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Response of Washington Navel Orange Trees to Calcium Chloride Foliar Application

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Thirteen-year-old Washington navel orange (*Citrus sinensis* L. Osbeck) trees grown in a private citrus orchard at Wady El-Mullak region, Abo-Hamad district, Sharkia Governorate were sprayed during 2012 and 2013 seasons with calcium chloride ($CaCl_2$) at 0.5, 1.0 and 2.0 % and water as control treatment when the fruits reached pea size (5 mm in diameter). The experimental trees were sprayed 6 times at the first and mid of May, June, October months during both seasons to investigate their influence on fruit drop and fruit retention percentages, as well as yield and fruit quality.

Spraying $CaCl_2$ at 1.0 % gave the maximum fruit retention percentage, number of fruits and yield/ tree, but reduced June and pre-harvest fruit drop percentages. Fruits juice of trees sprayed with $CaCl_2$ at 0.5 and 1.0 % contained the highest TSS and the lowest total acidity percentages and consequently the highest TSS/ acid ratio compared with those sprayed with 2.0 % $CaCl_2$ and water (control). Moreover, calcium chloride spraying at 1.0 % was the optimum treatment for improving fruit quality and enhancing the yield/ tree.

Keywords: Calcium chloride, Navel orange, Fruit drop (%), Fruit retention (%).

Orange trees (*Citrus sinensis* L. Osbeck) are considered one of the most popular and common fruits worldwide. In Egypt, total area reached 149584.32 ha (about 68.62 % of total citrus acreage). The productive area is 118778.99 ha that produce 2,786,397 tons with average of 9.86 ton/fed. Ministry of Agriculture Statistics (2012). Washington navel orange is one of the most important orange varieties grown in Egypt, as well as the export market. The acreage reached 74711.67 ha representing 49.96 % of orange acreage out of them 61843.28 ha is fruitful, producing about 1,398,426 tons with average of 9.50 tons/ fed. It confronts two serious problems, i.e. poor fruit set and heavy fruit drop which lead to reduce tree yield, especially in the newly reclaimed soils.

Calcium is a nutritional element that differs from others by being imported into fleshy fruit only in small amounts, much less than into leaves. Calcium uptake and distribution in plant is influenced by internal water movement and relative rate of Ca seems to be used along the transport pathway (Saure, 2005). Although Ca is sufficiently available in the soil, localized Ca deficiency may become a problem in several fruit crops, with the risk of large economic losses. Some authors postulated a competition for Ca between low-transpiring fruit and vigorously growing, highly transpiring leafy shoots (Montanaro *et al*., 2006). Exogenous applications of calcium markedly increase the calcium content in the flesh and affect some of the changes associated with ripening and senescence (Pooviah, 1979).

Calcium promotes early root formation and growth, improves general plant vigor, stiffness of stalks and improves fruit integrity. Calcium influences the uptake of other nutrients such as phosphorous, manganese, iron, zinc and boron (Polevoiy, 1989). Calcium is conceder one of the most important element for fruit crops in arid and semi-arid regions, since it is required for cell elongation and cell division (Rizzi and Abruzzese, 1990). Minor elements affect greatly the physiological processes and play an important role in fruit retention of many fruit trees, as well as, improve the yield and fruit quality (Singh & Sant Ram, 1983, Babu *et al*., 1984 and Khan *et al*., 1993). In addition, calcium functions appeared as a cross-linkage of the middle lamella, which binds cells together.

Calcium plays an important role in forming cross-bridges which influence cell wall strength (Fry, 2004). Exogenous applied calcium, therefore stabilizes and protect the plant cell wall from degrading enzymes which have major influences on firmness (White and Broadly, 2003).

Several studies have recorded the important role of pre and postharvest applications of calcium in improving fruit quality parameters in many fruit species (Rizk-Alla *et al*., 2006, Raeses & Drake, 2000 and Satour, 2010).

The aim of this study is to evaluate the effect of foliar calcium spraying on reducing June and pre-harvest fruit drop, as well as improving yield and fruit quality of Washington navel orange trees.

