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Effect of pre-harvest calcium sprays on yield, physical characteristics, and shelf life of mango (*Mangifera indica* L.) cv. Kesar

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Abstract

The experiment entitled "Effect of pre-harvest application of chemicals on yield, quality, and shelf Life of mango (*Mangifera indica* L.) cv. Kesar" was conducted during the year 2024-2025 at the Instructional cum Horticulture Farm and Nursery, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. In this experiment, uniformly grown five-year-old mango trees of cv. Kesar were tested for their physical and physiological characteristics under pre-harvest foliar sprays of Calcium chloride (CaCl_2) and Calcium nitrate ($\text{Ca}(\text{NO}_3)_2$) at 1% and 2% concentrations, applied at 15 and 30 days before harvest (DBH), along with a control. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments and three replications. In the physical parameters, the treatment T_8 (2% Calcium nitrate at 30 DBH) recorded the maximum fruit length (12.80 cm), fruit diameter (8.46 cm), fruit weight (391.00 g), and volume of fruit (384.80 ml). The maximum number of fruits per tree (78.67 fruits) was recorded in treatment T_4 (2% Calcium chloride at 30 DBH). In the physiological parameters evaluated over a 15-day storage period, treatment T_4 (2% Calcium chloride at 30 DBH) proved to be the most superior, maintaining the maximum fruit firmness (3.50 kg/cm^2) while recording the significantly minimum physiological loss in weight (8.48%) and minimum spoilage (16.67%). Furthermore, the T_4 treatment significantly delayed the ripening process to a maximum of 13.67 days and extended the overall shelf life to a maximum of 17.67 days.

Keywords: Mango cv. Kesar, pre-harvest application, calcium chloride, calcium nitrate, physical and physiological parameters, shelf life

Introduction

The mango (*Mangifera indica* L.) is an ancient tropical fruit, celebrated as the "king of fruits" and classified in the Anacardiaceae family. Botanically, the genus *Mangifera* comprises over 69 distinct species, but *Mangifera indica* is the most socio-economically significant and globally cultivated species. The 'Indo-Burma' region is generally accepted as the center of origin of the fruit. India maintains its undisputed global leadership in mango production, contributing approximately 50% of the world's total output, making it a pivotal component of the nation's agricultural economy.

Mango is a highly nutritious fruit, particularly noted for its high vitamin A content (approximately 4800 IU), ascorbic acid (Vitamin C), and dietary fiber. The biochemical composition of the mango pulp makes it a potent functional food, containing a unique array of phytochemicals, particularly polyphenols like mangiferin, which have been extensively researched for their pharmacological properties. Among the vast germplasm, the Kesar cultivar, commonly referred to as the "queen of mangoes," is highly valued for its exceptional keeping quality, firm flesh, and vibrant saffron-orange pulp with an exceptionally high pulp-to-stone ratio. Due to its robust field performance and higher, more consistent yields compared to varieties like Alphonso, Kesar has seen a significant expansion in its cultivation area within Maharashtra.

Despite its high demand, the supply chain for fresh mangoes is fraught with challenges because mango is a highly climacteric fruit, exhibiting a distinct surge in respiration and a massive burst of ethylene production immediately after harvest. Post-harvest losses for tropical fruits are significant, accounting for approximately 20 to 30 percent of total production.

These losses result from continuous, irreversible physiological changes, specifically cell wall degradation caused by enzymes such as polygalacturonase (PG), pectin methylesterase (PME), and cellulase, which break down the pectic substances in the middle lamella and lead to rapid over-ripening and senescence.

To mitigate these losses, pre-harvest interventions are gaining importance over reactive post-harvest methods. Specifically, the application of calcium salts—like Calcium Nitrate ($\text{Ca}(\text{NO}_3)_2$) and Calcium Chloride (CaCl_2)—is a highly promising strategy. Calcium is integral to the structural integrity of the cell wall, where it forms cross-bridges in the middle lamella, effectively reinforcing the fruit tissue, maintaining fruit firmness, and delaying the sensitivity of the fruit to ethylene. Considering the above facts, the present study entitled “Effect of pre-harvest application of chemicals on yield, quality and shelf life of mango (*Mangifera indica* L.) cv. Kesar” was planned to investigate the optimum concentration and timing of pre-harvest calcium sprays to enhance yield, market quality, and shelf life.

Materials and Methods

The present investigation was conducted at the Instructional cum Horticulture Farm and Nursery, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, during the year 2024-2025. The experiment was carried out on five-year-old, uniformly grown mango trees of cv. Kesar, planted under a high-density planting system at a spacing of 5 x 5 m. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments and three replications, utilizing two trees per treatment. The treatments comprised pre-harvest foliar sprays of Calcium chloride (CaCl_2) and Calcium nitrate ($\text{Ca}(\text{NO}_3)_2$) at 1% and 2% concentrations, applied at 15 and 30 days before harvest (DBH), along with a control (water spray).

