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ORIGINAL PAPER

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FRUIT YIELD AND QUALITY OF 'FLORIDA KING' PEACHES SUBJECTED TO FOLIAR CALCIUM CHLORIDE SPRAYS AT DIFFERENT GROWTH STAGES

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ABSTRACT

Peach fruit and trees are prone to various issues, regarding yield, quality and pest attack. Calcium plays several roles in plant and fruit development. Therefore the current study was conducted to evaluate the response of peach fruit to foliar application. The experiment was laid out in Randomized Complete Block Design with two factors factorial arrangement and three replicates. Calcium chloride was applied at the rate of 0, 1, 2 and 3%. The foliar application of calcium was done at pink bud stage, berry size fruit stage, and then at pit hardening stage of peach. The obtained results indicated that foliar application of calcium significantly improved peach fruit quality and yield. The highest fruit weight (142.6 g), yield tree^{-1} (15.6 kg), ascorbic acid content (6.67 mg·100 g^{-1}), total soluble solids (11.0°Bx), fruit juice pH (3.98), sugar to acid ratio (45.1), fruit firmness (3.90 kg·cm^{-2}) and fruit volume (155.6 cm^3) was obtained with the application of 3% solution of calcium chloride at pit hardening stage but it significantly reduced the percent titratable acidity (0.3%) and disease incidence (5.8%). It was concluded that 3% calcium chloride applied at the pit hardening stage significantly boosted peach quality and fruit yield.

Key words: peach, fruit quality, yield, calcium, foliar application

INTRODUCTION

Peach (*Prunus persica* L.) is an important horticultural fruit tree belonging to the Rosaceae family, originated from Persia (Iran) or China [Bassi and Monet 2008]. It is a healthy and delicious fruit consumed worldwide. The top five peach producing countries are China, Spain, USA, Italy and Greece. In Pakistan, it is also a very important crop both for fresh consumption and processing industry. It is the second most important stone fruit after plums, occupying an area of 14 385 ha in Pakistan with a production of 71 639 t [Fruit, Vegetables and Condiments Statistics of Pakistan 2016–2017].

During the last decade, although there has been an ample increase in peach growing area, but also a trivial improvement in average fruit yield. In recent years, the introduction of improved, low-chilling cultivars and better handling of fruit led to brisk increase in the production and commercialization of stone fruits like

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peaches throughout the world including Pakistan. The prominent peach growing areas in Pakistan includes northern areas and Baluchistan. In order to uplift productivity and quality of fruit crops, a lot of studies have been conducted regarding the use of growth regulators and minerals [Abd-El-Messeih et al. 2010, Ali et al. 2010].

Peach fruits are climacteric and highly perishable, ripen rapidly and have a short shelf life. Peach fruit yield and quality may decline due to less moisture and nutrient availability because of less rooting area. Flower drop may occur due to certain reasons, like nonfunctional flowers, missing reproductive structures, pollen germination fail, or winter stress. Pollination and fertilization may not occur followed by flower abscission [Yoshida et al. 2000]. Peach fruit is subjected to physical damage and pre-harvest contamination, due to which surface discoloration and other problems may occur [Crisosto et al. 2000]. Growth conditions, harvesting stage, and post-harvest factors like susceptibility to chilling temperature affect the fruit quality of peach. The yield and quality is also affected due to the attack of various diseases like brown rot, peach scab, anthracnose, bacterial spot, etc.

Calcium is a major part of cell wall and membranes, and plays essential role in their proper functioning. It also has important roles in pollen germination, cell division and elongation, environmental signaling and cell protection from toxins [Johnson 2008]. Calcium delays softening and reduces decay in fruits by improving cell rigidity and fruit firmness [Conway 1982]. Thus pre-harvest calcium application is beneficial and successful in reducing fruit rot and decay, maintaining rigidity, and improving quality [Biggs et al. 1997, Manganaris et al. 2005a, 2005b].

