DETERMINATION OF THE EFFECT OF SILICON FOLIAR APPLICATION ON THE QUALITY AND POST HARVEST RESISTANCE OF SWEET CHERRY

KARAAGRA, B. – EROGUL, D.*

Department of Horticulture, Faculty of Agriculture, University of Ege
35100 Bornova, İzmir, Türkiye

**Corresponding author*
e-mail: deniz.erogul@ege.edu.tr

(Received 29th Feb 2024; accepted 16th Jul 2024)

Abstract. Sweet cherry is a very sensitive fruit. It is essential to ensure quality fruit production during cultivation. In sweet cherries, it is possible to prevent fruit loss by increasing the quality and post-harvest strength through pre-harvest applications during cultivation. The use of silicon can positively affect fruit quality in the harvest and post-harvest stages. In this study, calcium silicate (Ca_2SiO_3), potassium silicate (K_2SiO_3), and silicon dioxide (SiO_2) were applied thrice to the cherry trees, at doses of 5 mM, 10 mM, and 15 mM. Measurements and analyses of the fruits were performed during and after the harvest, after two days of shelf life. The other fruits were stored using modified atmosphere packaging, at 0 ± 0.5°C and 90%–95% relative humidity for 2 and 21 days, and the quality characteristics were determined after two days of shelf life. Coloration progresses during ripening in cherries, with a decrease in C* and h° values. The chlorophyll content in the leaves increased with the application of silicon K_2SiO_3 which also increased fruit firmness. Silicon application in cherries increases the fruit's weight and size as well as the amount of total soluble solids and phenol content, especially 5 mM and 10 mM SiO_2 applications.
Keywords: *cherry, fruit quality, preharvest spray, shelf life, silisium*

Introduction

Silicon is an element that is available abundantly in the earth's crust at 28%, in soil solution at 3%–17%, and in the dry weight of land plants at 0.1%–10% depending on the species (Epstein, 1995; Ma and Takahashi, 2002; Liang et al., 2008). In nature, it is usually present in the form of Monosilicic acid (H_4SiO_4) and is taken up directly by plants in the form of silicic acid. Silicon is not regarded as an essential plant nutrient according to the classical criteria proposed by Arnon and Stout (1939). However, silicon has been officially declared a "beneficial nutrient for plants," by the American Association of Plant Food Control Officials (AAPFCO) and may be listed on the fertilizer labels (Heckman, 2013). According to the new definition, for an element to be a plant nutrient, first, it must be one of the internal components of the plant structure, and second, abnormalities in growth, development, and reproduction must occur with its deficiency (Epstein and Bloom, 2005). Based on the conducted studies, the new definition suggests that silicon is an essential element for plants, as its deficiency is associated with different abnormalities in plants (Rafi et al., 1997; Epstein, 1999; Ma and Takahashi, 2002; Ma et al., 2007).

Silicon is the only element that enhances resistance to abiotic and biotic stress conditions and confers resistance to multiple stress conditions (Ma, 2004). Silicon has positively affected the growth and development in many plants under stress conditions (Ma and Yamaji, 2008).

It is known that silicon improves photosynthetic activity; ensures the erectness of leaves and water balance, in the xylem tubes; increases drought tolerance; leaf water potential;

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

productivity; resistance to diseases and pests; reduces the toxic effect of minerals; provides nutrient balance; increases the amount of dry matter; and provides resistance to cold stress (Matoh et al., 1991; Melo et al., 2003; Ma, 2004; Gong et al., 2011). Polymerized silicon oxide (SiO_2) particles, that is, opaline phytoliths, provide stiffness and mechanical resistance to the walls of plant cells (Raven, 1983; Piperno et al., 2002; Ma, 2004). The cuticle layer of the leaves thicken with silicon accumulation. It has been determined that transpiration decreases in many plants with silicon treatment (Agarie et al., 1998). It is hypothesized that this effect may be attributed to the reduction in transpiration rate through the cuticular layers that have been thickened by silicon deposits (Savant and Korndörfer, 1999). Silicon is taken up by the leaves, branches, shoots, and roots of plants and it strengthens the cell wall, thickens the leaf cuticle, and increases photosynthetic activity and plant growth (Gao et al., 2004). With the use of silicon, many dicotyledons react positively to abiotic and biotic stress conditions (Ma, 2004; Fauteux et al., 2005). Silicon application in fruit growing is rare, where K_2SiO_3 is generally used.

The use of silicon in fruit growing is very limited. Positive effects have been observed in mango, loquat, apple, and apricot fruits with pre-harvest silicon applications. An increase in chlorophyll content and unsaturated fatty acids is observed following K_2SiO_3 applications in strawberries; a decrease in antioxidant enzymes in mango leaves. Also, an increase in fruit quality is observed with K_2SiO_3 application in mango cultivation. K_2SiO_3 application in loquat increased the fruit size, yield, and fruit quality characteristics. K_2SiO_3 application in strawberries decreased the transpiration rate and increased the water use efficiency. K_2SiO_3 application in apples increased the fruit weight, fruit size, and shelf life. K_2SiO_3 application in apricot increased the characteristics of the fruit quality and content of mineral matter in the leaves (Wang and Galletta, 1998; Gawad, 2017; Helaly et al., 2017; El Kholy et al., 2018; Dehghanipoodeh et al., 2018; Jaishankar et al., 2018).

Türkiye is the top cherry fruit producer in the world with a cultivation volume of 656.041 tons and exported 57290 tons of cherry to world (FAO, 2024). The variety, '0900 Ziraat' is a unique one exported by Türkiye and known all over the world as the Turkish sweet cherry and is a profitable investment opportunity because of its price and export potential (Erogul, 2018). Consumer acceptance of sweet cherries appears to be most related to sweetness, fruit size, flavor intensity, firmness and skin color (Sloulin, 1990; Cliff et al., 1996; Crisosto et al., 2003). The most preferable cherries are sweet, but fruits with not very sweet taste, large fruit size, red color, reniform fruit shape and medium long stalk are also preferred (Bujdosó et al., 2020).

Cherry is a fruit that has a significant place in domestic and foreign markets; it is difficult to produce and harvest, it is sensitive, and has limited post-harvest strength. Until now, there have been no studies on silicon use in cherries. In this study, silicon treatment has been applied to improve the quality of the cherries and to maintain this quality all through the export route, until it reaches the consumer. It is the aim of this study to determine the effects of this application on the changes in quality of the cherries at harvest and post harvest.

Materials and method

Materials

A commercial orchard (in Manisa, Türkiye) provided the cultivar "0900 Ziraat" of sweet cherries (*Prunus avium* L.). The study was carried out on the "0900 Ziraat" cherry cultivar grafted on a nine-year-old Gisela 6 rootstock. The planting intervals of

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

the trees were 2.5 × 5 meters and the Kordia, Starks Gold, and Regina varieties were used as pollinators. The cherry orchard was covered with a hail net. The orchard was exposed to the customary cultural procedures in the region, including summer pruning and drip fertigation, cultivation and pest management.