Materials and Methods

Uniform and disease free Washington navel orange trees of 13 years old budded on sour orange rootstock (*Citrus aurantium* L. Osbeck*)* and grown in a private citrus orchard in Wady El-Mullak region, Abo-Hamad district, Sharkia Governorate (Latitude, 30° 36' N, longitude, 32° 14' E, Altitude, 10 m above sea level) were selected for this investigation during the two successive seasons of 2012 and 2013. The trees were planted at 5 m apart, in sandy soil under drip irrigation system. All trees were supplied with standard doses of fertilizers and plant protection measures as recommended by the Egyptian Ministry of Agriculture. The experimental trees were foliar sprayed with calcium chloride ($CaCl_2$) at 0.5, 1.0 and 2.0 %, beside control trees which were water sprayed. Trees were sprayed with $CaCl_2$ 6 times during the different stages of fruit development beginning with pea size (5 mm in diameter) at the first and mid of May, June and October months during both seasons. The experimental trees were sprayed using a back pressure sprayer with 5 litters/ tree at the selected concentrations of calcium chloride solution. Tween-20 (2 ml/ l) as nonionic tensioactive was added to all solutions to improve absorption of $CaCl_2$.

In order to study the effect of the different treatments on tree growth, four branches were tagged from the different sides of each tree in late April for pea stage. The number of fruits on the previously tagged branches was counted and recorded at spraying date and after June drop. The fruit retention percentage at harvest (final fruit retention) was calculated during both seasons. Similarly, June drop and pre-harvest drop were also calculated.

The yield expressed as weight (kg/tree) and number of fruits per tree was recorded at harvest date in December of 2012 and 2013 seasons.

A sample of ten fruits per tree (replicate) were randomly taken at harvest to determine both fruit physical [fruit weight (g) and size (cm^3), fruit length, diameter, pulp and peel weights and peel thickness (cm) using a hand caliper and juice volume (cm^3)/ fruit] and chemical characteristics [total soluble solids (TSS) by a hand refractometer, titratable acidity percentage (TA) according to A.O.A.C. (1995) and TSS/TA ratio. Vitamin C as milligrams ascorbic acid/100 ml juice was also determined by titration against 2, 6-dichlorophenol endophenol dye (A.O.A.C., 1995).

The experimental design was a randomized complete blocks design (RCBD) with three replicates (one tree/ replicate) for each treatment. The SAS computer program (1996) was used to obtained ANOVA and LSD at 0.05 to compare the means.

Results and Discussion

Fruit drop percentage

Data in Table 1 indicated that June drop percentage was significantly decreased by spraying calcium chloride in both seasons. The trees sprayed with 1 % calcium chloride showed the least June drop percentage (65.44 & 64.67 %) on Washington navel orange trees in the first and second seasons, respectively followed by those 0.5 % sprayed without significant differences between them in both seasons. The maximum June drop percentage was recorded for control trees (82.35 & 83.14 %) and those sprayed by 2 % $CaCl_2$ (73.65 & 75.19 %) in the two seasons, respectively, without significant differences, especially in the second season.

Pre-harvest fruit drop percentage was markedly decreased by spraying calcium chloride in the two seasons, but significance was clear in the second season only. The lowest percentage was recorded for trees sprayed with 1 % $CaCl_2$ (20.59 %), followed by those sprayed with 0.5 % $CaCl_2$ (27.87 %) and 1 % $CaCl_2$ (34.57 %) without significant difference. Unsprayed trees gained the highest Pre-harvest fruit drop percentage (39.19 %). A tentative explanation for the increased fruit removal force, due to calcium sprays may be due to improving the formation of cellulose and lignin. These materials are required for building plant structure or preventing the abscission layer formation and consequently the reduction in pre-harvest fruit drop (Nijjar, 1985).

Similar results were found by Samaan *et al*. (2001) on Washington navel and Succari orange who declared significant decrement on pre-harvest dropping % due to $CaCl_2$ treatments in both cvs. El-Kobbia *et al*. (2011) reported that foliar sprays of different calcium compounds at pea or marble stage of Washington navel oranges significantly decreased June fruit drop. Pre-harvest fruit drop was decreased (63 to 100%) compared to the control.

