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Effects of calcium products applications on quality and shelf life of four peach varieties

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Preharvest foliar calcium (Ca) products sprays (@ 1%) supplied as Ca oxide, Ca chloride, or Ca thiosulfate were applied on four peach cvs. to determine the effect of Ca formulations on fruit quality and shelf life. Treatments were designed to cover the entire period of fruit growth from fruit set to maturity, thus each calcium formulation was applied three to four times at 6 to 15-days interval depending on fruit growth rate. Multiple harvest times were realized with the progress of fruit commercial maturity, fruit samples of the first and last harvest of each cv. were either analyzed or stored for shelf life evaluation. Treatments with Ca products resulted in a significant increase in fruit firmness, for both harvests of all peach cvs., maximum increase was obtained by Ca chloride applications in three cvs., while fruit acidity was slightly increased in three varieties. Applications of Ca also reduced the number of fruit with split pit. Postharvest fruit weight loss was decreased by Ca treatments after 8 days storage; maximum storage period occurred with Ca chloride treatment, followed by Ca oxide treatment at the second position. Decay incidence was consistently reduced by Ca application for all peach cvs, mostly for the first harvest, relatively to the second one; the lowest rate of decay was recorded for Ca chloride treatment.

Keys words: *Prunus persica*, firmness, storage, decay incidence

INTRODUCTION

The effectiveness of pre and post-harvest calcium salts on shelf - life and quality of peach fruits were studied by many authors. It was shown that calcium salts applied over 2-years period either as Ca chloride or Ca propionate four to five times over the growing season, increased firmness at harvest and after cold storage, especially when Ca chloride was the active ingredient used (Val and Fernandez, 2011). Evaluation of the development of physiological disorders after cold storage (2 weeks at 0 °C) indicated a lower susceptibility of Ca-treated fruits to internal browning and chilling injuries as compared to untreated peaches (Val and Fernandez, 2011). The application of calcium chloride @ 1.5% at pit hardening stage, 10 and 20 days after pit hardening, resulted in minimum physiological loss in weight, total sugars and maximum fruit firmness, sensory quality score, pulp: stone ratio, total phenolics and calcium content during storage period of 30 days at temperature 0-10 and RH 85-90% (Raja et al., 2015). In another study, the application of 6 or 10 preharvest calcium spray on cv. Andross peach resulted in a significant increase in the peel (25–42%) and in the flesh (11– 17%), 1 d after harvest. The increase of cell wall calcium corresponded to increase of calcium in the insoluble pectin fraction, whereas no differences were detected in the calcium of water-soluble pectin fraction. Calcium sprays resulted in significant decrease of brown rot development, although no effect on disease incidence was recorded (Manganaris et al., 2005). Other different results were obtained on mid- or late season peach and cultivars since foliar calcium sprays applied every 14 days, starting two weeks after bloom and continuing until one

week before harvest, did not affect fruit soluble solids concentration, fruit firmness, fruit internal breakdown, and fruit calcium concentration at harvest eventhough calcium concentration was raised in three of four varieties studied (Crisosto et al., 2000). Foliar application of calcium salts on ‘Florida King’ peach cultivar for two consecutive years resulted in an increase in fruit weight, fruit diameter, pulp: stone ratio and yield, and also higher fruit firmness, acidity and ascorbic acid contents than control (Ifran et al., 2014).

The objectives of this study were to determine the effect of different calcium formulations on quality and shelf life of peach varieties, and its relationship to the timing of fruit harvesting.

MATERIALS AND METHODS

The trials were conducted in a mature commercial orchard located ‘in land’ in Sefrou area (33°53’43.44’’N, 4°40’38.14’’O), over 2018-2019 season. The climate in this location is Mediterranean type, hot and dry in summer, cold and rainy in winter. The soil type is clay with 13 to 15% CaCO3, leading sometimes to micronutrients problems.

The plant material used in this study is composed of Prunus persica L. cv. ‘Red Robin’, ‘Coraline’, and ‘Rome Star’ grafted on GF677 rootstock, planted in 2003 with trees spaced 3.0 m apart in 5.0 m rows and trained to open an open-centre bush with 4 main branches; and cv. ‘Alexandra’ on GF677 rootstock planted in 2005 with trees spaced 1.5 m apart in 5 m rows and trained to ‘Y’ system. Trees were drip irrigated by auto-regulated drippers (4.2 L/h), 4 drippers per tree for the cv. ‘Caroline’ and 8 drippers per tree for the others.

Treatments consisted of pre-harvest spray of calcium formulations (1%) supplied as calcium oxide (CaO), calcium chloride (CaCl2), or calcium thiosulfate (CaO3S2) while control treatment received only water application. These treatments applied with a dorsal sprayer at the rate of 2 L/tree, were replicated four times in a randomized complete block design. Each treatment was applied early in the morning to three trees per plot separated by a one-tree buffer. Treatments were designed to cover the entire period of fruit growth from fruiset to maturity, thus each calcium formulation was applied three to four times at 6 to 15-days interval depending on fruit growth rate, 4 applications for ‘Alexandra’, and ‘Rome Star’ (May 25, June 10, 20, and 26); and ‘Red Robin’ (April 25, May 10, 21, and 26) and 3 applications for ‘Coraline’ (May 5, 20, and 26).