Method

Fruit treatments

Three different silicon sources were used in the study: calcium silicate (Ca_2SiO_3), potassium silicate (K_2SiO_3), and silicon dioxide (SiO_2). The study was established according to the randomized block design, with four replications and each of the three cherry trees were considered as one replicate. In each replicate, 2–2.5 kg of fruit was harvested, to represent the different aspects of fruits from each tree replicate. Foliar applications of Ca_2SiO_3, K_2SiO_3, and SiO_2, at doses of 5 mM, 10 mM, and 15 mM were applied to cherry trees during three periods immediately after fruit set, when the fruits were chickpea-sized, and at the color turning stage. Using a pneumatic backpack sprayer, treatments (10 L per tree) were applied, and spraying was done, to completely saturate the leaves. In the late afternoon, foliar sprays were administered with a backpack sprayer. In all treatments, including the control, a surfactant (Nu-Film-17®, Miller Chemical Corp., USA) was applied at 0.04%. Foliar application to cherry trees is explained in the following section.

1. Control (sprinkled with water)
2. 5 mM calcium silicate application (5 mM Ca_2SiO_3)
3. 10 mM calcium silicate application (10 mM Ca_2SiO_3)
4. 5 mM calcium silicate application (15 mM Ca_2SiO_3)
5. 5 mM potassium silicate application (5 mM K_2SiO_3)
6. 10 mM potassium silicate application (10 mM K_2SiO_3)
7. 15 mM potassium silicate application (15 mM K_2SiO_3)
8. 5 mM silicon dioxide application (5 mM SiO_2)
9. 10 mM silicon dioxide application (10 mM SiO_2)
10. 15 mM silicon dioxide application (15 mM SiO_2)

The cherries were hand-picked when they were ready to be marketed. The fruits were arranged in 5 kg plastic boxes. They were then quickly transported in a refrigerated truck to the university's post-harvest lab, where they were chosen for their uniform size, disease-free status, lack of mechanical damage, and healthy greenish stems.

The cherry fruits were pre-cooled with water to reduce the core temperature to 2°C. Some of the fruits were separated and kept on the shelf (20°C temperature and 65%–75% relative humidity) for two days, and then measured and analyzed. Another part of the cherry fruits was placed in a modified atmosphere package (MAP) (LifePack, Aypek Ltd., Bursa, Türkiye) and sealed with clips. The cherries were stored at 0 ± 0.5°C and 90%–95% relative humidity, for 21 days. After opening the packages of the samples collected weekly and keeping them on the shelf life for two days, they were measured and analyzed.

Fruit quality parameters

The average fruit weight was determined by weighing 30 cherry fruits from each replicate with a precision balance (XB 12100, Presica Instruments Ltd., Switzerland)

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

sensitive to 0.05 g, and dividing the weight by the total number of fruits. The fruit width, fruit length, and fruit stem length were measured with a digital caliper, sensitive to 0.01 mm. The firmness of the cherry fruits was measured from one side of the equatorial region of them using a fruit texture analyzer (Fruit Texture Analyzer, GS-15, GÜSS Manufacturing Ltd., South Africa) with a 6.0 mm diameter tip, immersed to a depth of 8 mm, at a speed of 10 cm/min. All measurement results were given in Newton's (N) force. The breaking force of cherry fruits was measured with a dynamometer (Somfy Tec., France), by breaking 20 cherry fruits, taken randomly from each replicate. Weight loss was determined by weighing the cherry fruits before storage and again after storage and shelf life, using a scale (XB 12100, Presica Instruments Ltd., Switzerland), with a precision of 0.05 g. The results were determined as a percentage (%).

With the use of a colorimeter (CR-300, Minolta Co, Osaka, Japan), which produced CIE L*, a*, and b* values, the color of the fruit flesh and skin was measured on the two sides of the equator of 15 different fruits. A light–dark color value from 0 (black) to 100 (white), a green–red color value from - 60 (green) to + 60 (red), and a blue–yellow color value from - 60 (blue) to + 60 (yellow) were represented by the letters L*, a*, and b*, respectively. These values were then used to determine the hue angle ($h° = \tan^{-1}$ [b*/a*]), which was given in degrees: 0° (red–purple), 90° (yellow), 180° (bluish green), and 270° (blue), as well as chroma ($C^* = [a^{*2} + b^{*2}]^{1/2}$), which represented the intensity or color saturation (McGuire, 1992).

As previously documented Singh et al. (2009), the titratable acidity (TA) and total soluble solid content (TSS) of the juice derived from 10 fruits was measured. Using a temperature-compensated digital refractometer (PR-1, Atago, Tokyo, Japan), the juice TSS was calculated and represented as a percent. Ten milliliters of juice with 0.1 N NaOH was titrated until the endpoint pH reached 8.1. TA was calculated and converted into a percentage of malic acid.

Thaipong et al. (2006) method was used to prepare fruit extracts, with some alterations for antioxidant activity and total phenol content analysis. With a 120-min incubation period for color development, the Folin-Ciocalteu method established by Swain and Hillis (1959) was used to quantify the total phenol content. Using a spectrophotometer (Cany 100 Bio, Varian, Mulgrave, Australia) to measure the absorbance at 725 nm, the data were represented as mg gallic acid equivalent (GAE)/100 g fresh weight (FW), using a reference curve for gallic acid (0–0.1 mg/mL).

In accordance with Benzie and Strain's (1996) earlier instructions, the ferric reducing ability of plasma (FRAP) assay was performed. This approach increased absorbance at 593 nm by converting a Fe (III)/tripyridyl triazine complex to its blue ferrous state by the action of reductants (antioxidants) in the sample. Using a Trolox (25–500 μmol) standard curve, the final results were reported in μmol Trolox equivalents (TE)/g fresh weight (FW).

Leaf chlorophyll content (mg/kg) was calculated by taking 0.25 g of the sample from the middle part of 10 randomly selected leaves of the same plant from each replicate and homogenized with 80% acetone. The resulting solution was taken into a 50 ml flask, made up to 50 ml with acetone, and shaken well. The sample was then filtered using filter paper and the filtrates were transferred to a spectrum cuvette and read at 663 nm and 645 nm wavelengths. The values obtained were calculated according to the formula below and the total chlorophyll, chlorophyll a, and chlorophyll b values were calculated in mg/kg (Arnon, 1949).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

Statistical analyses

The data obtained from the experiment were subjected to analysis of variance (ANOVA) using the IBM® SPSS® Statistics 19 (IBM, NY, USA) statistical package software. Differences between the averages after shelf storage, in addition to each storage period, were determined by the Duncan test ($p \leq 0.05$).

Results

Fruit weights increased with all Ca_2SiO_3 treatments, and 10 mM K_2SiO_3, 5 mM SiO_2, and 10 mM SiO_2 treatments (*Fig. 1*). Control fruit weights were between 8.46 and 8.69 g, with 5 and 15 mM K_2SiO_3 treatments. All of the Ca_2SiO_3 treatments and 10 mM K_2SiO_3 treatments had a high fruit weight of about 10 g. Fruit weights in 5 mM SiO_2 (10.81 g) and 10 mM SiO_2 (10.59 g) treatments were higher than 10 g.

