Journal of Soil Science and Plant Nutrition (2021) 21:1642–1652
https://doi.org/10.1007/s42729-021-00468-2

ORIGINAL PAPER

Pre-harvest Foliar Application of Calcium Chloride and Potassium Nitrate Influences Growth and Quality of Apricot (*Prunus armeniaca* L.) Fruit cv. 'Shahroudi'

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Received: 11 November 2020 / Accepted: 28 March 2021 / Published online: 7 April 2021

Abstract
The rapid ripening and fruit size are two important factors, which significantly influence the economy and marketability of apricot. Generally, the postharvest quality of fresh crops depends on the quality achieved at harvest time, which is influenced considerably by pre-harvest factors. Therefore, this study aimed to investigate the effect of foliar application of calcium chloride and potassium nitrate on the physical and biochemical attributes of apricot fruit. We evaluated the effect of foliar sprays of 0.5% or 1% calcium chloride ($CaCl_2$) and 1% or 2% potassium nitrate (KNO_3) on the yield and at harvest quality of apricot fruits cv. 'Shahroudi' during the 2019 and 2020 growing seasons. The experiment was conducted in a commercial apricot orchard located in Birjand, Iran. The results indicated that twice foliar spray of both chemicals at the pre-harvest stage affected most of the evaluated traits in both years. KNO_3 application at both concentrations significantly increased the length, width, and weight of apricot fruit and maintained total phenol content, vitamin C, and titratable acidity compared to the control. Interestingly, treated fruit with KNO_3 solution at both concentrations increased fruit width (150%), fruit length (160%), and fresh fruit weight (180%), compared to the control. Besides, KNO_3 (1% or 2%) and 1% $CaCl_2$ treatments significantly increased fruit firmness (25%) and calcium content (35%) of fruit pulp compared to the control. Overall, the results suggest practical multiple practical application of both chemicals (particularly KNO_3) at proper concentration and time during the growth season to improve the quality and increase the yield of apricot fruit 'Shahroudi' cultivar.

Keywords Calcium chloride · Foliar spraying · Potassium nitrate · *Prunus armeniaca* · Qualitative properties · Total phenol content

1 Introduction

Foliar fertilization is an important tool for the sustainable and productive management of crops. Foliar spray is a way to reduce the use of chemical fertilizers and their environmental hazards (Niu et al. 2021). Besides, by foliar feeding, nutrients can be delivered directly and quickly to the plant or fruit if needed. Some of the plant organs, like fruits, need nutrients such as calcium and potassium more than the whole plant; or in early spring, when the roots are still unable to absorb nutrients due to low soil temperatures, foliar spraying is vital (Fernández et al. 2013). In fruit trees, the primary periods of nitrogen (N) accumulation coincide with the vegetative growth in spring (Barker and Pilbeam 2015). Potassium (K) accumulation followed the same pattern as N accumulation. This demand for nutrients can be supplied from redistribution or uptake (Barker and Pilbeam 2015). The high demand for K and N during fruiting years, particularly during early growth, suggests that any reduction of root nutrient uptake during those periods could result in impaired fruit growth and yield (Barker and Pilbeam 2015). In many perennial high-value crops, foliar fertilizers should be applied during the period of highest nutrient demand under the premise that soil supply and root uptake may be inadequate to meet needs even with adequate soil-applied fertilizer (Fernández et al. 2013).

Foliar application of potassium salts is one of the most important practices of the new strategies applied in the integrated fruit production systems, improving fruit quality (Solhjoo et al. 2017). Among the different sources of

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potassium fertilizers, potassium nitrate (KNO_3) is used almost exclusively for foliar spray. KNO_3 fertilizer contains 38.5% K and 13% N (Fernández et al. 2013). Previous studies have revealed that the application of K involves in many physiological processes, such as where it impacts the mechanism of stomatal opening and closing by affecting cell water potential and turgor, photosynthesis, assimilate transport and enzyme activation, which have direct impact on crop productivity and fruit quality (Kanai et al. 2011). Prasad et al. (2015) showed that foliar spray of pear trees with 1.5 or 2% KNO_3 increases soluble solids, total sugar, and other biochemical properties such as vitamin C and total acid of treated pears and improved quality compared to the control. Aksoy et al. (1993) investigated the effect of multiple foliar application of 2% KNO_3 on apricot fruit of cv. 'Tokaloglu' in Turkey from late winter. They found that fruit weight and soluble solids significantly increased compared to control. In addition, they showed that spraying with 2% KNO_3 solution every 2 weeks performed better than spraying with 8% KNO_3 just once.

Pre-harvest spraying of fruit trees with different calcium (Ca) salts solution is one of the most useful strategies to improve the postharvest quality characteristics of fruits and reduce the use of fungicides because Ca increases the resistance of fruits pathogens (Martins et al. 2020; Öztürk et al. 2019). Calcium chloride ($CaCl_2$) application is a type of Ca source suggested by many researchers. Lal et al. (2011) reported that foliar spraying of apricot trees cv. 'Harcot' with 1.5% $CaCl_2$ effectively minimized weight loss in treated fruits during storage compared to control. Fruit quality traits (total soluble solids, titratable acidity, and vitamin C) were also better after 8 days of storage at the ambient condition compared to control. Yousefi et al. (2015) also indicated that the foliar application of 0.5% $CaCl_2$ in the apricot cultivar 'Jahangiri' improved some biochemical (protein, free amino acid, and vitamin C) and fruit quality attributes. Ca salt foliar sprays during fruit growth and development provide a safe mode of supplementing endogenous Ca in fresh fruits (Sinha et al. 2019).

