

Influence of Pre-Harvest Foliar Application of Micronutrients on Physico-Biochemical Attributes and Shelf Life of Mango (*Mangifera indica* L.) cv. Amrapali

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ABSTRACT

This study evaluated the effects of various foliar nutrient treatments on the physical biochemical characteristics and shelf life of Amrapali mango fruit. Treatments involving combinations of calcium chloride, borax, and zinc sulfate significantly enhanced pulp weight, fruit weight, pulp percentage, total sugar concentration, total soluble solids (TSS), and the TSS: titratable acidity (TA) ratio compared to the control. The greatest improvements were observed in treatment T5 (Calcium chloride 3.0% + Borax 0.5% + Zinc sulfate 0.3%). Additionally, all treatments reduced peel weight, stone weight, acidity, and physiological weight loss during storage, with T5 showing the most pronounced effects in maintaining fruit firmness and reducing the weight loss. These results suggest that the foliar application of these nutrients promotes fruit quality by enhancing carbohydrate accumulation, accelerating starch-to-sugar conversion, and delaying senescence, thereby improving the yield and postharvest fruit attributes of Amrapali mangoes.

Keywords : Amrapali mango, Foliar nutrient treatment, Calcium chloride, Borax, Zinc sulfate, Fruit quality

Introduction

The mango, scientifically known as *Mangifera indica* L., is part of the Anacardiaceae family and is one of India's most vital fruit crops, even earning the title of the national fruit. Originating from the Indo-Burma region (Pandey, 2015), mangoes have been cultivated in the Indian subcontinent for nearly 4000 years. India leads the world in mango production, accounting for 50% of the global output (Barman *et al.*, 2015). Mangoes, often referred to as the "King of Fruits," are the most beloved tropical fruits worldwide. They are rich in potassium and serve as an excellent source of vitamins A and C. The Amrapali

variety, known for its regular bearing and late maturation, experiences a 38% post-harvest loss at different marketing stages (Murthy *et al.*, 2009). Key post-harvest diseases include anthracnose (*Colletotrichum gloeosporioides*), stem-end rot (*Diplodiam entalensis*), and soft rot, which impact mango production (Panday and Dinesh, 2010). These diseases can originate in the field and remain inactive within the fruit until conditions become favorable for their activation. This significantly affects mango quality and shelf life, leading to black spots on the fruit skin during ripening and storage. Consequently, a pre-harvest application of an effective treatment is necessary to prevent these diseases and minimize the

additional chemical residues from post-harvest treatments (Rajkumar, 2014). Applying calcium chloride (CaCl_2) as a foliar spray before harvest boosts mango productivity by reducing fruit drop, enhancing quality, minimizing weight loss, delaying ripening, and extending storage life, thereby influencing various physicochemical parameters (Karemera and Habimana, 2014). Boron plays a role in sugar translocation, cell wall synthesis and structure, and lignification, all of which affect fruit quality. It supports pollination and viable seed production, both of which are crucial for normal fruit development. This is linked to some of the functions of calcium (Suman *et al.*, 2017). The sequential pre-harvest foliar application of Ca and boron significantly reduced physiological issues in the strawberry cv. Chandler (Singh *et al.*, 2007). Maximum fruit set, length, breadth, weight, retention, yield, pulp weight, pulp–stone ratio, total soluble solids (TSS), and sugar content were achieved when 0.4% borax was applied to new growth flushes before inflorescence, while fruit cracking, stone weight, and peel were minimized. The sequential pre-harvest foliar application of Ca and boron was highly effective in reducing physiological problems in the strawberry cv. Chandler (Singh *et al.*, 2007). Applying 0.4% borax to new growth flushes before flowering led to optimal fruit set, size, weight, retention, yield, pulp weight, pulp-to-stone ratio, total soluble solids (TSS), and sugar content, while minimizing fruit cracking, stone weight, and peel in the litchi cv. Dehradun (Kaur, 2017). According to Meena *et al.*, (2014), Zinc is vital for enzymatic processes and enhances growth and development by increasing auxin levels and aiding in fruit retention. Research on the pre-harvest use of various chemicals and plant growth regulators in mangoes is limited. Efforts will be made to standardize the pre-harvest application rates of Ca, boron, and Zn in mango cultivation. Considering these factors, the mango variety Amrapali was selected for this study.