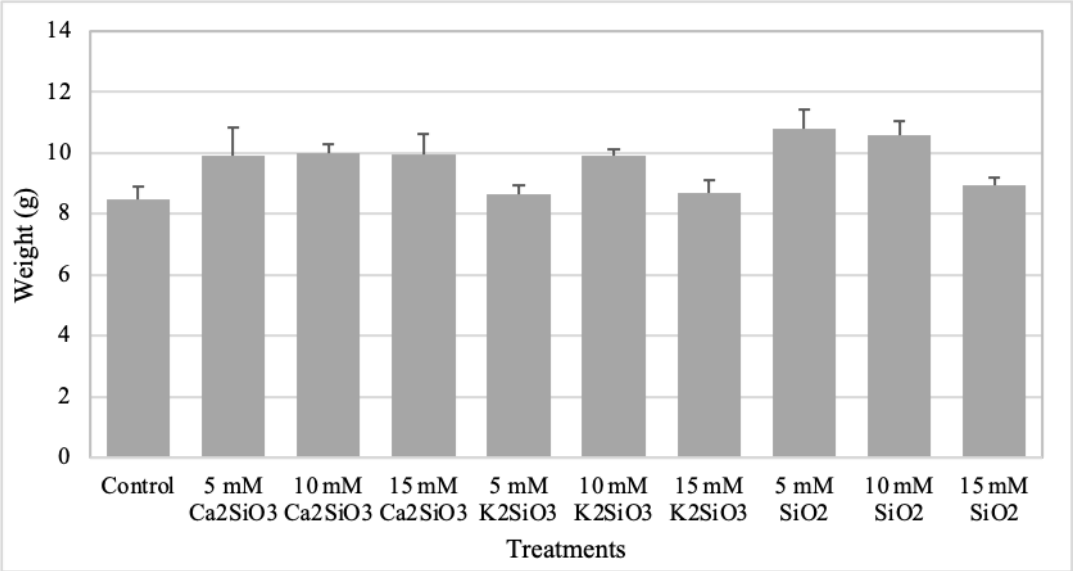

Figure 1. *Effects of foliar silicon treatments on average fruit weight*

The effects of foliar silicon applications on the width, length, stem length, breaking force, and firmness of cherry fruits are given in *Table 1*. In all treatments, except the control and 5 mM K_2SiO_3 treatment, the fruit width of the cherry was approximately 26 mm and above. In 5 mM SiO_2 (28.00 mm), 10 mM Ca_2SiO_3 (27.74 mm), and 10 mM SiO_2 treatments, it was found to be 27.65 mm. Likewise, the fruit length of these treatments was also high, between 25.26 mm and 25.62 mm.

Fruit widths in 5 and 15 mM Ca_2SiO_3 and 10 mM K_2SiO_3 treatments were determined to be between 26.15 mm and 26.54 mm. The width of the 5 mM SiO_2-treated cherry fruits was the highest (28.00 mm) and the length of the 5 mM SiO_2-treated cherry fruits was the highest (25.62 mm). Compared to the control, the 5 mM SiO_2 treatment increased fruit width by 13.82%, 10 mM SiO_2 treatment increased fruit width by 12.39%, and 10 mM Ca_2SiO_3 treatment increased fruit width by 12.76%. The fruit length was increased with silicon treatments. Compared to the control, 5 mM SiO_2 application increased fruit length by 11.85%, 10 mM SiO2 increased it by 10.11%, and 10 mM Ca_2SiO_3 increased it by 9.59%.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

The effects of foliar silicon applications on the stem length and breaking force of cherry fruits during the growing period did not show significant differences. The firmness of the cherry fruits treated with 10 mM K_2SiO_3 was the highest, with a value of 12.92 N, while the firmness of cherry fruits treated with 5 mM SiO_2 and 10 mM SiO_2 was similar to the 10 mM K_2SiO_3 treatment, and the firmness of the fruits was 12.52 N and 12.62 N, respectively. The firmness after the other treatments was found to be between 11.70 and 12.28 N.

Table 1. *The effects of foliar silicon applications on the width, length, stem length, fruit removal force, and firmness of cherry fruits*

Applications	Fruit width (mm)	Fruit length (mm)	Stem length (cm)	Fruit removal force (g)	Firmness (N)
Control	24.60 f**	22.94 f**	5.62^{NS}	487 ^{NS}	12.07 bc*
5 mM Ca_2SiO_3	26.46 bd	24.18 ce	5.27	480	12.05 bc
10 mM Ca_2SiO_3	27.74 ab	25.14 ac	5.18	489	12.02 bc
15 mM Ca_2SiO_3	26.15 ce	24.46 bd	5.35	472	11.70 c
5 mM K_2SiO_3	25.04 ef	23.18 ef	5.54	484	12.05 bc
10 mM K_2SiO_3	26.54 bd	24.09 de	5.28	505	12.92 a
15 mM K_2SiO_3	25.91 de	23.61 df	5.62	486	12.02 bc
5 mM SiO_2	28.00 a	25.66 a	5.49	492	12.52 ab
10 mM SiO_2	27.65 ab	25.26 ab	5.51	484	12.62 ab
15 mM SiO_2	25.71 de	23.88 df	5.57	470	12.28 ac

^{z} Means separation within columns by Duncan's multiple range test. $P \leq 0.05$
^{NS}, *, ** Nonsignificant or significant at $P \leq 0.05$. or 0.01, respectively

The TSS content of the fruits increased with silicon treatments (*Table 2*). The treatments with the highest amount of TSS content were found to be the 5 mM Ca_2SiO_3 and the 5 and 10 mM SiO_2 treatments. Silicon treatments increased the amount of TSS to between 14.18% and 27.22% compared to the control. This increase was higher in calcium silicate and silicon dioxide treatments. In this study of silicon treatments in cherries. The TSS content of cherries in control fruits was within the consumer acceptance of 14.80% and the TSS content of cherries with silicon treatments increased and was found between 16.90%–18.83%.

The TA content of cherry fruits also increased with silicon treatments (*Table 2*). The TA content of the cherry fruits treated with 5 mM Ca_2SiO_3 (1.89 g/100 mL). which had the highest TSS content was also found to be high. The 5 mM (1.58 g/100 mL) and 10 mM K_2SiO_3 (1.49 g/100 mL) treatments also yielded a high TA content. However, the TA content of all SiO_2 treatments and 15 mM K_2SiO_3 treatments were in the lower group (1.18–1.32 g/100 mL), but still higher than the control (1.06 g/100 mL).

The effects of the treatments on C* value, which expresses the brightness–darkness of cherry fruits, and h° value. Which expresses color saturation, were statistically significant. The C* value of silicon-treated cherry fruits (31.20–37.24) was lower than the control (43.17). Especially the C* value of the SiO_2-treated cherry fruits was found to be the lowest. In general, the h° value of the control fruits (24.86) was higher than that of the silicon-treated fruits (*Table 2*).

