

The Future of Agriculture

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Influence of Foliar Spraying with Salicylic Acid and Calcium Lactate on Yield, Quality and Storability of "Balady" Mandarin Fruits

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https://doi.org/10.37229/fsa.fja.2026.10.11

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Future Science Association

Available online free at
www.futurejournals.org

Print ISSN: 2687-8151

Online ISSN: 2687-8216

Received: 9 August 2026
Accepted: 25 September 2026
Published: 11 October 2026

Publisher's Note: FA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: This investigation was conducted for consecutive seasons (2021-2022 & 2022-2023) on 21-year-old ""Balady"" mandarin trees (*Citrus reticulata*) budded on sour orange rootstock in a private orchard located in Ashmon, Menoufia Governorate, Egypt, to study effect of foliar spraying with salicylic acid and calcium lactate on yield, quality and storability of "Balady" mandarin fruits. The trees were planted at 5x5 meters spacing, grown in clay loam soil and irrigated by flood irrigation system. Eight treatments were performed as follows: foliar spraying with salicylic acid at 500 ppm and three concentrations of calcium lactate (1%, 2% and 3%) were applied either solely or in combined with each other, in addition to the control treatment (spraying with water). All different treatments were foliar sprayed twice: after fruit set stage when the fruit diameter reaches 3-4 mm (Mid May) and the pre-coloring stage (Late September). Fruits of all treatments were cold stored at 5±1°C and 90-95% relative humidity (RH) for 60 days. Fruit quality was evaluated at harvest and during cold storage. The study revealed that the combined application of 500ppm salicylic acid and 3% calcium lactate had the best results in terms of ensuring the best increasing yield and improving fruit quality attributes as well as enhancing the storability of "Balady" mandarin fruits via reducing physiological loss in weight and decay, maintaining firmness, ascorbic acid and delaying the changes in total soluble solids, acidity compared to control during extended cold storage in both seasons.

Key words: "Balady" mandarin, yield, fruit quality, salicylic acid, calcium lactate, storability.

1. Introduction

Citrus is one of the most important horticultural crops in the world as well as in Egypt where it has a tremendous economical impact not only in the local market, but also for export. According to the Food and Agriculture Organization of the United Nations (FAO), the total harvested area of citrus fruits in Egypt reached 586,671 Feddan producing 5,571,000 tons. In the same year, the harvested area of tangerines, mandarins, clementines, and satsumas was approximately 126,431 Feddan producing 1,074,000 tons (**FAO, 2024**).

"Balady"" mandarin orchards is currently experiencing biotic and abiotic stress, which could lead to poorer fruit yield and quality. Citrus fruits are non-climactic, however the temperature and duration of storage affect how the fruit chemicals alter with time **(Ramezanian *et al.*, 2018**). Mandarin fruits may experience several physiological issues during handling and postharvest. Fruit rot, which is thought to be one of the main issues with mandarin fruits, is caused by softening and fungus attack. This not only has a detrimental effect on the fruit's shelf life and marketability but also results in large financial losses for producers and retail businesses (**Kassim *et al.*, 2020**).

Salicylic acid (SA) and calcium lactate (CL) have been reported to enhance nutrient uptake, thereby improving crop yield and quality while extending storability and promoting consistent fruit production (**Shaarawi *et al.*, 2016**). SA is a naturally occurring phenolic molecule that is essential for protecting plants from biotic and abiotic stressors. Furthermore, SA regulates plant growth by affecting cell division and expansion, two crucial processes that determine the size of plants and their organs (**Li *et al.*, 2022**). Foliar spraying of SA is effective in controlling tree growth and increase productivity with prolonged storability when applied on citrus trees (**Ashraf *et al.*, 2013, El-Gioushy, 2016, Ali and El Zayat, 2019**).

SA applications showed a positive effect on reducing fruit weight loss, decay incidence and fruit softening rate fruit by reducing the activation of cell wall degrading enzymes as cellulose, xylanase and poly galactouronase during storage (**Babalar *et al.*, 2007**). Salicylic acid can improve the fruit's resistance to pathogens by stimulating H_2O_2 production and other protective metabolites, which contribute to stronger defense responses and lower postharvest decay. H_2O_2 helps activate defense mechanisms against pathogen attack, while some metabolites contribute to cell-wall defense and cellular signaling **(Zhu *et al.*, 2016).** Moreover, SA at 400 – 500 ppm has been used as a firming agent for mandarin (**El-Shemy, 2019 and Ibrahim and Ali, 2022**).

Calcium plays an extremely important role in plant growth and development and in maintaining and modulating various cell functions. It is necessary to maintain membrane stability and is an integral part of the cell wall where it provides rigidity by contributing to the linkage between pectic substances within the cell wall (**Conway *et al.*, 2002**). Organic calcium salts such as gluconate, citrate, or lactate enhance nutritional value without undesirable taste, its avoid the bitterness or off flavors associated with that salt and the antibacterial properties, increase antioxidant capacity and are more bio-available than an inorganic salt like calcium chloride (**Fekry, 2018**). Numerous horticultural crops have been researched for the application of calcium lactate; it is associated with enhanced growth, yield, increased and improved fruit quality attributes as well as reduced incidence of physiological disorder and delayed ripening and senescence processes (**Lamikrana and Watson, 2007** and **Youssef *et al.*, 2017**).

The scope of the present research is to study the influence of salicylic acid and calcium lactate on yield, fruit quality, as well as the storage potential of "Balady" mandarin fruits.

2. Materials and Methods

This investigation was conducted for consecutive seasons (2021-2022 & 2022-2023) on 21-year-old, on – year ""Balady"" mandarin trees (*Citrus reticulata*) budded on sour orange rootstock in a private orchard located in Ashmon, Menoufia Governorate, Egypt (Lat. 30°22' N, Long. 30°56' E), and Fruit Handling Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt to study effect of foliar spraying with salicylic acid and calcium lactate on yield, fruit quality and storability of "Balady" mandarin trees. The trees were planted at a spacing of 5 × 5 meters, grown in clay loam soil (and irrigated by flood irrigation system.

Twenty-four uniform as possible and fruitful ""Balady"" mandarin trees were selected; each tree represents as replicate, and each treatment consisted of three replicates.

Eight foliar spray treatments were conducted as follows:

1. Salicylic acid at 500 ppm
2. Calcium lactate at 1%
3. Calcium lactate at 2%
4. Calcium lactate at 3%
5. Salicylic acid at 500 ppm + calcium lactate at 1%
6. Salicylic acid at 500 ppm + calcium lactate at 2%
7. Salicylic acid at 500 ppm + calcium lactate at 3%
8. Control (spraying with water)

Every treatment was foliar sprayed twice: after the fruit set stage (Mid May), when the fruit diameter reaches 3–4 mm and in the pre-coloring stage (Late September). Fruits were picked on January 3rd and 9th during 2022 and 2023 seasons, respectively, when a deep yellow or light orange coloration appears on the peel.