Apricot (*Prunus armeniaca* L.) is a soft, delicious fruit, climacteric, and highly perishable (Moradinezhad and Jahani 2019). Apricot is generally considered to be a rich source of carotenoids, ascorbic acid, polyphenols, iron, potassium, polysaccharides, fiber, and minerals (Muzzaffar et al. 2018). Iran is one of the leading producers of apricot fruit globally, like Turkey, China, Uzbekistan, and Pakistan (Li et al. 2020). Among different apricot cultivars in Iran, there is a high demand for the Shahroudi cultivar for fresh consumption due to its great taste and attractive appearance and color. Apricot is a valuable temperate fruit, with high nutritional value, health benefits, and tasty flavor as fresh fruit and cultivated widely in the world. However, depending on the cultivar, full mature apricots lose their postharvest quality and commercial acceptability within 1 week after harvest due to rapid ripening. Storing fruits at low temperatures may help extend the shelf life, but it is not enough for long-term storage or transportation of apricots (Pretel et al. 2000), as postharvest quality of fresh crops generally depends on the quality achieved at the time of harvest. Therefore, complementary techniques such as pre-harvest foliar fertilization using different nutrients and particularly K and Ca fertilizers during growth season are required to improve the quality at harvest (Alexa et al. 2018) and also prolong the shelf-life of fresh fruits (Aslantürk et al. 2021).

The positive effects of foliar fertilization with various N, K, and Ca fertilizers such as urea, potassium nitrate, calcium nitrate, and potassium sulfate have been proven on different fruit trees (Hegazi et al. 2011; Hosseini et al. 2021; Madani et al. 2016; Mandal et al. 2012; Sud and Bhutani 1988; Zeraatgar et al. 2018). However, little information has been reported about the pre-harvest application of KNO_3 or $CaCl_2$ on apricot (Aksoy et al. 1993; Mohit and Thakur 2017; Ozturk et al. 2001). Besides, the review of the literature showed no report regarding the foliar spray of $CaCl_2$ and KNO_3 on apricot tree 'Shahroudi' cultivar, which is one the most important commercial cultivars widely cultivated in Iran due to its tasty flavor and attractiveness as fresh fruit. Therefore, this study aimed to investigate the effect of foliar application of $CaCl_2$ and KNO_3 on the physical and biochemical attributes of apricot fruit 'Shahroudi' cultivar.

2 Material and Methods

2.1 Plant Material

The experiment was conducted in a commercial orchard located in Birjand (32° 86′ N latitude, 59° 22′ E longitude, 1480 m above sea level), South Khorasan province, Iran. Trees (10 years old) were selected for vegetative and crop load uniformity at random within the orchard. The trees were spaced 3 m between rows and 2.5 m within rows in the north-south orientation. These experiments were conducted on apricot trees cv. 'Shahroudi,' during the 2019 and 2020 growing seasons. The experimental trees received similar cultural practices including, fertilizers, irrigation, and plant protection, except for the experimental treatments. To determine the study site's soil texture, samples were taken from a depth of 0–60 cm, and the soil properties were examined in the laboratory, as shown in Table 1.

2.2 Pre-harvest Treatments of Calcium Chloride and Potassium Nitrate

A total of 25 trees were selected for this experiment (5 trees per treatment). The apricot trees were either treated by solutions of $CaCl_2$ (Merck, Germany) at 0.5 and 1% concentrations or KNO_3 (Merck, Germany) at 1 and 2% concentrations.

Table 1 Soil properties of the experiment site

Ec $ds.m^{-1}$	pH	Ca $meq.l^{-1}$	K $meq.l^{-1}$	P $meq.l^{-1}$	N %	Soil texture	Organic matter%	Clay %	Silt %	Sand %
6.2±0.3	8.3 ± 1.2	28 ± 1.9	11.3 ± 1.0	12.3 ± 1.4	0.03 ± 0.0	sandy loam	0.4 ± 0.0	15 ± 2.3	34 ± 2.9	51 ± 3.0

Data are expressed as mean ± standard error (SE)

Also, we considered spraying with distilled water as a control. We sprayed the solutions in the morning with a hand sprayer (on the shoots, leaves, and fruits). The trees were sprayed twice at the pre-harvest stage. The first foliar spraying was done on May 4 (about 45 days after fruit set), and the second spraying was done 2 weeks before the commercial harvest on May 24. Tween 20 (Merck, Germany) surfactant at 0.01% was added to all used solutions for foliar application. Apricots were harvested at a stage when the peel had light green color with yellow spots and with total soluble solids of approximately 10 °Bx. Harvested fruits were then transferred to the postharvest laboratory of the Department of Horticultural Science, University of Birjand.