The total phenol content of cherry fruits increased with silicon treatments. Also 5 mM SiO_2 application yielded very high phenol contents. The effects of different foliar

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

silicon applications on the antioxidant activity of cherry fruits during the growing period were similar to each other. Chlorophyll contents increased with silicon applications. With 15 mM SiO_2 application, chlorophyll-a and chlorophyll-b contents and accordingly total chlorophyll contents were found to be the highest, compared to other treatments (*Table 3*).

Table 2. *The effects of foliar silicon applications on C*, h°, TSS and TA content value of cherry fruits*

Applications	C* value	h° values	TSS content (%)	TA content (g/100 mL)
Control	43.17 a**	24.86 a*	14.80 e**	1.06 e**
5 mM Ca_2SiO_3	34.68 bc	19.57 b	18.83 a	1.89 a
10 mM Ca_2SiO_3	36.92 bc	20.80 b	18.30 ac	1.63 b
15 mM Ca_2SiO_3	36.00 bc	21.07 b	18.17 ac	1.56 b
5 mM K_2SiO_3	34.80 bc	20.10 b	17.43 cd	1.58 b
10 mM K_2SiO_3	35.83 bc	22.17 ab	17.97 bcd	1.49 bc
15 mM K_2SiO_3	37.24 b	22.38 ab	16.90 d	1.23 de
5 mM SiO_2	31.41 cd	18.86 b	18.67 ab	1.32 ce
10 mM SiO_2	31.20 d	19.53 b	18.67 ab	1.24 de
15 mM SiO_2	33.87 bd	21.38 b	17.57 bd	1.18 de

[z] Means separation within columns by Duncan's multiple range test. $P \leq 0.05$
[NS], *, ** Nonsignificant or significant at $P \leq 0.05$. or 0.01, respectively

Table 3. *Effects of foliar silicon applications on the total phenol content, antioxidant activity, chlorophyll a, b, and chlorophyll a + b*

Applications	Total phenol content (mg GAE/100 g)	Antioxidant activity (μmol TE/g)	Chl a (mg/kg)	Chl b (mg/kg)	Chl a + b (mg/kg)
Control	94.96 d**	8.45^{NS}	26.67 e	8.82 c	35.49 d
5 mM Ca_2SiO_3	110.29 ab	10.62	30.42 ce	10.99 ac	41.41 cd
10 mM Ca_2SiO_3	100.09 cd	9.32	28.15 de	9.06 bc	37.21 d
15 mM Ca_2SiO_3	100.47 cd	9.61	29.38 ce	9.15 bc	38.53 cd
5 mM K_2SiO_3	112 ab	10.71	33.83 bd	10.46 ac	44.29 bd
10 mM K_2SiO_3	107.48 bd	10.45	33.60 bd	10.76 ac	44.36 bd
15 mM K_2SiO_3	108.77 bc	9.58	38.10 ab	11.98 a	50.08 ab
5 mM SiO_2	119.63 a	11.14	35.13 bc	11.27 ab	46.40 ac
10 mM SiO_2	113.84 ab	11.05	32.14 be	10.45 ac	42.59 bd
15 mM SiO_2	107.55 bd	9.73	41.48 a	12.66 a	54.14 a

[z] Means separation within columns by Duncan's multiple range test. $P \leq 0.05$
[NS], *, ** Nonsignificant or significant at $P \leq 0.05$. or 0.01, respectively

Effects of silicon treatments on post-harvest durability of cherry fruits

Weight loss in cherries due to storage in modified atmosphere bags was low, even in control fruits. Weight loss in the control fruits varied between 1.56% and 1.85% while it was between 1.27% and 1.85% with the treatments. Weight loss in the 15 mM K_2SO_3

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

treatment was less than in the other treatments. Shelf life losses were higher after 0 + 2 days and 7 + 2 days shelf life. After this. the losses continued to decrease compared to the beginning (*Table 4*).

Table 4. *Effects of foliar silicon applications on the weight loss (%), firmness (N), C* and h° values of cherry fruits after shelf life and storage period*

Treatments	Weight loss (%)		Firmness (N)		C* value		h° value	
	0 + 2	21 + 2	0 + 2	21 + 2	0 + 2	21 + 2	0 + 2	21 + 2
Control	1.85^{NS}	1.56^{NS}	12.07 bc^{Z*}	12.44 c^{*}	34.49 a^{**}	33.86 a^{**}	20.42 a^{*}	22.03 a^{**}
5 mM Ca_2SiO_3	1.80	1.66	12.05 bc	12.37 c	26.69 cd	24.65 de	16.26 b	18.07 cd
10 mM Ca_2SiO_3	1.57	1.15	12.02 bc	12.52 c	29.11 bc	29.37 bc	17.72 ab	20.18 ad
15 mM Ca_2SiO_3	1.83	1.69	11.70 c	12.09 c	29.16 bc	28.51 bd	18.16 ab	19.00 bd
5 mM K_2SiO_3	1.85	1.63	12.05 bc	12.78 ac	25.98 d	25.54 ce	16.11 b	17.95 d
10 mM K_2SiO_3	1.62	1.70	12.92 a	13.63 a	29.86 b	27.32 be	18.96 ab	20.36 ac
15 mM K_2SiO_3	1.57	1.33	12.02 bc	13.43 ab	29.85 b	30.79 ab	18.25 ab	20.92 ab
5 mM SiO_2	1.83	1.27	12.52 ab	12.74 ac	26.64 cd	25.75 ce	17.66 ab	18.69 bd
10 mM SiO_2	1.50	1.63	12.62 ab	12.79 ac	27.01 cd	23.43 e	18.48 ab	17.85 d
15 mM SiO_2	1.85	1.60	12.28 ac	12.67 bc	30.31 b	24.63 de	19.24 ab	17.86 d

^{z} Means separation within columns by Duncan's multiple range test. $P \leq 0.05$
^{NS}, *, ** Nonsignificant or significant at $P \leq 0.05$. or 0.01, respectively

Compared to the initial values of firmness of the cherry fruits. there was no significant decrease in these values after storage + shelf life, including the control (*Table 4*). The cherry fruits were able to maintain their firmness at the end of 21 + 2 days. MAP bags had a great effect on this. The firmness of the cherry fruits treated with 10 mM K_2SiO_3 was found to be the highest.

The effect of treatments on C* and h° values of cherry fruits after shelf life (0 + 2 and 21 + 2 days) and storage periods was significant (*Table 4*). In both periods, the silicon-treated cherry fruits had the lowest C* value. Especially at 0 + 2 days, the C* value ranged between 25.98 and 30.31 in silicon treatments, while it was 34.49 in the control. The h° value of untreated cherry fruits was 27% and 16%, higher than those treated with silicon at 0 + 2 and 21 + 2 days, respectively.

After shelf-life, as well as during all storage periods, the content of TSS in the silicon-treated cherry fruits was found to be significantly higher than in the control. All SiO_2 treatments and 5 mM Ca_2SiO_3 treatments came under the high group. After 21 + 2 days of shelf life treatment, there was no significant change in the TSS content (*Table 5*).