Preparation of conducted treatments

Both salicylic acid and calcium lactate were purchased from sigma chemical company. Salicylic acid preparation: stock solution of salicylic acid was prepared by dissolving purified salicylic acid in 1% ethanol (**Ahmad *et al.*, 2013**), while, calcium lactate preparation: A stock solution of calcium lactate was prepared by dissolving in water before incorporating 0.5% acetic acid **(Yoon *et al.*, 2016**). All conducted treatments as well as control had Tween-80 (0.5% v/v) to improve the wetting properties of the solutions and adherence to fruits surface.

The following measurements were adopted of the applied treatments

1- Yield and its components

At January 3rd & 9th 2022 and 2023 years, respectively forty mature fruits from each tree/replicate were picked when a deep yellow or light orange coloration appears on the peel for fruit quality determination. At both experimental season yield estimated as number & weight in kilograms per each replicate (tree) then calculated to express as tones / feddan by the formula ((yield tones per feddan = number of fruits per tree *average tree yield in kilograms * number of trees per feddan)/1000).

2- Physical & chemical properties

Measurements included average fruit weight (g), dimensions (cm) (length and width), shape index (L/D), and average fruit rind weight (g). Average fruit firmness (g/mm2) was determined using an LFRA texture analyzer. Fruit juice was extracted by hand squeeze, weighed, and expressed as a percentage of fruit weight (w/w). Juice total soluble solids (TSS %) were measured using a hand refractometer, while total acidity (%) expressed as citric acid, and vitamin C content (mg ascorbic acid per 100 ml juice) were determined according to A.O.A.C. (2005). Moreover, TSS/acid ratio was calculated.

3- Cold Storability Experiment

The fruits were harvested at consumption maturity stage when a deep yellow or light orange coloration appears on the peel and uniform fruits in size and appearance with no physical defects or fungal infection were selected, surface washed with tap water and then air dried and placed in cartons boxes (60 cm x 40 cm x 10 cm) contained 25 fruits, each box represented as a replicate and each three replicates act as represent as treatment.

All treatments were subjected to cold storage at a temperature of 5 ± 1°C and a relative humidity of 90–95% for 60 days. Samples were taken at regular intervals (every 15 days) throughout the storage period specifically at days 0, 15, 30, 45, and 60 to evaluate the quality characteristics of the “Balady” mandarin fruits.

Fruit quality assessments during storage experiment

- Fruit weight loss (%) was calculated periodically by weighing the fruit at each interval and at the end of the cold storage period using the following formula:

Fruit weight loss (%) = [(Initial fruit weight - Fruit weight at sampling date) / Initial fruit weight] × 100

- Fruit decay (%) was determined periodically by calculating the weight of decay fruit (showing pathological disorders) and expressing it as a percentage using the formula:

Fruit decay (%) = [(Weight of decay fruit / Total fruit weight)] × 100

- General appearance (score) was evaluated periodically regarding taste, color, freshness, and flavor by ten trained panelists using a 9-to-1 scale, where: 9 = excellent, 7 = good, 5 = acceptable, 3 = poor, and 1 = unsalable fruit (ratings at this level or lower were considered unmarketable).
- Fruit firmness (g/mm²) was determined periodically using an LFRA texture analyzer.
- Fruit juice was extracted and weighed, and its percentage (%) relative to the fruit weight was calculated periodically.
- Total soluble solids (TSS%) were determined periodically using a handheld refractometer.
- Total acidity was determined periodically (as g citric acid/100 mL juice) according to the **A.O.A.C. (2005)**.
- Vitamin C content was determined periodically (as mg ascorbic acid/100 mL fruit juice) according to the **A.O.A.C. (2005)**.

Experimental Design and Statistical Analysis

Field experiment design was (RCBD) Randomized Complete Block Design. Meanwhile, cold storage experiment was arranged in a Factorial Completely Randomized Design (Factorial CRD) with two factors: the applied treatments and the cold storage intervals. Data recorded were subjected to statistical analysis according to Snedecor and **Cochran (1980)**. Averages were compared using the LSD values at **5%** level **(Steel and Torrie, 1980).**

3. Results and Discussion

1. Yield and its components

Data presented in Table (1) revealed that all evaluated foliar applications of salicylic acid (SA at 500 ppm) and calcium lactate (CL at 1%, 2%, and 3%), either solely or in combined treatments, significantly ($p \leq 0.05$) increased fruit weight, fruit number per tree, yield per tree, and total yield per feddan during both the 2021/2022 and 2022/2023 seasons compared to the control. The response was concentration-dependent for CL treatments. Notably, the combined application of 500 ppm SA + 3% CL proved to be the most effective treatment, yielding the highest fruit weight (182.9 and 201.8 g), maximum fruit number per tree (389.5 and 378.4), highest tree yield (71.2 and 76.4 kg), and maximum total yield per feddan (12.0 and 12.8 tons) in the first and second seasons, respectively. Overall, tree productivity and fruit weight were markedly higher in the second season across all treatments.

The improvement of yield and its components as a result of the use of salicylic acid may be due to its acts as a physiological signaling molecule that stimulates photosynthetic efficiency and enzymatic activity, regulates stomatal movement, and mitigates water stress. Furthermore, it downregulates ethylene biosynthesis and inhibits the formation of the abscission zone, thereby reducing fruit drop percentage and significantly increasing fruit retention per tree until harvest. Also Salicylic acid increasing of ATPase enzyme activity, thereby improving nutrient uptake. So, increasing of nutrient uptake rate can be as important reason for increasing yield in SA treated plants (**Ghassemi-Golezani and Farhangi-Abriz, 2018**). These results were in harmony with finding of **Ashraf *et al.* (2013)** on Kinnow mandarin trees, **Habasy (2015)** on Valencia orange trees, **El-Gioushy, (2016)** on Washington navel orange, **Mohamed and El-Tanany (2016)** on "Balady" mandarins and **Ali and El Zayat, (2019)** on Washington navel orange trees they cited that spraying SA significantly improved fruit yield. Concerning the promoting influence of calcium lactate (CL) were led to role of calcium lactate (CL) as a crucial structural element for cell wall

assembly and middle lamella integrity, which promotes fruit cell division and elongation. Additionally, it strengthens vascular connections, thereby enhancing fruit sink strength for carbohydrates and water accumulation, which directly translates into increased fruit weight and yield.

The positive effect of calcium lactate (CL) on yield and its components may be attributed to its role on decreasing cell wall susceptibility to enzymatic degradation through the inhibition of polygalacturonase (PG) and pectin methyl esterase (PME) enzymes activities as well as by binding to cellular polymers, and prevents the breakdown and disintegration of cells (**Abdel Ghany *et al.*, 2023**). The obtained results are in accordance with those by **Lal *et al.* (2015)** on kinnow mandarin, **Wahab *et al.* (2016)** on peach and **Fekry (2018)** on guava; they reported that yield and its components were enhanced by calcium application.