Calcium application delays senescence, enhances disease resistance and protects fruit cell wall from degradation [Volpin and Elad 1991, White and Broadley 2003]. It maintains fruit quality by reducing internal breakdown, respiration and ethylene production. Its deficiency led to reduction in root growth, small trees, leaf chlorosis and necrosis and at last defoliation. Calcium deficiency also results in smaller, less sweet, softer, and low quality fruits [Johnson 2008]. Keeping in view the above mentioned problems, the present study was undertaken to evaluate the effect of foliar application of calcium chloride for improving peach fruit yield and quality.

MATERIALS AND METHODS

The current study was undertaken to investigate the response of peaches to foliar application of calcium chloride at different growth stages at peach orchard, Horticulture farm (34°01'13.1"N, 71°27'52.8"E), The University of Agriculture Peshawar, Pakistan. The experiment was laid out in Randomized Complete Block Design (RCBD) with two factors (calcium chloride level and growth stages) factorial arrangement with three replications. Four level of calcium chloride viz; 0, 1, 2 and 3% were applied at pink bud (the stage when the calyx was about to split and the tip of the pink petals could be seen), berry (the time when fertilization succeeded and fruit set occurred) and pit hardening (the period when the growth curve became parallel to horizontal axis in a double sigmoidal curve) stages of peach. One hundred and eight peach plants of uniform size were selected and all were eight year old. The cultivar of peach was 'Florida King'. All management practices were performed throughout the growth period of peach. Every plant was fertilized with 60 kg farm manure and 3 kg NPK (10 : 10 : 10) compound fertilizer, as a normal recommended practice for peach orchard [Chaudhary 1994]. Calcium chloride solutions of various concentrations (0, 1, 2 and 3%) were prepared using analytical grade calcium chloride (36% Ca). The amount of Ca used per unit ha was 0.97, 1.94, and 2.91 kg respectively. The characteristics of soil where peach orchard was established are given in Table 1.

For observing yield attributes, several parameters were recorded such as fruit yield (kg) per tree, fruit weight (g) and volume (cm^3). The later was calculated by water displacement method [Meisami et al. 2009].

Fruit quality analysis

Fruit samples were taken for assessing the effect of foliar application of calcium chloride on quality of peach. The disease incidence was observed by considering major diseases of peach in the experimental site, inlcuding brown rot (*Monilinia fructicola*), peach scab (*Venturia carpophila*), bacterial spot of peach (*Xanthomonas arboricola*) and shot hole disease (*Wil-*

Table 1. Soil physico-chemical conditions of the experimental site

Sand	8.7%
Silt	51.3%
Clay	40.0%
Textural class	silty clay loam
Organic matter	0.845 $g \cdot kg^{-1}$
Total N	0.04 $g \cdot kg^{-1}$
$CaCO_3$	14.4%
pH 1 : 1 water	8.02
Electrical conductivity	0.87 $dS \cdot m^{-1}$
P	3.80 $mg \cdot kg^{-1}$
K	105 $mg \cdot kg^{-1}$
Zn	0.86 $mg \cdot kg^{-1}$

sonomyces carpophilus). Percent disease incidence of peach was calculated using the following formula

$$\text{Disease incidence \%} = \frac{\text{Diseased fruits}}{\text{Total fruits}} \times 100$$

Ascorbic acid content ($mg \cdot 100\ g^{-1}$) was estimated using dye solution made of 2,6-dichloroindophenol dye (50 mg) and sodium bicarbonate (42 mg). Standardization of dye solution for calculating ascorbic acid content is done by the following formula

$$\text{Dye factor (F)} = \frac{\text{Ascorbic acid solution (ml)}}{\text{Dye solution used (ml)}} \times 100$$

Ascorbic acid content was measured by the following relation

$$\text{Ascorbic acid content} = \frac{F \times T \times 100}{D \times S} \times 100$$

Where F, T, D and S stands for dye factor, millilitres of dye solution used from the burette, millilitres of diluted sample taken for titration and grams of peach juice taken for dilution.

Titratable acidity was determined by titrating unknown acidity against 0.1 N NaOH using phenolphthalein indicators. Following formula was used to compute titratable acidity [AOAC 1990].

$$\text{Percent titratable acidity} = \frac{F \times T \times N \times 100}{D \times S} \times 100$$

Where T, F, N, D and S correspond to millilitres of NaOH used, normality of NaOH, millilitres of sample taken for dilution, millilitres of diluted sample taken for titration and constant acid factor (for primary acid in the fruit) = 0.0067 (malic acid in peaches) respectively.

