# Fruit Growth and Sensory Evaluation of 'Hayward' Kiwifruit in Response to Preharvest Calcium Chloride Application and Orchard Location

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## Summary

In order to receive reliable results in the effect of preharvest calcium chloride ($CaCl_2$) application on fruit growth and sensory characteristics of kiwifruit (*Actinidia deliciosa* cultivar 'Hayward') at the harvest time, a field experiment was carried out in two commercial orchards at different locations. The vines were sprayed with $CaCl_2$ (1.5%), one, two, or three times in 35, 85 and 125 days after full bloom. The results showed that $CaCl_2$ treatment significantly reduced fruit size, fresh weight and total dry matter content. Moreover, fruit growth relative attributes such as relative growth index, daily relative growth rate, daily transpiration rate, total carbon received by fruit and yield threshold pressure significantly decreased by thrice application. After thrice application of $CaCl_2$, fruits showed better sensory quality. Overall, one time preharvest $CaCl_2$ application had no-significant effect on the most fruits characteristics, while thrice application of $CaCl_2$ could delay fruit ripening process.

## Key words

*Actinidia deliciosa*, daily transpiration, fruit size, growth index, ripening

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## Introduction

The appearance and quality of fresh fruits is a primary criterion in making purchasing decisions. Consumer's acceptance for ripe kiwifruits (*Actinidia deliciosa* cultivar 'Hayward') is fruit size and shape, sugar concentration, sugar-acid ratio, green pulp colour, and the sensory properties such as volatile content, texture, sweet-nectar odour, sweet pulp taste and appearance (Jaeger et al., 2003; Ghasemnezhad et al., 2013).

Previous studies showed that, there are three main stages in terms of the dominating metabolism in kiwifruit: (1) cell division [from 0 to 45 day after full bloom (DAFB)], (2) starch accumulation (from about 45 to about 120 DAFB) and (3) fruit maturation (from about 120 DAFB to harvest) (Richardson et al., 2004; Moscatello et al., 2011). During kiwifruit growth and development, numerous biochemicals, physiological and structural modifications happen and these changes determine the final fruit quality (Tavarini et al., 2009). Since the quality characteristics of fruits are strongly influenced by different factors, foliar application of macro and micro-nutrients during fruit development have very important role in improving quality of fruits (Shukla et al., 2011; Singh et al., 2007). Calcium is an essential element as well as a crucial regulator of growth and development in plants (Hepler, 2005), and participates in cross-linking negative charges, especially on the carboxylic residues of pectin, imparting significant structural rigidity to the cell wall (Hepler and Winship, 2010; Li et al., 2012).

Since, during fruit growth and development, small amount of calcium is transferred from leaves to fruits, and on the other hand, lenticels, cracks and surface discontinuities seem to have a significant positive effect on calcium penetration, direct calcium applications on the fruit surface is recommended and calcium sprays have been reported to be particularly effective in increasing calcium levels in many fleshy fruits (Manganaris et al., 2005; Manganaris et al., 2006). Preharvest treatment with calcium changes intracellular and extracellular processes such as fruit respiration rates and ethylene production, thereby causes retarding fruit ripening, softening and finally delays senescence (Tsantili et al., 2007).

Considerable attention has been given to calcium application to kiwifruit, since it was found that calcium application is effective way to maintain fruit quality, extend storability and potentially is related with the appearance of pitting incidence (Basiouny and Basiouny, 2000; Xie et al., 2003; Gerasopoulos and Drogoudi, 2005). Moreover, calcium makes fruit more acceptable by reducing colour change rate, maintain membrane permeability and slow ripening processes (Gerasopoulos and Drogoudi, 2005). It should also be noted that the beneficial effects of preharvest calcium sprays depend on many factors, including calcium source, frequency, method and timing of treatment, as well as orchard location, growth and environmental conditions and cultivar (Serrano et al., 2004; Manganaris et al., 2006).

Despite the importance of calcium content and the effects of calcium applications in many fruit species, there is little or no reliable information on the effect of $CaCl_2$ treatment on fruit relative growth characteristics and sensory quality of kiwifruit. Discussions in the papers outlined previous conclusion that application of $CaCl_2$ could change and/or enhance the postharvest quality of kiwifruit by changing fruits physiological and biochemical characteristics, with no detrimental effect on consumer's acceptance. Therefore, the main objective of this study was to define the influence of preharvest $CaCl_2$ applications on kiwifruit quality, with an emphasis on the growth relative and sensory attributes at the harvest time.

## Materials and methods

### Plant material and handling

The experiment was conducted during the 2013 growing season in two commercial full yieldness 'Hayward' kiwifruit orchards. The orchards located in Rasht (latitude of 37°21' N, longitude of 49°57' E and 5 m altitude) and Ramsar at the Iran Citrus Research Institute (latitude of 36°90' N, longitude of 50°65' E and 21 m altitude) in Iran. The both orchards are located in subtropical regions, where the mean annual temperature is about 15.9 and 21°C, rainfall 1359 and 1200 mm per year in Rasht and Ramsar respectively.