Observations were recorded on yield, physical dimensions, biochemical quality, and physiological parameters. Fruit length and diameter were measured using a Digital vernier caliper, while fruit volume was determined by the water displacement method. Fruit weight was recorded using a calibrated weighing scale, and the total number of fruits per tree was counted at harvest.

Physiological parameters were evaluated by storing the harvested fruits under ambient conditions. Physiological loss in weight (PLW) was calculated based on initial and final weights recorded at five-day intervals, while flesh firmness was measured using a penetrometer. Spoilage was expressed as the percentage of visibly decayed or rotten fruits. Days to ripening and total shelf life were determined through daily visual observation and textural evaluation until the fruit reached the optimum eating stage and subsequent decay.

Statistical Analysis

The data recorded for yield, quality, and physiological parameters were statistically analyzed as per the standard procedure for Randomized Block Design described by Panse and Sukhatme (1985) [8]. Mean differences were tested by the 'F' test at a five percent level of significance, and the Critical Difference (CD) at 5 percent was used for the comparison among treatments.

Results and Discussion

1. Yield Parameters

1.1 Fruit length (cm)

The maximum fruit length was recorded in the treatment T₈ (2% Calcium nitrate at 30 DBH) with 12.80 cm, which was statistically at par with treatments T₇ (12.40 cm), T₆ (12.00 cm), T₅ (11.70 cm), and T₄ (11.50 cm), whereas the minimum fruit length was recorded in the T₉ control (9.80 cm). The increase in fruit length might be attributed to the fact that calcium is essential for the structural integrity of both the cell wall and plasma membranes, which promotes cell division and cell elongation. Similar positive influences on physical parameters like fruit size with the application of calcium nitrate were reported by Alila and Achumi (2010) [1] and Karemera and Habimana (2014) [5]. The general pattern of progressive fruit length increment also conforms to the observations recorded by Banik and Sen (2004) [2] and Dutta and Dhua (2004) [4].

1.2 Fruit diameter (cm)

The maximum fruit diameter was recorded in T₈ (2% Calcium nitrate at 30 DBH) at 8.46 cm, which was statistically at par with treatments T₇ (8.22 cm), T₆ (8.06 cm), T₅ (7.84 cm), and T₄ (7.76 cm), whereas the minimum was recorded in the T₉ control (7.16 cm). The observed variation could be due to calcium compounds significantly improving the physical parameters of the fruit by maintaining cell wall rigidity and promoting cell enlargement. The nitrogen present in Calcium nitrate also stimulates rapid cell division and expansion, leading to an increase in fruit girth. Similar results were reported by Alila and Achumi (2010) [1], Karemera and Habimana (2014) [5], and Chatterjee *et al.* (2005) [3].

1.3 Fruit weight (g)

The maximum fruit weight was recorded in T₈ (2% Calcium nitrate at 30 DBH) with 391.00 g, which was statistically at par with treatments T₇ (380.00 g), T₆ (369.00 g), and T₅ (358.00 g), while the minimum fruit weight was recorded in the T₉ control (291.00 g). The differences in fruit weight indicate that calcium is essential for maintaining the structural integrity of the cell wall, which significantly reduces the physiological loss in weight and helps retain maximum moisture and mass within the fruit. Furthermore, the nitrogen supplied by Calcium nitrate supports cellular expansion and the accumulation of photosynthates. The findings are in close agreement with those reported by Rajkumar *et al.* (2006) [9], Lechaudel (2005) [6], and Mannan *et al.* (2003) [7].

1.4 Volume of fruit (ml)

The maximum fruit volume was recorded in treatment T₈ (2% Calcium nitrate at 30 DBH) at 384.80 ml, which was statistically at par with treatments T₇ (374.20 ml), T₆ (363.20 ml), and T₅ (352.60 ml), whereas the minimum fruit volume was recorded in the T₉ control (285.60 ml). The variation may be attributed to the crucial role calcium plays in maintaining cell membrane integrity and promoting cell enlargement, which directly contributes to the overall expansion of fruit tissues. Additionally, the availability of nitrogen from Calcium nitrate accelerates cell division and the accumulation of water and food materials within the cells. Similar findings were reported by Karemera and Habimana (2014) [5] and Dutta and Dhua (2004) [4].

1.5 Number of fruits per tree

The maximum number of fruits per tree was recorded in T₄ (2% Calcium chloride at 30 DBH) with 78.67 fruits, which was statistically at par with treatments T₃ (75.00 fruits) and T₁ (68.00 fruits), whereas the minimum was recorded in T₇ (55.00 fruits). The variation may be attributed to the physiological role of calcium in delaying the natural abscission process. Calcium acts as a vital binding agent in

the cell wall, reinforcing the middle lamella in the abscission zone of the fruit stalk and suppressing the synthesis of ethylene, a major hormonal trigger for fruit drop. This structural reinforcement makes the pedicel less susceptible to the action of cell wall-degrading hydrolytic enzymes, resulting in significantly lower pre-harvest fruit drop.