Multiple harvest times were realized with the progress of fruit commercial maturity, at each harvest, the number and weight of fruits for each plot of each variety were determined. To measure fruit quality characteristics, 10 fruits per replicate were randomly selected at the first and last harvest of each variety. The fruit quality traits measured were: weight, total soluble solids (ATAGO digital refractometer), titratable acidity (TA; g malic acid [L juice]-1, juice pH (data not given), flesh firmness (Digital Penetrometer PCE-PTR Mit PC-Schittstelle, fitted with a 9 mm tip). Post-harvest physiological disorders were visually monitored on sectioned fruits following the longitudinal axis.

To assess the effect of pre-harvest calcium formulations on shelf life of fruit, another randomly selected sample of 28 fruits per treatment (7 fruits/plot) from the first and last harvest of each variety, was held under ambient conditions (Temperature 15-20 °C, 50-70% RH), fruit weight loss and rot incidence (rotted fruits were daily eliminated) were evaluated each four days during the 2 weeks storage period.

Data were statistically analyzed with ANOVA. and significant treatment effects were separated by Student-Newman-Keuls test (5%), using IBM SPSS Statistics 20.0.0 program.

RESULTS

cv. ‘Alexandra’:

The crop weight per tree averaged 27.2 kg, for all treatments and ranged from 24.50 to 30.62 kg (Table 1). There were significant differences in crop weight between treatments due principally to the number of fruits per tree. Fruit weight and soluble solids concentration were not affected while fruit acidity was slightly decreased by calcium treatments. Fruit firmness was significantly affected by Ca treatments for both harvests; maximum increase was obtained for Ca chloride treated fruit, 28% in the first harvest and 25% in the second one, relatively to the respective control.

	Date of harvest	Treatments			
		Control	CO[1]	CC[2]	CTS[3]
Crop weight (kg/tree)	July 2 and 13	24.50 b*	27.31 ab	30.62 a	26.37 ab
Yield (T/ha)	July 2 and 13	29.94	33.37	37.42	32.25
Fruit weight (g)	July 2	183.2	190.1	184.4	184.0
	July 13	191.7	202.0	200.1	194.6
Fruit firmness (g/cm^2)	July 2	4.76 b	5.89 a	6.09 a	5.58 a
	July 13	4.75 c	5.34 b	5.93 a	5.15 bc
SSC (°Brix)	July 2	12.65	13.83	13.44	13.18
	July 13	10.35	11.33	11.18	10.58
Titratable acidity (g/l)	July 2	9.06	12.41	11.51	13.62
	July 13	10.39	13.15	11.83	13.92

[1]CO: Calcium Oxide; [2]CC: Calcium Chloride; [3]CTS: Calcium Thiosulfate
**Means followed by a different letter within a line are significantly different at 5% level using Student-Newman-Keuls test.*

Table 1: Effect of calcium applications on fruit characteristics of 'Alexandra' peach cv.

Taking into account 10% weight loss as limit inducing fruit shriveling, visual symptoms impacting fruit marketability (Crisosto et al., 1994), for the first harvest, weight loss of all fruits remained above the limits of acceptability after 8 days of storage (Figure 1). Thereafter only fruit treated with Ca oxide or Ca chloride were still within the limit of acceptable weight loss after 12 days of storage. All fruits of the last harvest recorded high weight loss exceeding the threshold value after just 4 days of storage.

The incidence of decay was significantly reduced by Ca applications the first 8 days storage, especially for the first harvest with Ca oxide and Ca chloride resulting in no decay (Figure 2). After 12 days storage, decay incidence of treated fruit ranged from 3 to 10% for the first harvest, and from 11 to 14% for the second harvest, relatively to the control to the control 12% and 14%, respectively.