Table 5 shows the TA content of the silicon-treated fruits was higher than the control. The decrease in TA values after 0 + 2, and 21 + 2 days was limited. There was no great decrease in the TA values. The TA values of the 5 mM SiO_2, 10 mM SiO_2, and 10 mM K_2SiO_3 applications were high. The TA content in the post-harvest cherries was 1.06% in the control 1.56%–1.89% in Ca_2SiO_3 treatments. 1.23%–1.58% in K_2SiO_3 treatments, and 1.18%–1.32% in SiO_2 treatments.

Silicon treatments increased the phenol content in the fruits (*Table 5*). The phenol content in the control treatments was found to be low. However, the phenol content in the treatments were above 100 mg GAE/100 g. The 5 mM Ca_2SiO_3, 5 mM SiO_2, and

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

10 mM SiO_2 treatments yielded a high phenol content. In addition to these applications, the 5 mM K_2SiO_3 application was found to have a high phenol content.

Although the effect of different silicon applications on the antioxidant activity of cherry fruits was found to be significant ($p \leq 0.05$) at 0 + 2 days, this effect disappeared in the following storage periods (*Table 5*). The effect of 5 mM K_2SiO_3, 5 mM SiO_2 and 10 mM SiO_2, 5 mM Ca_2SiO_3 and 15 mM Ca_2SiO_3 treatments on antioxidant activity was found to be above 10 μmol TE/g at 0 + 2 days. After 21 + 2 days the changes were not significant.

Table 5. *Effects of foliar silicon applications on the TSS content, TA content, total phenol content, antioxidant of cherry fruits after shelf life and storage period*

Treatments	TSS content (%)		TA content (g/100 mL)		Total phenol content (mg GAE/100 g)		Antioxidant activity (μmol TE/g)	
	0 + 2	21 + 2	0 + 2	21 + 2	0 + 2	21 + 2	0 + 2	21 + 2
Control	14.93 c^{z**}	14.63 d^{**}	0.97 c^{*}	0.84 c^{*}	98.70 c^{*}	87.82 c^{**}	8.39 c^{*}	9.03^{NS}
5 mM Ca_2SiO_3	17.80 a	18.33 ab	1.14 ab	1.07 a	118.20 a	105.03 a	10.35 ab	9.02
10 mM Ca_2SiO_3	17.00 ab	16.17 c	1.13 ab	1.02 ab	105.49 bc	94.13 bc	9.03 bc	8.62
15 mM Ca_2SiO_3	16.57 b	17.57 ab	1.12 ab	0.95 b	105.58 bc	94.28 bc	10.43 ab	8.72
5 mM K_2SiO_3	16.23 b	17.43 ab	1.03 bc	0.96 ab	107.21 bc	102.24 ab	11.32 a	9.15
10 mM K_2SiO_3	16.30 b	17.67 ab	1.13 ab	1.01 ab	110.27 ac	93.91 bc	9.29 bc	8.00
15 mM K_2SiO_3	16.33 b	16.47 bc	1.12 ab	0.95 b	100.92 bc	97.35 ac	9.65 bc	8.37
5 mM SiO_2	17.47 ab	17.67 ab	1.18 a	0.95 b	119.54 a	103.56 ab	10.82 ab	9.29
10 mM SiO_2	17.67 a	18.47 a	1.17 a	1.00 ab	111.78 ab	103.19 ab	11.17 ab	9.49
15 mM SiO_2	17.60 a	18.30 ab	1.05 abc	0.93 bc	100.67 bc	104.74 a	9.54 bc	9.63

[z] Means separation within columns by Duncan's multiple range test. $P \leq 0.05$
[NS], *, ** Nonsignificant or significant at $P \leq 0.05$. or 0.01, respectively

Discussion

Fruit size and weight are critical factors in determining the commercial market value of sweet cherries (Mitcham et al., 2002). In this study silicon treatments increased fruit weights. Even as fruit weight was approximately 10 g in all Ca_2SiO_3 and 10 mM K_2SiO_3 treatments, it was over 10 g in 5 mM SiO_2 and 10 mM SiO_2 treatments. The 10 mM Ca_2SiO_3, 5 mM SiO_2, and 10 mM SiO_2 treatments, in particular, increased fruit size, as also fruit width, which was over 27.5 mm. Similarly, fruit length also increased with silicon treatments. The results obtained regarding the weight and size of the cherry fruit with silicon treatments was similar to some previous studies. Indeed, Sener et al. (2021) found the highest fruit width and length in SiJ-treated Albion and Rubygem strawberry cultivars and in 5 mg/l silica gel treatments. Si treatment slightly improved the fruit weight of strawberries (Miyake and Takhashi, 1986; Hajiboland et al., 2012). Similarly, Aksoy (2019), who studied the Shiraz grape variety reported that the berry width, length, and weight values increased in parallel with the increase in foliar silicon doses. Salicylic acid applications in grapes also had positive effects on fruit weight (Bhavya, 2010). Potassium silicate applications also increased fruit weight in bananas (Hanumanthaiah et al., 2015; Ravishankar and Jagadeesh, 2016). Potassium silicate applications to apricots for two years increased fruit weight by 22%, fruit length by 35.63% and fruit width by 33.88% (Elsabagh et al., 2020). It was determined that potassium silicate applications to mango increased fruit weight by 29.71%, fruit length by 33.34%, and fruit diameter by 28.33% (Gawad, 2017). Potassium silicate applications to oranges increased fruit weight by 28% (El-Gioushy, 2016).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

Firmness is the most essential quality component determining sweet cherry consumer preference. After 21 + 2 days of storage + shelf life, no significant loss in firmness was observed in all treatments, including the control. The MAP bags had a great effect on this. In this study, 10 mM K_2SiO_3 treatment was the treatment that produced the highest firmness in all processes consistently, compared to the control. Similarly, pre-harvest potassium silicate treatments for apricots increased fruit firmness by 1.7%–2.7% compared to the control fruits (Elsabagh et al., 2020). Likewise, potassium silicate treatments increased fruit firmness by 3% in loquat fruits (El Kholy et al., 2018). It was also reported that firmness increased with potassium silicate applications in avocados. a tropical species (Kaluwa et al., 2010).

The lower C* and h° values of silicon-treated cherry fruits during both harvest and storage indicate that silicon enhances coloration. In cherry fruits. coloration progresses with ripening. with a decrease in C* and h° (Zoffoli et al., 2008). The skin color of the 'Brooks' cherry variety progresses from full light red to full dark red, as shown by a decline in C* from 42.30 to 23.77, and in h° from 26.15° to 11.80° (Crisosto et al., 2003). The non-climacteric nature of cherry fruits was effective in the limited color change during storage (Zoffoli et al., 2008).

There was no significant effect of silicon treatments on weight loss after storage or after storage plus shelf life. The used MAP bags were effective in this. The application of MAP was seen to be useful in postponing the physicochemical changes associated with quality degradation in sweet cherry (Petracek et al., 2002; Tian et al., 2004). Potassium silicate treatment reduced weight loss in lemon (Mditshwa et al., 2013) and loquat (El Kholy, 2018) fruits. The weight loss of bananas treated with potassium silicate before harvest and stored in polyethylene bags was 4.39%, while that of bananas in untreated polyethylene bags was 10.97% (Ravishankar and Jagadeesh, 2016).

