



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

Emine Kucuker<sup>1,a,\*</sup>, Kenan Celik<sup>2,b</sup>, Ceyda Kizgin Ozcengiz<sup>2,c</sup>, Ferhat Ogurlu<sup>2,d</sup>, Erdal Aglar<sup>3,e</sup>

<sup>1</sup>Siirt University, Faculty of Agriculture, Department of Horticulture, Siirt, Türkiye

<sup>2</sup>GAP International Agricultural Research and Training Center, Diyarbakır, Türkiye

<sup>3</sup>Van Yüzüncü Yıl University, Faculty of Agriculture, Department of Horticulture, Van, Türkiye

\*Corresponding author

### ARTICLE INFO

#### Research Article

Received : 27-12-2022

Accepted : 06-03-2023

#### Keywords:

Organic acids

Fruit firmness

Fruit colour

Fruit size

Sweet cherry

### ABSTRACT

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<sup>1</sup>-fruits. Salicylic 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. Titratable 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.

<sup>a</sup> [emine.kucuker@siirt.edu.tr](mailto:emine.kucuker@siirt.edu.tr)

<sup>b</sup> <https://orcid.org/0000-0002-4198-6262>

<sup>c</sup> [celikkenan@tarimorman.gov.tr](mailto:celikkenan@tarimorman.gov.tr)

<sup>d</sup> <https://orcid.org/0000-0002-5780-6342>

<sup>e</sup> [ceyda.kizginozcengiz@tarimorman.gov.tr](mailto:ceyda.kizginozcengiz@tarimorman.gov.tr)

<sup>f</sup> <https://orcid.org/0000-0002-5308-2607>

<sup>g</sup> [ferhat.ogurlu@tarimorman.gov.tr](mailto:ferhat.ogurlu@tarimorman.gov.tr)

<sup>h</sup> <https://orcid.org/0000-0002-6185-0397>

<sup>i</sup> [erdalaglar@gmail.com](mailto:erdalaglar@gmail.com)

<sup>j</sup> <https://orcid.org/0000-0002-4199-5716>



This work is licensed under Creative Commons Attribution 4.0 International License

## 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, colonize plant roots. De Silva et al. (2000) reported that PGPR such as *Azoarcus*, *Azospirillum*, *Azotobacter*, *Arthobacter*, *Bacillus*, *Clostridium*, *Enterobacter*, *Gluconacetobacter*, *Klebsiella*, *Pseudomonas* and *Serratia* (Arikan and Pirlak, 2016; Tripathi et al., 2005; Khalid et al., 2004; Esitken 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. The 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<sup>-1</sup> AVG, 3 trees for 0.5 mmol L<sup>-1</sup> SA, 3 trees for 250 mg L<sup>-1</sup> 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 (10<sup>9</sup> CFU ml<sup>-1</sup>) 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 "CSX, 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<sup>-1</sup> 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 CIEL\*, a\* and b\*. Chroma value= (a\*<sup>2</sup> + b\*<sup>2</sup>)<sup>1/2</sup> (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<sup>-100</sup>) 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 H<sub>2</sub>SO<sub>4</sub> 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 × 7.8 mm). Organic acids were determined at wavelengths of 214 and 280 nm. 0.009 N H<sub>2</sub>SO<sub>4</sub> 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 (Diaz-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 (Mannozi 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 of sweet cherry (Table 2). Our findings are similar to those of AVG (Noppakoonwong 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

| Treatments     | Fruit weight (g) | Fruit width (mm) | Fruit size (mm) |
|----------------|------------------|------------------|-----------------|
| Control        | 4.51 a           | 20.07 bc         | 17.60 ba        |
| AVG            | 3.22 c           | 17.88 d          | 17.22 b         |
| Salicylic acid | 4.49 a           | 20.53 ba         | 17.96 ba        |
| PGPR           | 4.01 b           | 19.65 c          | 18.57 a         |
| AVG + PGPR     | 3.55 c           | 17.31 d          | 16.82 b         |
| SA + PGPR      | 4.46 ba          | 20.96 a          | 17.86 ba        |

