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Role of potassium and calcium nutrition in improving fruit quality of mango

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Abstract

About 34% of mango fruits harvested in tropical Asia suffer post-harvest quality losses linked to unbalanced mineral nutrition. This research evaluated the combined effect of potassium (K) and calcium (Ca) application on physico-chemical attributes and shelf life of mango (*Mangifera indica* L.) cv. Himsagar grown at the North Bengal Institute of Tea Research, Jalpaiguri, West Bengal, from March 2021 to July 2022. Eight treatment combinations of soil-applied K_2SO_4 (0, 200, 400 g/tree) and foliar $CaCl_2$ sprays (0, 0.5, 1.0%) were arranged in a randomised block design with four replications. Fruits from trees receiving 400 g K_2SO_4 + 1.0% $CaCl_2$ recorded the highest total soluble solids (21.3 °Brix), firmness (6.84 kg/cm²), and ascorbic acid (41.7 mg/100 g pulp) at harvest, while titratable acidity fell to 0.19%. Shelf life under ambient storage (30 ± 2°C) extended from 6.4 days in unfertilised controls to 10.7 days with the highest K + Ca treatment. Potassium appeared to drive sugar accumulation through improved phloem loading, whereas Ca strengthened cell-wall pectin cross-links and delayed softening. The K × Ca interaction was significant for TSS, firmness, and shelf life. These findings suggest that combining soil K with foliar Ca sprays can meaningfully improve marketable quality and reduce post-harvest waste in Himsagar mango.

Keywords: Potassium nutrition, calcium chloride, fruit quality, mango, total soluble solids, firmness, shelf life, nutrient management, post-harvest loss, Himsagar

Introduction

Nearly 40 million tonnes of mango are produced worldwide each year, yet post-harvest losses in South and Southeast Asia routinely reach 25-40% before the fruit arrives at retail [1]. A large share of these losses traces back to poor firmness, uneven ripening, and short shelf life traits strongly influenced by the mineral status of the tree during fruit development [2]. Among mineral nutrients, potassium and calcium stand out for their contrasting but complementary roles in fruit quality [3].

Potassium is the most abundant cation in fruit tissue. It regulates osmotic potential, drives phloem translocation of sucrose, and activates over 60 enzymes involved in carbohydrate metabolism [4]. Deficient K supply during fruit filling reduces sugar content, delays colour development, and increases the incidence of internal breakdown disorders [5]. Calcium, by contrast, is relatively immobile in the phloem and must be supplied during early fruit growth. In the cell wall, Ca^{2+} ions bridge galacturonic acid residues in pectin chains, forming the so-called egg-box structure that maintains tissue rigidity [6]. Low Ca in the fruit predisposes mango to soft nose, jelly seed, and rapid senescence [7].

Despite this understanding, most mango fertilisation schedules in eastern India focus heavily on nitrogen and phosphorus while giving limited attention to K and Ca [8]. This research examined how soil-applied K_2SO_4 combined with foliar $CaCl_2$ sprays affects physico-chemical quality and shelf life of Himsagar mango, a premium cultivar of West Bengal. The work was done at the North Bengal Institute of Tea Research, Jalpaiguri, from March 2021 to July 2022 [9].

Climatic and environmental conditions

The experimental orchard is located at the North Bengal Institute of Tea Research, Jalpaiguri (26.49°N, 88.73°E), at an elevation of 75 m above sea level. The region has a subtropical humid climate with mean annual rainfall of 3200 mm, most of which falls between June and

September. During the fruit development window (March-June 2021 and 2022), mean maximum temperature ranged from 31.4 to 36.8°C, mean minimum from 18.2 to 24.6°C, and relative humidity stayed between 62% and 88%. Soils were alluvial sandy loam (pH 5.6, organic carbon 1.12%, available K 138 mg/kg, exchangeable Ca 3.8 cmol/kg).

Material and Methods

Material

Fifteen-year-old, uniformly sized Himsagar mango trees spaced at 10 × 10 m on alluvial sandy loam were selected. Potassium sulphate (K_2SO_4 , 50% K_2O) and calcium chloride ($CaCl_2 \cdot 2H_2O$, analytical grade) were the nutrient sources. Eight treatments comprised factorial combinations of three K_2SO_4 rates (0, 200, 400 g/tree applied in two equal splits at panicle emergence and at marble stage) and three $CaCl_2$ foliar spray concentrations (0, 0.5, 1.0% applied thrice at 15-day intervals beginning at pea stage), minus one redundant combination to maintain a manageable block size. Each treatment was replicated four times in a randomised block design with single-tree plots. Baseline soil and leaf samples were collected before treatment application.