Two orchards were selected assuming the climate, vines age, training and management system, vegetative and reproductive characteristics to be similar, although there are some differences because of their geographical separation. The 10-years old vines were spaced 6×4 m (417 vines $ha^{-1}$) and trained on a T-bare system in a medium-textured soil with 'Tomori' as pollinizer (8:1). The vines and the soil were managed according to standard cultural practices. The vines were regularly drip-irrigated during the season, water was supplied based on evaporative demand; meteorological data were recorded throughout the study.

In each orchard 54 vines were selected for preharvest $CaCl_2$ treatment. According to three main stages of the dominating metabolism in kiwifruit (Richardson et al., 2004; Moscatello et al., 2011), $CaCl_2$ (1.5%) application was performed at three times (35, 80 and 125 DAFB) during the growing season. A surfactant (0.01% Tween 20) was added during sprays for maximum calcium absorption. Treatments were arranged in a completely randomized block design with three replicates. Each replication consisted of three vines. Treatments were identified as follows: T0 (control, non-treated), T1: ($CaCl_2$ sprayed at 35 DAFB), T2: ($CaCl_2$ sprayed at 80 DAFB), T3: ($CaCl_2$ sprayed at 125 DAFB), T4: ($CaCl_2$ sprayed at 35 + 80 DAFB), T5: ($CaCl_2$ sprayed at 35 + 80 + 125 DAFB).

Thirty uniform and defect-free fruits from each treated and untreated vines were harvested when total soluble solids (TSS) content reached an average of 6.2-6.5% (Gerasopoulos and Drogoudi, 2005). Immediately, fruits were transferred to the laboratory and some quantitative and qualitative parameters were determined.

### Quality parameters related to fruit physical dimensions and fresh weight

In each treatment, ninety fruits were selected to determine fruit quality. Physical dimensions of length, diameter and volume of all fruits were measured. Fruits were weighed (fresh weight), percentage of fruit dry matter (%DM) (skin plus flesh) was determined after 48 h drying (60 °C) using a ventilated oven. Water content was calculated as the difference between fresh weight (FW) and dry weight (Montanaro et al., 2006).

Physical dimensions, fresh and dry weights were measured at two stages, 10 days after fruit set (DAFS) and immediately after harvest. Using these data, %DM, fruit DM content (FDMC) (g per fruit), percentage of excess DM per fruit (%EDMF), daily dry matter accumulation (DDMA) (mg DM per fruit$^{-1}$ d$^{-1}$) and the specific rates of fruit DM accumulation (SRFDMA) (g DM gFW$^{-1}$ d$^{-1}$) were calculated (Montanaro et al., 2010). Fruit density was calculated by water displacement method (Jan et al., 2013):

Fruit density (g cm$^{-3}$) = M/V

where M is the mass of fruit and V is the volume of fruit.

Fruit surface area (FSA) (cm$^2$ fruit$^{-1}$) was calculated as L×W×3.14; where L is the fruit length and W is the maximum fruit diameter (Montanaro et al., 2012).

### Fruit growth relative attributes

Relative growth index (RGI) was calculated as:

$$RGI = (FW_{t1} - FW_{t0})/[( FW_{t1} + FW_{t0})/2]$$

where $FW_{t1}$ and $FW_{t0}$ are stands for fresh weights (g) measured at harvest ($t_1$) and 10 DAFS ($t_0$), respectively (Gallego et al., 1997).

Daily relative growth rate (DRGR, g g$^{-1}$ day$^{-1}$) was calculated using the following equation (Morandi et al., 2010):

$$DRGR_{t1} = (FW_{t1} - FW_{t0})/[(t_1 - t_0)FW_{t0}]$$

where $FW_{t1}$ and $FW_{t0}$ are stands for fruit fresh weights (g) measured at harvest ($t_1$) and 10 DAFS ($t_0$), respectively.

The total carbon received (TCR) by fruit during the growing season ($C_t$) was estimated by assuming that the daily respiration rate ($C_r$) for a kiwifruit berry decreased from 1.4 to 0.1 mM $CO_2$ g$^{-1}$ dry matter day$^{-1}$ during the first 150 days after fruit set, following an exponential decay pattern and by assuming that the carbon remaining in fruit DM was approximately 48% (Montanaro et al., 2006).

$$C_t = DM\ (0.48 \times C_r)$$

$$C_r = (0.10635 + 1.31078\ e^{(-x/29.13114)})$$

where, DM is dry matter and x is day after fruit set.

The threshold pressure (Y) reflects properties of the cell wall and may vary during fruit growth and it was calculated according to Green et al. (1971) and Lechaudel et al. (2007).