Table 1. Response of yield and yield components of '"Balady"' mandarin trees to foliar spraying with salicylic acid (SA) and calcium lactate (CL) over two consecutive seasons.

Characteristics	Fruit weight (g)		Number of fruits/tree		Yield/tree (kg)		Yield/feddan (ton)	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
500ppm SA	147.7	171.5	339.3	344.7	50.1	59.1	8.4	9.9
1% CL	154.2	175.2	336.5	349.4	51.9	61.2	8.7	10.3
2% CL	161.4	183.5	343.4	357.6	55.4	65.6	9.3	11.0
3% CL	164.1	193.2	387.9	363.1	63.7	70.2	10.7	11.8
500ppm SA + 1% CL	177.8	196.5	369.1	370.7	65.6	72.8	11.0	12.2
500ppm SA + 2% CL	179.1	197.9	389.3	376.3	69.7	74.5	11.7	12.5
500ppm SA + 3% CL	182.9	201.8	389.5	378.4	71.2	76.4	12.0	12.8
Control	143.5	167.6	313.7	330.1	45.0	55.3	7.6	9.3
L.S.D. at 0.05	3.6	3.9	1.4	1.7	1.1	1.3	0.2	0.1

2- Fruit physical properties

Data in Table (2 and 3) showed that foliar application of salicylic acid (SA) and calcium lactate (CL), either individually or in combination, resulted in a significant increase in fruit dimensions (length and diameter) compared to the control. The combined treatment at the highest concentrations (500 ppm SA + 3% CL) recorded the significantly highest values for fruit length (6.11 and 6.07 cm) and fruit diameter (7.28 and 7.48cm) across both seasons, respectively. Conversely, the control treatment yielded the lowest values (5.47 and 5.59 cm for length; 6.77 and 6.93 cm for diameter). No significant variations were observed among treatments regarding the fruit shape index (L/D), with values ranging narrowly between 0.80 and 0.84 in both seasons. This indicates that the applied treatments preserved the characteristic oblate-spherical physical form of "Balady" mandarin fruit without causing structural deformities. Foliar treatments demonstrated a progressive increase in fruit rind weight with increasing calcium concentrations, particularly when combined with SA, compared to untreated control fruits. All foliar spray treatments significantly increased fruit juice weight and juice percentage relative to the control. The combination of 500 ppm SA + 3% CL was superior, achieving the highest fruit juice weight (97.3 and 107.2 g) and juice percentage (53.2% and 53.1%) in the first and second seasons, respectively, whereas the control produced the lowest juice percentage (47.0% and 46.0%).The enhanced physical attributes (fruit dimensions and juice content) which induced by foliar treatments can be attributed to the complementary biological functions of salicylic acid and calcium lactate, Salicylic acid acts as an endogenous plant growth regulator that promotes cell division and enlargement within fruit tissues. Furthermore, SA enhances photosynthetic efficiency, pigment synthesis, and carbohydrate accumulation, thereby improving source to sink translocation of photo assimilates to developing fruits. Calcium lactate (CL) acts throw calcium as an essential structural element involved in the synthesis of cell walls and the middle lamella. Foliar-applied calcium reinforces cell membrane integrity, enhances water retention capacity within juice sacs, and supports structural development, directly contributing to larger fruit dimensions and higher juice yield. The combination of 500 ppm SA with 3% CL exerted a clear synergistic effect. While SA acts as a metabolic stimulant that drives photo assimilate accumulation, calcium provides the structural stability required to accommodate cell expansion and prevent cellular degradation, maximizing fruit growth and juice accumulation. Foliar

applications of salicylic acid (SA) and calcium lactate (CL), applied either individually or in combination, significantly enhanced fruit firmness (gmm^2) compared to the control treatment in both experimental seasons. The combined treatment of 500 ppm + 3% CL proved to be the most effective, achieving the highest significant fruit firmness values (62.0 and 65.9 g/mm^2) in the first and second seasons, respectively. Fruit softening occurs as a result of cell wall breakdown caused by hydrolytic enzymes, including polygalacturonases, pectin methylesterases, β-galactosidase, and xylanase, together with the deterioration of cell membranes. Salicylic acid (SA) acts as an ethylene inhibitor, delaying fruit ripening and limiting softening through the suppression of cell wall-degrading enzyme activity (**Ghahremani *et al.*, 2021**). These results are in agreement with **Ashraf *et al.* (2013)** on kinnow mandarin, **Habasy (2015)** on Valencia orange trees, **El-Gioushy, (2016)** on Washington navel orange, **Mohamed and El-Tanany (2016)** on "Balady" mandarins and **Ali and El Zayat (2019)** on Washington navel orange trees they cited that the SA enhanced the fruit physical characteristics.

Table (2). Effect of foliar application of salicylic acid (SA) and calcium lactate (CL) on fruit length, diameter, shape index and rind weight of "Balady" mandarin during both seasons.

Characteristics	Fruit length (cm)		Fruit diameter (cm)		fruit shape index (L/D)		Fruit rind (g)	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
500ppm SA	5.50	5.63	6.81	6.97	0.81	0.81	33.7	38.9
1% CL	5.58	5.68	6.83	7.01	0.82	0.81	34.7	39.1
2% CL	5.59	5.71	6.89	7.06	0.81	0.81	36.2	40.6
3% CL	5.84	5.73	6.93	7.13	0.84	0.80	36.3	43.9
500ppm SA + 1% CL	5.87	5.83	6.98	7.16	0.84	0.81	39.3	41.9
500ppm SA + 2% CL	5.98	5.94	7.11	7.31	0.84	0.81	39.4	42.9
500ppm SA + 3% CL	6.11	6.07	7.28	7.48	0.84	0.81	39.9	44.4
Control	5.47	5.59	6.77	6.93	0.81	0.81	33.0	40.2
L.S.D. at 0.05	0.09	0.11	0.13	0.17	N.S	N.S	0.4	0.7

Table (3). Effect of foliar application of salicylic acid (SA) and calcium lactate (CL) on fruit firmness, juice weight and percentage of "Balady" mandarin during both seasons.