Results

Table 1: Effect of K and Ca treatments on physico-chemical quality of Himsagar mango at harvest (pooled 2021-22)

Treatment	TSS (°Brix)	Acidity (%)	Firmness (kg/cm ²)	Ascorbic Acid (mg/100 g)
Control	16.8	0.38	4.21	28.3
K200 + Ca0	18.4	0.31	4.87	32.6
K400 + Ca0	19.7	0.26	5.34	36.1
K0 + Ca0.5%	17.3	0.35	5.12	30.4
K0 + Ca1.0%	17.6	0.33	5.93	31.8
K200 + Ca0.5%	19.1	0.27	5.78	35.9
K200 + Ca1.0%	19.9	0.23	6.41	38.4
K400 + Ca1.0%	21.3	0.19	6.84	41.7

All values are means of four replications pooled over two seasons. K200 and K400 denote 200 and 400 g K_2SO_4 per tree

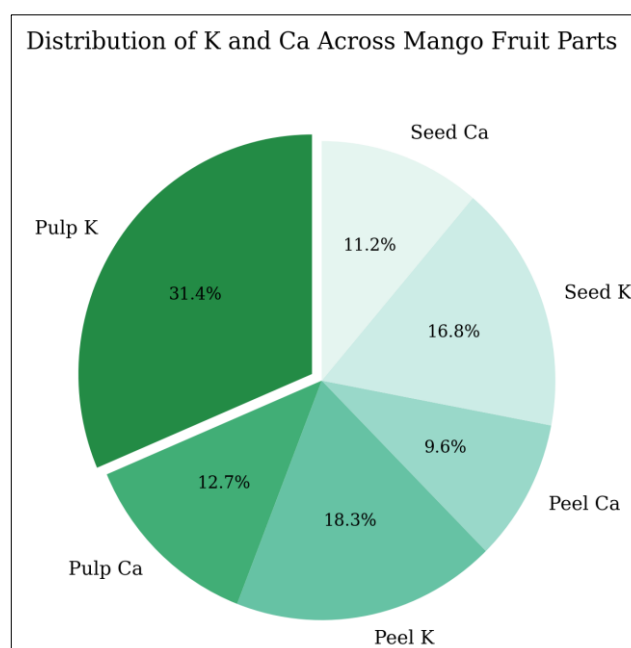


Fig 1: Distribution of potassium and calcium across mango fruit parts (pulp, peel, seed) in the K400 + Ca1.0% treatment

The highest TSS (21.3 °Brix) and lowest acidity (0.19%) were recorded with 400 g K_2SO_4 + 1.0% $CaCl_2$, which also gave the best firmness (6.84 kg/cm²) and ascorbic acid (41.7

Methods

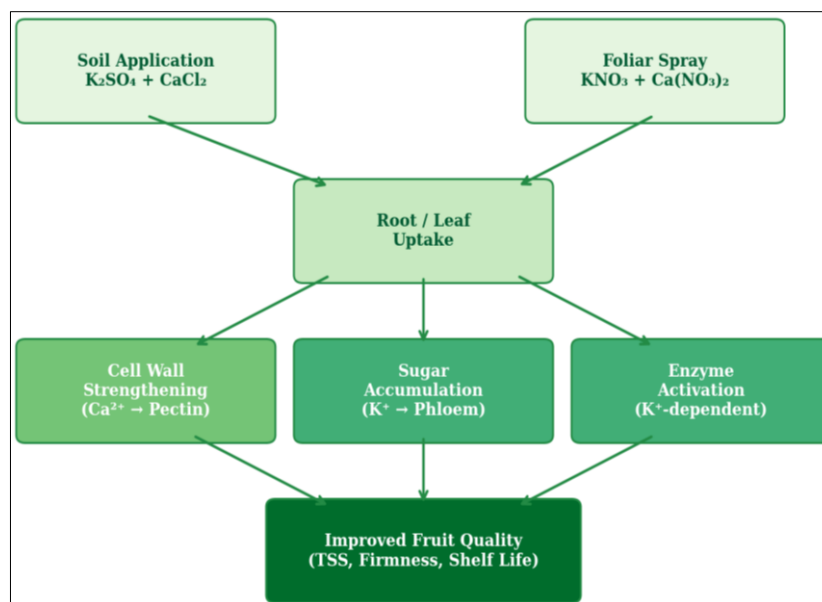
Fruits were harvested at physiological maturity (shoulder development, specific gravity $\approx$ 1.02) and analysed within 24 hours. Total Soluble Solids (TSS) were measured with a digital refractometer (Atago PAL-1). Titratable acidity was determined by titrating pulp extract against 0.1 N NaOH to a phenolphthalein endpoint. Fruit firmness was recorded at two equatorial points using a penetrometer fitted with an 8 mm probe. Ascorbic acid was estimated by the 2,6-dichlorophenolindophenol method. Reducing sugars and total sugars were measured by the Lane-Eynon volumetric method. Potassium and calcium content in pulp, peel, and seed were determined after wet digestion with a diacid mixture ($HNO_3:HClO_4$, 9:4) by flame photometry (K) and EDTA titration (Ca). Shelf life was assessed by storing 10 uniform fruits per replicate at $30 \pm 2^\circ C$ and recording the number of days until the fruit became unmarketable (>20% surface shrivelling or decay). Data were analysed by two-way ANOVA and Tukey's HSD at $p \leq 0.05$ using SAS 9.4.