Total soluble solids were determined using hand refractometer (Kernco, Instruments Co. Texas) and fruit pH was measured by using pH meter (Mode: INOLAB pH-720). The sugar to acid ratio was calculated by dividing the total soluble solids and titratable acidity.

$$\text{Sugar – acid ratio} = \frac{\text{Total soluble solids}}{\text{Titratable acidity}}$$

Fruit firmness was measured with the help of hand held Penetrometer (Effigi, FT-011) with 8 mm prob [Pocharski et al. 2000].

Fruit juice extractor was used for the extraction of juice in order to observe fruit juice content computed as

$$\text{Fruit juice \%} = \frac{\text{Average juice weight}}{\text{Average fruit weight}} \times 100$$

Statistical analysis

The data recorded was subjected to Analysis of Variance (ANOVA) technique appropriate for RCB design with two factors factorial arrangement. Means were compared by using Least Significance Differences (LSD) using STATIX version 8.1.

RESULTS AND DISCUSSION

The observed results of all the parameters are presented and discussed as follows:

Fruit yield

The results regarding fruit weight (Tab. 2) depicted that highest fruit weight (142.6 g) was obtained in plants receiving foliar application of $CaCl_2$ at the rate of 3% at pit hardening stage while minimum (92.1 g) was in case of control treatment at berry stage. $CaCl_2$ application effect on fruit weight was statistically at par with each other at all stages. Almost similar trend was obtained in case of fruit yield per tree and fruit

Table 2. Effect of $CaCl_2$ at different growth stages on fruit weight (g) of peaches

$CaCl_2$ concentration (%)	Pink bud	Berry size	Pit hardening	Mean
0	98.83	92.14	94.62	95.20 c
1	99.13	112.8	123.6	111.9 b
2	100.8	123.8	137.1	120.6 ab
3	92.38	137.2	142.6	124.0 a
Mean	97.78 b	116.5 a	124.5 a	

LSD: $CaCl_2$ = 12.0, Growth stages = 10.4, $CaCl_2$ × growth stages = 20.8. Means were subjected to ANOVA using RCBD. Means with different letters are statistically different from one another at P = 5%

Table 3. Effect of $CaCl_2$ at different growth stages on yield (kg) tree^{-1} of peaches

$CaCl_2$ concentration (%)	Pink bud	Berry size	Pit hardening	Mean
0	9.03	10.03	9.04	9.37 c
1	14.10	12.71	14.16	13.66 b
2	15.13	12.37	15.28	14.26 b
3	15.30	14.82	15.57	15.23 a
Mean	13.39 a	12.48 b	13.51 a	

LSD: $CaCl_2$ = 0.96, Growth stages = 0.83, $CaCl_2$ × growth stages = 1.67. Means were subjected to ANOVA using RCBD. Means with different letters are statistically different from one another at P = 5%

Table 4. Effect of $CaCl_2$ at different growth stages on fruit volume (cm^3) of peaches

$CaCl_2$ concentration (%)	Pink bud	Berry size	Pit hardening	Mean
0	103.53	105.53	109.52	106.19 c
1	110.27	121.23	131.42	120.97 b
2	112.74	136.88	150.81	133.47 a
3	103.40	150.83	155.60	136.61 a
Mean	107.48 b	128.62 a	136.84 a	

LSD: $CaCl_2$ = 11.43, Growth stages = 9.90, $CaCl_2$ × growth stages = 19.80. Means were subjected to ANOVA using RCBD. Means with different letters are statistically different from one another at P = 5%

volume (Tabs 3 and 4 respectively). The foliar $CaCl_2$ at the rate of 3% at pit hardening stage gave the highest yield (15.57 kg) per tree while the lowest (9.03 kg) was observed in control. Higher fruit weight, yield and volume with calcium supplementation might be attributed to the fact that it helps in cell growth and division, flowering, pollination and fertilization [Johnson 2008]. Calcium also enhance ammonium absorption, which improve photosynthesis and CO_2 intake which ultimately resulted in elevating fruit weight, volume and yield. The results of the current study are in line with the findings of El-Alakmy [2012] on peaches, and [Kirmani et al. 2013] on plum. Kassem et al. [2010] found increase in fruit volume with foliar application of calcium chloride. However, Bouzo and Cortez [2012] found no improvement in fruit yield or weight due to foliar sprays of calcium.

