but AVG decreased (If the fruit weight is 4.51 in the control application, 4.49 in the SA application and 4.10 in the PGPR, how can it be said that SA and PGPR increase the fruit weight). The fruits treated with SA, AVG and PGPR had higher fruit firmness values than the control’-fruits. Salislicylic acid treatments did not affect the rate of soluble solids content(SSC) in fruit, SSC rate was higher in PGPR treated-fruit, but AVG decreased the SSC. Titratatable acidity (TA) was lower in PGPR treated-fruit, but was higher in the AVG and SA treated-fruit. Fruits treated with the SA and AVG had higher fruit color values than control fruits, while the lowest color values was obtained with PGPR treatment. In general; PGPR, SA and AVG were effective in the concentration of organic acids, but their effects varied depending on the organic acid compounds. As a result, AVG and SA delayed fruit ripening and fruit softening while PGPR, AVG and SA improved fruit quality (It is not clear how this idea was reached). These applications can be considered as a promising method for improving fruit quality at harvest and maintaining post-harvest fruit quality of sweet cherry.

Introduction

Sweet Cherry, which is a temperate climate fruit with a very high commercial return, is a fruit species with a high consumer demand due to its flavor and many anti-inflammatory properties. Characteristics such as fruit size, fruit flesh firmness, fruit color and taste are among the most important quality parameters in sweet cherry fruit and the market value is directly proportional to the preservation of these quality parameters (Di Matteo et al., 2017). Since quality losses accelerate after harvest in sweet cherry, which is a non-climacteric fruit species, harvest time is of critical importance in order to maintain quality parameters. The prerequisite for offering quality products to the market is harvesting at the right time. Even a few days of the delaying in the harvest period may cause softening and color loss in the fruit flesh, which reduces the market value of the product. For this reason, practices that maintain fruit quality with appropriate planning in the pre-harvest period are very important (Giménez et al., 2014).

The necessity to supply the harvested fruit at tree maturity to the market quickly, causes low prices due to the accumulation of fruits harvested at the same period in the market. So, that push producers to search for delaying the harvest and preserving the quality with pre-harvest and post-harvest practices. Fruit size is a significant quality parameter that directly affects consumer demand in sweet cherry. Harvest time can be delayed with some applications before harvest and thus, fruit size could be increased (Webster et al., 2006).
AVG has been used to inhibit ethylene synthesis and delay ripening in various fruits (Webster et al., 2006). Pre-harvest AVG applications have positive effects on basic quality parameters such as fruit size, firmness and skin color as well as delaying ripening (Greene and Schupp, 2004).

Salicylic acid (SA) which has a significant role in plant development contributes to the control of biotic and abiotic stresses (Giménez et al. 2017; Hayat et al., 2010). Pre-harvest SA applications increased fruit size, weight, skin color and firmness in some table grape varieties (Champa et al., 2015); quality parameters and bioactive compounds in sweet cherry (Giménez et al., 2014) and maintain fruit characteristics such as firmness, soluble solids content, titratable acidity, sugars and organic acids in some orange cultivars (Ahmad et al., 2013a).

Plant growth promoting rhizobacteria (PGPR), which induce plant development and reduce disease and insect damage, colonies plant roots. De Silva et al. (2000) reported that PGPR such as Azorarcus, Azospirillum, Azotobacter, Arthrobotium, Bacillus, Clostridium, Enterobacter, Gluconacetobacter, Klebsiella, Pseudomonas and Serratia (Arikan and Pirlak, 2016; Tripathi et al., 2005; Khalid et al., 2004; Esikten et al., 2003) promote growth and increase yield in fruit species such as apple, citrus, blueberry, mulberry, apricot and strawberry.

The study was conducted to determine the effects of pre-harvest AVG, SA and PGPR applications on fruit quality characteristics of ‘Sweetheart’ sweet cherry cultivar.