### Fruit sensory quality analysis

Ten panelists were trained for kiwifruit sensory evaluation based on the following criteria: willingness to consume kiwi, knowledge of sensory tests, availability and no history of negative allergic reactions. The sensory panel underwent 8 h of training, during which they developed and defined a descriptive vocabulary of 10 attributes to establish differences in the sensory properties, color, texture, flavor and taste (Table 1), for comparing the treatments (Fernández-Sestelo et al., 2013; Shiri et al., 2013a; Shiri et al., 2013b).

### Statistical analysis

A randomized complete block experimental design with three replications was used. Data were analyzed as a combined experiment model by PROC ANOVA procedure by SAS software (Ver. 9.1 2002–2003, SAS Institute, Cary, NC, USA). Before analysis of variance, data were tested for normality and homoscedasticity using the Kolmogorov–Smirnov and Cochran tests, respectively. Least significant difference (LSD) at $P \leq 0.01$ was calculated to compare differences between means following a significant ANOVA effect.

**Table 1.** Fruit sensory attributes used in the presented quantitative descriptive analysis

| Attributes | Descriptors | Grouped and associate descriptors | Anchoring points(left-right) |
|---|---|---|---|
| Skin color | | | |
| | Brown | | Dark brown – pale brown |
| Pulp color | | | |
| | Green | | Verdant – greeny |
| Pulp texture | | | |
| | Pulp consistency | Degree of firmness of fruit flash | Soft, firm – hard |
| | Juicy | | Watery – semi dry |
| Taste | | | |
| | Sweet | Sugar, honey | None – very intensive |
| | Acid | Sour | None – very intensive |
| | Bitter | Metallic | None – very intensive |
| Flavor | | | |
| | Fruity, natural | Flavor characteristic for fully ripe kiwifruit or gooseberry fruits | None – very intensive |
| Skin | | | |
| | Skin resistance | Resistance of fruit skin when chewed | Soft, firm – hard |

The abbreviation, description and anchoring points for each attribute given

## Results

### Fruit size and growth relative attributes

The results showed that the orchards and $CaCl_2$ treatment significantly affected the fruit length and FSA, but their interaction has no significant effect (Table 2). Fruits harvested from Rasht orchard were longer in size and had higher FSA than those from Ramsar, additionally $CaCl_2$ application significantly

**Table 2.** Influence of $CaCl_2$ (1.5%) treatment and orchard location on fruit length, fruit surface area and dry matter (DM) of 'Hayward' kiwifruit

| | | Fruit length (mm) | Fruit surface area (cm$^2$ fruit$^{-1}$) | DM (%) |
|---|---|---|---|---|
| Orchard (O) | | *** | *** | *** |
| Treatment (T) | | *** | *** | NS |
| O × T | | NS | NS | NS |
| Orchard | Rasht | 68.4 a | 117.0 a | 16.6 b |
| | Ramsar | 66.4 b | 111.8 b | 18.3 a |
| Treatment | T0 | 69.7 a | 121.9 a | 17.6 a |
| | T1 | 67.7 bc | 115.3 bc | 17.4 a |
| | T2 | 67.0 c | 113.8 c | 17.5 a |
| | T3 | 69.0 ab | 117.6 b | 17.7 a |
| | T4 | 66.7 c | 113.8 c | 17.2 a |
| | T5 | 63.7 d | 103.3 d | 17.3 a |

NS and *** indicates non-significant and significant at $P \leq 0.001$, respectively. Means within each column followed by the same letter are not different at $P \leq 0.01$ based on LSD test.

**Table 3.** Influence of $CaCl_2$ (1.5%) treatment and orchard location on fruit diameter, length/diameter (L/D), volume, fresh weight (FW), fruit dry matter content (FDMC) and daily dry matter accumulation (DDMA) of 'Hayward' kiwifruit

| | | Fruit diameter (m) | L/D | Volume ($cm^2$) | FW (g) | FDMC (g DM $fruit^{-1}$) | DDMA (mg DM $fruit^{-1}$ $d^{-1}$) |
|---|---|---|---|---|---|---|---|
| Orchard (O) | | *** | * | *** | *** | NS | * |
| Treatment (T) | | *** | ** | *** | *** | *** | *** |
| O × T | | * | ** | *** | *** | ** | *** |
| Rasht | T0 | 560 a | 1.27 a | 112.2 a | 118.2 a | 19.8 a | 123.1 a |
| | T1 | 54.1 ab | 1.26 a | 102.2 cd | 107.1 b | 17.8 b | 110.6 b |
| | T2 | 54.6 ab | 1.25 a | 106.0 bc | 108.9 b | 18.1 b | 112.4 b |
| | T3 | 55.5 a | 1.24 b | 107.2 b | 110.5 b | 18.6 ab | 115.7 ab |
| | T4 | 54.9 a | 1.24 b | 106.8 b | 108.4 b | 17.8 b | 110.5 b |
| | T5 | 52.3 b | 1.25 ab | 99.6 d | 109.9 b | 18.1 b | 112.4 b |
| Ramsar | T0 | 55.4 a | 1.24 b | 108.4 a | 108.3 a | 20.0a | 124.1 a |
| | T1 | 54.9 ab | 1.22 b | 106.2 a | 105.9 ab | 19.1 a | 118.6 ab |
| | T2 | 53.6 bc | 1.22 b | 99.8 c | 99.8 c | 18.4 a | 114.4 b |
| | T3 | 53.0 c | 1.30 a | 103.3 bc | 102.5 bc | 19.1a | 118.5 ab |
| | T4 | 53.7 bc | 1.22 b | 106.3 ab | 105.4 ab | 18.9a | 117.1 b |
| | T5 | 51.0 d | 1.22 b | 86.3 d | 91.2 d | 16.5 b | 102.8 c |