Fruit quality

The results regarding fruit juice ascorbic acid content (Fig. 1a) revealed that highest ascorbic acid contents (6.67 mg·100 g^{-1}) were noted in peach fruits treated with 3% $CaCl_2$ at the pit hardening stage, while the lowest (4.18 mg·100 g^{-1}) was recorded in fruits left untreated at the berry sized fruit stage, which was at par with the other two stages. The treatments at dif-

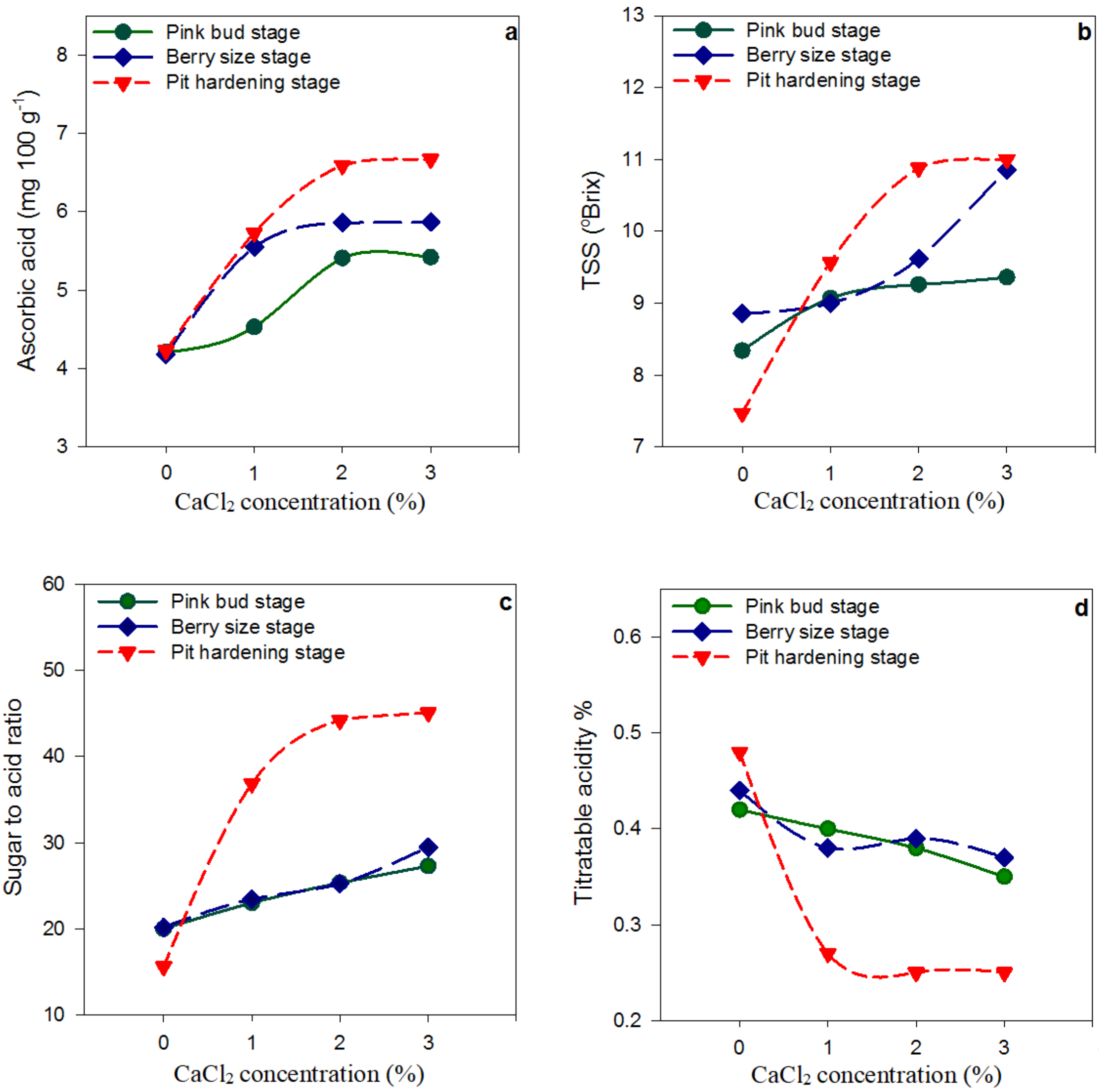

Fig. 1. Ascorbic acid content, total soluble solid content, sugar-acid ratio and titratable acidity of peach fruit juice as affected by foliar $CaCl_2$ sprays at different growth stages

ferent growth stages also had a significant effect on ascorbic acid content in peach fruits. The significant response with higher calcium application might be due the involvement of calcium in the intra and extracellular processes which caused changes in fruit quality, such as variations in total acid content [Conway et al. 2002]. Total acidity is the H^+ ions equivalence of the total organic acid anions in a solution (fruit juice). The findings of the current study are in line with the results of El-Alakmy [2012] who treated peaches with different calcium sources and found highest values of vitamin C content as compared to untreated fruits. Similar results were reported in persimmon [Kassem et al. 2010] in response to foliar application of calcium.

Total soluble solids (TSS) of the peach fruit juice (Fig. 1b) showed that the highest value (11.0°Bx) was observed in the samples receiving 3% $CaCl_2$ at pit hardening stage, which was at par with the value observed in the 2% level, while the lowest (7.47°Bx) was noted in control treatment at same stage. In case of growth stages, the $CaCl_2$ application at pit hardening stage resulted in highest TSS value, which was at par with the berry size fruit stage, while the minimum was observed at pink bud stage.

The application of calcium chloride slows down the ripening and respiration rate of the fruits, which give way to certain acids to change into sugars over the period of time [Raese and Drake 1993]. As total soluble solid content contains 75% sugars, so in this manner calcium application improved TSS in peach [Shah et al. 2002]. The findings of the current study are in line with the results of Brar et al. [1997] who