TSS concentrations greater than 15% are deemed appropriate for consuming sweet cherries (Kappel et al., 1996). The TSS content of 5 mM Ca_2SiO_3 and 5 and 10 mM SiO_2 treatments was the highest both after harvest and after storage + shelf life. In this study, Ca_2SiO_3, K_2SiO_3, and SiO_2 applications in cherry increased the TSS content. The TSS ranged from 11% to 20% in previous studies, and it remained approximately the same when stored in the refrigerator and MAP, for several weeks (Alique et al., 2003; Crisosto et al., 2003; Tian et al., 2004). In this study where silicon applications were made for cherries, the TSS content of cherries in control fruits was 14.80% within consumer acceptance limitations and the TSS content of cherries with silicon applications was found to be between 16.90% and 18.83%. Potassium silicate treatments in banana, apricot, orange, loquat, and mango fruits increased the TSS content in fruits (Ravishankar and Jagadeesh, 2016; El-Gioushy, 2016; Gawad, 2017; El Kholy et al., 2018; Elsabagh et al., 2020). Silicon and potassium caused excess sugar synthesis in the fruit, which increased the water-soluble dry matter content (Ravishankar and Jagadeesh, 2016). Salicylic acid treatments in blue grapes also increased the TSS content (Bhavya, 2010).

Silicon treatments has also helped to increase the TA content of cherry fruits after harvest. Although the content of TA in cherry fruits varies by cultivars, with levels ranging from 0.4% to 1.5%, the primary organic acid is malic acid (Esti et al., 2002; Bernalte et al., 2003). After storage + shelf life, the TA content of silicon-treated fruits is higher than that of the control. However, the content of TA decreases in apricot, mango, orange, and loquat fruits treated with potassium silicate (El-Gioushy, 2016; Gawad, 2017; El Kholy et al., 2018; Elsabagh et al., 2020). After storage and shelf life,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

TA values have been found to be lower. In SiO_2 applications, the losses in the amount of TA are the least.

In cherry, which is a non-climacteric fruit, when silicon treatments were applied, TSS and TA amounts after harvest and after storage + shelf life were higher than in the control fruits, and TSS content after storage + shelf life was generally preserved in cherry fruits, while there were losses in TA content. TSS, acidity, and visual attractiveness, all play crucial roles in determining consumer demand for this fruit (Crisosto et al., 2003). It has been found that TSS and titratable acidity (TA) are closely connected to the intensity of cherry flavor and that high TSS and TA levels boost customer acceptability (Crisosto et al., 2003; Kalyoncu et al., 2009).

In cherry fruits with silicon applications after harvest, storage, and shelf life, the phenol content of the fruits increased with silicon applications and it was found to be above 100 mg GAE/100 g. The 5 mM Ca_2SiO_3, 5 mM K_2SiO_3, 5 mM SiO_2, and 10 mM SiO_2 applications were the prominent applications. This was due to the fact that silicon application increased flavonoid and phenolic content (Maksimovic et al., 2007). Mditshwa et al. (2013) used potassium silicate on lemons at the end of harvest and determined that the phenol content increased. Phenolic content increased in apples with Si application (Tarabih et al., 2014). The effect of silicon treatments on the antioxidant activity of cherry fruits was not significant. Silicon treatments in bananas did not affect the antioxidant activity (Nikagolla et al., 2019). The antioxidant activity in cherry fruits tended to be higher with silicon treatments than the control, both at harvest and after storage + shelf life. Potassium silicate treatments in mango under drought stress conditions increased carotenoid, flavonoid, and anthocyanin concentrations (Helaly et al., 2017). Silicon was found to be effective as a source of antioxidants in avocados at the end of harvest (Tesfay et al., 2011). Silicon treatments increased the content of antioxidants and total phenols in the fruit, thus providing resistance to stress conditions in fruits, during long-term storage. Potassium silicate treatment reduced the concentration of antioxidant enzymes. These reductions may be attributable to its promoting effects on the synthesis of total antioxidants, namely total sugars, total free amino acids, and carotenoids (Pei et al., 2010).

Chlorophyll is a vital biomolecule involved in photosynthesis (Young and Lowe, 2018). Chlorophyll-a content in leaves increased with silicon applications. Chlorophyll-a and chlorophyll-b contents and accordingly total chlorophyll contents were found to be the highest, particularly with 15 mM SiO_2 application, compared to the other treatments. It was determined that the content of chlorophyll increased and the photosynthesis rate also increased accordingly with silicon applications in different plant species (Guével et al., 2007). Silicon treatment in plants can boost nutrient absorption and photosynthesis (Smith, 2011). In mango, chlorophyll content increased by 33.06% with potassium silicate treatment (Helaly et al., 2017; Gawad, 2017). Chlorophyll content increased in oranges when treated with potassium silicate (El-Gioushy, 2016).

Conclusions

In conclusion, in this study the effects of different silicon sources and its amounts on the fruit quality and post-harvest durability of cherries was investigated the fruit weight, fruit size, TSS, TA, total phenol, and chlorophyll contents increased with silicon treatments.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

In the studies conducted so far on different species, K_2SiO_3 was generally used as a silicon source. In this study, it was determined that Ca_2SiO_3 and SiO_2 applications can also be used effectively.

Ca_2SiO_3 treatments increased fruit weight and size. If Ca_2SiO_3 applications are desired to be used, 5 mM and 10 mM Ca_2SiO_3 applications should be preferred because they provide higher fruit firmness.

Among all K_2SiO_3 treatments tested in this study, the 10 mM K_2SiO_3 application increased fruit weight, fruit size, TSS, and TA. After storage + shelf-life, the TSS, TA, and breaking force of the treated fruits were high. It was one of the most important and recommended treatments, especially because it increases fruit firmness.

The 5 mM and 10 mM SiO_2 applications increased the fruit weight and size, TSS, and phenol content after harvest. After storage + shelf life, the breaking force of fruits and phenol content was high. Although TA values were lower than the other treatments after harvest, they were higher than those of the control. At the end of storage + shelf life period, it was one of the treatments 5 mM and 10 mM SiO_2 with high TA content. Among the treatments, 5 mM and 10 mM SiO_2 increased the phenol content the most. Even though it was not as much as the K_2SiO_3 application, it had an increasing effect on fruit firmness. The 5 mM and 10 mM SiO_2 treatments were the main recommended treatments, because they yielded the highest fruit weight and size, while maintaining other quality parameters.

Acknowledgments. This study was supported by Ege University Scientific Research Fund (contract no: 22862-YL).

Declaration of competing interest. The authors report no competing interest.

Credit authorship contribution statement. Deniz Erogul: methodology, writing, review, editing, supervision, project administration. Batuhan Karaagra: investigation, validation.

REFERENCES

[1] Agarie, S., Uchida, H., Agata, W., Kubota, F., Kaufman, P. B. (1998): Effects of silicon on transpiration and leaf conductance in rice plants (*Oryza sativa* L.) Japanese. – J. Crop Sci. 1: 89-95.