Materials and Methods

The experiment was carried out at Patiyapura farm, College of Agriculture, Parul University, during the period 2024-25 on 15-year-old mango trees of the Amrapali variety, which were of similar vigor and size. The location is in a sub-tropical region with coordinates 32.73° N latitude and 74.87° E longitude, and it is situated at an elevation of 327 meters above

sea level. The annual rainfall in this area is approximately 1,200 mm. Foliar nutrient application was conducted in the morning when the mangoes were at the pea stage. The experimental site is located in Patiyapura, Vadodara district, Gujarat, within the sub-tropical agro-climatic zone, with coordinates around 22.30° N latitude and 73.20° E longitude. The area is at an elevation of about 35-40 meters above sea level and has an average annual rainfall of approximately 800–810 mm, primarily during the southwest monsoon season. Nutrient application was done in the morning at the pea stage to improve absorption and minimize spray loss. The different treatment combinations used were T1 (Water Spray), T2 (Calcium Chloride at 4.0%), T3 (Borax at 0.6%), T4 (Zinc Sulfate at 0.4%), T5 (Calcium Chloride at 4.0% + Borax at 0.6%), T6 (Calcium Chloride at 4.0% + Borax at 0.6%), T7 (Calcium Chloride at 4.0% + Zinc Sulfate at 0.4%), T8 (Borax at 0.6%), and T9 (Borax at 0.6% + Zinc Sulfate at 0.4%). The weights of the pulp, stone, peel, and entire fruit were measured in three repetitions for each treatment. The pulp percentage was calculated by dividing the pulp weight by the total fruit weight, and the results were presented as percentages. The stone weights were also recorded. Total soluble solids, total sugars, reducing sugars, and titratable acidity were analyzed following standard methods from AOAC (1995). Ascorbic acid content was measured using the method described by Ruck (1969), with some modifications. To determine yield, the total number of fruits harvested from each replication was counted and weighed using an electronic balance, and the yield was recorded in kilograms per tree. Weight loss during post-harvest storage was measured by weighing both treated and control fruits on days 0, 3, 6, 9, 12, and 15. Weight loss was calculated as the difference between the initial and subsequent fruit weights, expressed as a percentage. The formula used for calculating weight loss (P.L.W) is $(\text{Initial weight} - \text{Final weight} / \text{Initial weight}) \times 100$, as suggested by Srivastava and Tandon (1968). The experiment was conducted using a randomized block design (RBD) with three replications, each consisting of one tree. All data collected during the study were statistically analyzed according to the guidelines provided by Panse and Sukhatme (2000).

Results and Discussion

As shown in Table 1, all treatments resulted in an

increase in pulp weights when compared to the control group. The treatment T5, which included Calcium chloride 3.0%, Borax 0.5%, and Zinc sulfate 0.3%, recorded the highest pulp weight at 152.53 g. This was followed by T8, consisting of Borax 0.5% and Zinc Sulfate 0.3%, with a pulp weight of 134.80 g, while the control group, T1, had the lowest pulp weight. The increase in pulp weight is likely due to enhanced fruit size and weight, attributed to the accumulation of photo synthates in mature fruits, facilitated by foliar nutrients. Similar findings were reported by Bhowick *et al.*, (2012) for Amrapali mangoes treated with 0.75% borax, which resulted in maximum fruit weight. The highest stone weight was observed in T8 (Borax 0.5% + Zinc sulfate 0.3%), followed by T5 (Calcium chloride 3.0% + Borax 0.5% + Zinc sulfate 0.3%). The control, T1, recorded the lowest stone weight at 25.30 g. These results are in line with those of Singh *et al.* (2017) and Hassanzai *et al.* (2021) for mango cv. Amrapali treated with a nutrient mixture. All treatments led to significantly lower peel weights compared to T1 (control). The pulp percentages from all treatments were notably higher than those from the control. The highest fruit weight, 197.19 g, was recorded in T5 (Calcium chloride 3.0% + Borax 0.5% + Zinc sulfate 0.3%), while T1 had the lowest fruit weight at 152.15 g. Kumar *et al.* (2004) noted a significant increase in fruit weight with foliar spray of zinc, boron, and copper, and Jitendra *et al.*, (2017). The highest pulp percentage, 77.36%, was found in T5 (Calcium chloride 3.0% + Borax 0.5% + Zinc sulfate 0.3%), followed by T8 (Borax 0.5% + Zinc sulfate 0.3%) at 73.10%, with the lowest pulp percentage, 62.83%, in treatment T1 (control). These findings are consistent with those of Bhusan and Panda (2015), Bhusan *et al.* (2015), and Yadav *et al.* (2018). The control group, T1, had the highest percentage of stones at 16.63%, whereas T5

al. (2021) for mango cv. Amrapali treated with a nutrient mixture. All treatments led to significantly lower peel weights compared to T1 (control). The pulp percentages from all treatments were notably higher than those from the control. The highest fruit weight, 197.19 g, was recorded in T5 (Calcium chloride 3.0% + Borax 0.5% + Zinc sulfate 0.3%), while T1 had the lowest fruit weight at 152.15 g. Kumar *et al.* (2004) noted a significant increase in fruit weight with foliar spray of zinc, boron, and copper, and Jitendra *et al.*, (2017). The highest pulp percentage, 77.36%, was found in T5 (Calcium chloride 3.0% + Borax 0.5% + Zinc sulfate 0.3%), followed by T8 (Borax 0.5% + Zinc sulfate 0.3%) at 73.10%, with the lowest pulp percentage, 62.83%, in treatment T1 (control). These findings are consistent with those of Bhusan and Panda (2015), Bhusan *et al.* (2015), and Yadav *et al.* (2018). The control group, T1, had the highest percentage of stones at 16.63%, whereas T5