Material and Methods

Material

In the study carried out in GAP International Agricultural Research and Training Center, Diyarbakir, Turkey in 2021 year. 15 years old trees of ‘Sweet Heart’ grafted on Gisela 5 were used. he planting density of the trees were 4m x 2m. The experiment was designed according to the randomized blocks experimental design with 3 blocks. Each block consisted of 3 trees with similar crop load. In the experiment, 6 different treatments were determined. In each block, 3 trees were selected for control, 3 trees for 250 mg L⁻¹ AVG, 3 trees for 0.5 mmol L⁻¹ SA, 3 trees for 250 mg L⁻¹ PGPR, 3 trees for PGPR+SA, 3 trees for PGPR+AVG. ReTain containing 15% AVG was used for applications. Growth regulators were sprayed on the selected trees 3 weeks (28 May 2021) before the estimated harvest date (20 June 2021). Sylgard 309 spreader adhesive was used to increase the solution effectiveness. Bacterial suspension (109 CFU ml⁻¹) of Bacillus T8 was used for PGPR applications. The application were made three times (at full bloom stage, 15 and 30 days after full bloom, but distilled water was applied to control trees SA were applied with a low-pressure ridge pump during a rain-free and wind-free period at pit hardening, initial color changes and onset of ripening stages.

Fruit Quality Characteristics

Fruit weight, geometric diameter, flesh firmness and color were determined by taking the average values of the measurements of 50 fruit obtained from each treatment tree in each block. Fruit weight (g) was determined by a digital scale with a precision of 0.01 g (Radwag, Poland). The values of the dimensional characteristics [length (U), width (G) and thickness (K)] were measured with a digital caliper (Model No: CDZ6 °C SX, Mitutoyo, Japan) with an accuracy of 0.01 mm and the geometric diameter (GC)= (U×G+K)/3 was determined by the equation (Mohsenin, 1970). Fruit flesh firmness was determined in Newtons (N) with the maximum force required to pierce the fruit at its vertical dimension. The measurements were made with a Zwick Z0.5 (Zwick/Roell Z0.5, Germany) universal testing machine with a 1.8 mm thick stainless steel tip capable of applying a maximum force of 500 N at a test speed of 0.5 mm s⁻¹ and a maximum depth of 5 mm.

The color characteristics of the fruit were determined by measuring the middle of both cheeks of the fruit using a colorimeter (Minolta, model CR-400, Tokyo, Japan). Fruit skin color was determined in terms of CIE L*, a* and b*. Chroma value= (a²+b²)¹/2 (McGuire, 1992).

A total of 45 fruit obtained from each tree were divided into 3 groups consisting of 15 fruit for SSC and TA measurements. The fruits of each group were squeezed separately in an electric juicer to obtain fruit juice. In the obtained juices, SSC was measured with a digital hand refractometer (PALZ1, McCormick Fruit Tech., Yakima, Wash.). For titratable acidity (TA) measurements, 10 ml of the juice obtained from each group was taken, 10 ml of distilled water was added and the samples were expressed in terms of malic acid (g malic acid g⁻¹) based on the amount of NaOH consumed in titration with 0.1 N sodium hydroxide (NaOH) until pH 8.1 was reached.

Organic acids: Extraction of organic acids in fresh and dried samples was carried out with the modification of the method reported by Bevilacqua and Califano (1989). 10 g of sample was taken into centrifuge tubes and then 10 mL of 0.009 N H2SO4 was added to the samples and homogenised. The samples were mixed for 1 hour and centrifuged at 14,000 rpm for 15 minutes. The liquid (supernatant) remaining at the top of the centrifuge tube was filtered through filter paper, then passed through a 0.45 µm membrane filter and finally through the SEP-PAK C18 cartridge. It was injected into the HPLC (Agilent HPLC 1100 series G 1322 A, Germany) device and the separations were performed on the appropriate column (Aminex HPX - 87 H, 300 mm x 7.8 mm). Organic acids were determined at wavelengths of 214 and 280 nm. 0.009 N H2SO4 solution was used as mobile phase.

The experiment was designed according to a randomized block design. All statistical analyses were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC, USA) and the significance of differences between means (P<0.05) was checked by Tukey test.

Result and Discussions

Fruit size, color, firmness, TSS and TA values, which are the main quality parameters for cherries, directly affect consumer demands (Díaz-Mula et al., 2009; Valero and Serrano, 2010). Compared to the control treatment, SA, PGPR and SA + PGPR treatments provided significant increases in fruit weight and fruit diameter values. On the other hand, AVG and AVG x PGPR treatments gave significantly lower results (Table 1). Webster et al. (2006) suggested that AVG’s effect varied depending on to
cultivars and that, AVG had no significant effect on the quality parameters of ‘Stella’ cultivar, but increased the fruit size of ‘Colney’ cherries. Giménez et al. (2014, 2017) reported that pre-harvest SA and ASA treatments increased fruit size values in sweet cherry. In previous studies, it was determined that PGPR application that fruit weight increased in sweet cherry (Esitken et al., 2006) and apple (Pirlak et al., 2007), but they did not affect fruit weight in blueberry (Ngugi et al., 2005).