Characteristics	Fruit firmness (g/mm^2)		Fruit juice weight (g)		Fruit juice (%)	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season
500ppm SA	57.6	58.5	73.6	83.5	49.8	48.7
1% CL	58.7	59.4	76.5	84.6	49.6	48.3
2% CL	59.3	60.7	82.2	90.3	50.9	49.2
3% CL	59.7	61.0	84.3	94.7	51.4	49.0
500ppm SA + 1% CL	59.9	62.5	92.6	97.9	52.1	49.8
500ppm SA + 2% CL	60.5	63.6	94.0	104.5	52.5	52.8
500ppm SA + 3% CL	62.0	65.9	97.3	107.2	53.2	53.1
Control	48.7	49.8	67.4	77.1	47.0	46.0
L.S.D. at 0.05	1.3	1.8	1.3	1.7	0.4	0.3

Concerning the promoting influence of calcium lactate on fruit physical properties may be attributed to its ability to decrease cell wall susceptibility to enzymatic hydrolysis by suppressing the activity of polygalacturonase and pectin methylesterase, while also interacting with cellular polymers to maintain cell integrity and prevent cellular breakdown and disintegration (**Abdel Ghany *et al.*, 2023**). The obtained results are in accordance with those by **Lal *et al.* (2015)** on kinnow mandarin, **Wahab *et al.* (2016)** on peach and **Fekry (2018)** on guava; they reported that yield and cluster weight were enhanced by calcium application.

3- Fruit chemical properties

As shown in Table (4), all chemical properties of fruits *i.e.* total soluble solids (TSS), total acidity, TSS/acid ratio and vitamin C were significantly influenced by foliar spraying of salicylic acid or calcium lactate at different doses either individually or in combined form as compared to control. Control fruits exhibited the significantly highest Total soluble solids (TSS %) in both seasons (12.61% and 12.93%, respectively). Foliar applications generally resulted in a slight reduction in TSS% , with the lowest values recorded for the combined application of salicylic acid and calcium lactate at 500 ppm SA + 3% CL (12.01% and 12.14%). Meanwhile, control fruits significantly reduced juice acidity compared to the other treatments, recording (0.97% and 0.97% in the first and second seasons, respectively). Conversely, increasing CL concentration particularly in combination with SA (500 ppm SA + 3% CL) led to higher acidity levels, reaching up to (1.22% and 1.24%). Among the TSS/acid ratio, the highest maturity index (TSS/acid ratio) was achieved by control fruits (13.00 and 13.33), followed by the single application of 500 ppm SA (12.56 and 13.07). In contrast, combined applications of SA and CL reduced this ratio, recording the lowest values under 500 ppm SA + 3% CL (9.84 and 9.79) in both seasons respectively. All foliar treatments significantly increased fruit juice vitamin C content (mg/100/ml juice) compared to the control, which yielded the lowest values (35.7 and 38.6 mg/100 ml juice). The combination treatments (SA + CL) were most effective in enhancing vitamin C levels, reaching a peak of (41.3 and 40.6 mg/100 ml juice) under 500 ppm SA + 3% CL.

Table (4). Effect of foliar application of salicylic acid (SA) and calcium lactate (CL) on fruit chemical properties of "Balady" mandarin during both seasons.

Characteristics	TSS (%)		Total acidity (%)		TSS/acid ratio		Vitamin C (mg /100 ml juice)	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
500ppm SA	12.43	12.81	0.99	0.98	12.56	13.07	38.3	39.2
1% CL	12.31	12.63	1.02	0.98	12.07	12.89	38.8	39.3
2% CL	12.13	12.32	1.14	1.01	10.64	12.20	39.3	39.5
3% CL	12.09	12.24	1.15	1.09	10.51	11.23	40.4	39.8
500ppm SA + 1%CL	12.02	12.19	1.18	1.18	10.19	10.33	40.6	40.3
500ppm SA + 2%CL	12.01	12.16	1.20	1.21	10.01	10.05	41.1	40.5
500ppm SA + 3%CL	12.01	12.14	1.22	1.24	9.84	9.79	41.3	40.6
Control	12.61	12.93	0.97	0.97	13.00	13.33	35.7	38.6
L.S.D. at 0.05	0.17	0.11	0.02	0.01	0.17	0.23	0.2	0.1

The progressive decrease in TSS% accompanied by higher acidity levels under increased calcium lactate (CL) concentrations either solely or combined with salicylic acid (SA) can be attributed to the physiological role of calcium in reinforcing cell walls and the middle lamella through pectin binding to form calcium pectates. This structural stabilization delays fruit ripening slightly than non-treated fruits, suppresses respiration rates, and decelerates the metabolic breakdown of organic acids during fruit development compared to untreated control fruits. The significant enhancement of vitamin C (ascorbic acid) content following SA and CL foliar sprays is driven by complementary antioxidant mechanisms. Salicylic acid serves as a signaling molecule that activates key antioxidant enzymes, shielding ascorbic acid from oxidative degradation. These results are in agreement with **Ashraf *et al.* (2013)** on kinnow mandarin, **Habasy (2015)** on Valencia orange trees, **El-Gioushy, (2016)** on Washington navel orange, **Mohamed and El-Tanany (2016)** on "Balady" mandarins and **Ali and El Zayat (2019)** on Washington navel orange trees they cited that the SA enhanced the fruit chemical characteristics.

Regarding the stimulating effect of calcium on fruit chemical properties, it may be due to its role in cell division, mitosis and carbohydrate metabolism (**Ilyas *et al.*, 2014**). The obtained results are in harmony with **Lal *et al.* (2015)** on kinnow mandarin, **Wahab *et al.* (2016)** on peach and **Fekry (2018)** on guava; they reported that chemical properties of fruits were enhanced by calcium application.

Storability

Fruit physical properties

- **Weight loss**

Data presented in Table (5) showed that fruit weight loss percentage gradually increased with the prolongation of the cold storage period for all treatments in both seasons. It can be seen that the pre-harvest application of salicylic acid or calcium lactate at different doses either in solely or in combined form resulted in a significant decrease in the fruit weight loss percentage as compared to the control with storage period advanced. The reduction in weight loss percentage was obtained by the combined application of salicylic acid at 500 ppm and calcium lactate at 3%, while the highest percentage of this one was significantly attained by control after 60 days of cold storage in both seasons.

Table (5). Effect of foliar application of salicylic acid (SA) and calcium lactate (CL) on fruit weight loss (%) of "Balady" mandarin during cold storage over both seasons.

	1st season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	0.00	10.15	15.39	20.96	27.30	14.76
1% CL	0.00	8.89	14.69	20.86	27.87	14.46
2% CL	0.00	8.76	13.15	17.82	23.13	12.57
3% CL	0.00	8.45	12.82	17.47	22.75	12.30
500ppm SA + 1% CL	0.00	7.12	12.38	17.97	24.34	12.36
500ppm SA + 2% CL	0.00	6.94	11.94	17.26	23.31	11.89
500ppm SA + 3% CL	0.00	6.65	9.94	13.44	17.42	9.49
Control	0.00	10.29	16.43	22.96	30.39	16.01
Means (D)	0.00	8.41	13.34	18.59	24.56	
L.S.D. at 0.05	(T) =6.31		(D) =4.99		(TXD) =14.11	
	2nd season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	0.00	9.78	14.21	21.33	29.82	15.03
1% CL	0.00	9.26	13.02	18.21	25.99	13.30
2% CL	0.00	9.09	12.67	16.99	22.18	12.19
3% CL	0.00	8.77	12.23	16.32	20.65	11.59
500ppm SA + 1% CL	0.00	8.53	11.75	15.69	19.76	11.15
500ppm SA + 2% CL	0.00	7.32	10.36	14.03	17.84	9.91
500ppm SA + 3% CL	0.00	5.41	7.69	11.23	14.91	7.85
Control	0.00	10.03	15.14	23.67	32.91	16.35
Means (D)	0.00	8.52	12.13	17.18	23.01	
L.S.D. at 0.05	(T) =6.87		(D) =5.43		(TXD) =15.36	