NS, *, **, or *** indicates non-significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.
Means within each column followed by the same letter are not different at $P \leq 0.01$ based on LSD test.

**Table 4.** Influence of $CaCl_2$ (1.5%) treatment and orchard location on specific rates of fruit dry matter accumulation (SRFDMA), excess dry matter per fruit (EDMF), fruit water content (FWC), fruit density (FD), relative growth index (RGI) and daily relative growth rate (DRGR) of 'Hayward' kiwifruit

| | | SRFDMA (mg DM $gFW^{-1}$ $d^{-1}$) | EDMF (%) | FWC(g) | FD (g $cm^{-3}$) | RGI | DRGR (g $g^{-1}$ $day^{-1}$) |
|---|---|---|---|---|---|---|---|
| Orchard (O) | | *** † | *** | *** | *** | *** | *** |
| Treatment (T) | | *** | *** | *** | *** | *** | *** |
| O × T | | *** | ** | *** | *** | *** | *** |
| Rasht | T0 | 1.041 a | 99.490 a | 98.4 a | 1.054 b | 1.938 a | 0.417 a |
| | T1 | 1.032 b | 99.433 b | 89.3 b | 1.049 b | 1.931 b | 0.378 c |
| | T2 | 1.031 b | 99.442 b | 90.9 b | 1.028 c | 1.933 b | 0.384 bc |
| | T3 | 1.047 a | 99.457 ab | 91.8 b | 1.027 c | 1.934 b | 0.389 b |
| | T4 | 1.025 cd | 99.431 b | 90.6 b | 1.019 c | 1.932 b | 0.382 bc |
| | T5 | 1.022 d | 99.441 b | 91.8 b | 1.107 a | 1.930 b | 0.386 bc |
| Ramsar | T0 | 1.145 a | 99.414 a | 88.4 a | 0.999 b | 1.927 a | 0.349 a |
| | T1 | 1.126 b | 99.386 a | 86.2 a | 0.971 c | 1.924 ab | 0.339 b |
| | T2 | 1.146 a | 99.365 a | 81.4 b | 0.999 b | 1.920 c | 0.321 c |
| | T3 | 1.159 a | 99.387 a | 83.4 b | 0.992 bc | 1.922 bc | 0.330 bc |
| | T4 | 1.118 bc | 99.379 a | 86.5 a | 0.991 bc | 1.925 ab | 0.339 b |
| | T5 | 1.110 c | 99.292 b | 74.7 c | 1.057 a | 1.913 d | 0.293 d |

NS, *, **, or *** indicates non-significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.
Means within each column followed by the same letter are not different at $P \leq 0.01$ based on LSD test.

($P \leq 0.001$) reduced fruit length and FSA in both orchards. The inhibitory effects of $CaCl_2$ treatment increased along with increasing in application frequency.

As the Table 2 illustrates, fruits dry DM percent was higher in Ramsar orchard (18.28%) than in Rasht (16.62%), however preharvest calcium application did not have significant effect on fruit DM content.

The fruit physical dimensions (diameter, volume and length/diameter) also showed a significant difference between two orchards and $CaCl_2$ application. Furthermore, a significant difference was found between interaction effects of orchards and calcium treatment (Table 3). In both orchards, application of $CaCl_2$ significantly reduced fruit physical dimensions, whereas in Ramsar orchard, higher length/diameter was obtained in T3 (1.30) than T0 (1.24).

Percentage of fruit fresh weight was significantly ($P \leq 0.001$) affected by the orchard, calcium treatment and the interaction between orchard and calcium application. Preharvest application of calcium significantly reduced percentage of fruit FW from 118.2 to 106.9 g and from 108.3 to 91.2 g in control as compared with T5 in Rasht and Ramsar orchards, respectively (Table 3).

No significant difference was found between two orchards in fruit DM content (FDMC) (18.37 and 18.66 g DM $fruit^{-1}$ in Rasht and Ramsar, respectively). In contrast, $CaCl_2$ application significantly reduced FDMC, as the highest amount was found in control (19.82 and 19.97 g DM $fruit^{-1}$ in Rasht and Ramsar, respectively) (Table3).

