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Research Article

Effects of preharvest salicylic acid and oxalic acid treatments on blackberry (cv. Bursa 1) fruit quality

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Abstract: The aim of the current study was to determine how the pre-harvest different dosages of oxalic acid (OA) and salicylic acid (SA) affect the quality of blackberry (cv. Bursa 1) fruits at harvest. Thus, blackberry plants were sprayed with solutions containing 0.5 mM SA, 1 mM SA, 2.5 mM OA, and 5 mM OA seven and fourteen days to before the commercial maturity of fruits. Some characteristics of these fruits were investigated, including their biochemistry (phenolic compounds, organic acids, and general phytochemical characteristics), pomology (fruit width, fruit length, and fruit weight), and physiology (respiration). Regarding the results, the application of SA and OA increased fruit size and fruit weight by up to 40% and 23%, respectively, while leading to a reduction in soluble solid content by up to 7%. However, the organic acids and phenolic compounds with antioxidant impact were unaffected by this decline and were found to increase, especially with OA application. The control group's respiration rate was the highest among the harvested fruits, and the treatments lowered it by 30%. Consequently, the pre-harvest application of oxalic acid or salicylic acid could enhance the quality characteristics of blackberry fruit.

1. INTRODUCTION

Wild forms of blackberry (*Rubus fruticosus*), which belongs to the *Rubus* genusof the Rosaceae, are frequently encountered, especially in the Black Sea and transitional regions of Türkiye. This shows that Türkiye is among the centers of origin (Yilmaz *et al*., 2009). Despite this, Türkiye's blackberry culture is new compared to other major species (Onur, 1999). In fact, with a production of 3583 tons, our country is still far behind its blackberry production potential (TurkStat, 2023).

In contrast to the decreasing agricultural areas, there are changes in people's diets due to the continuous increase in the world population and the pandemic conditions we are in (King *et al*., 2020). In this context, blackberry, which belongs to the group of berries defined as functional foods, is a species with a wide range of uses that is integrated into many industry products and

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consumed fresh due to its aroma (Finn & Clark, 2012). Blackberries contain high levels of different biochemicals with high antioxidant effects, such as vitamins, minerals, polyphenols, and organic acids (Memete *et al*., 2023). This antioxidative effect is reported to reduce the risk of many chronic diseases, including microbial diseases, cancer, and cardiovascular diseases (Aglar *et al*., 2021; Martins *et al*., 2023). Since it is an early-fruiting and regular crop, a highly adaptable and labor-intensive agricultural branch, it is important as a complementary product in agricultural enterprises, especially regarding the utilization of women and child labor (Funt, 2017).

Despite the increasing cultivation and production of blackberries (FAO, 2022), optimization in their production has not yet been fully achieved, highlighting the need for practices that enhance both yield and quality (Finn and Clark, 2012). Consequently, pre-harvest practices aimed at improving fruit quality during harvest and ensuring post-harvest quality preservation, while taking pre-harvest factors into account, have recently gained significant importance (Batool *et al*., 2022; Garcia-Pastor *et al*., 2020; Hazarika & Marak, 2022; Martinez-Camacho *et al*., 2022; Onik *et al*., 2021;).Salicylic acid, also known as a plant growth regulator, and oxalic acid, an organic acid, regulate many different physiological events in plants (Hayat *et al*., 2013; Prasad & Shivay, 2017). In studies where these compounds are applied separately or together, it is stated that aging is delayed by suppressing ethylene production (Ansarifar, 2019), and weight and bioactive substance loss are reduced by reducing respiration and transpiration rates (Bal, 2019; Batool *et al*., 2022). They reduce the softening of fruits by reducing the activity of pectin methylesterase and polygalacturonase enzymes (Kumar *et al*., 2021). Fresh-cut fruits and vegetables inhibit polyphenol oxidase enzyme activity, keeping the product fresh longer (Liao *et al*., 2021). Increasing the synthesis of antioxidant-derived compounds increases tolerance to biotic and abiotic stress factors (Hayat *et al*., 2013; Prasad & Shivay, 2017). They ensure the maintenance of intracellular homeostasis (Kant *et al*., 2013).

This study investigated the effects of different doses of oxalic acid and salicylic acid, applied to plants before harvest, on the quality of blackberry fruits from the Bursa 1 cultivar harvested at eating maturity.