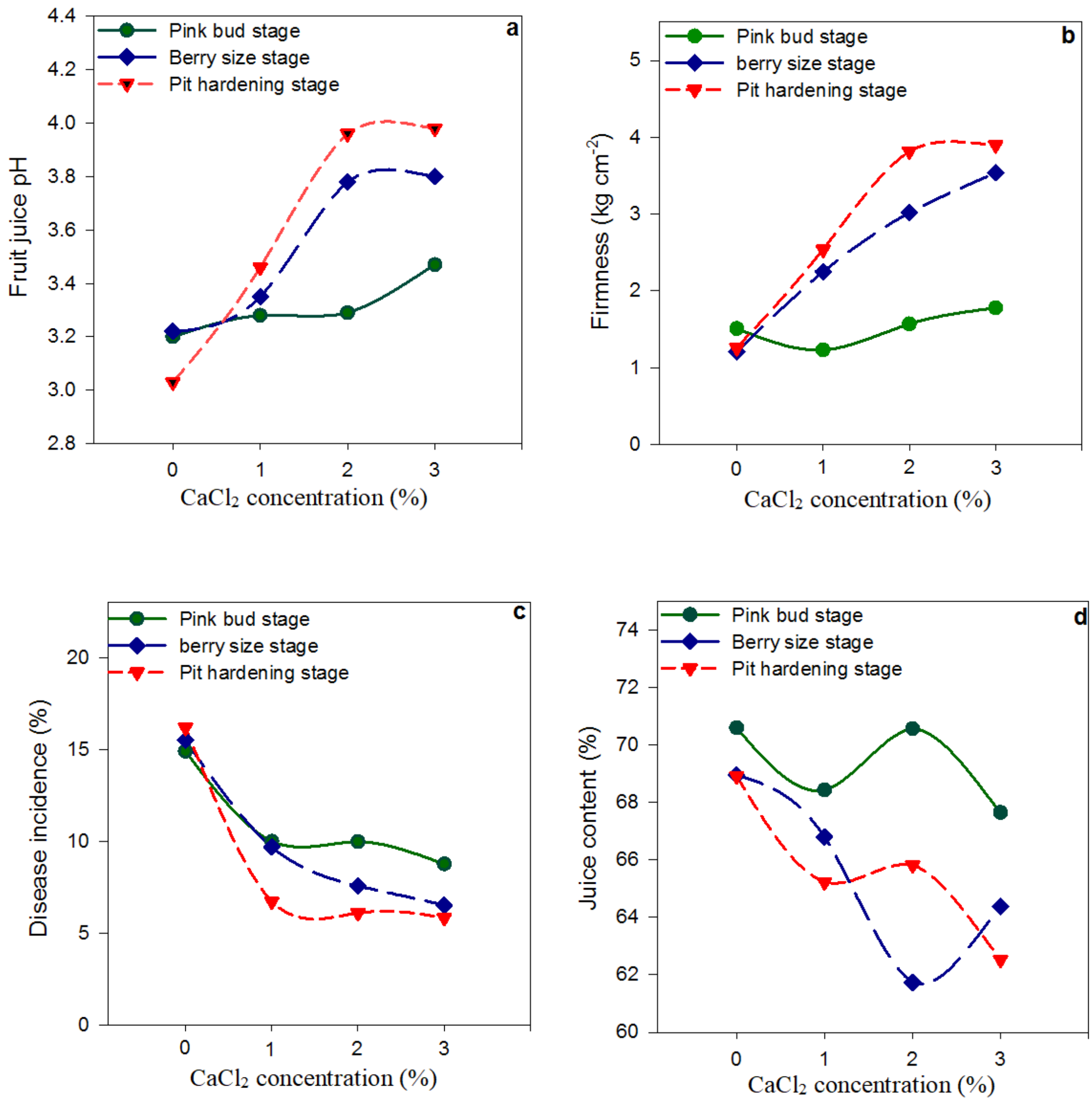

Fig. 2. Fruit juice pH, fruit firmness, disease incidence and juice content of peaches as affected by foliar sprays of $CaCl_2$ at different growth stages

noticed increased soluble solid contents with pre-harvest calcium sprays on peaches. Similarly, Farag et al. [2012] applied $CaCl_2$ at pit hardening stage of apricot and found increase in TSS. However, Correia et al. [2019] observed that SSC index was not increased by Calcium foliar application.

Sugar-acid ratio of the peach fruit juice (Fig. 1c) revealed that highest (45.08) value was recorded in the samples receiving 3% $CaCl_2$ at pit hardening stage, whereas the lowest (15.64) was observed in control treatment at the same stage. All treatments with foliar application of $CaCl_2$ were at par with each other, however their application at pit hardening stage depicted profound results compared with other stages. Calcium application resulted in the conversion of acids to sugars, that's why the highest values for sugar to acid ratio are obtained in the current study. Furthermore, as the fruit ripens, carbohydrates change into sugars and acids diminished, which leads to higher sugar to acid ratio. The results of the present study are in accordance with the findings of Farag et al. [2012] who noted highest sugar to acid ratio in apricot fruits with $CaCl_2$ application at pit hardening stage while Sarrwy et al. [2012] found the same in grapes.