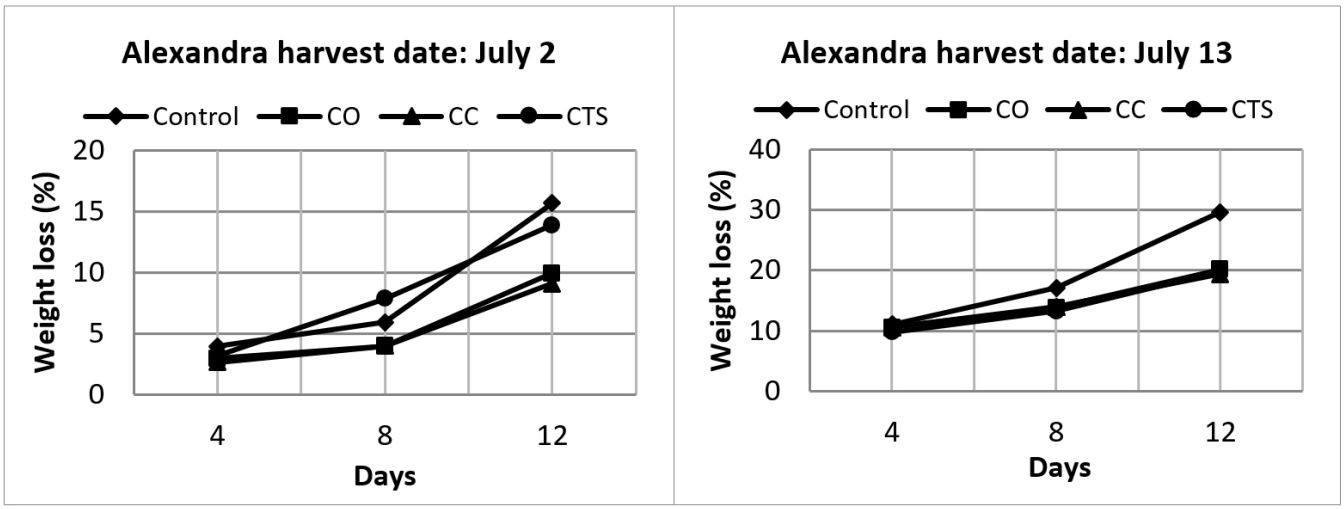

Figure 1: Effect of calcium applications on post-harvest weight loss of 'Alexandra' peach cv.

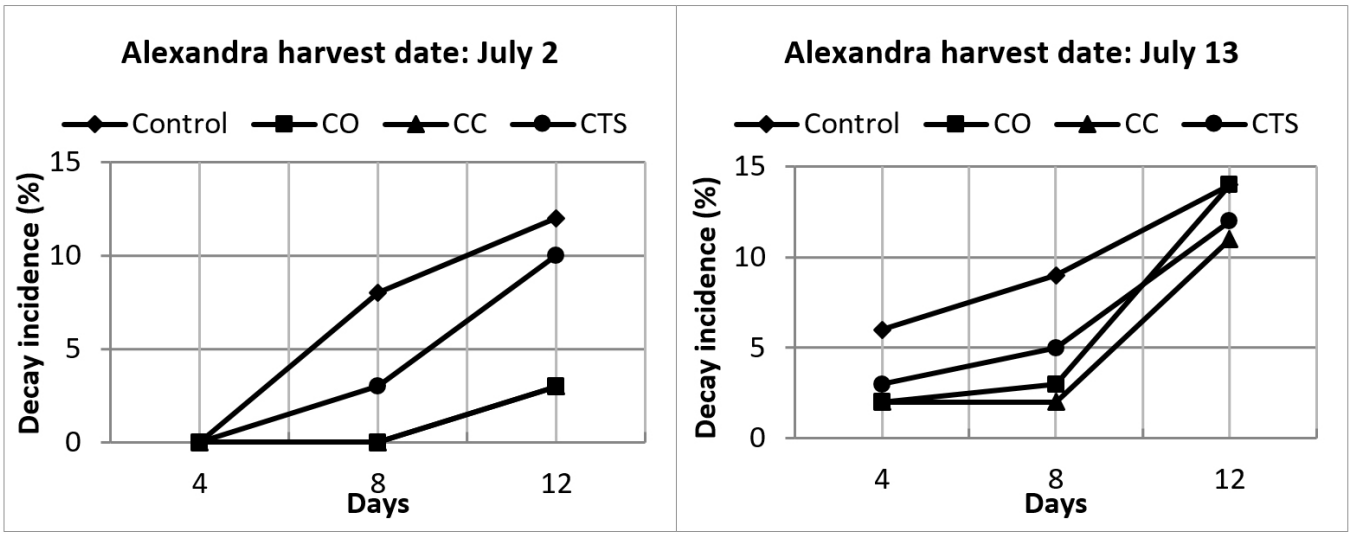

Figure 2: Effect of calcium applications on post-harvest decay incidence of 'Alexandra' peach cv.

There was no significant difference in trees crop weight between treatments, the crop weight averaged 42.84 kg per tree and ranged from 41.64 to 45.27 kg per tree (Table 2). Fruit weight and soluble solids concentration were not significantly affected by Ca treatments while fruit acidity was increased for both harvest dates. Fruit firmness was significantly increased for all Ca treatments; maximum increase was obtained by Ca thio-sulfate treatments, 32% in the first harvest and 26% in the second harvest, compared to their respective controls.

	Date of harvest	Treatments			
		Control	CO[1]	CC[2]	CTS[3]
Crop weight (kg/tree)	May 28 and June 9	41.95	41.64	45.27	42.5
Yield (T/ha)	May 28 and June 9	27.94	27.73	30.15	28.31
Fruit weight (g)	May 28	171.8	183.8	174.8	169.5
	June 9	174.1	186.1	178.6	172.1
Fruit firmness (g/cm^2)	May 28	3.85 b*	4.76 a	4.90 a	5.07 a
	June 9	4.21 b	5.09 a	5.24 a	5.31 a
SSC (°Brix)	May 28	10.32	10.47	11.03	10.87
	June 9	10.84	11.97	11.46	10.02
Titratable acidity (g/l)	May 28	8.32	11.24	9.63	13.22
	June 9	8.54	11.84	10.40	12.88

[1]CO: Calcium Oxide; [2]CC: Calcium Chloride; [3]CTS: Calcium Thiosulfate
**Means followed by a different letter within a line are significantly different at 5% level using Student-Newman-Keuls test.*

Table 2: Effect of calcium applications on fruit characteristics of 'Coraline' peach cv.