The increase in the fruit weight loss during cold storage may due to respiration and transpiration (**Ennab *et al.*, 2020**). These results are in line with those obtained by **Ramezanian *et al.* (2018)** on Washington navel orange, and **El-Shemy (2019)** on Ponkan mandarin and **Kavanagh *et al.* (2026)** on Lane Late Navel Oranges and Summerina Mandarins, they found that fruits treated with salicylic acid had the lowest weight loss percentage compared to the untreated citrus with storage period advanced.

The attenuation of physiological weight loss in calcium-treated fruits may be attributed to the preservation of fruit firmness and tissue structural integrity through the suppression of enzymatic activities responsible for cellular disintegration, consequently restricting gaseous exchange. (**Gupta *et al.*, 2011**). The obtained results are also similar to those achieved by **Fekry (2018)** on guava, **Riaz *et al.* (2020)** on sweet orange and **El-Bana and Ennab (2023)** on mandarin fruits, they reported that calcium treatments significantly reduced the weight loss percentage of fruits during cold storage.

- **Decay**

As shown in Table (6), a significant gradual increase in fruit decay percentage was observed with the prolongation of the cold storage period for all treatments in both seasons. It can be observed that the pre-harvest application of salicylic acid or calcium lactate at different doses either in solely or in combined form resulted in a significant decrease in the percentage of fruit decay compared to the control with storage period advanced. The combined application of salicylic acid at 500 ppm and calcium lactate at 3% significantly reduced the increase of fruit decay percentage after 60 days of cold storage in both seasons.

Table (6). Effect of foliar application of salicylic acid (SA) and calcium lactate (CL) on fruit decay (%) of "Balady" mandarin during cold storage over both seasons.

	1st season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	0.00	0.76	2.07	7.44	13.05	4.66
1% CL	0.00	0.63	1.80	6.34	11.16	3.99
2% CL	0.00	0.52	1.57	5.41	9.56	3.41
3% CL	0.00	0.44	1.41	4.73	8.40	2.99
500ppm SA + 1% CL	0.00	0.37	1.26	4.14	7.38	2.63
500ppm SA + 2% CL	0.00	0.23	0.97	2.95	5.34	1.90
500ppm SA + 3% CL	0.00	0.11	0.73	1.93	3.60	1.27
Control	0.00	0.99	2.54	9.39	16.39	5.86
Means (D)	0.00	0.51	1.54	5.29	9.36	
L.S.D. at 0.05	(T) =4.27		(D) =3.38		(TXD) =9.55	
	2nd season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	0.00	0.81	2.17	7.86	13.77	4.92
1% CL	0.00	0.69	1.92	6.85	12.03	4.30
2% CL	0.00	0.58	1.70	5.91	10.43	3.72
3% CL	0.00	0.49	1.51	5.15	9.12	3.26
500ppm SA + 1% CL	0.00	0.41	1.35	4.47	7.96	2.84
500ppm SA + 2% CL	0.00	0.32	1.16	3.71	6.65	2.37
500ppm SA + 3% CL	0.00	0.17	0.85	2.44	4.47	1.59
Control	0.00	1.07	2.71	10.07	17.55	6.28
Means (D)	0.00	0.57	1.67	5.81	10.25	
L.S.D. at 0.05	(T) =4.33		(D) =3.42		(TXD) =9.68	

Fruits are affected by post-harvest diseases and disturbances during storage as a result of physiological changes and aging process (**Pruskyand Keen, 1993**). Salicylic acid (SA) significantly decreased fruit decay by improving antioxidant enzyme activity, strengthening resistance to fungal infections, and increasing the accumulation of water and defense-related metabolites, including ornithine, threonine, and polymethoxylated flavones. (**Zhu *et al.*, 2016**). These results are in line with those obtained by **El-Shemy (2019)** on Ponkan mandarin and **Kavanagh *et al.* (2026)** on Lane Late Navel Oranges and

Summerina Mandarins, they found that fruits treated with salicylic acid had the lowest fruit decay percentage compared to the untreated citrus with storage period advanced.

The incorporation of calcium ions in fruit tissue increases the stability of the cell wall and middle lamella by calcium treatment which can be expected to improve fruit resistance to enzymes caused by fungal pathogens (**Hernandez-Munoz *et al.*, 2008**). The obtained results are similar to those achieved by **Fekry (2018)** on guava, **Riaz *et al.* (2020)** on sweet orange and **El-Bana and Ennab (2023)** on mandarin fruits, they reported that calcium treatments significantly reduced the decay percentage and of fruits during cold storage.

- **General appearance**

As shown in Table (7), a significant gradual decrease in general appearance score was observed with the prolongation of the cold storage period for all treatments in both seasons. It can be observed that the pre-harvest application of salicylic acid or calcium lactate at different doses either in solely or in combined form resulted in a significant maintain on the score of general appearance compared to the control with storage period advanced. The combined application of salicylic acid at 500 ppm and calcium lactate at 3% significantly reduced the decrease score of general appearance, whereas, control significantly had the lowest score after 60 days of cold storage in both seasons.

Table (7). Effect of foliar application of salicylic acid (SA) and calcium lactate (CL) on fruit general appearance (score) of "Balady" mandarin during cold storage over both seasons

	1st season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	9.00	9.00	8.67	7.33	7.00	8.00
1% CL	9.00	9.00	8.67	7.67	7.33	8.17
2% CL	9.00	9.00	8.67	8.00	7.67	8.34
3% CL	9.00	9.00	8.67	8.00	7.67	8.34
500ppm SA + 1% CL	9.00	9.00	9.00	8.00	7.67	8.42
500ppm SA + 2% CL	9.00	9.00	9.00	8.33	7.67	8.50
500ppm SA + 3% CL	9.00	9.00	9.00	8.33	8.00	8.58
Control	9.00	8.67	8.33	7.00	6.67	7.67
Means (D)	9.00	8.96	8.75	7.83	7.46	
L.S.D. at 0.05	(T) =0.83		(D) =0.66		(TXD) =1.86	
	2nd season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	9.00	8.33	8.00	7.67	7.00	7.75
1% CL	9.00	8.67	8.00	7.67	7.00	7.84
2% CL	9.00	8.67	8.00	7.67	7.00	7.84
3% CL	9.00	8.67	8.33	7.67	7.33	8.00
500ppm SA + 1% CL	9.00	8.67	8.33	8.00	7.33	8.08
500ppm SA + 2% CL	9.00	9.00	8.33	8.00	7.33	8.17
500ppm SA + 3% CL	9.00	9.00	8.67	8.33	7.67	8.42
Control	9.00	8.00	7.67	7.33	6.33	7.33
Means (D)	9.00	8.63	8.17	7.79	7.12	
L.S.D. at 0.05	(T) =0.92		(D) =0.73		(TXD) =2.06	