The highest fruit titratable acidity (Fig. 1d) was observed in control treatment (0.48) at pit hardening stage while the treatment of 3% $CaCl_2$ at the same stage gave out the lowest value (0.25). The foliar levels of $CaCl_2$ were statistically at par for fruit titratable acidity. The fruits treated at the pit hardening stage had the lowest value of fruit titratable acidity. Titratable acidity is considered as an important parameter in maintaining fruit quality, and it depends upon concentration of organic acids [Kazemi et al. 2011]. Calcium brought about reduction in total acid contents by causing alteration in cellular processes [Conway 1987]. More so, $CaCl_2$ reduces the acid content, as it slows down respiration rate and delays fruit ripening, thus reducing the acid utilization in respiration process and changing some of these acids into sugars [Raese and Drake 1993]. The data regarding fruit juice pH (Fig. 2a) depicted that highest pH (3.98) was obtained with the application of $CaCl_2$ at the rate of 3% at the pit hardening stage while lowest (3.03) was noted in control treatment at the same stage. Percent acidity and pH are correlated with each other. Higher the percent acidity, lower will be the pH and vice versa. Calcium affects the fruit quality by causing changes in the normal cellular operations and processes. As a result, it alters other processes such as lowering the acidity of the cells [Conway 1987]. Fruit ripening is delayed due to calcium application, as it slows down the respiration process. The present findings are in harmony with the results of Farag et al. [2012] who used $CaCl_2$ with ethephon on apricot fruits at pit hardening stage and found decrease in acid content. Kassem et al. [2010] and Sarrwy et al. [2012] also recorded decrease in the titratable acidity of persimmon and date palm fruits respectively when calcium was applied to them as foliar spray at the pre-harvest.