2. MATERIAL and METHODS

2.1. Plant Material

In this study, we used ‘Bursa 1’ blackberry plants cultivated in the experimental fields of Isparta University of Applied Sciences, Faculty of Agriculture, Isparta, Türkiye, in 2023. The plants were originally planted in 2015 with a row and intra-row spacing of 3.5 m × 1.2 m. The study site is located at an altitude of 1009 m, at coordinates 37° 50′ 13.6464” N and 30° 32′ 17.6316” E. The soil in the area is clayey-loam with moderate alkalinity and very high lime content. The organic matter and extractable P and Zn levels were low, the K content was medium, and the Mn, Fe, and Cu levels were sufficient, based on the criteria outlined by Jackson (1962) (see Table 1).

Table 1. Some physical and chemical characteristics of the experimental soil.

pH (1/2.5 water)	Structure	Lime (%)	Organic material	Nutrients that can be extracted (mg/kg)					
				P	K	Fe	Cu	Zn	Mn
8.1	Clayey-loam	26.0	1.9	12.6	124	3.1	0.9	0.38	2.9

2.2. Pre-Harvest Treatments of the Plant Materials

The plants were divided into five groups, with ten plants in each group. Whole above parts of plants were sprayed with an aqueous solution of salicylic acid (0.5 mM and 1 mM doses) or oxalic acid (2.5 mM and 5 mM doses) containing 0.01% Tween-20 to ensure that applied chemicals spread and adhered homogeneously as a thin film layer. Application concentrations were determined by preliminary studies. Chemicals used are capable of breaking down easily in a short time. So, they do not have any drawbacks in terms of residue. Distilled water containing 0.01% Tween-20 was applied to the plants in the control group. The solution was sprayed (approximately 1 L per plant) with a hand sprayer on days 7 and 14 before commercial harvest (in order to set harvest time in advance, there were fruits on the plants at different ripening stages); harvesting was performed according to the color and taste (Eskimez *et al*., 2019). At the commercial ripeness stage, fruits of standard quality and size were harvested and transported to the laboratory without wasting any time.

2.3. Determination of the Pomological and Physiological Characteristics

2.3.1. *Fruit weight, length, and width*

Fruit weight was measured using an electronic balance (CPA 16001S; Sartorius, Göttingen, Germany), with an accuracy of 0.01 g. The width and length of the fruits were determined using a vernier caliper with a precision of 0.01 mm. The weight and size of the fruits were assessed based on 50 randomly selected fruits (Eskimez *et al*., 2019).

2.3.2. *Soluble solid content (SSC) and titratable acidity (TA)*

From each treatment group, 20 fruits on the day of analysis were squeezed with a juice extractor (Arzum AR1060, Istanbul, Turkey) and filtered with coarse filter paper to obtain juice samples, which were used for further analysis. SSC was measured using a digital refractometer (Atago Pocket PAL-1, Tokyo, Japan), and the results are presented as percentile values (Karaçalı, 2012). For determining TA, the fruit juice samples were titrated with 0.1 N sodium hydroxyl solution using phenolphthalein as an indicator. The results were expressed as malic acid %, and calculations were performed using the formula described by Karaçalı (2012).

2.3.3. *Respiration rate*

The fruits (100–125 g) were placed in a 500 mL glass jar, hermetically sealed, and incubated for 1 h at room temperature. Gas samples were collected by a gas-tight syringe after 1 h and injected. All measurements were made in split/splitless (S/SL) of the inlet in the split mode with a gas sampling valve with 1-mL gas sample using a fused silica capillary column (GS-GASPRO, 30 m x 0.32 mm ID., USA); a thermal conductivity detector (TCD) was used for respiration rate measurements.

2.3.4. *Extract preparation*

To prepare the fruit extracts for both HPLC and spectrophotometrical analyses, 10 g of fruit samples from each repetition were extracted with 10 mL of 80% acetone containing 0.2% formic acid, using a homogenizer for 2 min. Then, the samples were centrifuged (Eppendorf 5804R, NY, USA) at 20,000 *g* for 20 min at 4 °C (Selcuk and Erkan, 2016). Analyses were conducted when the last group was done. Extracts of previous groups were separated were stored at –20 °C till analyses.