Table 1: Effect of pre-harvest application of chemicals on physical characteristics and yield of mango cv. Kesar

Treatments	Length of fruit (cm)	Diameter of fruit (cm)	Weight of fruit (g)	Volume of fruit (ml)	No. of Fruits per tree
T ₁	10.9	7.44	320	314.6	68 (8.24)
T ₂	11.2	7.62	330	324.6	63 (7.93)
T ₃	11	7.54	326	319.6	75 (8.66)
T ₄	11.5	7.76	349	342.6	78.67 (8.86)
T ₅	11.7	7.84	358	352.6	65 (8.06)
T ₆	12	8.06	369	363.2	58 (7.61)
T ₇	12.4	8.22	380	374.2	55 (7.41)
T ₈	12.8	8.46	391	384.8	57 (7.54)
T ₉	9.8	7.16	291	285.6	61.33 (7.83)
SE(m)±	0.51	0.24	13.53	13.4	0.24
CD at 5%	1.5	0.72	40.58	40.19	0.7
CV%	7.72	5.33	6.78	6.82	5.08

* No. of fruits per tree (values in parentheses are square-root transformed)

3. Physiological Parameter

3.1 Physiological loss in weight (%)

A continuous and progressive increase in the physiological loss in weight (PLW) of mango fruits was observed across all treatments as the storage period advanced. At 15 days, the significantly minimum physiological loss in weight was recorded in treatment T₄ (2% Calcium chloride at 30 DBH) with 8.48%. Conversely, the significantly maximum weight loss (16.06%) was recorded in the T₉ control treatment. This continuous loss in mass is a natural consequence of the physiological processes of transpiration and respiration. The significant reduction in PLW in calcium-treated fruits is attributed to the physiological role of calcium in preserving cell membrane integrity and reinforcing the cell wall architecture. Exogenous calcium strongly binds with pectic substances to thicken the middle lamella, which restricts cellular permeability, retards the respiratory rate, and

effectively minimizes moisture evaporation from the fruit surface. These observations are in strong agreement with the findings of Karemera and Habimana (2014) ^[5] and Swaminathan *et al.* (2016) ^[10].

3.2 Firmness (kg/cm²)

The firmness of mango fruits exhibited a progressive decline from the day of harvest up to the end of the storage period across all treatments. Towards the end of the storage period (15 days), the significantly maximum firmness (3.50 kg/cm²) was observed in treatment T₄ (2% Calcium chloride at 30 DBH). However, the significantly minimum firmness was recorded in the T₉ control with a remarkably low value of 0.35 kg/cm². The loss of fruit firmness is primarily caused by the enzymatic degradation of insoluble pectic substances into soluble forms within the cell wall.

Table 2: Effect of pre-harvest chemical treatments on physiological parameters of mango cv. Kesar during storage

Character	Days After Harvesting	T ₁	T ₂	T ₃	T ₄	T ₄	T ₆	T ₇	T ₈	T ₉	SE(m)±	CD at 5%	CV%
Physiological Loss in Weight (%)	0	0	0	0	0	0	0	0	0	0			
	5	3.66	3.75	3.11	2.83	4.41	4.54	4.05	4.16	5.35	0.14	0.43	6.27
	10	7.32	7.5	6.23	5.66	8.82	9.09	8.11	8.33	10.71	0.29	0.89	6.42
	15	10.97	11.25	9.35	8.48	13.23	13.63	12.16	12.5	16.06	0.44	1.33	6.44
Firmness (kg/cm ²)	0	6.84	6.75	7.25	7.45	6.14	6.05	6.45	6.36	5.25	0.06	0.18	1.6
	5	5.35	5.2	5.86	6.2	4.5	4.4	4.85	4.75	3.25	0.06	0.18	2.1
	10	3.81	3.65	4.5	4.9	2.9	2.8	3.25	3.15	1.2	0.05	0.15	2.6
	15	2.1	1.95	2.95	3.5	1.35	1.25	1.7	1.6	0.35	0.04	0.12	3.8
Spoilage% (values in parentheses are Arcsine transformed)	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	16.67 (24.10)	0.43	1.29	27.83
	10	8.33 (16.78)	16.67 (24.10)	8.33 (16.78)	0	25.00 (30.00)	25.00 (30.00)	16.67 (24.10)	16.67 (24.10)	83.33 (65.90)	1.73	5.2	11.66
	15	83.33 (65.90)	83.33 (65.90)	25.00 (30.00)	16.67 (24.10)	91.67 (73.22)	100.00 (90.00)	75.00 (60.00)	75.00 (60.00)	100.00 (90.00)	2.04	6.12	5.69

Calcium acts as a crucial binding agent, forming calcium pectate cross-linkages in the middle lamella, which provides rigidity, suppresses the overall respiration rate, and restricts

the action of cell wall-degrading enzymes. These findings are in strong agreement with the reports of Karemera and Habimana (2014) ^[5] and Swaminathan *et al.* (2016) ^[10].