2.3 Measurement of Fruit Physical Properties

To evaluate the traits, 10 fruits were used in each treatment. Fruit length and width were measured using a digital caliper (LINEAR, 49–923) to the nearest hundredth of a millimeter and expressed in millimeters. Also, the fruit weight was obtained using an accurate digital scale (A&D FX-5000i, Japan) with an accuracy of 0.01 g, and the data were expressed in grams. The firmness of apricot fruit was measured by a digital penetrometer (Fruit Hardness Tester, Model FHT 200, Extech Co., USA) with a 2-mm probe. Data were presented in Newton. The color components include L^* (brightness), a^* (redness and greens), b^* (yellowness and blue color), chroma (purity of color), and hue (color angle) of apricot fruit skin measured using a colorimeter (TES, 135-TAIWAN).

2.4 Measurement of Fruit Chemical Properties

Total soluble solids in apricot juice were measured using a handheld refractometer (RF 10, Brix, 0–32%, Extech Co., USA), and data were expressed as °Bx. To check titratable acidity, the apricot pulp was homogenized in 40-ml distilled water and filtered to extract the juice. A 10-ml apricot juice was taken in a titration flask and titrated against 0.1 N NaOH in the presence of phenolphthalein, till permanent light pink color appeared. The TA is expressed as the percentage of malic acid. Total phenolic content was determined using the Folin-Ciocalteu method (Emmons et al. 1999), by mixing 8.25 ml of deionized water, 0.5 ml of extract (fresh weight), 0.75 ml of 20% Na_2CO_3, and 0.5 ml of reagent Folin-Ciocalteu. After a 40-min reaction in a water bath at 40 °C, the absorbance at 755 nm was measured using a spectrophotometer (Bio Quest, CE 2502). The final results were expressed as mg of gallic acid per gram of fresh apricot (Chuah et al. 2008). To determine the calcium content of fruit tissue, pulp samples were separately put in tap water for 10 min, then washed in distilled water, and dried at 60 °C in an air-circulating oven; 0.25 g of the dried pulp was then digested in 5-mL H_2SO_4 on a hot plate at 450 °C in a fume chamber for 7 min. Then, 10-mL H_2O_2 was added into the mixtures, and the heating was continued for another 4 min. The solution mixtures were brought up to 100-mL with distilled water. Calcium ion concentration was measured with an atomic absorption spectrophotometer, and the results were expressed as mg Ca g^{-1} dry weight (DW). Vitamin C content was determined using 2,6-dichlorophenol indophenols (Nielsen 2010). The results were expressed as mg 100 g^{-1} of fresh weight (FW).

2.5 Experimental Design and Statistical Analysis

The experiment was conducted using a randomized complete block design (RCBD). Three replicates were used for each treatment, and all results were expressed as mean ± standard error (SE). Analysis of variance was performed with the Genstat program (Discovery Edition, version 9.2, 2009, VSN, International, UK) to evaluate significance. The LSD test at the level of 1% ($P \leq 0.01$) was also used to identify the significant differences between the means.

3 Results

The obtained results of the analysis of variance for all evaluated traits were similar in the 2019 and 2020 growing seasons. In other words, the data of experiments in both years were not significantly different, and therefore, they were combined in the tables.

3.1 Length, Width, Length to Width Ratio, and Fruit Weight

The data analyzed showed that foliar application of apricot tree significantly affected the physical properties evaluated of fruit such as length, width, weight, firmness, and length to width ratio. As shown in Table 2, foliar application of KNO_3

Table 2 The effect of foliar application with calcium chloride ($CaCl_2$) and potassium nitrate (KNO_3) on width, length, length to width ratio, fresh weight, and firmness of apricot fruit

Treatment		Width (mm)	Length (mm)	Length to width ratio	Fresh weight (gr)	Firmness (N)
Control		18.9 ± 0.5^b	37.6 ± 0.3^b	1.98 ± 0.06^b	22.71 ± 0.0^b	11.67 ± 0.8^c
$CaCl_2$	0.5%	19.2 ± 0.2^b	37.6 ± 0.3^b	1.95 ± 0.03^b	23.35 ± 0.0^b	11.85 ± 0.9^c
	1%	18.3 ± 0.2^b	36.9 ± 0.4^b	2.01 ± 0.0^b	24.50 ± 0.0^b	15.98 ± 0.4^a
KNO_3	1%	48.3 ± 0.5^a	59.8 ± 0.4^a	1.23 ± 0.04^a	50.63 ± 0.0^a	14.20 ± 0.8^b
	2%	50.3 ± 0.3^a	60.2 ± 0.7^a	1.19 ± 0.03^a	51.08 ± 0.1^a	14.80 ± 0.3^b
Level of significant (1%)		**	**	**	**	**
LSD		0.91	5.52	0.08	2.83	1.15

Means ± SE followed by different letters in the same column for the same evaluated parameter are significantly different ($P \leq 0.01$) according to the LSD test

(1 or 2%) had the most significant effect on the diameter, length, and size of apricot fruit (Fig. 1), while the lowest amount of diameter, length, and size was obtained from control and $CaCl_2$ treatment (0.5 or 1%). The diameter of fruits treated with KNO_3 at a concentration of 2% was 50.3 mm, while the average diameter of fruit in control samples was 18.9 mm. Also, foliar application of KNO_3 increased the fruit length by 22.6 mm compared to the control and significantly decreased the fruit length to width ratio. Also, the results showed that the lowest fruit weight (22.71 g) was obtained in control. Meanwhile, KNO_3 treatment increased the fruit weight twofold than the control, and the highest fruit weight (51.08 g) was related to 2% KNO_3 treatment. However, no significant difference was observed between 2% and 1% KNO_3 treatments.