Fruit flesh firmness, which decreases as a result of the degradation of cell wall components such as pectin substances, hemicellulose and cellulose (Wang et al., 2015) and the decrease in turgor pressure in the cell as fruit maturity progresses (Mannozzi et al., 2018), is an important quality parameter that determines the storage potential of the fruit (Ozturk et al., 2012; Cheng et al., 2020). Fruit flesh firmness, which has an important effect on marketing and post-harvest processes in fruit, decreases with the progress of maturity. AVG, SA and PGPR treatments maintained the fruit flesh firmness. The highest flesh firmness was obtained from SA+PGPR (20.82) treatment. This study showed that AVG, SA and PGPR treatments can be used reliably to maintain the fruit flesh firmness. The highest flesh firmness was obtained from SA+PGPR (20.82) treatment. This study showed that AVG, SA and PGPR treatments can be used reliably to maintain the fruit flesh firmness of sweet cherry (Table 2). Our findings are similar to those of AVG (Noppakoowoong et al., 2005), SA (Giménez et al., 2014, 2017) and PGPR treatments (Esitken, 2011) which delay ripening and slow down fruit softening.

Towards ripening, cherries generally exhibit increasing SSC and decreasing TA values. In our study, SSC values decreased significantly with AVG treatments while TA values increased significantly. Although SA treatments (SA, SA+PGPR) had similar values with control fruit, PGPR treatments significantly increased SSC value. Although the SSC values of AVG+PGPR and SA+PGPR treatments were similar with the control fruit, PGPR treatments had the highest SSC value (25.14). In contrast to SSC, TA values were found to be lowest value (1.86) among all treatments in PGPR (Table 2). The fact that Ozturk et al. (2013), suggested that AVG delayed ripening and consequently decreased SSC and increased TA values of fruit for ‘0900 Ziraat’ sweet Cherry. Ahmad et al. (2013b) determined that pre-harvest SA treatment significantly increased SSC content. Giménez et al. (2014) found that SA applications increased SSC value and TA value in 4 different sweet cherry cultivars. Again, our findings are compatible with the study of Arikan and Pirlak (2016) in which they investigated the effects of PGPR applications on fruit quality parameters in sweet cherry.

Significant decreases in $L^*$ values were observed with the progression of ripening. The lowest $L^*$ values were recorded with control and PGPR application, whereas other applications have higher $L^*$ values. Color values decreased significantly with AVG treatment. AVG-treated fruit had significantly higher the $L^*$ values (Table 3), Webster et al. (2006) reported a delay in the skin colour development of ‘Stella’ and ‘Colney’ sweet cherry cultivars treated AVG. Cetinbas and Butar (2013) reported the same case for ‘0900 Ziraat’ sweet cherries with AVG treatments. AVG has been reported to retard the development of red skin color in various other red-skinned fruit species (Greene and Schupp 2004).

### Table 1. The effects of AVG, SA and PGPR treatments on fruit weight and fruit diameter of ‘Sweetheart’ sweet cherry

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Fruit weight (g)</th>
<th>Fruit width (mm)</th>
<th>Fruit size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4.51 a</td>
<td>20.07 bc</td>
<td>17.60 ba</td>
</tr>
<tr>
<td>AVG</td>
<td>3.22 c</td>
<td>17.88 d</td>
<td>17.22 b</td>
</tr>
<tr>
<td>Salicylic acid</td>
<td>4.49 a</td>
<td>20.53 ba</td>
<td>17.96 ba</td>
</tr>
<tr>
<td>PGPR</td>
<td>4.01 b</td>
<td>19.65 e</td>
<td>18.57 a</td>
</tr>
<tr>
<td>AVG + PGPR</td>
<td>3.55 c</td>
<td>17.31 d</td>
<td>16.82 b</td>
</tr>
<tr>
<td>SA + PGPR</td>
<td>4.46 ba</td>
<td>20.96 a</td>
<td>17.86 ba</td>
</tr>
</tbody>
</table>