3.3 Spoilage (%)

The spoilage of mango fruits was significantly influenced by the pre-harvest chemical applications. By the end of the 15-day storage period, the significantly minimum spoilage (24.10 transformed value) was recorded in treatment T₄ (2% Calcium chloride at 30 DBH) whereas, the significantly maximum spoilage (90.00 transformed value, effectively 100%) was recorded in the T₉ control treatment. Spoilage during storage is a natural consequence of senescence, over-ripening, and subsequent high susceptibility to post-harvest pathogenic infections like anthracnose and stem-end rot. Calcium chloride highly effective because it combines with pectic acid to form a rigid 'calcium pectate' network in the middle lamella. This biochemical reinforcement preserves structural integrity, making it highly resistant to cell wall-degrading enzymes and physically tougher for fungal pathogens to penetrate. The results are supported by the findings of Karemera and Habimana (2014) [5] and Swaminathan *et al.* (2016) [10].

4. Days to ripening

The number of days required for the ripening of fruit was significantly altered by the applied treatments. The significantly maximum number of days to ripening (13.67 days) was recorded in treatment T₄ (2% Calcium chloride at 30 DBH), whereas the minimum number of days to ripening (6.33 days) was observed in the T₉ control treatment. The rapid ripening in control fruits is a consequence of the sudden climacteric rise in respiration rate and the

uninhibited synthesis of ethylene gas. Calcium chloride effectively delayed this process by accumulating in the fruit cell walls and forming cross-bridges. This structural reinforcement acts as a physical barrier that restricts gaseous exchange, suppresses the overall respiration rate, and significantly inhibits the autocatalytic production of ethylene. These findings are in strong agreement with the reports of Swaminathan *et al.* (2016) [10] and Karemera and Habimana (2014) [5].

5. Shelf life (Days)

The shelf life of mango fruit was highly significantly affected by the pre-harvest chemical applications. The significantly maximum shelf life (17.67 days) was recorded in treatment T₄ (2% Calcium chloride at 30 DBH), while the significantly minimum shelf life (9.33 days) was observed in the T₉ control treatment. The early onset of spoilage in the control is due to an uninhibited respiration rate, rapid ethylene synthesis, higher physiological loss in weight, and accelerated breakdown of cell wall constituents. Conversely, calcium incorporation enhances cellular rigidity, reduces cell membrane permeability, minimizes the transpiration rate, and restricts the activity of cell wall-degrading enzymes. Consequently, the entire ripening process is delayed, extending the physiological longevity of the fruit. These findings are in strong conformity with the observations of Swaminathan *et al.* (2016) [10] and Karemera and Habimana (2014) [5].

Table 3: Shelf life (Days)

Treatments	Days to ripening	Shelf life
T ₁	10.33 (3.29)	13.67 (3.76)
T ₂	10.00 (3.24)	13.33 (3.72)
T ₃	11.67 (3.49)	16.05 (4.07)
T ₄	13.67 (3.76)	17.67 (4.26)
T ₅	8.33 (2.97)	11.33 (3.44)
T ₆	8.00 (2.92)	11.00 (3.39)
T ₇	9.33 (3.14)	12.33 (3.58)
T ₈	9.00 (3.08)	12.00 (3.54)
T ₉	6.33 (2.61)	9.33 (3.14)
SE(m)±	0.05	0.06
CD at 5%	0.15	0.18
CV%	2.73	2.84

* Values in parentheses are square-root transformed

Conclusion

Based on the results of the present investigation, it can be concluded that the pre-harvest foliar application of calcium salts significantly improves the yield, physical dimensions, and post-harvest longevity of mango cv. Kesar.

The application of (T₈) 2% Calcium nitrate at 30 days before harvest (DBH) is the most effective treatment for maximizing the physical dimensions and yield components of the fruit, recording the highest fruit length, diameter, weight, and volume. Conversely, the pre-harvest spray of (T₄) 2% Calcium chloride at 30 DBH emerges as the most superior treatment for maximizing fruit retention (highest number of fruits per tree) and enhancing physiological longevity during ambient storage. This treatment effectively maintains fruit firmness, minimizes physiological loss in weight and spoilage, delays the ripening process, and extends the overall shelf life of the mangoes to a maximum of 17.67 days.

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