3.2 Firmness

$CaCl_2$ 1% and KNO_3 at both applied concentrations significantly increased firmness compared to the control. According to Table 2, the highest average tissue firmness of apricot fruit was obtained in treated fruits with $CaCl_2$ 1% (15.98 N), followed by KNO_3 treatments at concentrations of 1 and 2%, and the lowest was related to the control (11.67 N) and $CaCl_2$ 0.5% (11.85 N).

3.3 Color Attributes of Fruit Skin

Foliar spraying with $CaCl_2$ and KNO_3 had no significant effect on the skin color characteristics of apricot fruit (Table 3). The results revealed that the applied treatments had no negative impact on the control and did not reduce the lightness of the skin.

3.4 Total Soluble Solids (TSS), Titratable Acidity (TA), and TSS/TA Ratio

The results showed that foliar application of $CaCl_2$ and KNO_3 had no significant effect on TSS (Fig. 2a). However, the TA (Fig. 2b) and TSS/TA (Fig. 2c) values were affected by foliar application. The lowest TA (0.80%) was obtained from control samples. However, there was no significant difference between the control and 0.5% $CaCl_2$ treatment. Also, the highest TA value (1.46%) was recorded in treated fruits with 2% KNO_3, which had no significant difference with 1% KNO_3 treatment. The results indicated that the highest TSS/TA ratio (14.31) was related to the control samples while the lowest TSS/TA ratio (7.98) was found in treated trees with 1% KNO_3. No significant difference was found between 1%, 2% KNO_3, and 1% $CaCl_2$ treatments.

3.5 Total Phenolic Compounds (TPC)

All treatments used in the experiment showed an increase in phenolic compounds compared to the control (Fig. 2d). The results showed that the lowest phenol (60.81 mg GAE g^{-1} FW) was obtained from control fruits, whereas the highest phenol value (62.97 mg GAE g^{-1} FW) was related to treated fruits with 2% KNO_3. However, there was no significant difference between 1%, 2% KNO_3, and 1% $CaCl_2$ treatments. Also, no significant difference was observed between 0.5% and 1% $CaCl_2$ treatments.

3.6 Ascorbic Acid Content

All treatments used in the experiment showed a significant increase in the ascorbic acid (vitamin C) content of apricot fruit compared to the control (Fig. 2e). There was no significant difference between different levels of $CaCl_2$ and KNO_3 treatments. Nevertheless, the highest ascorbic acid value was obtained in treated fruit with KNO_3 2% (18.89 mg g^{-1}), and, the lowest amount was observed in control (12.43 mg g^{-1}).

3.7 Calcium Content of Fruit Pulp

The results showed that all treatments increased the calcium content of apricot fruit compared to the control. As expected,

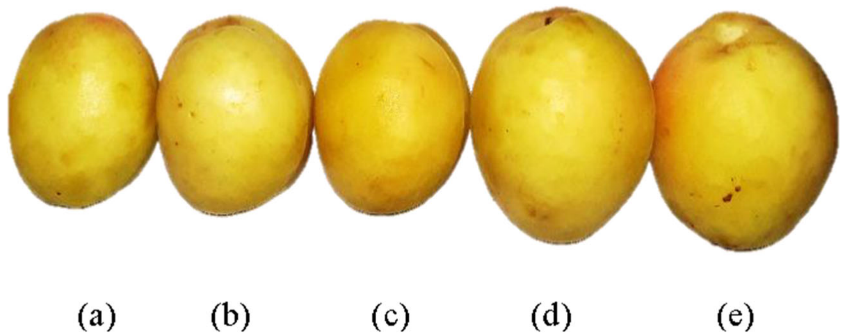

Fig. 1 The effect of foliar application with calcium chloride ($CaCl_2$) and potassium nitrate (KNO_3) on size and appearance quality of apricot fruit Shahroudi cultivar. **a** control, **b** calcium chloride 0.5%, **c** calcium chloride 1%, **d** potassium nitrate 1%, and **e** potassium nitrate 2%

the highest average calcium content (96.77 mg $^{-1}$) was obtained from fruits treated with 1% $CaCl_2$, whereas the lowest calcium content value (50.44 mg g^{-1} DW) was recorded in the control. Also, there was no significant difference between the treatments of KNO_3 (1 or 2%) and $CaCl_2$ 0.5% (Fig. 2f).