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

| Treatments     | Fruit firmness (N) | SSC (%)  | TA (%)  |
|----------------|--------------------|----------|---------|
| Control        | 15.13 c            | 23.94 b  | 2.01 c  |
| AVG            | 18.00 b            | 21.81 c  | 2.30 ab |
| Salicylic acid | 17.10 b            | 23.39 b  | 2.43 a  |
| PGPR           | 16.60 bc           | 25.14 a  | 1.86 c  |
| AVG + PGPR     | 16.63 bc           | 24.30 ab | 2.40 ab |
| SA + PGPR      | 20.82 a            | 23.30 b  | 2.23 b  |

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

| Treatments     | Fruit colour parameters |         |        |
|----------------|-------------------------|---------|--------|
|                | $L^*$                   | $a^*$   | $b^*$  |
| Control        | 29.98 b                 | 14.99 d | 4.01 c |
| AVG            | 32.68 a                 | 23.16 b | 7.12 a |
| Salicylic acid | 33.48 a                 | 35.29 a | 6.87 a |
| PGPR           | 29.22 b                 | 10.68 e | 2.97 d |
| AVG + PGPR     | 33.15 a                 | 23.44 b | 7.73 a |
| SA + PGPR      | 32.67 a                 | 19.10 c | 5.49 b |

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

Table 4. The effects of AVG, SA acid and PGPR treatments on organic acids of ‘Sweetheart’ sweet cherry cultivar

| Treatments     | Organic acids (mg/100g) |               |            |               |              |
|----------------|-------------------------|---------------|------------|---------------|--------------|
|                | Citric acid             | Tartaric acid | Malic acid | Succinic acid | Fumaric acid |
| Control        | 3.49 c                  | 17.72 c       | 7.20 b     | 0.40 de       | 0.52 ba      |
| AVG            | 4.84 a                  | 23.61 a       | 8.62 a     | 0.53 b        | 0.57 ab      |
| Salicylic acid | 4.20 b                  | 20.61 b       | 9.54 a     | 0.43 dc       | 0.60 a       |
| PGPR           | 4.47 c                  | 15.95 c       | 9.27 a     | 0.38 e        | 0.57 ba      |
| AVG + PGPR     | 3.83 cb                 | 25.61 a       | 9.41 a     | 0.46 cd       | 0.61 a       |
| SA + PGPR      | 4.96 a                  | 24.40 a       | 9.29 a     | 0.59 a        | 0.50 ba      |

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).

Citric 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 for maintaining the postharvest fruit quality of sweet cherry.