2.3.5. *Spectrophotometric analysis*

2.3.5.1. Total Phenolic Content (TPC). The TPC was evaluated using the Folin-Ciocalteu technique as described and modified by Lola-Luz *et al*. (2014). The fruit juice was mixed with the Folin–Ciocalteu reagent and distilled water at a ratio of 1:1:18 (v/v/v) and left undisturbed for 8 min. Then, 7% sodium carbonate was added. After 2 h of incubation in the dark, the absorbance of the bluish solution was measured at 725 nm (Varian, Cary 100 Bio; Melbourne, Australia). Gallic acid was used as an external standard for plotting the calibration curve, and the results were expressed as gallic acid equivalent (GAE) of fruit juice (mg GAE 100 ml^{-1}).

2.3.5.2. Total Flavonoid Content (TFC). The aluminum chloride colorimetric method was used for determining the TFC, as described by Chang *et al*. (2002). Briefly, 50 µL of juice was collected in 10 mL tubes and mixed with 950 µL of methanol and 4 mL of distilled water. Then, 300 µL of sodium nitrite solution (5% in water) was added to the mixture. Then, 300 µL aluminum chloride solution (10% in water) was added and the mixture was left undisturbed for 5 min. Next, 2 mL of sodium hydroxide solution (1 M, in water) was added, and the total volume of the mixture was made up to 10 mL by adding distilled water. After incubating the mixture for 15 min, spectrophotometric analyses were conducted at 510 nm. The TFC was calculated from the quercetin calibration curve, and the results were expressed as mg quercetin equivalent per liter.

2.3.5.3. DPPH Assay. Antioxidant activity analyses were performed using the DPPH method. First, 50% inhibition concentration (IC_{50}) was calculated by evaluating percentage inhibition against the sample concentration. Then, concentrations up to the IC_{50} value of the samples were taken and the ability to remove DPPH radicals was determined using the method described by Mertoğlu *et al*. (2022). All results were expressed as percentages (%) in which ascorbic acid was used as an indicator.

2.3.6. *Quantification of organic acids and phenolic compounds by HPLC-UV*

Samples were first shaken for 1 h and centrifuged at 14,000 rpm for 15 min. Then, the supernatant was filtered using a 0.45 µm membrane filter. The filtered juice was analyzed by an Agilent 1260 HPLC device (Agilent Technologies, CA, USA) equipped with the Chemstation software, a quaternary pump, an autosampler, and a UV detector.

The organic acids were determined using an ACE-C18 column (4 mm × 150 mm, 5 µm; Hichrom Ltd., Theale, UK). The mobile phase consisted of a 10 mM aqueous solution of potassium phosphate (pH 2.2 with *ortho*-phosphoric acid) with a flow rate of 1 mL min^{-1}. The injection volume was 20 µL and the detector was set to 245 nm for ascorbic acid and 210 nm for all other organic acids (Fu *et al*., 2015).

An ACE-C18 (4.6 mm × 150 mm, 5 µm; Hichrom Ltd., Theale, UK) column was used for the chromatographic separation of phenolic compounds. Details of chromatographic conditions are given in Table 2.

Table 2. Chromatographic conditions of HPLC method.

Parameters	Conditions	
Mobile phase	A: Ultrapure water containing 0.1% acetic acid. B: Acetonitrile containing 0.1% acetic acid.	
Mobile phase flow rate	1.0 mL min^{-1}	
Column	ACE-C18 (4.6 mm × 150 mm, 5 µm)	
Column temperature	25 °C.	
Injection volume	10 µL	
Run time	30 min.	
Detection wavelengths	280 nm for syringic acid, protocatechic acid, and gallic acid. 225 nm for vanillic acid. 305 nm for p-coumaric acid. 330 nm for caffeic acid and chlorogenic acid.	
Elution	Gradient	
	Time min.	B% (Volume)
	0.00	8
	3.25	10
	8.00	12
	15.00	25
	15.80	30
	25.00	90
	25.40	100
	30.00	100

The mobile phase flow rate was maintained at 1.0 mL min^{-1}. Mobile phase A was ultrapure water containing 0.1% acetic acid, whereas mobile phase B was acetonitrile containing 0.1% acetic acid. The gradient conditions were as follows: 0–3.25 min, 8–10% B; 3.25–8 min, 10–12% B; 8–15 min, 12–25% B; 15–15.8 min, 25–30% B; 15.8–25 min, 30–90% B; 25–25.4 min, 90–100% B; 25.4–30 min, 100% B. The injection volume was 10 µL and the column temperature was maintained at 25 °C. The detection wavelengths were selected based on the wavelengths at which the phenolic compounds to be analyzed had maximum absorption. Syringic acid, protocatechuic acid, ferulic acid, ellagic acid, quercetin icand gallic acid were detected at 280 nm. Caffeic acid was detected at 330 nm while *p*-coumaric acid was detected at 305 nm (Wen *et al*., 2005).