4 Discussion

Fruit size is considered to be one of the important external factors in determining fruit quality in apricot as it dramatically influences consumers' appeal. Nitrogen (N) is the most important factor in plant growth and development. The form of N (nitrate or ammonium) is one of the important factors on the growth, development, and the yield of plants. N has been shown to increase leaf area and increase photosynthesis (Atkinson et al. 2015). Carbohydrates produced in the process of photosynthesis are transported to the fruits (as main sinks) through the phloem, which increases the fruit size (both length and diameter) (Barker and Pilbeam 2015). The results of the present study showed that foliar application of KNO_3 fertilizer caused a significant increase in apricot fruit size. This increase is probably due to the presence of N in KNO_3 fertilizer. However, the role of K in this case cannot be ignored. Although, K is not a component of organic molecules or plant structure and is involved as a free ion in several physiological and biochemical processes (Atkinson et al. 2015). However, K increases the photosynthetic intensity of chloroplasts and the rate at which leaf material is transported through the phloem to storage tissues, thereby improving fruit yield and quality (Atkinson et al. 2015). Improving fruit yield and quality can be attributed to the effect of K on the entry of carbohydrates or the synthesis of plant regulators into young fruits (Fernández et al. 2013). Mohit and Thakur (2017) reported that the application of different nitrogen fertilizers such as urea and calcium nitrate significantly increased the yield and quality of apricot fruit. They stated that the maximum fruit width, length, and weight were obtained where the highest concentration of calcium nitrate was applied. Nitrogen has been shown to increase fruit size by increasing cell division and cell elongation (Sušin et al. 2006). Also, previous studies have shown that adequate nitrogen is essential for leaf growth, fruit formation, and fruit size, which ultimately leads to the production of a high-yield crop (Ben-Oliel et al. 2005; Zhang et al. 2019). Besides, previous researches indicated that foliar spraying of different fruit trees with potassium fertilizers such as KNO_3 in olive (Hegazi et al. 2011) and potassium sulfate in fig (Soliman et al. 2018) increased fruit length, weight, and yield. Fruits with the larger size in the present study in KNO_3-treated trees may be a result of the fact that potassium and nitrogen are involved in several physiological, biological, and biochemical processes, such as stimulating cell division, cell elongation, as well as biosynthesis and the transport of organic nutrients and carbohydrate accumulation in the plant (Cronje et al. 2009). Increased vegetative growth and fruit quality are associated with potassium and nitrogen in cell growth, sugar transport, and tourniquet pressure (Solhjoo et al. 2017). Similarly, other researchers have stated that

Table 3 The effect of foliar application with calcium chloride ($CaCl_2$) and potassium nitrate (KNO_3) on apricot fruit color parameters

Treatment		L^*	a^*	b^*	Hue°	Chroma
Control		69.28±4.5	−4.19±0.4	37.66±0.0	56.83±2.8	38.56±1.8
$CaCl_2$	0.5%	70.75±3.8	−3.74±0.2	38.64±0.0	56.82±3.1	38.16±2.4
	1%	72.13±4.2	−4.71±0.4	39.38±0.0	56.87±2.4	39.00±2.0
KNO_3	1%	71.36±5.7	−3.89±0.6	39.10±0.0	55.92±4.5	38.97±2.1
	2%	72.11±4.8	−4.48±0.5	38.50±0.1	56.84±2.3	39.12±1.9
Level of significant (1%)		ns	ns	ns	ns	ns
LSD		4.81	0.17	4.58	2.75	2.17

Means ± SE followed by different letters in the same column for the same evaluated parameter are significantly different ($P \leq 0.01$) according to the LSD test