## References

- Ahmad S, Singh Z, Iqbal Z. 2013a. Effect of pre harvest spray of salicylic acid on the shelf life and quality of ‘Lane late’ sweet orange (*Citrus sinensis* L.) during cold storage. *Acta Hort.*1012:103-112. <https://doi.org/10.17660/ActaHortic.2013.1012.7>
- Ahmad I, SMA Basra, Afzal I, Farooq M, Wahid A. 2013b. Growth improvement in spring maize through exogenous application of ascorbic acid, salicylic acid and hydrogen peroxide. *Int. J. Agric. Biol.*, 15: 95–100
- Amarante CVTD, Drehmer AMF, Souza F, Francescato P. 2005. Preharvest spraying with gibberellic acid (GA3) and aminoethoxyvinylglycine (AVG) delays fruit maturity and reduces fruit losses on peaches. *Rev Bras Frutic* 27:1–5. <https://doi.org/10.1590/S0100-29452005000100003>
- Arikan Ş, Pirlak L. 2016. Effects of plant growth promoting rhizobacteria (PGPR) on growth, yield and fruit quality of sour cherry (*Prunus cerasus* L.). 58(4), 221-226. <https://doi.org/10.1007/s10341-016-0278-6>
- Bevilacqua AE, Califano AN. 1989. Determination of organic acids in dairy products by high performance liquid chromatography. *J Food Sci.* 54, 1076-1077, 1079. [doi:10.1111/j.1365-2621.1989.tb07948.x](https://doi.org/10.1111/j.1365-2621.1989.tb07948.x)
- Champa WAH, Gill MIS, Mahajan BVC. 2015. Preharvest salicylic acid treatments to improve quality and postharvest life of table grapes (*Vitis vinifera* L.) cv. Flame Seedless. *J Food Sci Technol* 52, 3607–3616 <https://doi.org/10.1007/s13197-014-1422-7>
- Cheng SB, Yu Y, Guo JY, Chen GG, Guo MR. 2020. Effect of 1-methylcyclopropene and chitosan treatment on the storage quality of jujube fruit and its related enzyme activities. *Sci. Hortic.* 265, 109281. <https://doi.org/10.1016/j.scienta.2020.109281>
- Cetinbaş M, Butar S. 2013. Aminoethoxyvinylglycine (AVG) delays maturation and improves fruit size and firmness of cv. ‘0900 Ziraat’ sweet cherry. *Eur J Hortic Sci* 78:126–131
- De Silva A, Petterson K, Rothrock C, Moore J. 2000. Growth promotion of highbush blueberry by fungal and bacterial inoculants. *HortScience*, 35: 1228–1230. <https://doi.org/10.21273/HORTSCI.35.7.1228>
- Di Matteo A, Russo R, Graziani G, Ritieni A, Di Vaio C. 2017. Characterization of autochthonous sweetcherry cultivars (*Prunus avium* L.) of southern Italy for fruit quality, bioactive compounds and antioxidant activity. *J Sci Food Agric*, 97: 2782–2794. <https://doi.org/10.1002/jsfa.8106>
- Díaz-Mula HM, Castillo S, Martínez-Romero D, Valero D, Zapata PJ, Guillén F. 2009. Organoleptic, nutritive and functional properties of sweet cherry as affected by cultivar and ripening stage. *Food Sci Technol Int* 15:535–543. <https://doi.org/10.1177/1082013209351868>
- Esti M, Cinquanta L, Sinesio F, Moneta E, Di Matteo M. 2002. Physicochemical and sensory fruit characteristics of two sweet cherry cultivars after cool storage *Food Chem.*, 76, pp. 399-405. [https://doi.org/10.1016/S0308-8146\(01\)00231-X](https://doi.org/10.1016/S0308-8146(01)00231-X)
- Esitken A. 2011. Use of plant growth promoting rhizobacteria in horticultural crops. In: Dinesh KM (ed) *Bacteria in agrobiology: Crop ecosystems*. Springer, Heidelberg, pp 189–235
- Esitken A, Karlıdag H, Ercisli S, Turan M, Sahin F. 2003. The effects of spraying a growth promoting bacterium on the yield, growth and nutrient element composition of leaves of apricot (*Prunus armeniaca* L. cv. Hacıhaliloglu). *Aust J Agric Res* 54:377–380. <https://doi.org/10.1071/AR02098>
- Esitken A, Pirlak L, Turan M, Sahin F. 2006. Effects of floral and foliar application of plant growth promoting rhizobacteria (PGPR) on yield, growth and nutrition of sweet cherry. *Scientia Horticulture*, 110, 324-327. <https://doi.org/10.1016/j.scienta.2006.07.023>
- Gimenez MJ, Valverde JM, Valero D, Guillen F, Martinez-Romero D, Serano M, Castillo S. 2014. Quality and antioxidant properties on sweet cherries as affected by preharvest salicylic and acetylsalicylic acids treatments. *Food Chemistry*, 160: 226-232. <https://doi.org/10.1016/j.foodchem.2014.03.107>