Fruit weight loss during 12 days storage ranged from 10.31% to 17.91% for the first harvest, and from 11.64% to 24.26% for the last harvest (Figure 2). According to Crisosto et al. (1994), 10% weight loss limit for peach, occurred within 8.5 days for control fruit, 11 days for Ca oxide, and 9 days for Ca chloride and Ca thiosulfate treatments, in the first harvest. For the last fruit harvest, weight loss limit was achieved after 12 days for Ca oxide treatment, 9 to 10 days for the rest of treatments.

Incidence of decay was reduced by all Ca treatments for both harvests but consistently for the first one (Figure 4). The rate of incidence was relatively low during the first eight days storage, but increased rapidly thereafter to attain 15% and 26% after 12 days storage, for the control of the first and last harvest, respectively. However the Ca treatments incidence results ranged from 7 to 12% for the first harvest and from 18 to 22% for the second harvest. Ca chloride treatment resulted in the lowest decay incidence for both harvests.

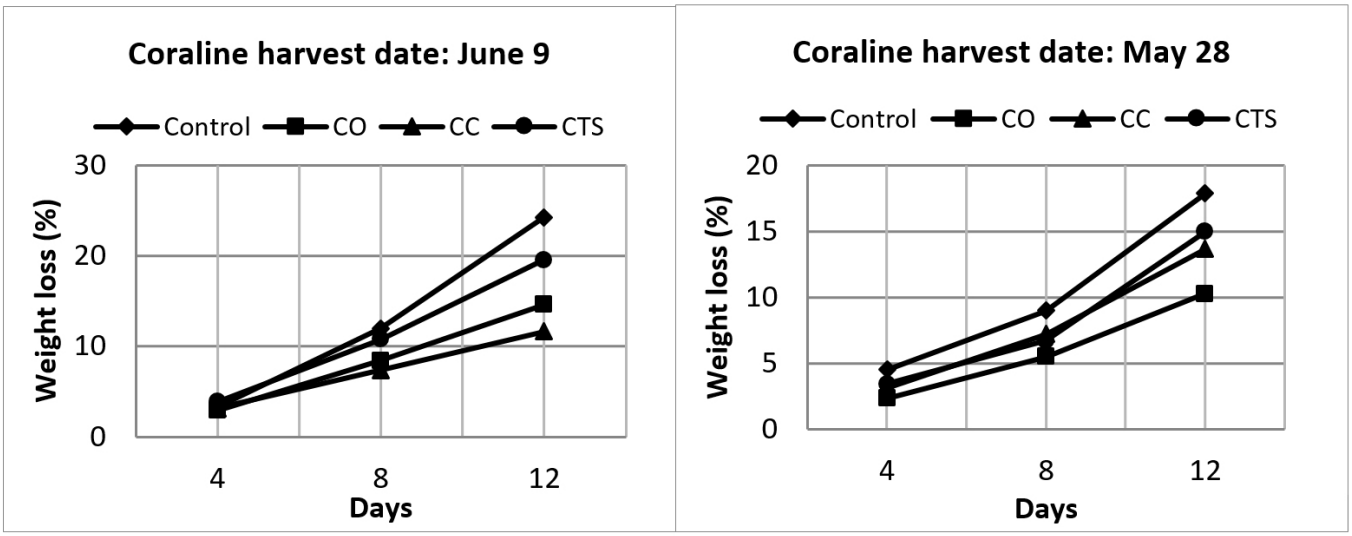

Figure 3: Effect of calcium applications on post-harvest weight loss of 'Coraline' peach cv.