[2] Aksoy, F. (2019): The effect of foliar silicon applications on nutrition status some quality characteristics and yield of wine grape (Shiraz) grown under water stress. – MSc thesis, Graduate School of Natural and Applied Sciences, Ege University.

[3] Alique, R., Martinez, M. A., Alonso J. (2003): Influence of the modified atmosphere packaging on shelf life and quality of Navalinda sweet cherry. – Eur. Food Res. Technol. 217: 416-420.

[4] Arnon, D. I. (1949): Copper enzymes in isolated chloroplasts. Polyphenoloxidase in Beta vulgaris. – Plant Physiology 24(1): 1-15.

[5] Arnon, D. I., Stout, P. R. (1939): The essentiality of certain elements in minute quantity for plants with special reference to copper. – Plant Physiol. 14: 371-375.

[6] Benzie I. E. F., Strain J. J. (1996): The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. – Anal. Biochem. 239: 70-76.

[7] Bernalte, M. J., Sabio E., Hernández, M. T., Gervasini, C. (2003): Influence of storage delay of Van sweet cherry. – Postharvest Biol. Technol. 28: 303-312.

[8] Bhavya, H. K. (2010): Effect of foliar silicic acid and boron in Bengaluru Blue grapes. – M.Sc. (Hort.) thesis, Univ. Agric. Sci., Bengaluru.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

[9] Bujdosó, G., Hrotkó, K., Feldmane, D., Giovannini, D., Demirsoy, H., Tao, R., Ercisli, S., Ertek, N., Malchev, S. (2020): What kind of sweet cherries do the final consumers prefer? – South Western J. Hortic. Biol. Env. 11(1): 37-481.
[10] Cliff, M. A., Dever, M. C., Hall, J. W., Girard, B. (1995): Development and evaluation of multiple regression models for prediction of sweet cherry liking. – Food Res. Int. 28(6): 583-589.
[11] Crisosto, C. H., Crisosto, G. M., Metheney, P. (2003): Consumer acceptance of Brooks and Bing cherries is mainly dependent on fruit SSC and visual skin colour. – Postharvest Biol. Technol. 28: 159-167.
[12] Dehghanipoodeh S., Ghobadi, C., Baninasab, B., Gheysari, M., Bidabadi, S. S. (2018): Effect of silicon on growth and development of strawberry under water deficit conditions. – Hortic. Plant J. 4(6): 226-232.
[13] El Kholy, M. F., Mahmoud, A. A., Mehaisen, S. M. A. (2018): Impact of potassium silicate sprays on fruiting, fruit quality and fruit storability of Loquat trees. – Middle East J. Agric. Res. *7*(1): 139-153.
[14] El-Gioushy, S. F. (2016): Productivity fruit quality and nutritional status of Washington navel orange trees as influenced by foliar application with salicylic acid and potassium silicate combinations. – J. Ornam. Hortic. 8(2): 98-107.
[15] Elsabagh, A. M. S., Ali, M. M., Haikal, A. M., Abdelhady A. H. (2020): Effect of some pre- harvest treatments on quality of fruit of amal apricot cultivar. – N.Y. Sci. J. 13(7): 16-24.
[16] Epstein, E. (1995): Photosynthesis. inorganic plant nutrition, solutions, and problems. – Photosynth. Res. 46: 37-39.
[17] Epstein, E. (1999): Silicon - annual review on plant physiology. – Pl. Mol. Biol. 50: 641-644.
[18] Epstein. E., Bloom, A. (2005): Mineral Nutrition of Plants. Principles and Perspectives. 2nd Ed. – Sinauer Associates, Sunderland, MA.
[19] Erogul, D. (2018): An overview of sweet cherry fruit cultivation in Turkey – Trends in Horticulture 1(1).
[20] Esti, M., Cinquanta, L., Sinesio, F., Moneta, E., Mateo, M. D. (2002): Physicochemical and sensory fruit characteristics of two sweet cherry cultivars after cool storage. – Food Chem. 76: 399-405.
[21] FAO (2024): Food and Agricultural Organization. – htpp://www.fao.org (accessed on 15.05.2024).
[22] Fauteux, F., Rémus-Borel, W., Menzies, J., Bélanger, R. (2005): Silicon and plant disease resistance against pathogenic fungi. – FEMS Microbiol. Lett. 249: 1-6.
[23] Gao X., Zou, C., Wang, L., Zhang, F. (2004): Silicon improves water use efficiency in maize plants. – J. Plant Nutr. 27: 1457-1470.
[24] Gawad, N. M. A. (2017): Effect of some treatments for overcoming frost injury and improving productivity also fruit quality of mango (*Mangifera indica* L.) c. v." Hindi khasa". – Middle East. J. Appl. Sci. 7(2): 373-384.
[25] Guével, M. H., Menzies, J. G., Bélanger, R. R. (2007): Effect of root and foliar applications of soluble silicon on powdery mildew control and growth of wheat plants. – Eur. J. Plant Pathol. 119: 429-436.
[26] Hajiboland, R. (2012): Effect of Micronutrient Deficiencies on Plants Stress Responses. – In: Ahmad, P., Prasad, M. N. V. (eds.) Abiotic Stress Responses In Plants. – Springer, New York, pp. 283-329.
[27] Hanumanthaiah, M. R., Kulapatihipparagi, R. C., Vijendrakumar, D. M., Renuka, K., Kumar, K., Santhosha, K. V. (2015): Effect of soil and foliar application of silicon on fruit quality parameters of banana cv. neypoovan under hill zone. – Plant Arch. 15(1): 221-224.
[28] Heckman, J. (2013): Silicon: a beneficial substance. – Better Crops with Plant Food 97(4): 14-16.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