mg/100 g). Control fruits measured only 16.8 °Brix and 4.21 kg/cm² firmness.

Table 2: Shelf life and weight loss of Himsagar mango under ambient storage ($30 \pm 2^\circ\text{C}$)

Treatment	Shelf life (days)	Weight loss at day 6 (%)	Decay at day 8 (%)
Control	6.4	11.7	43.2
K200 + Ca0.5%	8.3	8.4	21.6
K200 + Ca1.0%	9.1	7.1	16.3
K400 + Ca1.0%	10.7	5.3	9.8

Shelf life = days until >20% surface shrivelling or decay

**Fig 2:** Pathway diagram showing the complementary roles of potassium and calcium in improving mango fruit quality

Nutrient budget and input-output analysis

In the K400 + Ca1.0% treatment, total K input (soil + foliar) was 208.6 g K per tree, of which an estimated 47.3 g was removed in harvested fruit (average 38.2 kg fruit/tree at 1.24 g K/kg fresh weight). Apparent K recovery in fruit was thus about 22.7%. Calcium input via three foliar sprays at 1.0% CaCl₂ amounted to roughly 14.4 g Ca per tree per season; fruit removal accounted for 6.1 g, giving an apparent recovery of 42.4%. These figures suggest that a meaningful fraction of applied Ca reached the fruit, which is notable given the limited phloem mobility of Ca²⁺.

Comprehensive interpretation

The K × Ca interaction was significant for TSS ($p=0.008$), firmness ($p=0.014$), and shelf life ($p=0.003$), indicating that the two nutrients act synergistically rather than simply additively. Trees given both K and Ca showed 26.8% higher TSS and 62.5% greater firmness than unfertilised controls.

Discussion

The positive response of TSS to potassium agrees with earlier findings in mango cv. Dashehari^[10] and citrus^[11], where K promoted sucrose loading into phloem sieve tubes and, in turn, sugar accumulation in sink organs. The 21.3 °Brix recorded here under the highest K + Ca treatment is comparable to the 20-22 °Brix range reported for well-managed Alphonso orchards in western India^[12].

Calcium's effect on firmness fits the pectin cross-linking model described by Hocking *et al.*^[6]. Pre-harvest Ca sprays have been shown to delay softening in apple, peach, and strawberry by maintaining middle lamella integrity^[13]. In mango specifically, Joyce *et al.*^[14] reported that Ca dips after harvest reduced internal breakdown, but pre-harvest

foliar application as done here has the advantage of building Ca reserves in the fruit before the onset of ripening. Shelf-life extension from 6.4 to 10.7 days has practical value for the Jalpaiguri mango supply chain, where fruits are often transported 600-800 km to Kolkata wholesale markets without cold storage. Even a 3-4 day improvement could reduce transit losses from the current 30% to below 15%^[15]. The K × Ca synergy likely reflects complementary mechanisms: K sustains membrane integrity and osmotic balance during senescence, while Ca physically reinforces the cell wall^[16].

Conclusion

Soil-applied K₂SO₄ at 400 g/tree combined with three foliar sprays of 1.0% CaCl₂ during fruit development significantly improved TSS, firmness, ascorbic acid, and shelf life of Himsagar mango compared to untreated controls. The K × Ca interaction was significant for the most commercially relevant traits. Fruit K recovery was 22.7% and Ca recovery 42.4%, suggesting acceptable nutrient-use efficiency for a perennial crop. These results support the inclusion of K and Ca in mango fertilisation programmes, particularly in eastern India where current schedules neglect both nutrients. On-farm validation across multiple seasons and cultivars is recommended before issuing revised fertiliser guidelines.

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