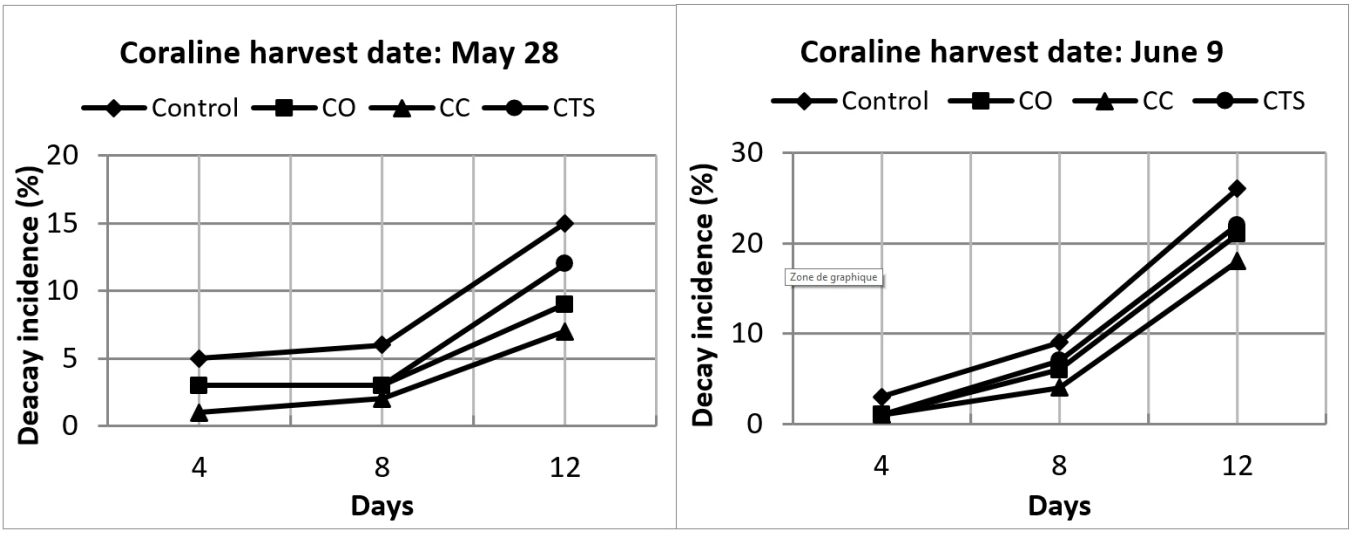

Figure 4: Effect of calcium applications on post-harvest decay incidence of 'Coraline' peach cv.

cv. 'Red Robin'

The average crop weight of the cv. Red Robin was 38 kg/tree; there was no significant difference between treatments (Table 3). Fruit weight was not affected, while fruit soluble solids concentration was significantly increased for all Ca treatments of second harvest, relatively to the control, this is not the case of the first harvest. All Ca treatments resulted in significant increases in fruit firmness and decreases in fruit acidity of both harvests. Maximum increases (22% relatively to respective controls) were obtained by Ca chloride in both harvests and Ca oxide treatment in the second harvest.

	Date of harvest	Treatments			
		Control	CO[1]	CC[2]	CTS[3]
Crop weight (kg/tree)	May 28 and June 8	39.29	36.21	36.66	39.84
Yield (T/ha)	May 28 and June 8	26.17	24.12	24.41	26.53
Fruit weight (g)	May 28	146.0	141.9	143.6	145.9
	June 8	151.7	151.3	152.0	152.2
Fruit firmness (g/cm^2)	May 28	4.66 c*	5.12 b	5.97 a	5.22 b
	June 8	4.67 b	5.72 a	5.71 a	5.37 a
SSC (°Brix)	May 28	10.29	10.23	10.54	10.19
	June 8	9.48 b	10.69 a	10.79 a	11.01 a
Titratable acidity (g/l)	May 28	8.12 a	7.14 b	6.21 c	6.05 c
	June 8	8.50 a	6.31 b	8.16 a	6.26 b

[1]CO: Calcium Oxide; [2]CC: Calcium Chloride; [3]CTS: Calcium Thiosulfate
**Means followed by a different letter within a line are significantly different at 5% level using Student-Newman-Keuls test.*

Table 3: Effect of calcium applications on fruit characteristics of 'Red Robin' peach cv.

The highest trend of weight loss was recorded for control fruit relatively to treated fruits. The later fruits had the same lower trend of weight loss up to 8 days storage, followed by different weight loss thereafter (Figure 3). The fruit treated with Ca chloride had the lowest weight loss throughout the storage period and reached the threshold value after 12 days storage. For the second harvest, taking into account 10% weight loss as limit inducing fruit shriveling, visual symptoms impacting fruit marketability, only fruit treated with Ca chloride was still within the limits of acceptability after 8 days storage.

The application of Ca treatments reduced the incidences of decay, significantly the first harvest and slightly the second one (Figure 6). After 12 days storage, all Ca treated fruit recorded 2% decay and the control 12% for the first harvest, while in the second harvest Ca treated fruit decay recorded 15 to 16% and the control 23%.