Means in columns the same letter do not differ according to Tukey’s test at P<0.05

### Table 2. The effects of AVG, SA and PGPR treatments on fruit firmness, SSC and TA of ‘Sweetheart’ sweet cherry

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Fruit firmness (N)</th>
<th>SSC (%)</th>
<th>TA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>15.13 c</td>
<td>23.94 b</td>
<td>2.01 c</td>
</tr>
<tr>
<td>AVG</td>
<td>18.00 b</td>
<td>21.81 c</td>
<td>2.30 ab</td>
</tr>
<tr>
<td>Salicylic acid</td>
<td>17.10 b</td>
<td>23.39 b</td>
<td>2.43 a</td>
</tr>
<tr>
<td>PGPR</td>
<td>16.60 bc</td>
<td>25.14 a</td>
<td>1.86 c</td>
</tr>
<tr>
<td>AVG + PGPR</td>
<td>16.63 bc</td>
<td>24.30 ab</td>
<td>2.40 ab</td>
</tr>
<tr>
<td>SA + PGPR</td>
<td>20.82 a</td>
<td>23.30 b</td>
<td>2.23 b</td>
</tr>
</tbody>
</table>

Means in columns the same letter do not differ according to Tukey’s test at P<0.05

### Table 3. The effects of AVG, SA and PGPR treatments on fruit color parameters of ‘Sweetheart’ sweet cherry

<table>
<thead>
<tr>
<th>Treatments</th>
<th>$L^*$</th>
<th>$a^*$</th>
<th>$b^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>29.98 b</td>
<td>14.99 d</td>
<td>4.01 c</td>
</tr>
<tr>
<td>AVG</td>
<td>32.68 a</td>
<td>23.16 b</td>
<td>7.12 a</td>
</tr>
<tr>
<td>Salicylic acid</td>
<td>33.48 a</td>
<td>35.29 a</td>
<td>6.87 a</td>
</tr>
<tr>
<td>PGPR</td>
<td>29.22 b</td>
<td>10.68 e</td>
<td>2.97 d</td>
</tr>
<tr>
<td>AVG + PGPR</td>
<td>33.15 a</td>
<td>23.44 b</td>
<td>7.73 a</td>
</tr>
<tr>
<td>SA + PGPR</td>
<td>32.67 a</td>
<td>19.10 c</td>
<td>5.49 b</td>
</tr>
</tbody>
</table>

Means in columns the same letter do not differ according to Tukey’s test at P<0.05
Romani et al. (1983) reported that AVG inhibits the accumulation of color pigments affecting the development of red color and thus delays fruit coloring. Pre-harvest SA treatment would stimulate the anthocyanin synthesis probably via activation of the phenylpropanoid pathway, although the chroma value decreased similarly in both control and treated sweet cherries, showing the typical red color darkening (Valero et al., 2010).

Citic acid and tartaric acid contents of AVG, AVG+PGPR, SA and SA+PGPR treated fruit were higher than the control before harvest. PGPR treatments had similar values with the control. Malic acid values were significantly higher than the control in all treatments, but the difference between the treatments was similar. The lowest succinic acid value was found in PGPR treated fruits and it was similar to the control. SA treatment gave significantly higher results than the other treatments. Fumaric acid values of SA, AVG and PGPR treatments were similar to the control treatment. SA and AVG treatments had the highest values and the difference between them was insignificant. Pre-harvest spray of SA significantly increased the citric acid (Table 4).

### Conclusion

The results of this study showed that pre-harvest AVG, SA ve PGPR applications affected the fruit quality characteristics such as fruit size, firmness, color, biochemical content. AVG and SA delayed fruit ripening and fruit softening. Our results in the present research suggest that these applications can be considered as a promising method for improving fruit quality at harvest and fort he maintaining the postharvest fruit quality of sweet cherry.

### References


Serrano E, Storebakken T, Penn M, Overland M, Hansen JO, Mydland LT. 2011. Responses in rainbow trout (Oncorhynchus mykiss) to increasing dietary doses of lupanine, the main quinolizidine alkaloid found in yellow lupins (Lupinus luteus). Aquaculture, 318 (1/2): 122-127. https://doi.org/10.1016/j.aquaculture.2011.05.004