Peach fruit firmness was strongly affected by the $CaCl_2$ treatments at different growth stages (Fig. 2b). The maximum firmness (3.90 $kg \cdot cm^{-2}$) was observed in the plants treated with 3% $CaCl_2$ at the pit hardening stage whereas the lowest (1.21 $kg \cdot cm^{-2}$) was observed in control treatment at the berry sized fruit stage. In different growth stages, the treatment at pit hardening stage and pink bud stage had the highest and the lowest effect on fruit firmness respectively.

Calcium is a major part of membrane and wall of the cells [Johnson 2008]. In the cell wall before cell separation, calcium is considered as the last barrier. It gives strength to the cell wall by making cross bridges between them, makes cell rigid, reduces decay and delay softening, and thereby increases fruit firmness [Conway 1982, Fry 2004]. The results are in accordance with El-Badawy [2012] who treated peach fruits with 4% $CaCl_2$ and found significant increase in peach fruit firmness as compared to control. Similarly, Navjot and Mahajan [2010] observed an increment in the firmness of peach fruits when treated with 6% $CaCl_2$. On the other hand, Crisosto et al. [2000] found no improvement in fruit firmness or other quality attributes due to foliar calcium sprays.

The trend of disease incidence (Fig. 2c) was the same as obtained for titratable acidity with maximum in control and minimum with the application of 3% $CaCl_2$ at pit hardening stage. Calcium has a major function that it reduces the effect of insects and diseases on the plants and fruits. It increases disease resistance and resists the fungal infections in fruits [Volpin and Elad 1991]. Calcium makes cross bridges between the cell walls, which give it strength. Application of calcium on the fruits and plants protects them from the enzymes that degrade cell wall [White and Broadley 2003]. In peach fruits, calcium chloride enhances the natural resistance against the brown rot invasion. It not only increases the host resistance, but also inhibits the growth of fungus to reduce the polygalacturonase activity of the fungus [Biggs et al. 1997] by stopping it from reaching its active sites in the cells. The findings of the current study are analogous to the results of Thomidis et al. [2007] who reported a significant reduction of peach brown rot incidence with the application of calcium chloride and other calcium formulations in peach trees. Mohsen [2011] also observed significantly positive effects of calcium on apples and apricots respectively against the disease incidence. Apart from these, Manganaris et al. [2005a] observed that calcium sprays doesn't inhibit disease incidence of peach. The application of calcium chloride at various stages has a non-significant effect on fruit juice content of peach (Fig. 2d). Similar to this study, Shukla [2011] also reported non-significant results regarding percent juice content of gooseberry fruits when treated with calcium.

CONCLUSION

This experiment was conducted to observe the response of 'Florida King' peaches to foliar application of calcium chloride at different fruit growth stages. Results showed that, the foliar application of calcium chloride at different growth stages significantly influenced the yield and fruit quality parameters. It can be concluded that 3% calcium chloride applied at the pit hardening fruit stage caused significant increase in fruit weight, yield tree^{-1}, fruit volume, ascorbic acid content, total soluble solids, fruit juice pH, sugar to acid ratio, and fruit firmness, but resulted in significant decrease in percent titratable acidity and disease incidence. Percent juice content showed no response to any treatment. Therefore, it can be concluded that foliar calcium application not only improved yield of peach but also resulted in good quality fruit production.

AUTHORS CONTRIBUTIONS

All the authors contributed equally to this research work and article.

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