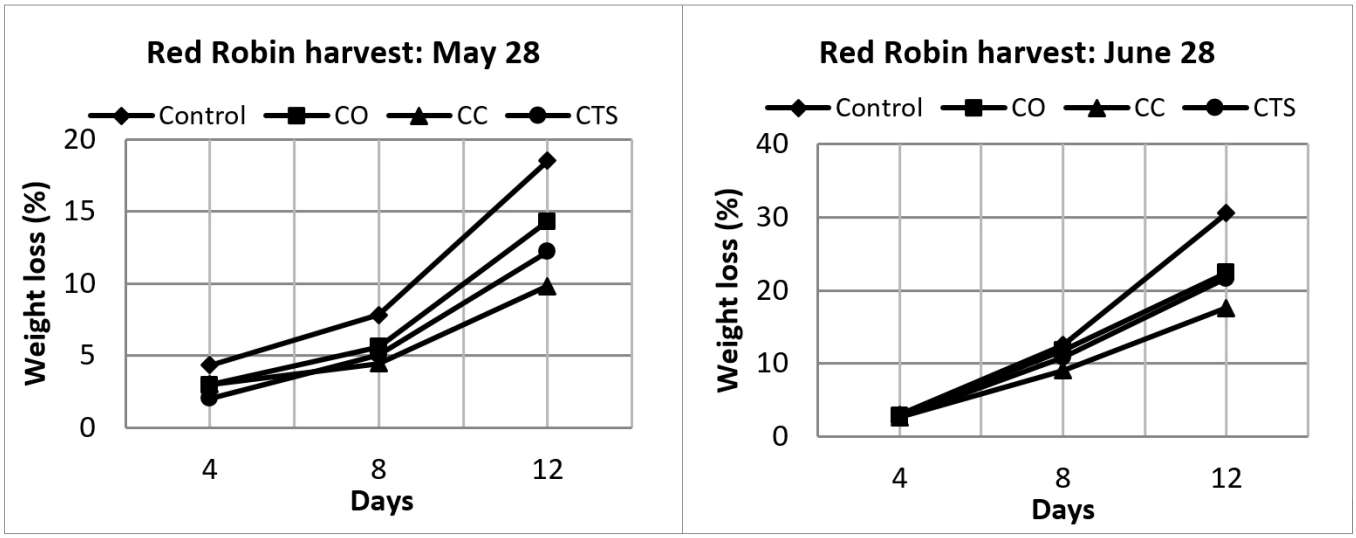

Figure 5: Effect of calcium applications on post-harvest weight loss of 'Red Robin' peach cv.

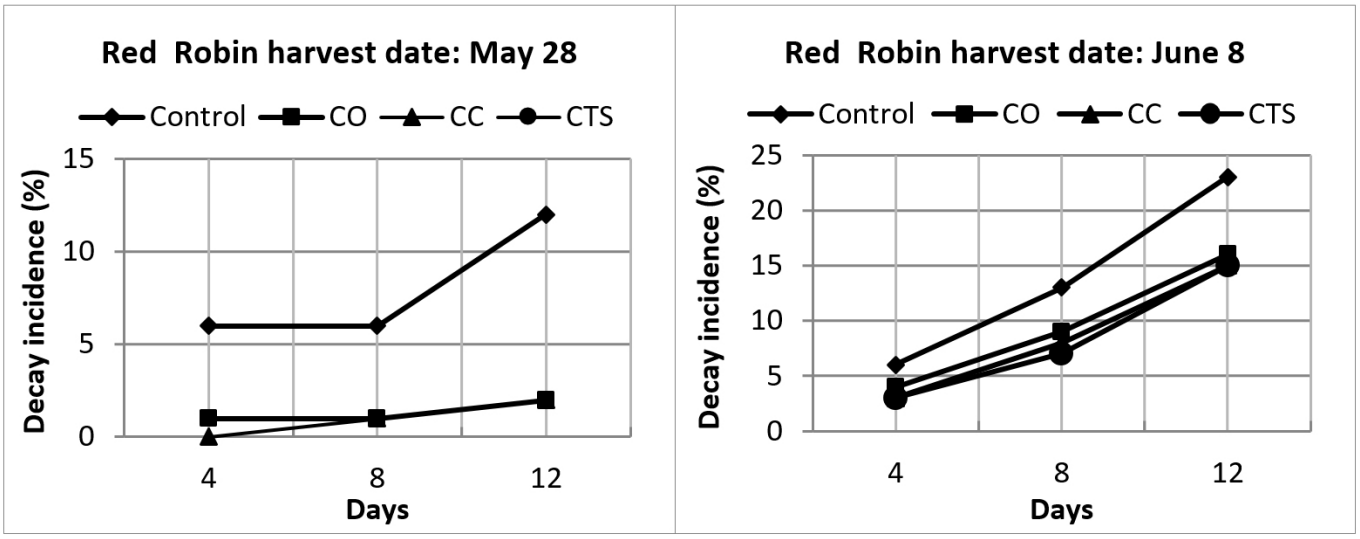

Figure 6: Effect of calcium applications on post-harvest decay incidence of 'Red Robin' peach cv.

cv. 'Rome Star':

The average crop weight par tree corresponded to 53.85 kg and ranged from 49.74 to 55.69 kg (Table 4). There were significant differences in crop weight between control (49.74 kg/tree) and

treated trees (54.92 to 55.69 kg/tree), due mainly to the number of fruits per tree. Fruit quality parameters including berry weight and soluble solids concentration were unaffected by Ca applications at any crop harvest date. Fruit acidity was slightly decreased for both harvests. However, fruit firmness was significantly increased by Ca applications for all harvests. The maximum increase was obtained by Ca chloride applications, 18.4% relatively to the control in the first harvest and 32.4 relatively to the control in the second harvest.

	Date of harvest	Treatments			
		Control	CO[1]	CC[2]	CTS[3]
Crop weight (kg/tree)	July 3 and 17	49.74 b*	55.05 a	54.92 a	55.69 a
Yield (t/ha)	July 3 and 17	33.12	36.63	36.57	37.09
Fruit weight (g)	July 3	207.7	213.1	208.3	207.5
	July 17	196.7	213.9	209.2	201.6
Fruit firmness (g/cm^2)	July 3	5.28 b	6.06 a	6.25 a	5.73 ab
	July 17	4.44 c	5.02 b	5.88 a	5.28 b
SSC (°Brix)	July 3	11.47	11.74	12.08	12.41
	July 17	10.23	11.08	10.95	10.63
Titratable acidity (g/l)	July 3	8.86	11.47	10.44	13.67
	July 17	10.75	14.3	12.38	13.82

[1]CO: Calcium Oxide; [2]CC: Calcium Chloride; [3]CTS: Calcium Thiosulfate
**Means followed by a different letter within a line are significantly different at 5% level using Student-Newman-Keuls test.*

Table 4: Effect of calcium applications on fruit characteristics of 'Rome Star' peach cv.