2.4. Statistical Analysis

The trees in field were divided to five repetitions and each repetition consisted of ten plants according to randomized parcel design. The data were evaluated by the analysis of variance (ANOVA) using one-way ANOVA in the statistical analysis software Minitab-17. Significant differences (at $p < 0.05$) among treatments were determined using Tukey's multiple comparison test (Düzgüneş *et al*., 1987).

3. RESULTS and DISCUSSION

3.1. Fruit Weight, Fruit Length and Fruit Width

The effects of SA and OA treatments on fruit weight, fruit length, and fruit width of Bursa 1 blackberry cultivar at harvest were found to be statistically significant ($p<0.05$), and the results are presented in Figure 1. When fruit weight, length and width were considered, higher values were obtained in all treatments compared to the control. The highest fruit weight (18.2 g) was found in SA 1 mM treatment, followed by OA 5 mM (15.5 g), SA 0.5 mM (15.3 g), OA 2.5 mM (14.9 g), and control (14.8 g). Fruit size has a strong positive relationship with fruit weight and is the most important trait affecting weight along with volume (Çolak *et al*., 2022; Yaman, 2022). The results of the study were in this direction, and the longest (23.5 mm) and widest (3.1 mm) fruits were measured in 1 mM SA treatment, where the highest fruit weight was obtained. OA was in the same statistical group as the control regarding these characteristics. When pre-harvest SA treatment was applied to plum trees, the fruit weight of the treated trees was found to be around 25% higher than that of the controls (Martinez-Espla *et al*., 2019). In another study conducted on cherries, the application of pre-harvest SA resulted in an increase in fruit weight between 13% and 37% (Gimenez *et al*., 2014). This improvement in pomological traits is thought to be since salicylic acid is mainly involved in the processes of cell division and expansion.

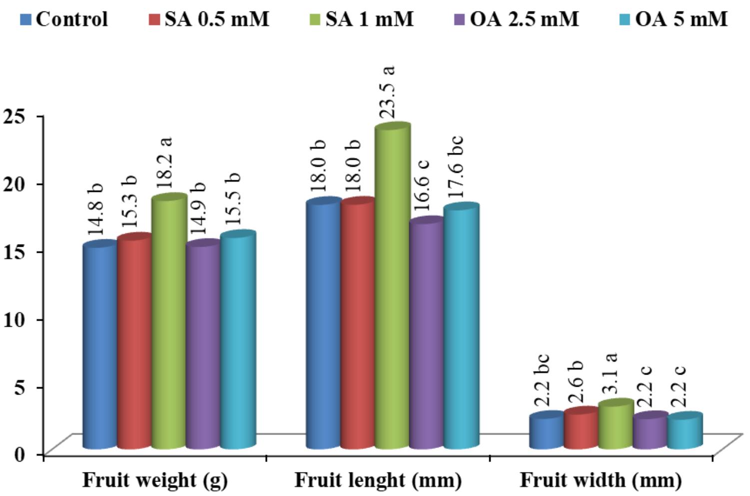


Figure 1. Effects of pre-harvest SA and OA treatments on fruit weight, fruit width and fruit length at harvest of Bursa 1 blackberry cultivar.

3.2. Soluble Solid Content, Titratable Acidity and Respiration Rate

The ripeness and flavor of horticultural crops are shaped by the composition of sugars and organic acids and the ratio of their sum to each other (Obenland *et al.*, 2011). Therefore, the accumulation and conservation of these molecules is very important. In the study, the SCC value was lower than the control in the fruits obtained from all treatment groups (see Figure 2). The highest SSC (16.2%) was measured in the control and distinguieshed statistically from 5 mM OA (15.6%), 2.5 mM OA (15.5%), 0.5 mM SA (15.1%) and 1 mM SA (15.1%) treatments ($p<0.05$). This is thought to be mostly caused by the treatments' effects on fruit size, as larger fruits have more intercellular space and less dry matter accumulation per unit area (Çolak *et al.*, 2022).