The results showed that along with decreasing DM content by $CaCl_2$ treatment (Table 2), SRFDMA (mg DM $gFW^{-1}$ $d^{-1}$), DDMA (mg DM $fruit^{-1}$ $d^{-1}$) and % EDMF also decreased by

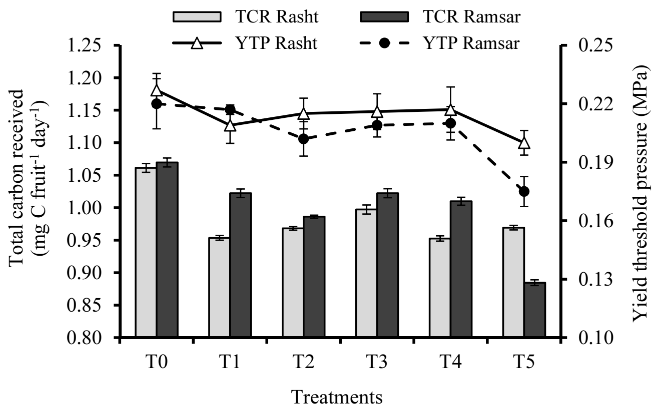


**Figure 1.** Effect of $CaCl_2$ (1.5%) application and orchard location on total carbon received (TCR) and yield threshold pressure (YTP) of 'Hayward' kiwifruit. The values are the means ± SE

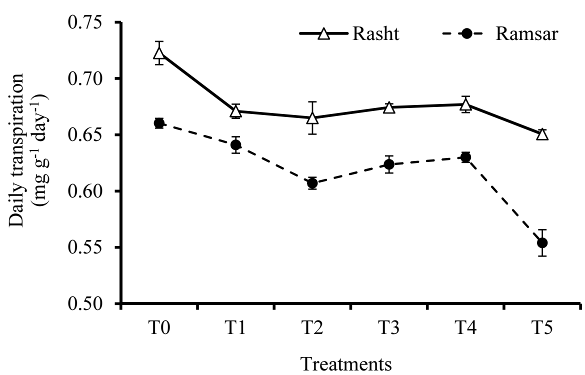


**Figure 2.** Effect of $CaCl_2$ (1.5%) application and orchard location on daily transpiration of 'Hayward' kiwifruit. The values are the means ± SE

$CaCl_2$ treatment (Tables 3 and 4). Moreover, it was revealed that inhibitory effect increased along with increase of $CaCl_2$ application times, as the thrice application had the lowest amount of above mentioned attributes.

Table 3 illustrates the comparison of fruit water content (FWC) under $CaCl_2$ treatment. Fruits harvested from Rasht orchard had higher FWC than Ramsar (19.14 and 83.41 g, respectively). Furthermore, $CaCl_2$ application gradually reduced FWC, as the highest FWC was found in control (98.38 and 88.39 g in Rasht and Ramsar, respectively).

Fruit density was significantly affected by orchard location, $CaCl_2$ treatment and their interaction ($P \leq 0.001$). Compared with the control, T5 significantly enhanced fruit density from 1.054 to 1.107 g $cm^{-3}$ and from 1.005 to 1.057 g $cm^{-3}$ in Rasht and Ramsar, respectively.

### Fruit growth relative attributes

Orchard, $CaCl_2$ treatment and their interaction ($P \leq 0.001$) had significant effect on RGI and DRGR (Table 4). $CaCl_2$ treatment slightly reduced fruit relative growth characteristics, as the lowest amount was found in thrice application of $CaCl_2$ (T5).

Changes in TCR, yield threshold pressure (YTP) and daily transpiration showed the similar patterns (Fig. 1 and 2). It was found that along with increase in application times, these characteristics significantly reduced, as the T5 had the lowest amount as compared with others.

### Sensory quality parameters

Sensory quality was assessed as a consequence of $CaCl_2$ treatment. No significant difference was found for fruits sensory quality in $CaCl_2$ treated and untreated fruits with the exception in T5. Both orchards showed similar results by $CaCl_2$ application. As Fig. 3 A and B showed when kiwifruit vines were sprayed three times with 1.5% $CaCl_2$ the sensory quality properties such as fruit pulp and flesh colour, flavor and firmness were improved.