Weight loss of the first fruit harvest achieved 8 days storage within the limit of acceptance, only for Ca oxide or Ca chloride treated fruits while the other fruits recoded higher weight loss (Figure 7). For the last harvest, all treated fruits exceeded weight loss limit prior to 8 days storage, except Ca chloride treated fruits being acceptable, with regard to weight loss limit.

Incidences of decay were minimal for Ca treated fruit in the first harvest, ranging from 0 to 4% and from 4 to 11% after 8 and 12 days storage, respectively; corresponding to 9 and 15% for the control. For the second harvest there was a slight decrease in decay incidence following Ca applications (Figure 8).

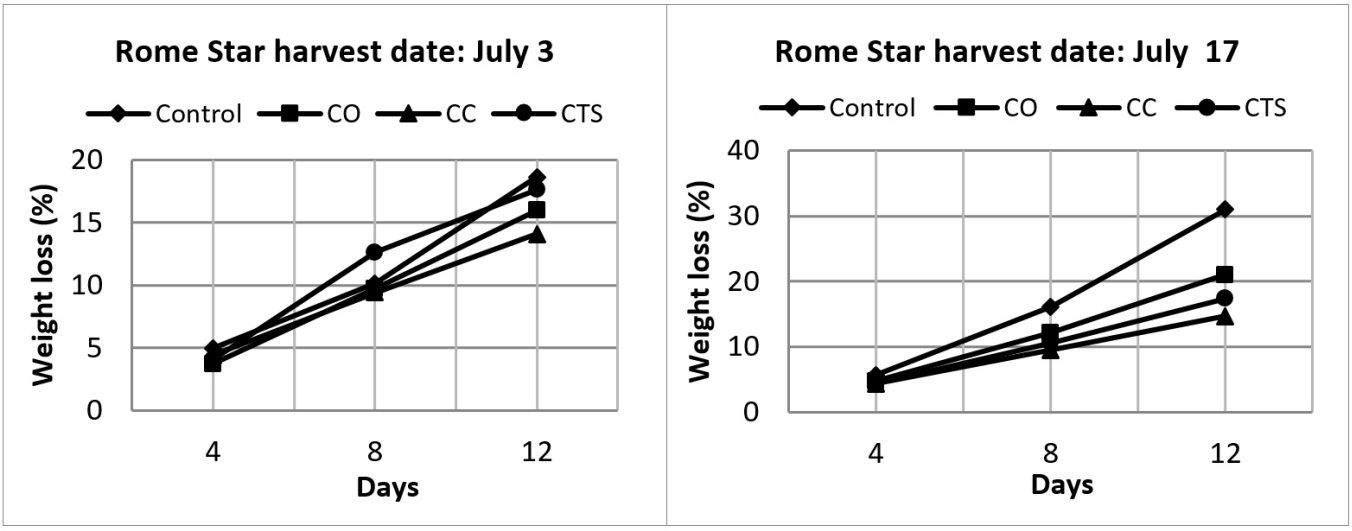

Figure 7: Effect of calcium applications on post-harvest weight loss of 'Rome Star' peach cv.