- Gimenez MJ, Serrano M, Valverde JM, Martínez-Romero D, Castillo S, Valero D, Guillén F. 2017. Preharvest salicylic acid and acetylsalicylic acid treatments preserve quality and enhance antioxidant systems during postharvest storage of sweet cherry cultivars. *J Sci Food Agric*. 2017 Mar;97(4):1220-1228. doi: 10.1002/jsfa.7853. Epub 2016 Aug 5. PMID: 27312073. <https://doi.org/10.1002/jsfa.7853>
- Greene DW, Schupp JR. 2004. Effect of aminoethoxyvinylglycine (AVG) on preharvest drop, fruit quality, and maturation of 'McIntosh' apples. II. Effect of timing and concentration relationships and spray volume. *Hort Science* 39:1036-1041. <https://doi.org/10.21273/HORTSCI.39.5.1036>
- Greene DW. 2006. An update on preharvest drop control of apples with aminoethoxyvinylglycine (ReTain). *Acta Hort* 727:311-319. <https://doi.org/10.17660/ActaHortic.2006.727.37>
- Hayat QS, Irfan M, Ahmad A. 2010. Effect of exogenous salicylic acid under changing environment: A review. *Environ. Exp. Bot.* 68:14-25. <https://doi.org/10.1016/j.envexpbot.2009.08.005>
- Khalid A, Arshad M, Zahir ZA. 2004. Screening plant growth-promoting rhizobacteria for improving growth and yield of wheat. *Journal Appl Microbiol* 96(3):473-480. <https://doi.org/10.1046/j.1365-2672.2003.02161.x>
- Kim IS, Choi CD, Lee HJ, Byun JK. 2004. Effect of aminoethoxyvinylglycine on preharvest drop, fruit quality of 'Mibaekdo' peaches. *Acta Hort* 653:173-178. <https://doi.org/10.17660/ActaHortic.2004.653.24>
- Mannozi C, Tylewicz U, Chinnici F, Siroli L, Rocculi P, Rosa MD, Romani S. 2018. Effects of chitosan based coatings enriched with procyanidin by-product on quality of fresh blueberries during storage. *Food Chem*. 251, 18-24. <https://doi.org/10.1016/j.foodchem>
- Mc Guire. 1992. Reporting of objective color measurements. *HortScience*; 27:1254-5. <https://doi.org/10.21273/HORTSCI.27.12.1254>
- Ngugi HK, Dedej S, Delaplane KS, Savelle AT, Scherm H. 2005. Effect of flower-applied serenade biofungicide (*Bacillus subtilis*) on pollination-related variables in rabbiteye blueberry. *Biol Control* 33:32-38. <https://doi.org/10.1016/j.biocontrol.2005.01.002>
- Noppakoonwong U, Sripinta P, Rath AC, George AP, Nissen RJ. 2005. Effect of Retain and potassium chloride on peach fruit quality in the subtropical highlands of Thailand. *Production technologies for low-chill temperate fruits. Reports from the second international workshop*, Chiang Mai, 19-23 April
- Ozturk B, Kucuker E, Saracoglu O, Yildiz K, Ozkan Y. 2013. Effect of plant growth regulators on fruit quality and biochemical content of '0900 Ziraat' sweet cherry cultivar. *J Tekirdag Agric Fac* 10:82-89
- Ozturk B, Kucuker E, Karaman S, Ozkan Y. 2012. The effects of cold storage and aminoethoxyvinylglycine (AVG) on bioactive compounds of plum fruit (*Prunus salicina* Lindell cv. 'Black Amber'). *Postharvest Biol. Technol.* 72, 35-41. <https://doi.org/10.1016/j.postharvbio.2012.04.015>
- Pirlak L, Turan M, Sahin F, Esitken A. 2007. Floral and foliar application of plant growth promoting rhizobacteria (PGPR) to apples increases yield, growth and nutrient element contents of leaves. *Journal of Sustainable Agriculture*, 30, 145-155. [https://doi.org/10.1300/J064v30n04\\_11](https://doi.org/10.1300/J064v30n04_11)
- Romani R, Labavith J, Yamashita T, Hess B, Rae H. 1983. Preharvest AVG treatment of 'Bartlett' pear fruits: effects on ripening, color change, and volatiles. *J. Am. Soc. Hort. Sci.* 108, 1046-1049. <https://doi.org/10.21273/jashs.108.6.1046>
- Serrano E, Storebakken T, Penn M, Overland M, Hansen JO, Mydland LT. 2011. Responses in rainbow trout (*Oncorhynchus mykiss*) to increasing dietary doses of lupinine, 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>
- Tripathi M, Munot HP, Schouche Y, Meyer JM, Goel R. 2005. Isolation and functional characterization of siderophore-producing lead and cadmium resistant *Pseudomonas putida* KNP9. *Curr Microbiol* 50:233-237. <https://doi.org/10.1007/s00284-004-4459-4>
- Valero D, Serrano M. 2010. *Postharvest Biology and Technology for Preserving Fruit Quality*, CRC Press, Boca Raton, USA, 1stedn.
- Wang L, Jin P, Wang J, Jiang LL, Shan TM, Zheng YH. 2015. Effect of baminobutyric acid on cell wall modification and senescence in sweet cherry during storage at 20 C. *Food Chem*. 175, 471-477. <https://doi.org/10.1016/j.foodchem>
- Webster AD, Spencer JE, Dover C, Atkinson CJ. 2006. The influence of sprays of gibberellic acid (GA3) and aminoethoxyvinylglycine (AVG) on fruit abscission, fruit ripening and quality of two sweet cherry cultivars. *Acta Hort* 727:467-472. <https://doi.org/10.17660/ActaHortic.2006.727.57>