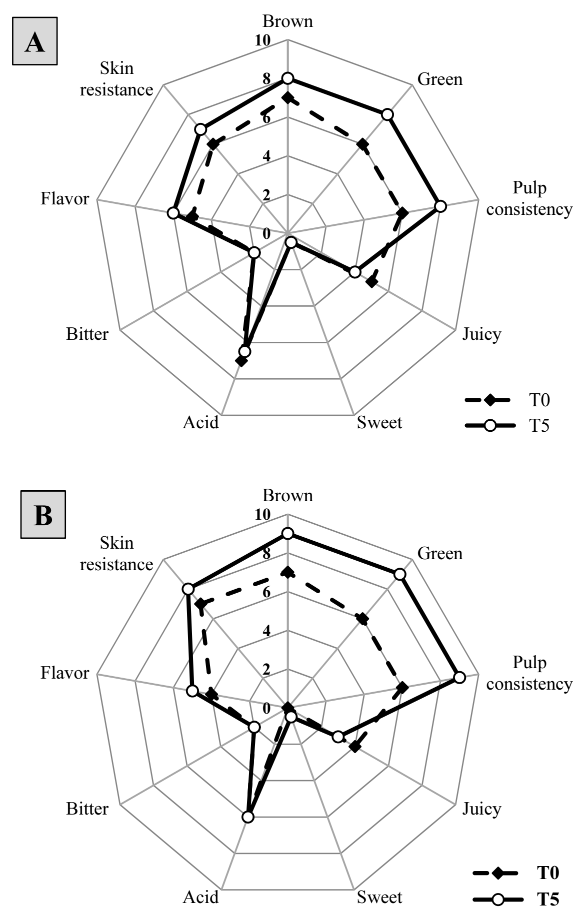


**Figure 3.** Fruit sensory attributes of thrice application of $CaCl_2$ (1.5%) treatment (T5) and control (T0) of 'Hayward' kiwifruit growing in Rasht (A) and Ramsar (B) orchards. For each variable, the possible range of values was 0-10

## Discussion

The fruit size at harvest depends on a number of environmental and management factors and complex interactions between physiological processes (Basile et al., 2012). This study showed that thrice application of $CaCl_2$ reduced fruit size and growth related parameters. In part, it could be due to the role of calcium in increasing mechanical strength of cell walls that can limit cell expansion. Cell elongation is influenced by external factors such as light, temperature, and plant growth regulators such as auxin and gibberellic acids (Heggie and Halliday, 2005). The ability of high concentrations of calcium ions to inhibit cell elongation has long been recognized. Furthermore, plastic extensibility was closely correlated with the growth rate of plant cells and decreasing in calcium content has the direct effects on increasing plastic extensibility and cell wall loosening (Virk and Cleland, 1988).

These results also showed that preharvest $CaCl_2$ application significantly reduced fruit growth relative attributes, as these inhibitory effects increased along with increasing in spraying times. The most negative effect was found when fruits were sprayed thrice with $CaCl_2$ during 35, 80 and 125 days after full bloom. The inhibitory effect of calcium on extensibility of the cell walls and growth would appear to be indirect. It could be a response to a calcium-mediated change in the cell wall metabolism, or it could simply be a consequence of the growth inhibition; inhibition of auxin-induced growth by respiratory inhibitors such as potassium cyanide (KCN), 2,4-dinitrophenol (DNP) and N-ethylmaleimide has been shown to result in a stiffening of the cell wall (Cleland and Rayle, 1977; Cunninghame and Hall, 1986; Jackson and Hall, 1993).

Alternatively, calcium may simply alter proteins or polysaccharides so that an $H^+$-enhanced enzymatic wall-loosening reaction cannot occur (Holdaway-Clarke and Hepler, 2003; Hepler, 2005). Furthermore, recently calcium was suggested to inhibit cell elongation by destabilizing cortical microtubules via regulating a microtube-destabilizing protein 25 (MDP25) (Li et al., 2011).

The import of sugars into the fruit is strongly related to fruit transpiration, indicating the importance of water loss through the fruit surface to fruit growth quality (Li et al., 2001). In addition, the relationships have been found between fruit calcium accumulation and fruit transpiration as affected by fruit microenvironment. It seems that decreasing in fruit transpiration by $CaCl_2$ application may be attributed to change in fruit cell properties (such as fruit surface area and fruit density) and decrease in fruit size. Furthermore, decrease in fruit transpiration could be caused by reduction in total carbon received by fruit and yield threshold pressure.

It was found that one and two times application of $CaCl_2$ had no significant effect on fruit sensory quality, while thrice application had better quality as compared with others. Sugar metabolism and carbon fluxes have important role in fruit sensory quality and their effects on quality traits may be opposite (e.g., enhancing water fluxes into fruit increases fruit size but decreases sugar concentration) (Génard and Lescourret, 2004; Lescourret and Génard, 2005). Improvement of sensory quality in thrice treated fruit by $CaCl_2$ (such as pulp and flesh colour, flavor and firmness) may be related to decrease in fruit size, higher sugar concentration and fruit density.

## Conclusion

This study revealed that in most characteristics, there was no significant difference between one time application of $CaCl_2$ with untreated fruits, in contrast, thrice application of $CaCl_2$ had significant effect on fruit growth attributes and was more effective in retarding fruit ripening process. Furthermore, fruit size, FW and total fruit DM content significantly decreased. The inhibitory effects of $CaCl_2$ application on fruit growth characteristics increased along with increasing in spraying times, while the thrice application of $CaCl_2$ (T5) showed the lowest values as compared with the control and other calcium treatments. Quality of a product encompasses sensory properties (appearance, texture, taste) and functional properties and defects. Thrice application of $CaCl_2$ produced firmer fruit and improved fruit sensory quality. In the light of these results, commercial application of thrice spraying with $CaCl_2$ (1.5%) can be considered for the retarding fruit ripening and maintenance of quality.