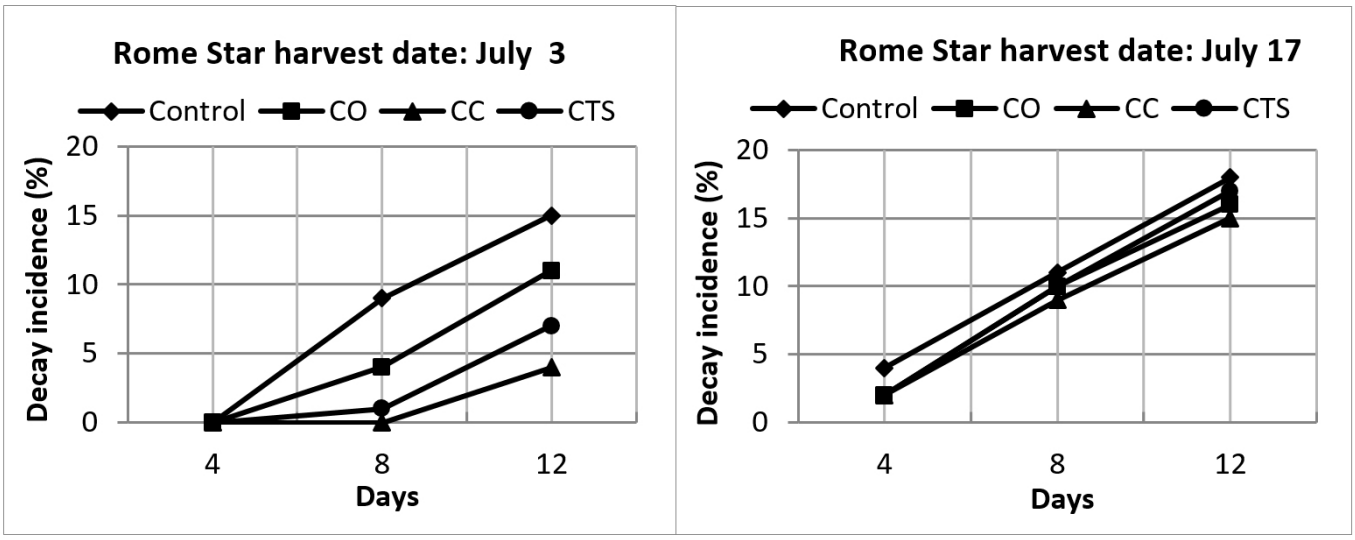

Figure 8: Effect of calcium applications on post-harvest decay incidence of 'Rome Star' peach cv.

DISCUSSION

Multiple applications of calcium across all peach cvs. resulted in a significant increase in fruit firmness, for both harvests, maximum increase was obtained by Ca chloride applications in three cvs. 'Alexandra', 'Red Robin', and 'Rome Star'. It was shown that the application of multiple Ca-containing sprays increased fruit firmness at harvest and after cold storage of peach, especially when Ca chloride was the active ingredient used (Val and Fernandez, 2011). Other studies also reported that Ca chloride sprays improved peach firmness (Lysiak et al., 2008; Raja et al., 2015).

Fruit acidity also was increased in three cvs. 'Alexandra', 'Caroline', and 'Rome Star', while a slight increase was obtained in fruit soluble solids concentration for 'Rome Star' and 'Alexandra' cvs, following Ca applications. In another study, Ca chloride (1%) also resulted in higher fruit firmness, acidity and ascorbic acid (Ifran et al., 2014).

Shelf life measured as the number of days when fruit weight loss is lower than 10% limit, all fruits from different cvs and harvests withstand 4 days storage, except 'Alexandra' fruit harvested in July 13. All Ca treatments decreased the rate of weight loss (except 'Coraline' Ca thiosulfate treated

fruit of the last harvest). The threshold of 8 days storage was reached for almost all cvs first harvest, however in the last harvest only ‘Coraline’ and ‘Rome Star’ fruits maintained acceptable quality. The effect of Ca treatments was also noticeable after 8 days storage; almost all Ca applications decreased the rate of weight loss, except for Ca thiosulfate treated fruit of ‘Alexandra’ and ‘Rome Star’ of the first harvest.

Maximum storage period within acceptable fruit weight loss limit were: for ‘Coraline’, 11 days for Ca oxide and 10 days for Ca chloride treated fruit, respectively for the first and last harvest; for ‘Red Robin’, 12 days for Ca chloride treated fruit of the first harvest; for ‘Alexandra’, 12 days for the first harvest of fruit, for treated either with Ca chloride or Ca oxide, for ‘Rome Star’, only Ca chloride maintained a good quality fruit at the of 8 days storage, while the other treatments were limited to 7 days storage and the control less than 6 days.

Correlation general trend over all cvs harvests demonstrated negative correlations between fruit weight loss and quality traits i.e. fruit weight, firmness, soluble solids concentration, and acidity. In another study, Ca chloride @ 1.5% (three sprays) resulted in minimum peach weight loss, total sugars and maximum fruit firmness (Raja et al., 2015).

The daily rate of weight loss, for ‘Coraline’ fruit, averaged across all storage period ranged from 0.86 to 1.49% and from 0.97 to 2.02% for the first and last harvest, respectively. These values ranged for ‘Red Star’ fruit, from 0.82 to 1.54%, and from 1.47 to 2.55%, for the first and last harvest, respectively. For ‘Alexandra’ fruit, daily weight loss ranged from 0.76 to 1.31% and from 1.62 to 2.47% for the first and last harvest, respectively. Values recorded for ‘Rome Star’ fruit ranged from 1.17 to 1.55% and from 1.22 to 2.58% for the first and last harvest, respectively. The highest daily weight loss was always recorded for control treatments.

Decay incidence was consistently reduced by Ca application for all peach cvs, mostly for the first harvest, relatively to the second one. Decay incidence rate was higher in the late harvested stored fruit, probably due to higher seasonal ambient temperatures during storage. In laboratory work, it was shown that some calcium salts reduced growth of Monilinia fructicola by approximately 65% compared with the control, and inhibited fungal polygalacturonase activity (Biggs et al., 1997).

The lowest rate of decay was recorded for Ca chloride treatment overall Ca treatments of peach cvs. It was found that Ca chloride application on harvested peach fruit cv. Earli Grande’ effectively reduced fruit (Grupta et al., 2011).

Applications of Ca also reduced the number of fruit with split pit (data not given), averaged across all cultivars Ca chloride treatment resulted in the least rate, i.e. 2.97% while the other treatments recorded lower rate, 3.90 and 4.53% for Ca thiosulfate and Ca oxide, respectively compared to control (5.15%).

CONCLUSION

Multiple preharvest applications of Ca compounds on four peach cvs. improved fruit firmness and shelf life by reducing fruit weight loss and decay incidence. The best results were obtained by Ca chloride treatment, followed by Ca oxide treatment.

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