[29] Helaly, M. N., El-Hoseiny, H., El-Sheery, N. I., Rastogi, A., Kalaji, H. M. (2017): Regulation and physiological role of silicon in alleviating drought stress of mango. – Plant Physiol. Biochem. 118: 31-44.
[30] Jaishankar, H. P., Kukanoor, L., Jholgiker, P., Hipparagi, K., Gorabal, K., Nishani, S., Karadiguddi, M. (2018): Influence of pre-harvest sprays on physical and physiological parameters of custard apple cv. Balanagar. – Int. J. Chem. Stud. 6(5): 297-301.
[31] Kaluwa, K., Bertling, I., Bower, J. P., Tesfay, S. Z. (2010): Silicon application effects on 'Hass' avocado fruit physiology. – South African Avocado Growers' Association Yearbook 33: 44-47.
[32] Kalyoncu, I. H., Ersoy, N., Yilmaz M. (2009): Some physicochemical properties and mineral contents of sweet cherry (*Prunus avium* L.) type grown in Konya. – Afr. J. Biotechnol. 8: 2744-2749.
[33] Kappel, F., Fisher-Fleming, B., Hogue, E. (1996): Fruit characteristics and sensory attributes of an ideal sweet cherry. – Hortic. Sci. 31: 443-446.
[34] Liang, Y., Zhu, J., Li, Z., Chu, G., Ding, Y., Zhang, J., Sun, V. (2008): Role of silicon in enhancing resistance of freezing stress in two contrasting winter wheat cultivars. – Environ. Exp. Bot. 64: 286-294.
[35] Ma, J. F. (2004): Role of silicon in enhancing the resistance of plants to biotic and abiotic stresses. – Soil Sci. Plant Nutr. 50(1): 11-18.
[36] Ma, J. F., Takahashi E. (2002): Soil, Fertilizer, and Plant Silicon Research in Japan. 1st Ed. – Elsevier Science, Amsterdam.
[37] Ma. J. F., Yamaji, N. (2008): Functions and transport of silicon in plants. – Cell Moll Life Sci. 65: 3049-3057.
[38] Ma, J. F., Yamaji, N., Mitani, N., Tamai, K., Konishi, S., Fujiwara, T., Katsuhara, M., Yano M. (2007): An efflux transporter of silicon in rice. – Nature 448: 209-212.
[39] Maksimovic, J. D., Bogdanovic, J., Maksimovic, V., Nikolic, M. (2007): Silicon modulates the metabolism and utilization of phenolic compounds in cucumber (*Cucumis sativus* L.) grown at excess manganese. – J. Plant Nutr. Soil Sci. 170: 739-744.
[40] Matoh, T., Murata, S., Takahashi, E. (1991): Effect of silicate application on photosynthesis of rice plants. – J. Soil Sci. Plant Nutr. 62: 248-251.
[41] McGuire, R. G. (1992): Reporting of objective color measurements. – Hortic. Sci. 27: 1254-1255.
[42] Mditshwa, A., Bower, J. P., Bertling, I., Mathaba, N., Tesfay, S. Z. (2013): The potential of postharvest silicon dips to regulate phenolics in citrus peel as a method to mitigate chilling injury in lemons. – Afr. J. Biotechnol. 12: 1482-1489.
[43] Melo, S. P., Korndorfer, C. M., Korndorfer, G. H., Lana, R. M., Santan, D. G. (2003): Silicon accumulation and water deficient tolerance in grasses. – Sci. Agricola. 60: 755-759.
[44] Mitcham, E. J., Crisosto, C. H., Kader, A. A. (2002): Sweet cherry recommendations for maintaining postharvest quality. – Postharvest Technology Research and Information Centre 29. May 2003.
[45] Miyake, Y., Takahashi, E. (1986): Effect of silicon on the growth and fruit production of strawberry plants in a solution culture. – Soil Sci. Plant Nutr. 32(2): 321-326.
[46] Nikagolla, D. N., Udugala-Ganehenege, M. Y., Daundasekera, W. A. M. (2019): Postharvest application of potassium silicate improves keeping quality of banana. – J. Hortic. Sci. Biotechnol. 94(6): 735-743.
[47] Pei, Z. F., Ming, D. F., Liu, D., Wan, G. L., Gang, X. X., Gang, H. J., Zhou, W. J. (2010): Silicon improves the tolerance to water-deficit stress induced by polyethylene glycol in wheat (*Triticum aestivum* L.) seedlings. – J. Plant Growth Regul. 29: 106-115.
[48] Petracek, P. D., Joles, D. W., Shirazi, A., Cameron, A. C. (2002): Modified atmosphere packaging of sweet cherry (*Prunus avium* L. ev. 'Sams') fruit: metabolic responses to oxygen, carbon dioxide, and temperature. – Postharvest Biol. Technol. 24(3): 259-270.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707

[49] Piperno, D., Holst, I., Wessel-Beaver, L., Andres, T. C. (2002): Evidence for the control of phytolith formation in Cucurbita fruits by the hard rind (Hr) genetic locus: archaeological and ecological implications. – Proc. Natl. Acad. Sci. U.S.A. 99: 10923-10928.
[50] Rafi, M. M., Epstein, E., Falk, R. H. (1997): Silicon deprivation causes physical abnormalities in wheat (*Triticum aestivum* L.). – J. Plant Physiol. 151: 497-501.
[51] Raven, J. A. (1983): The transport and function of silicon in plants. – Biol. Rev. 58: 179-207.
[52] Ravishankar, M. P., Jagadeesh, S. L. (2016): Effect of silicon bunch spraying and bunch bag ging on fruit yield, quality and shelf life of 'NEYPOOVAN' banana. – HRS. 5(3): 218-223.
[53] Savant, N. K., Korndörfer, G. H. (1999): Silicon nutrition and sugarcane production: a review. – J. Plant Nutr. 22: 1853-1903.
[54] Sener, S., Duran, C. N., Kurt, Z. (2021): The effect of silica gel application on plant growth, yield and fruit quality in greenhouse strawberry production. – J. of AARI. 31(2): 265-273.
[55] Singh, S. P., Singh, Z., Swinny, E. E. (2009): Post harvest nitric oxide fumigation delays fruit ripening and alleviates chilling injury during cold storage of Japanese plums (*Prunus salicina* Lindell.). – Post harvest Biol. Technol. 53: 101-108.
[56] Sloulin, W. (1990): Cherry quality survey: status report. – Proc. Washington State Hort. Assn. 86: 226-227.
[57] Smith, A. (2011): Silicon's key role in plant growth. – Australian Grain, March-April.
[58] Swain, T., Hillis, W. E. (1959): The phenolic constituents of *Prunus domestica* L. the quantitative analysis of phenolic constituents. – J. Sci. Food Agric. 10: 63-68.
[59] Tarabih M. E., El-Eryan, E. E., El-Metwaly, M. A. (2014): Physiological and pathological impacts of potassium silicate on storability of anna apple fruits. – Am. J. Plant Physiol. 9(2): 52-67.
[60] Tesfay, S. Z., Bertling, I., Bower, J. P. (2011): Effects of postharvest potassium silicate application on phenolics and other anti-oxidant systems aligned to avocado fruit quality. – Postharvest Biol. Technol. 60: 92-99.
[61] Thaipong, K., Boonprakob, U., Crosby, K., Cisneros-Zevallos, L., Byrne, D. H. (2006): Comparison of ABTS, DPPH, FRA. and ORAC assays for estimating antioxidant activity from guava fruit extracts. – J. Food Compos. Anal. 19: 669-675.
[62] Tian, S. P., Jiang A. L., Xu, Y., Wang, Y. S. (2004): Responses of physiology and quality of sweet cherry fruit to different atmosphere in storage. – Food Chem. 87: 43-49.
[63] Wang, S. Y., Galletta, G. J. (1998): Foliar application of potassium silicate induces metabolic changes in strawberry plants. – J. Plant Nutr. 21(1): 157-167.
[64] Young, A., Lowe, G. (2018): Carotenoids - antioxidant properties. – Antioxidants 7(2): 28-31.
[65] Zoffoli, J. P., Muñoz S., Valenzuela, L., Reyes, M., Barros, F. (2008): Manipulation of 'Van' sweet cherry crop load influences fruit quality and susceptibility to impact bruising. – Acta Hortic. 795: 877-882.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_46934707