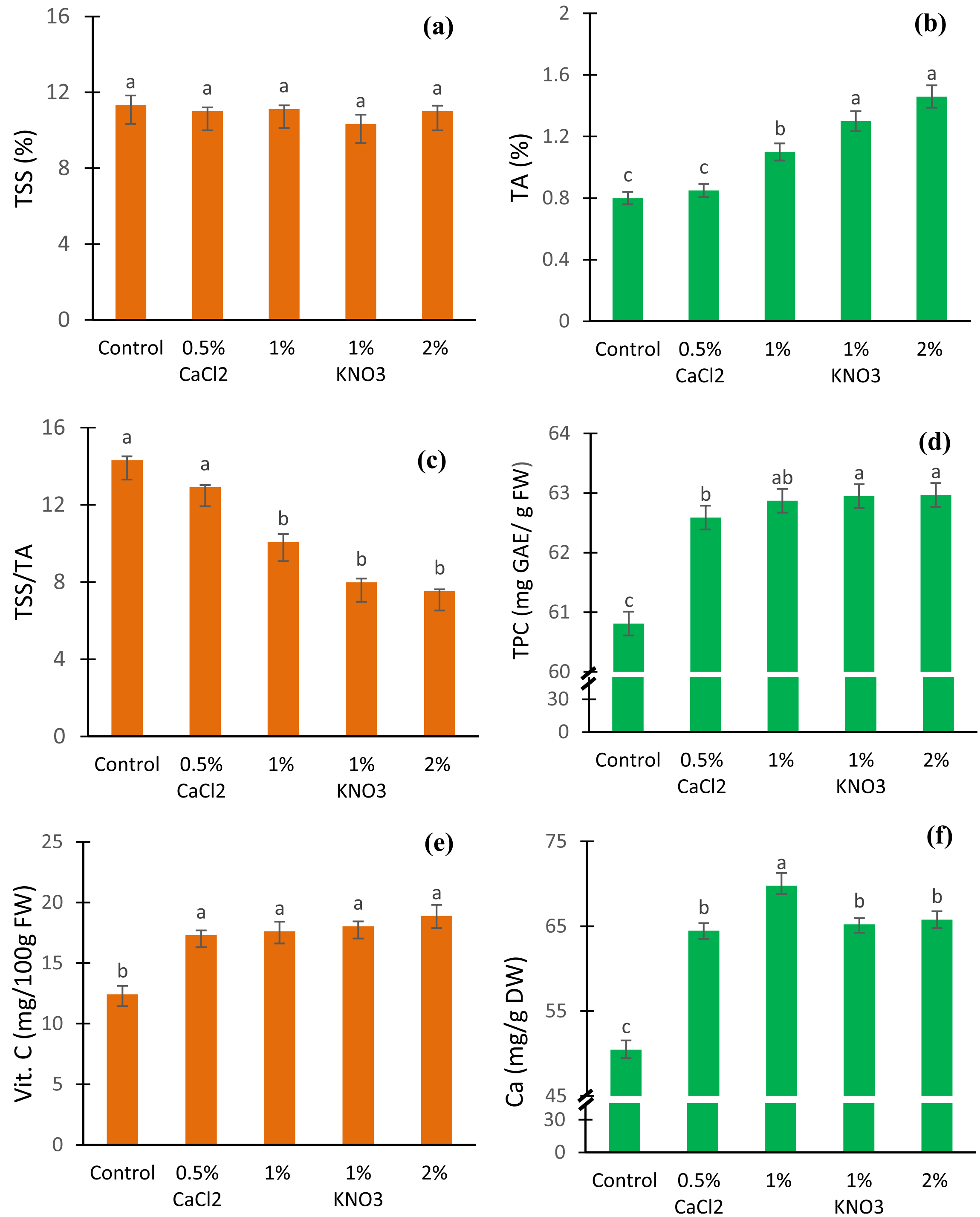

Fig. 2 The effect of foliar application with calcium chloride (CaCl2) and potassium nitrate (KNO3) at different concentrations on total soluble solids (TSS) (**a**), titratable acidity (TA) (**b**), TSS/TA (**c**), total phenol content (TPC) (**d**), vitamin C (**e**), and calcium content (Ca) (**f**) of apricot fruit at harvest. Error bars represent the standard error deviation. Symbols with the same letter are not significantly different at $P \leq 0.01$ (LSD test)

KNO_3 application increases the yield of barberry (Hosseini et al. 2021) and apple fruit (Mosa et al. 2015). The significant reduction in fruit length to width ratio in KNO_3 treated fruits may be related to increased fruit pit and or pulp size (Ramezani and Shekafandeh 2011).

The texture of fresh fruit is an essential factor in determining quality. Various factors, including Ca, affect the fluidity of cell membranes. It is proven that Ca can prevent ripening and senescence by cross-linking with pectic polymers in the cell wall and protecting cell membrane integrity (Mohebbi et al.

2020). Ghorbani et al. (2017) reported that $CaCl_2$ (5 g L^{-1}) maintained the firmness of apple fruit tissue because calcium serves as an intermolecular binding agent that stabilizes pectin-protein complexes of the middle lamella. Ca also plays an important role in the cell membrane by inducing rigidification at the membrane surface of apple fruit tissue. Thus, the maintenance of higher firmness in treated fruits might be due to the thickening of the middle lamella of fruit cells owing to increased formation of deposition of calcium pectate (Ortiz et al. 2011). $CaCl_2$ is more effective in improving the firmness of fruits by delaying senescence, preserving the cellular structure, and retarding respiration rate (Ekinci et al. 2016). The enzyme polygalacturonase (PG) degrades pectin in most fruits, leading to the softening of fruit tissue. Pectin methylesterase (PME) is also a pectin-degrading enzyme, which causes pectin to depolymerize by activating polygalacturonase. Ethylene has been shown to synthesize PG and PME enzymes. In this regard, Tzoutzoukou and Bouranis (1997) showed that foliar application of apricot trees (cv. Bebekou) with $CaCl_2$ significantly reduces ethylene production, which leads to a decrease in cell wall-destroying enzymes (PG and PME) and reduces the rate of fruit respiration rate. They also reported that foliar application of apricot trees with 0.5% $CaCl_2$ at 13, 17, and 21 days before harvest maintains tissue firmness greater than control at harvest. They stated that the higher firmness of apricot fruit in $CaCl_2$-treated samples is because $CaCl_2$ treatment reduced ethylene production more than three times compared to control and also inhibited the rate of respiration. There are also similar reports on different fruits such as peaches (Manganaris et al. 2007), plums (Kirmani et al. 2013), and strawberries (Langer et al. 2019). Besides, the results showed that not only $CaCl_2$ (1%) but also KNO_3 (2% and 1%) treatments significantly maintained the firmness of fruit tissue compared to the control. It has been shown that K makes high osmotic pressure and turgor pressure, which can provide power for cell division, cell wall extension, and cell expansion and finally, reduce fruit splitting (Fernandes et al. 2017). Therefore, it can be concluded that the K in KNO_3 has prevented the softening of apricot fruit tissue by increasing the flexibility and thickness of the cell membrane. Similarly, EL-Seginy (2006) reported that soil fertilization of K (120 kg K_2O/fed/year) of apricot trees (cv. Canino) in Egypt increased the firmness. Besides, EL-Seginy (2006) showed that the amount of potassium is directly related to water content in the fruit. Potassium caused water storage in the tissues, thus increasing the freshness and strength of the fruit. However, with increasing fruit size, Ca accumulation time decreases, and fruit firmness reduces compared to samples treated with $CaCl_2$ (Atkinson et al. 2015).