Table 1. Effect of foliar nutrition on pulp weight, stone weight, peel weight and pulp/stone ratio of mango cv. Amrapali

Treatment	Pulp weight	Stone weight	Peel weight	Fruit weight	Pulp %	Stone %	Yield/plant (kg)
T1 Control	95.59	25.30	31.32	152.15	62.83	16.63	17.42
T2 Calcium chloride (3.0%)	115.2	26.38	28.21	164.52	70.03	16.03	20.23
T3 Borax (0.5%)	124.13	27.14	21.18	170.23	72.92	15.95	29.03
T4 Zinc sulphate (0.3%)	120.19	27.44	22.52	168.18	71.47	16.32	23.44
T5 Calcium chloride (3.0%) + Borax (0.5%) + Zinc sulphate (0.3%)	152.53	28.11	18.14	197.19	77.36	14.25	25.18
T6 Calcium chloride (3.0%) + Borax (0.5%)	126.46	27.55	19.82	173.23	73.00	15.91	24.45
T7 Calcium chloride (3.0%) + Zinc sulphate (0.3%)	122.50	26.59	22.5	168.19	72.83	15.81	24.59
T8 Borax (0.5%) + Zinc sulphate (0.3%)	134.80	28.48	18.43	182.19	73.10	15.63	25.85
CD at 5%	1.69	1.67	0.29	1.78	1.16	1.12	4.31
SE(m)	0.55	0.54	0.87	0.58	0.38	0.36	1.41

Table 2. Effect of foliar nutrition on total sugars, reducing sugars and non-reducing sugars of mango cv. Amrapali

Treatment	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	TSS (°Brix)	TA	TSS/TA
T1 Control	13.87	2.10	10.10	16	0.34	47.39
T2 Calcium chloride (3.0%)	14.14	2.18	11.77	16.73	0.32	59.46
T3 Borax (0.5%)	15.83	2.39	12.73	17.75	0.27	66.81
T4 Zinc sulphate (0.3%)	15.07	2.23	12.62	17.79	0.24	74.40
T5 Calcium chloride (3.0%) + Borax (0.5%) + Zinc sulphate (0.3%)	17.37	2.60	13.91	19.79	0.22	88.81
T6 Calcium chloride (3.0%) + Borax (0.5%)	16.67	2.53	14.30	16.57	0.27	60.49
T7 Calcium chloride (3.0%) + Zinc sulphate (0.3%)	15.48	2.36	13.40	16.33	0.24	67.37
T8 Borax (0.5%) + Zinc sulphate (0.3%)	16.95	2.54	14.41	18.47	0.26	72.96
CD at 5%	0.04	0.08	0.41	2.34	N/A	20.18
SE(m)	0.01	0.03	0.13	0.76	0.03	6.59

(Calcium chloride 3.0% + Borax 0.5% + Zinc sulfate 0.3%) had the lowest at 14.25%. T3 Borax (0.5%) achieved the highest production per tree at 29.03 kg, while T1 Control had the lowest yield at 17.42 kg per tree.

Boron has been recognized for its involvement in hormonal metabolism, which is associated with increased starch production and quicker carbohydrate transfer in plants that have been treated. These results are consistent with previous research on mangos by Singh and Maurya (2004), Singh *et al.* (2012), Singh *et al.* (2019) and Dheware *et al.* (2020). As shown in Table 2, the highest total sugar content was recorded at 17.37% for T5 (Calcium chloride 3.0% + Borax 0.5% + Zinc sulfate 0.3%), followed by 16.95% for T8 (Borax 0.5% + Zinc sulfate 0.3%), and 13.87% for T1 (control). The natural ripening process, which involves the enzymatic conversion of carbohydrates such as starch into sugars, may account for the increase in sugar content in mango fruits. Furthermore, Wahdan *et al.* (2011) observed an increase in fruit sugars, and we found that total reducing sugars were highest in T5 (calcium chloride 3.0% + borax 0.5% + zinc sulfate 0.3%) at 2.60%, followed by T8 at 2.54%, and T1 (control) at 2.10%. Wali *et al.* (2022) reported similar findings for guava. T5 (calcium chloride 3.0% + borax 0.5% + zinc sulfate 0.3%) showed the highest total soluble solids (T.S.S.) at 19.79 °Brix, while the control T1 had the lowest at 16 °Brix. The increase in TSS during fruit ripening may be due to the conversion of insoluble starch into soluble sugars and moisture loss (Koksal *et al.* 1994). All treatments effectively reduced the acidity of mature Kesar mangoes. According to the results, Amrapali with T5 (calcium chloride 3.0% + borax