TABLE 1. Effect of some calcium chloride spray treatments on floral and fruiting characteristics of Washington navel orange trees (2012 and 2013 seasons).

Treatments $CaCl_2$ (%)	June drop (%)	Pre-harvest fruit drop (%)	Fruit retention (%) at harvest	Number of harvested fruits/ tree	Yield/ tree (kg)	
					value	± % *
	First season (2012)					
0.0 % Control	82.35a	33.62a	11.69c	270.33d	55.54d	-
0.5 %	70.30bc	23.86a	22.58ab	371.33b	81.26b	146.31
1.0 %	65.44c	21.60a	26.92a	417.67a	95.91a	172.69
2.0 %	73.65b	27.74a	19.04b	312.00c	70.71c	127.31
LSD at 0.05	4.97	ns	4.46	36.11	9.97	-
Second season (2013)						
0.0 % Control	83.14a	39.19a	10.14d	283.00d	59.13d	-
0.5 %	69.32b	27.87ab	22.09b	386.00b	86.83b	146.85
1.0 %	64.67b	20.59b	28.02a	446.00a	100.40a	169.80
2.0 %	75.19a	34.57ab	16.25c	338.67c	74.37c	125.77
LSD at 0.05	5.60	16.00	5.03	46.78	12.44	-

* ± % in yield/ tree in relation to control
Values followed by the same letter (s) in a column are not significantly different at p = 0.05.

Fruit retention percentage

Data presented in Table 1 showed that spraying calcium chloride significantly increased the percentage of fruit retention as compared with the control in both seasons. The increase ranged between 162.87 – 230.28% in the first season and 160.26 – 276.33% in the second one for the above mentioned treatments over the control. The trees sprayed with 1 % calcium chloride showed the highest fruit retention percentage (26.92 and 28.02 %) in the first and second seasons, respectively, followed by those sprayed with 0.5 % $CaCl_2$ (22.58 and 22.09 %) without significant differences especially in the first season. Trees sprayed with 2 % $CaCl_2$ came in the third rank (19.04 and 16.25 %) in the two seasons, respectively. The lowest fruit retention percentages (11.69 and 10.14 %) were recorded for water sprayed trees (control) in the two seasons, respectively.

The obtained results go in line with the findings of El-Kobbia *et al.* (2011) on Washington navel orange who cleared that foliar sprays of different calcium compounds at pea or marble stage significantly increased fruit retention. Final fruit retention was increased by 23 – 69 % over the control. Also, Singh & Sant Ram (1983), Babu *et al.* (1984), Khan *et al.* (1993), Abd El-Mageed & Abd El-Fattah (2007), Fawzia *et al.* (2008) and Abd El-Messeih *et al.* (2010) stated that fruit retention percentages on trees of many fruit species had been improved under similar applications with calcium.

Fruit yield/ tree

Foliar application of calcium chloride significantly affected tree yield either as number of the harvested fruits and/or kilogram/ tree in the two seasons (Table 1). Trees sprayed with water (control) produced the least number of fruits/ tree (270.33 & 283.00 fruits/ tree) and the lowest yield/ tree (55.54 & 59.13 kg/ tree) in the two seasons, respectively. The larger number of fruits/ tree (417.67 & 446.00) and the highest yield/ tree (95.91 and 100.40 kg/ tree) were recorded for trees sprayed with 1 % $CaCl_2$, followed by those sprayed with 0.5 % $CaCl_2$ (371.33 & 386.00 fruit/ tree and 81.26 & 86.83 kg/ tree) 2 % $CaCl_2$ (312.00 & 338.67 fruit/ tree and 70.71 & 74.37 kg/ tree) in the first and second seasons, respectively. The yield of trees sprayed with calcium chloride at 1, 0.5 and 2 % was 172.69, 146.31 and 127.31 % higher than those sprayed with water in the first season, respectively. The corresponding increment percentages in the second season were (169.80, 146.85 and 125.77 %), respectively. Trees sprayed with 1 and 0.5 % $CaCl_2$ produced higher yields (135.64 & 114.92 %) and (125.00 & 116.75 %) than those 2 % $CaCl_2$ sprayed in the two seasons, respectively. At the same manner, the data clarified significantly higher yield for 1 % $CaCl_2$ sprayed trees (118.03 and 115.63 %) compared to those sprayed with 0.5 % $CaCl_2$ in the two seasons, respectively.