The results revealed that the applied treatments in the foliar application had no negative impact on the color attributes and did not change the lightness of the skin. The results of the current study were in line with the findings of Hernández-Muñoz et al. (2006) on strawberry and Moradinezhad et al. (2019) on jujube fruit.

The titratable acidity is directly related to the concentration of organic acids present in the fruit, which are an important parameter in maintaining the quality of fruits. Hosseini et al. (2021) reported that foliar application of KNO_3 had no significant effect on the TSS of barberry fruit. Titratable acidity is directly related to the concentration of organic acids present in the fruit, which are an important parameter in maintaining the quality of fruits (Moradinezhad and Jahani 2019). In apricot, malic acid is the main organic acid. Prasad et al. (2015) reported that foliar application of $CaCl_2$ and KNO_3 at a concentration of 2% significantly increased the TA of mango fruit. They stated that calcium and KNO_3 being the source of nitrogen might have modified the vegetative growth, which increases metabolism and consequently increases the acidity of fruits. Table 3 shows that the highest TA value was recorded in the KNO_3 treatments, while the lowest TA was obtained in control samples. The lower TA may be attributed to a marked increase in malic enzyme and pyruvate decarboxylation reaction during the climacteric period, proportional to the rise in the respiration rate and other metabolic biodegradable response (Mandal et al. 2012). Therefore, it may be concluded that the pre-harvest spray of KNO_3 treatment can preserve the sensorial quality of the apricot fruit. Similar results were obtained by Mandal et al. (2012) on guava fruit. A correct balance between sugar and acid contents is crucial for the processing industry. Also, it is essential for the fresh-market production industry because such a ratio determines fruit taste (Caretto et al. 2008). The results also showed that the highest amount of TSS/TA ratio was observed in control followed by calcium chloride 0.5% and the lowest was found in KNO_3 treatments. Rabiei et al. (2010) also showed that foliar application of apple trees with KNO_3 reduced TSS/TA ratio. They stated that the reduction in TSS/TA ratio might be because the application of potassium slows down the respiration rate and senescence process in the fruit. EL-Seginy (2006) showed that the application of potassium fertilizer did not have a significant effect on the titratable acidity of apricot cv. Canino, which is inconsistent with the results of the current study. These various reports in TSS, TA, and TSS/TA ratio may also be related to the difference between different fruits or apricot cultivars studied in terms of ripening stage and their total soluble solids and titratable acidity of fruit at harvest time.

During growth, many metabolic processes in plants produce reactive oxygen species, but plants have effective antioxidant mechanisms to eliminate reactive oxygen species. One of these mechanisms is the production of phenolic compounds in plants. Phenolic compounds prevent membrane peroxidation by repelling oxygen free radicals and stabilize cell membranes. A close relationship has been reported between K nutritional status and the reduction of free radicals (Leibar et al. 2017). They reported that K plays a very important role in regulating the turgor pressure of protective cells and stomatal movements. The results of the present study showed that the highest phenol content was obtained in 2% KNO_3 treatment. Presumably, this increase in total phenol content was related to the role of K in enhancing carbon dioxide fixation, transferring photosynthetic material into other sinks, and preventing the transfer of photosynthetic electrons to oxygen, thus reducing the production of oxygen free radicals and causing accumulation of phenol content. Nguyen et al. (2010) reported that the total phenol content increases with increasing K concentration in basil leaves. They stated that K stimulates the production pathways of secondary metabolites, therefore increasing the total phenol content in potassium-treated samples. Similar to the results of the current study, Ranjbar et al. (2018) reported that Ca increases the amount of total phenol in apple fruit. They suggested that since Ca increases the polysaccharide content in the fruit cell wall and the permeability of the membrane; therefore, the wall strength and cell membrane can be maintained, which leads to preventing the oxidation of phenolic compound. Potassium is an activator for enzymes involved in photosynthesis and the biosynthesis of starch and proteins. When plant growth increases and more photosynthates are produced at higher potassium rates, increased phenolic concentrations may correspondingly occur due to the allocating excess fixed carbon to the Shikimic pathway (Barker and Pilbeam 2015). Medan (2020) reported that foliar application of K and Ca chelate of the apricot trees cv. 'Royal' significantly increased leaf area and leaf chlorophyll content. Therefore, the synthesis of secondary metabolites, including phenolic compounds, is also affected.