0.5% + zinc sulphate 0.3%) had the lowest titratable acidity at 0.22%. The reduction in fruit acidity with pre-harvest nutrient spray could be attributed to increased carbohydrate translocation and metabolic conversion from acidity to sugar, possibly involving the reversal of the glycolytic pathway used in respiration, or both. Karemera and Habimana (2014) and Dhahiya *et al.* (2001) reported similar findings. T5 (calcium chloride 3.0% + borax 0.5% + zinc sulfate 0.3%) had the highest TSS: TA ratio (88.81), whereas T1 (control) had the lowest (47.39). By treating different fruits with various calcium sources, Peter *et al.* (1999) demonstrated that CaCl₂ can convert starch into sugar more rapidly than other substances. The results shown in Table 3 and Fig. 4 clearly indicate that different nutrients significantly reduced physiological weight. On the third, sixth, ninth, twelfth, and fifteenth days of storage, treatment T1 (control) experienced the most physiological weight

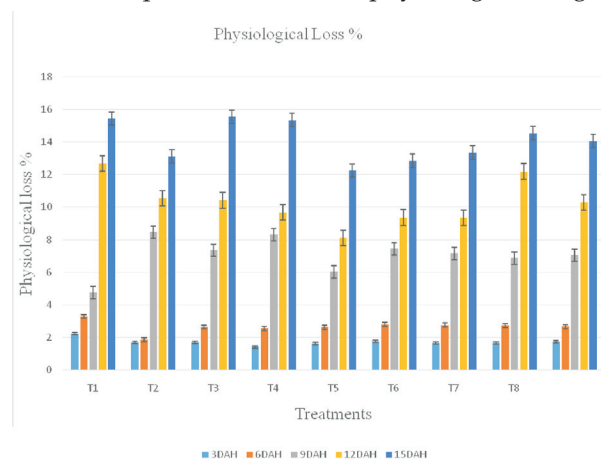


Fig. 1. Effect of different nutrients on Physiological Loss weight (%) of mango fruits cv. Amrapali

Table 3. Effect of different nutrients on Physiological Loss weight (%) of mango fruits cv. Amrapali

Treatments		PWL %					
		Days of Storage					Mean
		3 DAH	6 DAH	9 DAH	12 DAH	15 DAH	
T1	Control	2.22	3.28	4.75	12.68	15.45	7.68
T2	Calcium chloride (3.0%)	1.68	1.85	8.46	10.54	13.12	7.13
T3	Borax (0.5%)	1.67	2.63	7.35	10.42	15.56	7.53
T4	Zinc sulphate (0.3%)	1.40	2.54	8.32	9.68	15.36	7.46
T5	Calcium chloride (3.0%) + Borax (0.5%) + Zinc sulphate (0.3%)	1.61	2.62	6.02	8.1	12.25	6.12
T6	Calcium chloride (3.0%) + Borax (0.5%)	1.75	2.78	7.45	9.36	12.85	6.84
T7	Calcium chloride (3.0%) + Zinc sulphate (0.3%)	1.65	2.74	7.15	9.34	13.36	6.85
T8	Borax (0.5%) + Zinc sulphate (0.3%)	1.63	2.71	6.86	12.2	14.56	7.59
Mean		1.70	2.64	7.05	10.29	14.06	

loss (7.88%), whereas T5 (Calcium chloride 3.0% + Borax 0.5% + Zinc sulfate 0.3%) had the lowest (5.30), followed by T6 (Calcium chloride 3.0% + Borax 0.5%) (5.60). The data in the table suggest that several treatments significantly affected physiological weight loss. On the third, sixth, twelfth, and fifteenth days of storage, treatment T1 (Control) experienced the most physiological loss (7.68%), whereas treatment T5 (calcium chloride 3.0% + borax 0.5% + zinc sulphate 0.3%) experienced the lowest loss (6.12%). The consistency of calcium in the cell wall, which causes fruit firmness, respiratory rate retardation, and senescence delay, may be the reason for the reduction in weight loss caused by application (Singh *et al.*, 1993).

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Conflict of interest - The authors declare that there is no conflict of interests regarding the publication of this paper.

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