The obtained results are in harmony with those reported by Samaan *et al.*, (2001) on Washington navel and Succari oranges. Abd-Allah (2006) stated that foliar application of boric acid and calcium chelate produced the highest number of Washington navel orange fruits. Yield of Thompson Seedless grape was improved by $CaCl_2$ spraying (Marzouk and Kassem, 2011). On the contrary, Sharma *et al.*, (2002) on Kagzi Kalan lemon found that $CaCl_2$ at 0.75 or 1.0 % at half grown stage of fruit development reduced fruit weight and yield to undesirable level. Goran *et al.*, (2013) showed that foliar application of $CaCl_2$ insignificantly affected the yield of Thomson navel orange and Unshiu tangerine trees.

Fruit physical characteristics

As shown in Table 2, fruit weight, size and pulp weight of Washington navel orange fruits were significantly affected by spraying calcium chloride in the two seasons. Trees sprayed with 1 % $CaCl_2$ showed the highest values, followed by those sprayed by 2 % in the first season without significant differences. In the second season, trees sprayed with $CaCl_2$ at 0.5, 1 and 2 % gained the highest fruit weight, size and pulp weight without significant differences. Untreated (control) trees recorded the lowest values of the previous parameters.

Foliar application of $CaCl_2$ significantly affected the peel weight in the second season only and the peel thickness in both seasons. Foliar applications of 0.5, 1 % and 2 % $CaCl_2$ produced the highest peel weight and thickness compared to those of control trees in the two seasons without significant differences between $CaCl_2$ sprayed treatments.

Juice volume of Washington navel orange fruit was significantly affected by spraying calcium chloride in the two seasons (Table 2). However, trees sprayed with 1 % $CaCl_2$ exhibited the highest juice volume/ fruit (128.58 and 119.07 cm^3 juice/ fruit) in the first and second seasons, respectively without significant differences between it and those sprayed with 2 % $CaCl_2$ in the two seasons and 0.5 % $CaCl_2$ in the second season only. Water foliar application (control) revealed the lowest juice volume/ fruit (102.71 and 108.51 cm^3 juice/ fruit) in the first and second seasons, respectively. Fruit juice percentage similarly followed the same trend, especially in the first season.

TABLE 2. Effect of some calcium chloride spray treatments on physical properties of Washington navel orange fruits (2012 and 2013 seasons).

Treatments ($CaCl_2$ %)	Fruit weight (g)	Fruit size (cm^3)	Pulp weight (g)	Peel weight (g)	Peel thickness (mm)	Juice/ fruit volume (cm^3)	Juice/ fruit %	Fruit length (cm)	Fruit diameter (cm)
	First season (2012)								
0.0 % Control	205.50c	222.00c	142.80c	60.40a	3.80b	102.71c	49.98b	7.94a	7.46a
0.5 %	218.93b	231.91b	153.27b	63.80a	4.34ab	114.09b	52.18ab	8.04a	7.47a
1.0 %	229.53a	248.29a	165.33a	62.60a	4.49a	128.58a	56.01a	8.08a	7.49a
2.0 %	226.73ab	239.92ab	161.67ab	63.13a	4.54a	123.40ab	54.44a	8.19a	7.55a
LSD at 0.05	8.03	9.41	8.43	ns	0.65	10.91	4.06	ns	ns
Second season (2013)									
0.0 % Control	208.96b	220.30b	149.80b	58.07b	3.67b	108.51b	51.93a	7.85a	7.47ab
0.5 %	225.00a	244.86a	158.60a	64.80a	4.28a	117.55a	52.26a	8.10a	7.42b
1.0 %	224.80a	239.21a	160.33a	63.60a	4.31a	119.07a	52.99a	8.16a	7.64a
2.0 %	219.70a	228.48ab	154.33ab	63.63a	4.43a	118.96a	54.15a	8.24a	7.68a
LSD at 0.05	7.26	18.90	8.08	4.63	0.58	2.99	ns	ns	0.21

Values followed by the same letter (s) in a column are not significantly different at p = 0.05 .