Vitamin C (ascorbic acid) has important antioxidant and metabolic functions in both plants and animals, but humans and a few other animal species have lost the capacity to synthesize it. Plant-derived ascorbic acid is thus the major source of vitamin C in the human diet (Alkadi 2020). Ascorbate usually acts as an antioxidant. It typically reacts with oxidants of active oxygen species (ROS), such as the hydroxyl radical formed from hydrogen peroxide. Ascorbate can terminate chain radical reactions by electron transfer. On the other hand, it has been proven that one of the reasons for the increase of ROS is the production of ethylene in plants. Moreover, an increase in the hormone ethylene has been shown to cause the synthesis of ascorbic acid hydrolyzing enzymes (such as ascorbate oxidase and ascorbate peroxidase) (Alkadi 2020). Our results showed that the application of $CaCl_2$ and KNO_3 maintained the level of vitamin C in apricot fruit compared to the control. Foliar application of these chemicals preserved vitamin C likely due to delayed ripening and/or reduced ethylene production. Kazemi (2013) reported that the treatment of strawberry fruits with KNO_3 significantly increased ascorbic acid content, which is consistent with the results of the current study. They stated that the increase in vitamin C content was due to the synthesis of enzymes and proteins by potassium application. In addition, Ramezanian et al. (2009) found that foliar $CaCl_2$ spraying on pomegranate fruits at the full bloom stage increased the ascorbic acid content of fruits at harvest. Because Ca delays the synthesis of ethylene, and ROS may be reduced, vitamin C levels in the fruit maintained. Higher vitamin C content in $CaCl_2$-treated fruits could be related to inhibiting the action of calcium on the activity of ascorbic acid oxidase that uses ascorbate as a substrate (Singh et al. 2005), which is in line with the results of the current study. Similar results have been reported by Yousefi et al. (2015) on apricot fruit cv. Jahangiri. They showed that foliar application of 0.5% $CaCl_2$ (46 days after full bloom) increased the amount of vitamin C by 3-fold compared to the control at harvest.

Many physiological disorders of fruits are associated with low Ca levels, and because of its phloem immobility, foliage-applied Ca is not redistributed from sprayed leaves to the fruit (Atkinson et al. 2015). Generally accepted is that multiple sprays as well as the concurrent application of Ca to leaves, stems, and fruit are required and early-season sprays appear to be more effective than late-season sprays (Fernández et al. 2013). It is well-known that Ca is an essential substance in maintaining the structure of the cell wall, which also reduces ethylene and delays the ripening process of fresh products (Mohebbi et al. 2020). Ngamchuachit et al. (2014) reported that with increasing applied Ca concentrations ($CaCl_2$ and Ca lactate), the Ca content of the tissue also increased. They showed that Ca treatment reduces ion leakage, which is why maintaining cell wall integrity in calcium-treated fruits. Our results showed that foliar application with $CaCl_2$ 1% increased the calcium content of fruit tissue by about 40% compared to control. This increase in tissue Ca content may be due to Ca treatment that contains more available Ca ions to interact with the binding sites in the cell wall and plasma membrane. In agreement with our results, Tzoutzoukou and Bouranis (1997) reported that pre-harvest multiple foliar application of apricot trees with $CaCl_2$ at 0.5% concentration, resulting in a 50% increase in the calcium content of fruit pulp in apricot cv. Bebekou. Also, the firming effect of Ca-treated apricot results primarily from the interaction with the cell wall and middle lamella, which is consistent with the results obtained from the evaluation of tissue firmness in the present study. Madani et al. (2016) also reported similar results on papaya fruit. Similar to our results, Yousefi et al. (2015) reported that foliar application of $CaCl_2$ (0.5%) significantly increased the calcium content of apricot fruit cv. Jahangiri.

5 Conclusions

Higher yield and fruit size are important for the producer, while nutritional value and firmness are more important qualitative factors from consumers and postharvest viewpoint because apricot is a highly perishable fruit. Interestingly, obtained results of the present study revealed that pre-harvest foliar spray of potassium nitrate (KNO_3) at a concentration of 1% has a great potential for fertilization of apricot and is recommendable for practical application on apricot trees as fruit fresh weight doubled, firmness increased, and the nutritional value of apricot fruit improved by increasing the total phenol, calcium content, and vitamin C compared to the control. Moreover, calcium chloride ($CaCl_2$) 1% significantly increased the strength and calcium content of treated fruit more than KNO_3 treatment. It is well-known that increased calcium content also effectively extends the quality of fresh apricot and reduces postharvest losses during long-term storage and marketing. So, it can be concluded that likely a combination of KNO_3 and $CaCl_2$ 1% multiple application at pre-harvest stage has more beneficial and economic effects on quantitative and qualitative traits of fresh apricot. Therefore, further study is required to investigate the influence of the pre-harvest multiple foliar application of these chemicals and their combined effect on the yield and quality of fresh apricot fruit at harvest.

Availability of Data and Material All data presented in the manuscript.
Code Availability Not applicable.

Funding The authors would like to acknowledge the financial support of the University of Birjand for this research under contract number of 26135/D on 12/11/1398.

Declarations

Ethics Approval The authors will follow the Ethical Responsibilities of Authors and COPE rules.

Consent to Participate On behalf of all co-authors, I believe the participants are giving informed consent to participate in this study.

Consent for Publication I, Farid Moradinezhad, give my consent for a submitted manuscript to be published in the *Journal of Soil Science and Plant Nutrition* free of charge.

Conflict of Interest The authors declare no competing interests.

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