Analysis of the blackberry respiration rate at harvest regarding groups shown in Figure 2 revealed that, differences between the groups were significant and the order was as follows; control (4.0 mL CO_2 kg^{-1}h^{-1})> five mM OA (3.3 mL CO_2 kg^{-1}h^{-1})> 2.5 mM OA (3.2 mL CO_2 kg^{-1}h^{-1})> one mM SA (3.1 mL CO_2 kg^{-1}h^{-1})> 0.5 mM SA (2.8 mL CO_2 kg^{-1}h^{-1}). It has been previously reported that application of SA and OA slow down metabolic activity and downregulate the *ACO1* and *ACS2* genes responsible for ethylene biosynthesis, which are involved in ethylene production, resulting in late harvest (Kumar *et al.*, 2021). Thus, SA indicating potential for post-harvest use as well. As seen in Figure 2 pre-harvest SA treatment reduced respiration up to 30% at harvest. A grape study's findings highlighted how pre-harvest applied SA could effectively effectively lowering weight loss and bioactive compund loss by lowering transpiration and respiration (Sabır & Sabır, 2017).

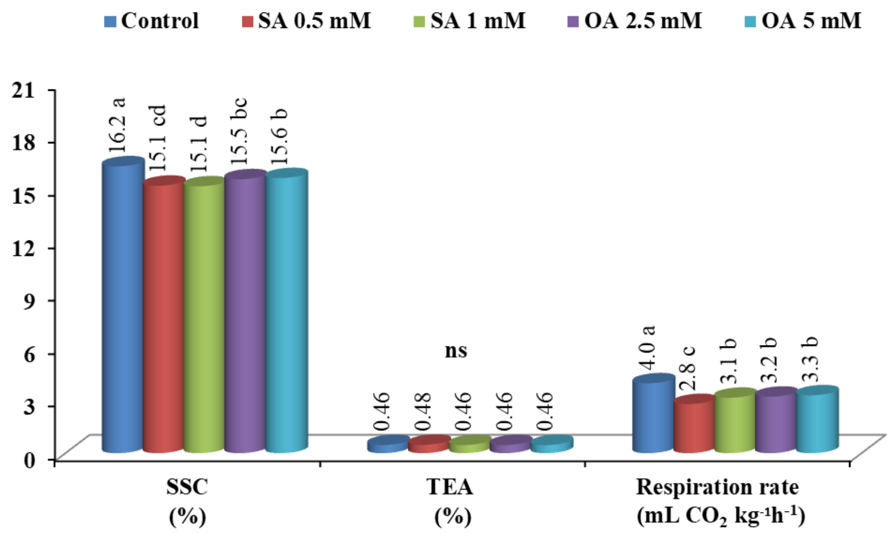


Figure 2. Effects of pre-harvest SA and OA treatments on water-soluble dry matter, titratable acidity and respiration rate of Bursa 1 blackberry cultivar at harvest.

In addition to their many health benefits, fruits and vegetables are a good source of natural antioxidants, which offer protection against harmful reactive oxygen species (ROS) and are linked to lower incidence and mortality rates of degenerative diseases like cancer and cardiovascular disease (Robinson *et al.*, 2020). Because of their effects on low density lipoproteins, phytochemicals like phenolics, flavonoids, and anthocyanins-all of which are generated by the phenylpropanoid pathway have been linked to a decreased risk of heart disease by the ability to scavenge reactive oxygen species (ROS) (Yang & Kortesniemi, 2015). They are also significant because they add to the color, astringency, bitterness, and flavor of fruits and vegetables, which are characteristics of high nutritional quality (Xu *et al*., 2023).

Figure 3 illustrates how preharvest SA and OA treatments affected the total phenolic content of blackberries at harvest. Treatments had statistically significant effects on the TPC at harvest ($p<0.05$). TPC of the OA and SA treatments was higher than that of the control. Among the treatments OA-treated blackberries had higher TPC than SA-treated blackberries. The 5 mM OA treatment had the highest total phenolic content (730.6 mg GAE $100mL^{-1}$), which was followed by the 2.5 mM OA (706.1 mg GAE $100mL^{-1}$), 1 mM SA (697.0 mg GAE $100mL^{-1}$), 0.5 mM SA (683.3 mg GAE 100mL), and control (683.1 mg GAE $100mL^{-1}$).