It is clear from data in Table 2 that, fruit dimensions were not significantly affected by foliar application of calcium chloride in the two seasons, except fruit diameter which was significantly affected in the second season only. However, trees sprayed with 2 and 1 % $CaCl_2$ and those of control significantly exhibited similar values of fruit diameter (7.68, 7.64 and 7.47 mm), whereas spraying trees by 0.5 % $CaCl_2$ induced lower fruit diameter (7.42 mm) without significant difference between it and unsprayed trees.

These findings are entirely in agreement with those reported by Samaan *et al*. (2001) on Washington navel and Succari oranges and Goran *et al*. (2013) on Thomson navel orange and Unshiu tangerine. They reported that the highest fruit size, juice volume and peel thickness were found on trees sprayed with calcium chloride. Sharma *et al*. (2002) working on Kagzi Kalan lemon found that spraying $CaCl_2$ at 0.5 % produced rough and thick skinned fruits. Ramezanian *et al*. (2009) fond that calcium chloride at concentrations of 2 and 4 % significantly increased average fruit weight of pomegranate fruits. Cluster and berry quality characters of Thompson Seedless grape were improved by $CaCl_2$ spraying (Marzouk and Kassem, 2011).

Fruit chemical characteristics

Data illustrated in Table 3 indicated that the TSS, total acidity percentages as well as TSS/ acid ratio in fruit juice of Washington navel orange trees were significantly affected by spraying calcium chloride in the two seasons. In the first season, unsprayed (control) trees revealed the maximum TSS percentage (16.10 %), followed by those sprayed with 1 and 0.5 % $CaCl_2$ (15.00 and 14.97 %) without significant difference between the last two $CaCl_2$ levels. The lowest percentage (14.04 %) was recorded for trees sprayed with 2 % $CaCl_2$. In the second season, the trees sprayed with 1 and 0.5 % $CaCl_2$ gained the highest TSS percentages (19.93 and 15.67 %), while, those unsprayed trees and sprayed with 2 % $CaCl_2$ exhibited the lowermost percentages (14.50 and 14.67 %), respectively, without significant differences between each two treatments. Total acidity percentages followed exactly an opposite trend for TSS percentages in the two seasons. Regarding the TSS/ acid ratio values take similar trend for TSS percentage where the highest TSS/ acid ratios (21.58) in the first and in the second (21.56 & 20.53) seasons were recorded for trees sprayed with water and those sprayed with $CaCl_2$ at 1 % and 0.5 %, respectively, while the lowest percentages (14.98 and 15.28) were recorded for trees foliar sprayed with 2 % $CaCl_2$ in the two seasons, respectively.

TABLE 3. Effect of some calcium chloride spray treatments on some chemical constituents of Washington navel orange juice (2012 and 2013 seasons).

Treatments $CaCl_2$ (%)	**TSS (%)**	**Total acidity (%)**	**TSS/ acid ratio**	**Vitamin C content (mg/ 100 ml juice)**
	First season (2012)			
0.0 % Control	16.10a	0.75b	21.58a	58.67b
0.5 %	14.97b	0.81ab	18.55ab	68.48a
1.0 %	15.00b	0.81ab	18.71ab	70.01a
2.0 %	14.07c	0.94a	14.98b	61.01b
LSD at 0.05	0.84	0.15	3.97	3.52
	Second season (2013)			
0.0 % Control	14.50b	0.92a	15.92b	56.49c
0.5 %	15.67a	0.76b	20.53a	67.93a
1.0 %	15.93a	0.74b	21.56a	69.85a
2.0 %	14.67b	0.96a	15.28b	61.17b
LSD at 0.05	0.74	0.09	2.44	4.55

Values followed by the same letter (s) in a column are not significantly different at p = 0.05 .