This may be due to that salicylic acid and calcium lactate application reduce weight loss, maintain firmness and delay senescence of fruits (**Luna- Guzman and Barrett, 2000**). These results are in line with those obtained by **Kavanagh *et al.* (2026)**, they found that Lane Late Navel Oranges and Summerina Mandarins treated with salicylic acid had the highest preferred overall acceptability score compared to the untreated citrus with storage period advanced. On the other hand, **Riaz *et al.* (2020)** on sweet orange and

El-Bana and Ennab (2023) on mandarin fruits, they reported that calcium treatments significantly maintain the overall acceptability score of fruits during cold storage.

- **Fruit firmness**

Data presented in Table (8) showed that fruit firmness gradually reduced with the prolongation of the cold storage period for all treatments in both seasons. It can be seen that the pre-harvest application of salicylic acid or calcium lactate at different doses either in solely or in combined form resulted in a significant maintain on the fruit firmness as compared to the control with storage period advanced. The reduction in the lowest fruit firmness was obtained by the combined application of salicylic acid at 500 ppm and calcium lactate at 3%, while the lowest one was significantly attained by control after 60 days of cold storage in both seasons.

Table (8). Effect of foliar application of salicylic acid (SA) and calcium lactate (CL) on fruit firmness (g/mm^2) of "Balady" mandarin during cold storage over both seasons

	1st season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	57.6	45.4	34.2	26.6	22.2	37.2
1% CL	58.7	46.2	36.2	28.9	24.1	38.8
2% CL	59.3	46.0	37.0	30.7	25.6	39.7
3% CL	59.7	47.0	37.0	32.1	26.8	40.5
500ppm SA + 1% CL	59.9	48.2	37.6	34.0	28.4	41.6
500ppm SA + 2% CL	60.5	49.4	40.1	36.4	30.4	43.4
500ppm SA + 3% CL	62.0	50.2	41.9	37.4	31.3	44.6
Control	48.7	40.9	31.1	25.0	20.9	33.3
Means (D)	58.3	46.7	36.9	31.4	26.2	
L.S.D. at 0.05	(T) =10.9		(D) =8.6		(TXD) =24.4	
	2nd season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	58.5	44.5	30.2	25.7	19.9	35.8
1% CL	59.4	46.3	30.8	27.6	21.4	37.1
2% CL	60.7	47.1	32.0	29.4	22.8	38.4
3% CL	61.0	48.4	34.1	30.4	23.6	39.5
500ppm SA + 1% CL	62.5	48.4	38.6	31.0	24.0	40.9
500ppm SA + 2% CL	63.6	49.2	41.8	34.1	26.4	43.0
500ppm SA + 3% CL	65.9	49.6	43.1	37.4	28.9	45.0
Control	49.8	44.1	30.0	24.3	18.8	33.4
Means (D)	60.2	47.2	35.1	30.0	23.2	
L.S.D. at 0.05	(T) =11.3		(D) =8.9		(TXD) =25.3	

The decline in fruit firmness during the postharvest period is primarily attributed to the dissolution of the middle lamella, reduced cell-to-cell adhesion, and weakening of parenchyma cell walls due to the activity of cell wall-modifying enzymes, ultimately resulting in fruit shriveling and softening (**Mahajan *et al.*, 2017**). SA has been reported to reduce respiration rate, delay softening, and maintain fruit quality during storage for mandarins, oranges and lemons (**Haider *et al.*, 2020**, **Zhao *et al.*, 2021** and **Chen *et al.*, 2023**). These results are in line with those obtained by **Ramezanian *et al.* (2018)** on Washington navel orange, **El-Shemy (2019)** on Ponkan mandarin and **Kavanagh *et al.* (2026)** on Lane Late Navel Oranges and Summerina Mandarins, they found that fruits treated with salicylic acid had the highest fruit firmness compared to the untreated citrus with storage period advanced.

Calcium ions play an important role in maintaining fruit firmness by strengthening fruit tissues and cell walls, especially the middle lamella, which enhances cell-to-cell adhesion and consequently slows

down the processes of fruit ripening and senescence. (**Vicente *et al.*, 2007**). The obtained results are also similar to those achieved by **Fekry (2018)** on guava, **Riaz *et al.*, (2020)** on sweet orange and **El-Bana and Ennab (2023)** on mandarin fruits, they reported that calcium treatments significantly maintain the firmness of fruits during cold storage.

- **Fruit juice**

As shown in Table (9), a significant gradual decrease in fruit juice percentage was observed with the prolongation of the cold storage period for all treatments in both seasons. It can be observed that the pre-harvest application of salicylic acid or calcium lactate at different doses either in solely or in combined form resulted in a significant maintain on the percentage of fruit juice compared to the control with storage period advanced. The combined application of salicylic acid at 500 ppm and calcium lactate at 3% significantly reduced the decrease of fruit juice, whereas, control significantly had the lowest percentage of this one after 60 days of cold storage in both seasons.

Table (9). Effect of foliar application with salicylic acid (SA) and calcium lactate (CL) on fruit juice (%) of "Balady" mandarin during cold storage over both seasons.

	1st season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	49.8	47.1	44.5	42.5	40.1	44.8
1% CL	49.6	47.0	44.5	42.4	40.1	44.7
2% CL	50.9	48.1	45.5	43.4	41.0	45.8
3% CL	51.4	48.7	46.1	43.9	41.6	46.3
500ppm SA + 1% CL	52.1	49.2	46.5	44.2	41.8	46.8
500ppm SA + 2% CL	52.5	49.6	46.8	44.7	42.2	47.1
500ppm SA + 3% CL	53.2	50.4	47.7	45.5	43.1	48.0
Control	47.0	44.5	42.1	40.1	37.9	42.3
Means (D)	50.8	48.1	45.4	43.3	41.0	
L.S.D. at 0.05	(T) =5.2		(D) =4.1		(TXD) =11.6	
	2nd season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	48.7	46.0	43.8	41.7	39.4	43.9
1% CL	48.3	45.7	43.6	41.6	39.4	43.7
2% CL	49.2	46.5	44.4	42.3	40.0	44.5
3% CL	49	46.4	44.2	42.2	40.0	44.4
500ppm SA + 1% CL	49.8	47.1	44.8	42.7	40.3	44.9
500ppm SA + 2% CL	52.8	49.8	47.6	45.4	42.8	47.7
500ppm SA + 3% CL	53.1	50.3	47.9	45.8	43.3	48.1
Control	46	43.5	41.5	39.6	37.5	41.6
Means (D)	49.6	46.9	44.7	42.7	40.3	
L.S.D. at 0.05	(T) =5.9		(D) =4.7		(TXD) =13.2	

Fruit chemical properties

- **Total soluble solids (TSS)**

Data presented in Table (10) showed that total soluble solids percentage gradually increased with the extension of the cold storage period for all treatments in both seasons. It can be seen that the pre-harvest application of salicylic acid or calcium lactate at different doses either in solely or in combined form resulted in a significant decrease in the percentage of total soluble solids as compared to the control with

storage period advanced. The reduction in total soluble solids percentage was obtained by the combined application of salicylic acid at 500 ppm and calcium lactate at 3%, while the highest percentage of this one was significantly attained by control after 60 days of cold storage in both seasons.