The highest total phenolic content (730.6 mg GAE $100mL^{-1}$) was measured in 5 mM OA treatment, followed by 2.5 mM OA (706.1 mg GAE $100mL^{-1}$), one mM SA (697.0 mg GAE $100mL^{-1}$), 0.5 mM SA (683.3 mg GAE $100mL^{-1}$) and control treatment (683.1 mg GAE $100mL^{-1}$). Many species such as mango (Zheng *et al*., 2012), banana (Huang *et al*., 2013) and cherry (Martínez-Esplá *et al*., 2014) have shown evidence of an increase in the TPC at harvest when OA was applied prior to harvest; however further research was needed to determine the mechanism underlying this effect (Serna-Escolano *et al*., 2021). Activation of phenylalanine ammonia-lyase (PAL) activity, a crucial enzyme in the phenylpropanoid pathway involved in phenolic production, may be the cause of the effect of OA treatment on increasing phenolic (Martínez-Esplá *et al*. ,2019). Likewise Mirdehghan *et al*. (2012) SA may boost the activity of phenylalanine ammonia lyase, an enzyme involved in the synthesis of flavonoids and phenolics via the phenylpropanoid pathway, and hence increase the quantity of phenolic compounds.

The effect of OA and SA treatments on the total flavonoid content of blackberries is shown in Figure 3, and the effect of treatments was found to be statistically significant ($p<0.05$). Fruits treated with 0.5 mM (587.3 mg CE L^{-1}) of SA and 5 mM (600.7 mg CE L^{-1}) of OA had a lower TPC, while highest concentration of flavonoids were measured from 2.5 mM OA (665.9 mg CE L^{-1}) and 1 mM SA (644.1 mg CE L^{-1}). According to reports, OA and SA functions as a natural antioxidants by decreasing ascorbic acid oxidation and inhibiting lipid peroxidation in vitro in a concentration-dependent manner (Batool *et al*., 2022; Gacnik *et al*., 2021). A crucial enzyme in the phenylpropanoid pathway, phenylalanine ammonia-lyase (PAL) catalyzes the conversion of phenylalanine to trans-cinnamic acid. Shikimic acid route, the primary metabolism, and the phenylpropanoid pathway, the secondary metabolism, are linked by the PAL (Dixon & Paiva, 1995). These findings lead us to hypothesize that activation of PAL enzyme activity may be the cause of the greater total phenol and flavonoid concentrations in blackberry fruits treated with OA and SA at harvest.

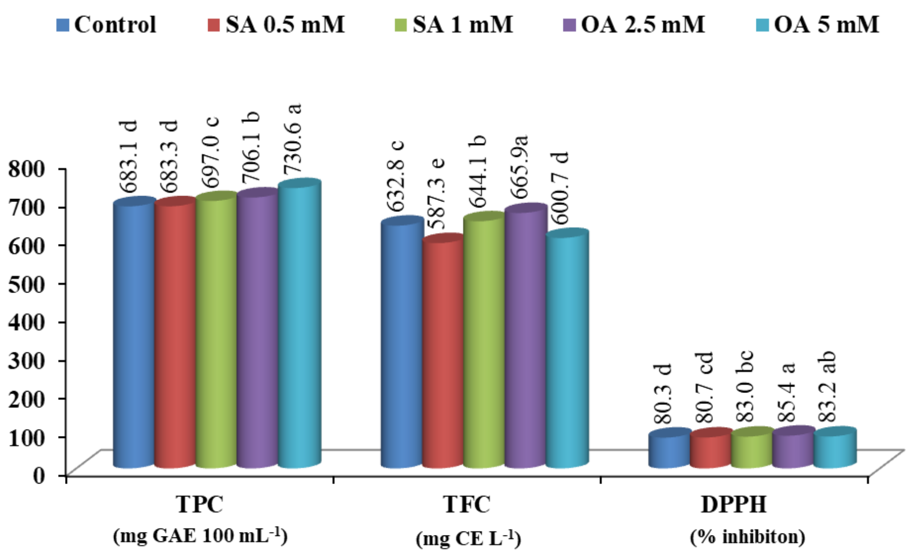
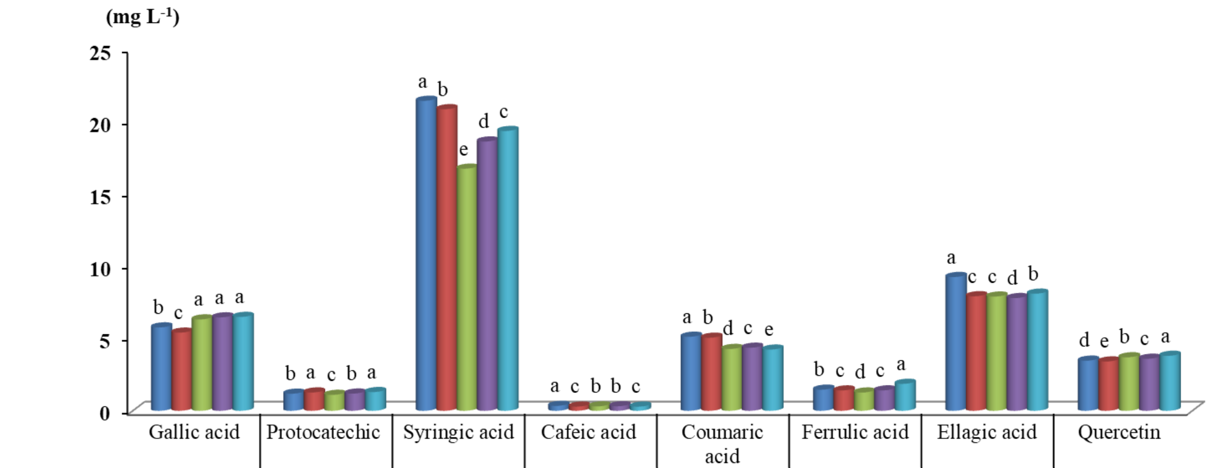