## References


Basile B., Giaccone M., Cirillo C., Ritieni A., Graziani G., Shahak Y., Forlani M. (2012). Photo-selective hail nets affect fruit size and quality in Hayward kiwifruit. Sci Hortic 141: 91-97

Basiouny F.M., Basiouny A. (2000). Effects of liquid calcium and control atmosphere on storability and quality of kiwifruit (*Actinidia chinensis* Planch cv. 'Hayward'). Acta Hort 518: 213-221

Cleland R.E., Rayle DL. (1977). Re-evaluation of effect of calcium-ions on auxin-induced elongation. Plant Physiol 60: 709-712

Cunninghame M.E., Hall J.L. (1986). The effect of calcium antagonists and inhibitors of secretory processes on auxin-induced elongation and fine structure of *Pisum sativum* stem segments. Protoplasma1 33: 149-159

Fernández-Sestelo A., Sendra de Saá R., Pérez-Lamela C., Torrado-Agrasar A., Rúa M.L., Pastrana-Castro L. (2013). Overall quality properties in pressurized kiwi purée: Microbial, physicochemical, nutritive and sensory tests during refrigerated storage. Innov Food Sci Emerg Technol 20: 64-72

Gallego P.P., Martinez A., Zarra I. (1997). Analysis of the growth kinetic of fruits of *Actinidia deliciosa*. Biol Plant 39(4): 615-622

Génard M., Lescourret F. (2004). Modeling fruit quality: ecophysiological, agronomical and ecological perspectives. In: Production practices and quality assessment of food crops, preharvest practice. Kluwer Academic Press, Dordrecht. (R Dris, SM Jain, eds), The Netherlands. 47-82

Gerasopoulos D., Drogoudi PD. (2005). Summer-pruning and preharvest calcium chloride sprays affect storability and low temperature breakdown incidence in kiwifruit. Postharvest Biol Technol 36: 303-308

Ghasemnezhad M., Ghorbanalipour R., Shiri M.A. (2013). Changes in physiological characteristics of kiwifruit Harvested at different maturity stages after cold storage. Agric Conspec Sci 78(1): 41-47

Green P.B., Erickson R.O., Buggy J. (1971). Metabolic and physical control of cell elongation rate. Plant Physiol 47: 423-430

Heggie L., Halliday K.J. (2005). The highs and lows of plant life: temperature and light interactions in development. Int J Dev Biol 49: 675-687

Hepler P.K. (2005). Calcium: A central regulator of plant growth and development. Plant Cell 17: 2142-2155

Hepler P.K., Winship L.J. (2010). Calcium at the cell wall-cytoplast interface. J Integr Plant Biol 52: 147-160

Holdaway-Clarke T.L., Hepler P.K. (2003). Control of pollen tube growth: Role of ion gradients and fluxes. New Phytol 159: 539-563

Jackson C.K., Hall J.L. (1993). A fine structural analysis of auxin-induced elongation of *Cucumber* hypocotyls, and the effects of calcium antagonists and ionophores. Ann Bot 72(3): 193-204

Jaeger S., Rossiter K.L., Wismer W.V., Harker F.R. (2003). Consumer-driven product development in the kiwifruit industry. Food Qual Preference 14: 187-198

Jan I., Rab A., Sajid M. (2013). Influence of calcium chloride on physical characteristics and soft rot incidence on fruit of apple cultivars. J Anim Plant Sci 23(5): 1353-1359

Lechaudel M., Vercambre G., Lescourret F., Normand F., Génard M. (2007). An analysis of elastic and plastic fruit growth of mango in response to various assimilate supplies. Tree Physiol 27: 219-230

Lescourret F., Génard M. (2005). A virtual peach fruit model simulating changes in fruit quality during the final stage of fruit growth. Tree Physiol 25: 1303-1315

Li C., Tao, J., Zhao D., You C., Ge J. (2012). Effect of calcium sprays on mechanical strength and cell wall fractions of herbaceous peony (*Paeonia lactiflora* pall.) inflorescence stems. Int J Molec Sci 13: 4704-4713

Li J.J., Wang X.L., Qin T., Zhang Y., Liu X.M., Sun J.B., Zhou Y., Zhu L., Zhang Z.D., Yuan M., Mao T.L. (2011). MDP25, a novel calcium regulatory protein, mediates hypocotyl cell elongation by destabilizing cortical microtubules in *Arabidopsis*. Plant Cell 23: 4411-4427