Foliar application of $CaCl_2$ significantly affected the ascorbic acid contents in the fruit juice of Washington navel orange trees in both seasons (Table 3). Fruit harvested from $CaCl_2$ sprayed trees at 1 and 0.5 % exhibited the maximum ascorbic acid content (70.01 & 68.48 mg/100 ml juice) and (69.85 & 67.93 mg/100 ml juice) in the two seasons, respectively without significant differences. The lowest ascorbic acid content was recorded for untreated trees (58.67 and 56.49 mg/100 ml juice) and those sprayed with 2 % $CaCl_2$ (61.01 and 61.17 mg/1 ml juice) without significant differences in the first season.

These results are in line with those achieved by Wills *et al*. (1988) who reported that pre-harvest application of calcium ammonium nitrate was of effective influence on soluble solids and acidity of Tommy Atkins mango fruits.

Similar results were found by Singh *et al*. (1998) and Samaan *et al*. (2001) since, they found that the highest TSS percentage, TSS/ acid ratio and vitamin C content along with lower acidity percentage were observed when trees were sprayed with $CaCl_2$. Ramezanian *et al.* (2009) indicated that spraying calcium chloride at 2 and 4% significantly increased ascorbic acid content of pomegranate fruits. On the other hand, Chahal and Bal (2012) and Sandhu *et al*. (1989) on Kinnow mandarin and Goran *et al*. (2013) on Thomson navel orange and Unshiu tangerine reported that spraying $CaCl_2$ led to decrease TSS and ascorbic acid contents in fruit juice. Mukherjee and Datta (1967) indicated that the lower TSS level in the calcium treated fruits may be due to low respiration rate which could have slowed down the conversion of starch and other polysaccharides in sugars. The higher acid content of the Kinnow fruits with calcium application may be attributed to its role in lowering membrane permeability and hence reduced respiration rate (Godara *et al*., 2002).

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استجابة أشجار البرتقال بسرة واشنطن للرش الورقي بكلوريد الكالسيوم

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تم رش أشجار البرتقال بسرة واشنطن عمر ١٣ سنة المنزرعة بأحد حدائق الموالح الخاصة بمنطقة وادي الملاك – مركز أبو حماد – محافظة الشرقية خلال موسمي ٢٠١٢ و ٢٠١٣ بمستويات مختلفة من كلوريد الكالسيوم (صفر ، ٠,٥ ، ١ و ٢ ٪) عندما وصلت الثمار لحجم حبة البسلة (قطر ٥ مللي) حيث رشت الأشجار ٦ مرات في أوائل ومنتصف أشهر مايو، يونيو وأكتوبر في كل موسم لدراسة تأثير هذه المعاملات علي نسب تساقط الثمار والثمار المتبقية وكمية المحصول وجودة الثمار.

أعطي رش كلوريد الكالسيوم بمعدل ١ ٪ أكبر زيادة في نسبة الثمار المتبقية ، المحصول، وعدد الثمار لكل شجرة ، مع خفض نسبة تساقط يونيو وتساقط الثمار قبل الجمع . واحتوي عصير ثمار الأشجار التي تم رشها بكلوريد الكالسيوم بمعدل ٠,٥ و ١ ٪ أعلي نسبة للمواد الصلبة الكلية الذائبة وأقل نسبة للحموضة الكلية وبالتالي أعلي نسبة للمواد الصلبة الكلية الذائبة/ الحموضة (TSS/ acid ratio) مقارنة بمثيلتها التي رشت بكلوريد الكالسيوم بمعدل ٢ ٪ و الماء. كانت معاملة رش أشجار البرتقال بسرة ٦ مرات بكلوريد الكالسيوم بمعدل ١ ٪ هي المعاملة المثلي لتحسين جودة الثمار وزيادة محصول الشجرة.