Figure 3. Effects of pre-harvest SA and OA treatments on total phenolic content, total flavonoid content and DPPH values.

Antioxidant enzymes, together with antioxidant compounds (phenolics, flavonoids, etc.), play a role in scavenging free radicals and ROS formed during the development of crops (El-Zaeddi *et al*., 2017). An increase in the antioxidant capacity of products has also been reported with pre- or post-harvest applications (Sayyari *et al*., 2011; Valero *et al*., 2011). In the present study, the antioxidant activities of blackberries at harvest were slightly increased by pre-harvest SA and OA treatments. Similar to the total phenolic and total flavonoid contents, the lowest antioxidant activity (80.3%) was measured in the control treatment, while the highest values were measured in the OA treatment (see Figure 3). Similar to the results of this study, higher antioxidant activity at harvest in OA-treated fruits was also reported in studies conducted in different species (El-Zaeddi *et al*., 2017; Martinez-Espla *et al*., 2014).

Phenolic compounds are extremely important in terms of their positive effects on health and their regulation of important physiological events. The variation of the phenolic compounds analyzed according to the treatments showed significant differences between the treatments, as shown in the Figure 4. Among the phenolic compounds examined, syringic acid, which is prominent in terms of quantity, had the highest value in the control group (21.44 mg L^{-1}) and the lowest value (16.74 mg L^{-1}) in the group treated with one mM SA (see Figure 4). A similar situation was observed in other phenolic compounds, and in general, a decrease in phenolic compounds was observed as a result of the treatments compared to the control. This is thought to be mainly due to the increase in fruit weight in parallel with the treatments. As it is known, the increase in cell size leads to an increase in intercellular space (Çolak *et al*., 2022). This causes a decrease in the amount of biochemicals produced per unit area. There are studies on the negative correlation between pomological and chemical properties of fruit in different species (Yaman, 2022). It is also known that SA and OA delay phytochemical accumulation by suppressing the effect of ethylene and abscisic acid (Ansarifar, 2019; Kumar *et al*., 2021).