Li S.H., Génard M., Bussi C., Huguet J.G., Habib R., Besset J., Laurent R. (2001). Fruit quality and leaf photosynthesis in response to microenvironment modification around individual fruit by covering the fruit with plastic in nectarine and peach trees. J Hortic Sci Biotechnol 76: 61-69

Manganaris G.A., Vasilakakis M., Diamantidis G., Mignani I. (2006). Effect of in-season calcium applications on cell wall physicochemical properties of nectarine fruit (*Prunus persica* var. nectarine Ait. Maxim) after harvest or cold storage. J Sci Food Agric 86: 2597-2602

Manganaris G.A., Vasilakakis M., Mignani I., Diamantidis G., Tzavella-Klonari K. (2005). The effect of preharvest calcium sprays on quality attributes, physicochemical aspects of cell wall components and susceptibility to brown rot of peach fruits (*Prunus persica* L. cv. Andross). Sci Hortic 107: 43-50

Montanaro G., Dichio B., Xiloyannis C., Lang A. (2012). Fruit transpiration in kiwifruit: environmental drivers and predictive model. AoB Plant doi:10.1093/aobpla/pls036

Montanaro G., Dichio B., Xiloyannis C. (2010). Significance of fruit transpiration on calcium nutrition in developing apricot fruit. J Plant Nutr Soil Sci 173: 618-622

Montanaro G., Dichio B., Xiloyannis C., Celano G. (2006). Light influences transpiration and calcium accumulation in fruit of kiwifruit plants (*Actinidia deliciosa* var. *deliciosa*). Plant Sci 170: 520-527

Montanaro G., Dichio B., Xiloyannis C. (2012). Fruit transpiration: mechanisms and significance for fruit nutrition and growth. In: Advances in selected plant physiology aspects. (G Montanaro, ed), InTech.

Morandi B., Manfrini L., Losciale P., Zibordi M., Grappadelli L.C. (2010). Changes in vascular and transpiration flows affect the seasonal and daily growth of kiwifruit (*Actinidia deliciosa*) berry. Ann Bot 105: 913-923

Moscatello S., Famiani F., Proietti S., Farinelli D., Battistelli A. (2011). Sucrose synthase dominates carbohydrate metabolism and relative growth rate in growing kiwifruit (*Actinidia deliciosa*, cv Hayward). Sci Hortic 128: 197-205

Richardson A.C., Marsh K.B., Boldingh H.L., Pichering A.H., Bulley S.M., Frearson N.J., Ferguson A.R., Thornber S.E., Bolitho K.M., MacRae E.A. (2004). High growing temperatures reduce fruit carbohydrate and vitamin C in kiwifruit. Plant Cell Environ 27: 423-435

Serrano M., Martinez-Romero D., Castillo S., Guillen F., Valero D. (2004). Effect of preharvest sprays containing calcium, magnesium and titanium on the quality of peaches and nectarines at harvest and during postharvest storage. J Sci Food Agric 84: 1270-1276

Sharma B.D. (2000). Integrated nutrient management in arid horticultural crops. In: compendium of short course at NRCAH. Bikaner, 122-130

Shiri M.A., Bakhshi D., Ghasemnezhad M., Dadi M., Papachatzis A., Kalorizou H. (2013a). Chitosan coating improves the shelf life and postharvest quality of table grape (*Vitis vinifera*) cultivar "Shahroudi". Turk J Agric Forest 37: 148-156

Shiri M.A., Ghasemnezhad M., Bakhshi D., Sarikhani H. (2013b). Effect of postharvest putrescine application and chitosan coating on maintaining quality of table grape cv. "Shahroudi" during long-term storage. J. Food Process Prese 37(5): 999-1007

Shukla A.K. (2011). Effect of foliar application of calcium and boron on growth, productivity and quality of Indian gooseberry (*Emblica officinalis*). Indian J Agric Sci 81(7): 628-632

Singh R., Sharma R.R., Tyagi S.K. (2007). Pre-harvest foliar application of calcium and boron influences physiological disorders, fruit yield and quality of strawberry (*Fragaria × ananassa* Duch.). Sci Hortic 112(2): 215-220

Tavarini S., Degl'Innocenti E., Remorini D., Massai R., Guidi L. (2009). Polygalacturonase and β-galactosidase activities in Hayward kiwifruit as affected by light exposure, maturity stage and storage time. Sci Hortic 120: 342-347

Tsantili E., Rouskas D., Christopoulos M.V., Stanidis V., Akrivos J., Papanikolaou D. (2007). Effects of two pre-harvest calcium treatments on physiological and quality parameters in 'Vogue' cherries during storage. J Horti Sci Biotechnol 82(4): 657-663

Virk S.S., Cleland R.E. (1988). Calcium and the mechanical properties of soybean hypocotyl cell walls: possible role of calcium and protons in cell-wall loosening. Planta 176(1): 60-67

Xie M., Jiang G.H., Kawada K. (2003). Effect of preharvest Ca-chelate treatment on the storage quality of kiwifruit. Act Hortic 610: 317-324

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