The increase in fruit TSS with advancement of storage period may be due to the increase in the percentage of dry matter through respiration and metabolic activity and the loss of moisture from the fruit through transpiration (**Nandaniya *et al.*, 2017**). These results are in line with those obtained by **Ramezanian *et al.* (2018)** on Washington navel orange, **El-Shemy (2019)** on Ponkan mandarin and **Kavanagh *et al*. (2026)** on Lane Late Navel Oranges and Summerina Mandarins, they found that fruits treated with salicylic acid had the lowest total soluble solids percentage compared to the untreated citrus with storage period advanced.

The decrease in TSS with calcium can be due to its film forming properties which decrease moisture loss, and thus, retaining the TSS concentration (**Han *et al.*, 2004**) or may be due to the role of calcium in delaying metabolic activity of fruits during storage (**Chulaki *et al.*, 2017**). The obtained results are also similar to those achieved by **Fekry (2018)** on guava, **Riaz *et al.*, (2020)** on sweet orange and **El-Bana and Ennab (2023)** on mandarin fruits, they reported that calcium lactate treatments significantly reduced the total sugar percentage of fruits during cold storage.

Table (10). Effect of foliar application of salicylic acid (SA) and calcium lactate (CL) on fruit juice TSS (%) of "Balady" mandarin during cold storage over both seasons

	1st season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	12.43	12.70	12.96	13.24	13.52	12.97
1% CL	12.31	12.58	12.83	13.11	13.39	12.84
2% CL	12.13	12.40	12.64	12.92	13.19	12.66
3% CL	12.09	12.35	12.59	12.86	13.12	12.60
500ppm SA + 1% CL	12.02	12.28	12.51	12.78	13.04	12.53
500ppm SA + 2% CL	12.01	12.26	12.50	12.76	13.02	12.51
500ppm SA + 3% CL	12.01	12.26	12.49	12.75	13.01	12.50
Control	12.61	12.89	13.15	13.43	13.72	13.16
Means (D)	12.20	12.47	12.71	12.98	13.25	
L.S.D. at 0.05	(T) =1.48		(D) =1.17		(TXD) =3.31	
	2nd season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	12.81	13.13	13.52	13.86	14.28	13.52
1% CL	12.63	12.95	13.33	13.67	14.08	13.33
2% CL	12.32	12.63	13.01	13.33	13.73	13.00
3% CL	12.24	12.54	12.92	13.24	13.63	12.91
500ppm SA + 1% CL	12.19	12.49	12.86	13.18	13.57	12.86
500ppm SA + 2% CL	12.16	12.46	12.82	13.13	13.51	12.82
500ppm SA + 3% CL	12.14	12.43	12.79	13.10	13.49	12.79
Control	12.93	13.25	13.65	13.99	14.41	13.65
Means (D)	12.43	12.74	13.11	13.44	13.84	
L.S.D. at 0.05	(T) =1.07		(D) =0.85		(TXD) =2.39	

- **Total acidity**

As shown in Table (11), a significant gradual decrease in the total acidity was observed with the prolongation of the cold storage period for all treatments in both seasons. It can be observed that the pre-harvest application of salicylic acid or calcium lactate at different doses either in solely or in combined form resulted in a significant maintain on the total acidity compared to the control with storage period advanced. Control fruits exhibited the lowest significant total acidity, whereas, the combined application of salicylic acid at 500 ppm and calcium lactate at 3% significantly decrease the reducing of total acidity after 60 days of cold storage in both seasons.

The gradual decrease in the fruit acidity during storage at low temperature and may be due to the conversion of acids into sugars and the rapid use of organic acids in the respiration process (**Chulaki *et al.*, 2017**). These results are in line with those obtained by **Ramezanian *et al.* (2018)** on Washington navel orange, **El-Shemy (2019)** on Ponkan mandarin and **Kavanagh et al. (2026)** on Lane Late Navel Oranges and Summerina Mandarins, they found that fruits treated with salicylic acid had the highest total acidity percentage compared to the untreated citrus with storage period advanced.

Calcium has also been found effective in maintaining higher fruit acidity during low-temperature storage. This effect may be attributed to reduced hydrolysis of organic acids, resulting in increased organic acid retention in calcium-treated fruits, as well as their slower oxidation due to decreased respiration rates. (**Gupta *et al.*, 2011**). The obtained results are also similar to those achieved by **Fekry (2018)** on guava, **Riaz *et al.*, (2020)** on sweet orange and **El-Bana and Ennab (2023)** on mandarin fruits, they found that calcium application maintain higher rates of acids during cold storage.

Table (11). Effect of foliar application of salicylic acid (SA) and calcium lactate (CL) on fruit juice acidity (%) of "Balady" mandarin during cold storage over both seasons

	1st season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	0.99	0.94	0.87	0.83	0.77	0.88
1% CL	1.02	0.96	0.90	0.85	0.80	0.91
2% CL	1.14	1.08	1.01	0.96	0.89	1.02
3% CL	1.15	1.09	1.02	0.96	0.90	1.02
500ppm SA + 1% CL	1.18	1.11	1.04	0.98	0.92	1.05
500ppm SA + 2% CL	1.20	1.14	1.06	1.01	0.94	1.07
500ppm SA + 3% CL	1.22	1.15	1.08	1.02	0.96	1.09
Control	0.97	0.92	0.86	0.81	0.75	0.86
Means (D)	1.11	1.05	0.98	0.93	0.87	
L.S.D. at 0.05	(T) =0.19		(D) =0.15		(TXD) =0.42	
	2nd season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	0.98	0.92	0.87	0.82	0.76	0.87
1% CL	0.98	0.92	0.87	0.82	0.76	0.87
2% CL	1.01	0.94	0.89	0.84	0.79	0.89
3% CL	1.09	1.02	0.97	0.91	0.85	0.97
500ppm SA + 1% CL	1.18	1.10	1.04	0.98	0.92	1.04
500ppm SA + 2% CL	1.21	1.13	1.07	1.01	0.95	1.07
500ppm SA + 3% CL	1.24	1.16	1.10	1.04	0.98	1.10
Control	0.97	0.91	0.86	0.81	0.76	0.86
Means (D)	1.08	1.01	0.96	0.90	0.85	
L.S.D. at 0.05	(T) =0.23		(D) =0.18		(TXD) =0.51	

- **Vitamin C**

Data presented in Table (12) showed that fruit juice content of vitamin C gradually reduced with the prolongation of the cold storage period for all treatments in both seasons. It can be seen that the pre-harvest application of salicylic acid or calcium lactate at different doses either in solely or in combined form resulted in a significant maintain on the fruit juice content of vitamin C as compared to the control with storage period advanced. The reduction in the lowest fruit juice content of vitamin C was obtained by the combined application of salicylic acid at 500 ppm and calcium lactate at 3%, while the lowest one was significantly attained by control after 60 days of cold storage in both seasons.