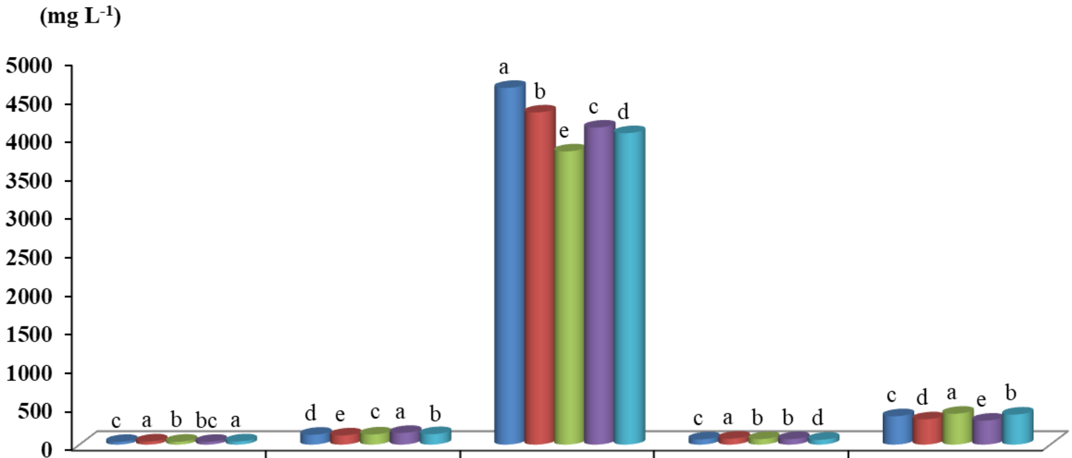


	Gallic acid	Protocatechic	Syringic acid	Cafeic acid	Coumaric acid	Ferrulic acid	Ellagic acid	Quercetin
Control	5,77	1,18	21,44	0,34	5,12	1,46	9,25	3,47
SA 0.5 mM	5,41	1,27	20,85	0,29	5,05	1,41	7,92	3,41
SA 1 mM	6,32	1,10	16,74	0,31	4,28	1,26	7,90	3,70
OA 2.5 mM	6,46	1,19	18,62	0,32	4,36	1,41	7,80	3,60
OA 5 mM	6,49	1,30	19,35	0,29	4,23	1,87	8,10	3,80

Figure 4. Effects of pre-harvest SA and OA applications on some phenolic compounds.

The organic acids examined in the study are given in Figure 5, and the effects of the treatments on all organic acids were found to be significant. Malic acid was determined as the dominant organic acid. The finding is in line with the study conducted by Kafkas *et al*. (2006), while Mikulic-Petkovsek *et al*. (2017) reported that citric acid was found to be the dominant acid of the same variety. On the other hand, it was observed that the dominant acid may vary under different factors in blackberry species (Mikulic-Petkovsek, 2021). The order of the organic acids analyzed was Malic acid> citric acid> tartaric acid> ascorbic acid> oxalic acid (see Figure 5).

Taste, which is the main reason for consumer preference, is one of the criteria shaped by organic acids, and the main reason for taste loss is the breakdown of organic acids (Obenland *et al*., 2011). In addition, organic acids are the main components that provide a low-pH environment in fruits and limit the activity of harmful microorganisms that cause spoilage (Adamczak *et al*., 2019). The effects of the applied chemicals on organic acids showed differences. While the control stood out in terms of the dominant organic acid, oxalic and tartaric acid accumulation increased with oxalic acid applications. Salicylic acid stimulated the accumulation of ascorbic acid and citric acid. Although similar results were obtained in all groups in terms of cumulative acid accumulation, fruit size and weight were higher in the treated groups. Therefore, it can be said that oxalic and salicylic acid treatments contributed to organic acid accumulation. SA and OA contribute positively to the accumulation of organic acids by increasing citrate synthase and NAD-malate dehydrogenase enzyme activities that synthesize organic acids (Brizzolara *et al*., 2020).



	Oxalic acid	Tartaric acid	Malic acid	Ascorbic acid	Citric acid
Control	35,00	127,67	4631,33	68,00	368,33
SA 0.5 mM	40,67	119,00	4312,33	77,67	328,33
SA 1 mM	37,00	131,67	3806,67	71,67	400,67
OA 2.5 mM	35,67	151,67	4116,33	71,33	311,00
OA 5 mM	41,67	135,67	4043,33	63,33	390,00

Figure 5. Effects of pre-harvest SA and OA applications on some organic acids.

4. CONCLUSION

In the current study how the preharvest application of SA and OA effect some quality characteristics of blackberry fruits were investigated. Regarding the results, applied OA and SA doses had positive effects on the pomological, biochemical and physiological characteristics examined at harvest. It was determined that SA applications (especially 1 mM SA) decreased the respiration rate at harvest, decreased the amount of SCC by increasing the fruit weight. On the other hand, OA applications were found to be more effective in improving biochemical characteristics as well as quality characteristics. As a result, it was observed that OA and SA applied before harvest could contribute to the improvement of quality characteristics and biochemical contents of Bursa 1 blackberry cultivar at harvest. However, the doses and timing of application of these substances may vary among species and even cultivars, and further research on this subject is thought to be necessary.

Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research and publishing ethics. The scientific and legal responsibility for manuscripts published in IJSM belongs to the authors.

Authorship Contribution Statement

Kerem Mertoğlu: Conceptualization, investigation, methodology, software, writing – original draft, review and editing. **İlknur Eskimez:** Conceptualization, investigation, methodology, software, writing – original draft, review and editing. **Mehmet Polat:** Resources and editing.

Derya Erbaş: Conceptualization, investigation, methodology, software, writing–original draft, review and editing. **İbrahim Bulduk:** Formal analysis, validation, methodology.

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