The ascorbic acid content of fruits gradually decreased with increasing storage duration; however, foliar treatments helped reduce the rate of this decline. According to **Umebese and Bankole (2013),** foliar application of SA can enhance nitrate reductase enzyme activity, which is associated with a slower rate of ascorbic acid reduction.

These results are in line with those obtained by **El-Shemy (2019)** on Ponkan mandarin and **Kavanagh *et al.* (2026)** on Lane Late Navel Oranges and Summerina Mandarins, they found that fruits treated with salicylic acid had the highest fruit juice content of vitamin C compared to the untreated citrus with storage period advanced. On the other hand, **Riaz *et al.* (2020)** on sweet orange and **El-Bana and Ennab (2023)** on mandarin fruits, they reported that calcium lactate treatments significantly maintain the vitamin C of fruits during cold storage.

Table (12). Effect of foliar application of salicylic acid (SA) and calcium lactate (CL) on fruit juice vitamin C content (mg /100 ml juice) of "Balady" mandarin during cold storage over both seasons

	1st season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	38.3	32.6	27.3	21.9	20.5	28.1
1% CL	38.8	34.0	30.9	25.3	23.7	30.5
2% CL	39.3	34.7	31.4	25.9	24.2	31.1
3% CL	40.4	35.6	31.8	26.4	24.7	31.8
500ppm SA + 1% CL	40.6	36.8	32.3	27.9	26.1	32.7
500ppm SA + 2% CL	41.1	37.7	32.5	28.3	26.5	33.2
500ppm SA + 3% CL	41.3	38.1	34.7	31.8	29.7	35.1
Control	35.7	31.2	26.9	21.1	20.2	27.0
Means (D)	39.4	35.1	31.0	26.1	24.4	
L.S.D. at 0.05	(T) =7.9		(D) =6.2		(TXD) =17.7	
	2nd season					
Date (D)	**Days in cold storage (D)**					
Treatment (T)	**0**	**15**	**30**	**45**	**60**	**Means (T)**
500ppm SA	39.2	34.7	29.5	19.7	19.2	28.5
1% CL	39.3	35.4	29.9	20.3	19.8	28.9
2% CL	39.5	35.7	31.6	22.4	21.8	30.2
3% CL	39.8	35.9	32.0	23.7	23.1	30.9
500ppm SA + 1% CL	40.3	36.3	32.2	24.1	23.5	31.3
500ppm SA + 2% CL	40.5	36.4	33.2	27.3	26.6	32.8
500ppm SA + 3% CL	40.6	36.9	33.5	29.3	28.9	33.8
Control	38.6	33.6	27.6	18.4	18.3	27.3
Means (D)	39.7	35.6	31.2	23.2	22.7	
L.S.D. at 0.05	(T) =6.4		(D) =5.1		(TXD) =14.3	

4. Conclusion

Based on the obtained results, it can be concluded that the foliar application of salicylic acid (SA) and calcium lactate (CL) is an effective and cost-efficient strategy to enhance the yield, fruit quality, and postharvest performance of "'Balady'" mandarin. Combined or individual applications of SA and CL significantly improved overall yield and fruit quality attributes while mitigating the adverse effects of prolonged storage. Specifically, foliar sprays of salicylic acid at **500 ppm** and calcium lactate at **3%** were most effective not only in yield and fruit quality but also in reducing physiological weight loss and decay, while maintaining fruit tissue firmness and ascorbic acid content during extended cold storage compared to the control.

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تأثير الرش الورقي بحمض الساليسيليك ولاكتات الكالسيوم على المحصول والجودة والقدرة التخزينية لثمار اليوسفي البلدي

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الملخص

أجريت هذه الدراسة على مدار موسمين متتاليين (2021-2022 ، 2022-2023) على أشجار يوسفي بلدي (*Citrus reticulata*) عمرها 21 عاماً ، مثمرة ومطعومة على أصل النارنج، بمزرعة خاصة بمركز أشمون - بمحافظة المنوفية فى مصر. هدفت الدراسة إلى بحث تأثير الرش الورقي بحمض الساليسيليك ولاكتات الكالسيوم على المحصول وجودة الثمار والقدرة التخزينية لها . الأشجار منزرعة على مسافات 5×5 متر في تربة طينية طميية وتروى بنظام الري بالغمر. شملت التجربة علي ثماني معاملات: الرش الورقي بحمض الساليسيليك بتركيز 500 جزء في المليون وثلاثة تركيزات من لاكتات الكالسيوم (1%، 2%، 3%) تم إجرائها إما بشكل منفرد أو بالاشتراك مع بعضها البعض، بالإضافة إلى معاملة المقارنة (الرش بالماء). تم تطبيق جميع المعاملات رشاً على الأوراق مرتين: الأولى بعد مرحلة العقد (عندما وصل قطر الثمرة إلى 3-4 مم، أي في منتصف شهر مايو)، والثانية في مرحلة ما قبل التلوين (في أواخر شهر سبتمبر). حُفظت ثمار جميع المعاملات تحت ظروف التخزين المبرد عند درجة حرارة 5±1 درجة مئوية ورطوبة نسبية تتراوح بين 90-95% لمدة 60 يوماً. تم اجراء تقييم جودة الثمار عند الحصاد وخلال فترة التخزين المبرد. وأظهرت النتائج أن المعاملة المشتركة بحمض الساليسيليك (500 جزء في المليون) ولاكتات الكالسيوم (3%) حققت أفضل النتائج فيما يتعلق بزيادة المحصول وتحسين خصائص جودة الثمار، كما أطالت فترة صلاحية الثمار للتخزين لثمار و ذلك من خلال تقليل الفقد الفسيولوجي في الوزن ونسبة التلف، والحفاظ على صلابة الثمار ومحتواها من حمض الأسكوربيك، وتأخير التغيرات في محتوى الثمار من المواد الصلبة الذائبة الكلية والحموضة مقارنة بمعاملة المقارنة، وذلك خلال فترات التخزين المبرد في كلا الموسمين.

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