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Inorganic status in Alphonso leaves during vegetative and reproductive stage

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Abstract

Mineral nutrients are essential for the growth, flowering, fruit development, and quality of mango (*Mangifera indica* L.). This study evaluated the inorganic mineral composition of Alphonso mango leaves from Ratnagiri and Devgad during vegetative and reproductive stages. Acid-digested leaf samples were analyzed for Na, K, Ca, Mg, Fe, Mn, P, and Zn. Significant variations were observed between growth stages and locations. Reproductive-stage leaves showed higher concentrations of Ca, P, Fe, Mn, and Zn. Devgad leaves contained comparatively higher levels of Ca, Mg, Fe, Mn, and P, which may contribute to the superior fruit quality and early maturity of Devgad Alphonso mangoes. These findings provide useful information for nutrient management and improving mango productivity and fruit quality.

Introduction

Mineral nutrients are indispensable for the growth, development, productivity, and fruit quality of mango (*Mangifera indica* L.). They constitute the structural and functional components of plant cells and play essential roles in numerous physiological and biochemical processes, including photosynthesis, respiration, enzyme activation, osmoregulation, carbohydrate metabolism, protein synthesis, and reproductive development. The root system serves not only as an anchoring organ but also as the primary site for the continuous uptake of mineral nutrients and water from the soil, which are subsequently transported to different plant organs to support normal growth and development. Adequate mineral nutrition is therefore fundamental for maintaining plant vigor, optimizing vegetative growth, ensuring successful flowering and fruit set, and improving fruit yield and quality. (Hasanuzzaman, Mirza., et al., 2020).

Nutrient deficiency or imbalance adversely affects tree growth, leaf composition, flowering behaviour, fruit development, and overall productivity. The nutritional status of mango trees changes

with different phenological stages because nutrient demand varies during vegetative flushing, leaf maturation, flowering, fruit development, and fruit maturation. During the vegetative phase, nutrients are primarily utilized for shoot growth, leaf expansion, and canopy development, whereas during the reproductive phase, large quantities of mineral nutrients are mobilized towards flowers and developing fruits. (Sharma, et al., 2019). Consequently, studying seasonal variations in mineral composition provides valuable information regarding nutrient translocation and utilization in mango orchards.

Among the commercially cultivated mango cultivars, Alphonso is recognized worldwide for its exceptional fruit quality, attractive colour, rich flavour, pleasant aroma, and high export value. In Maharashtra, Alphonso mangoes produced in the Devgad region have acquired a distinctive reputation in national and international markets because of their superior size, shape, texture, taste, aroma, and shelf life. Although Devgad and Ratnagiri possess similar coastal climatic conditions, noticeable differences exist in the quality of fruits harvested from these regions. These variations are believed to arise partly from differences in soil properties, mineral availability, nutrient uptake, and their subsequent distribution within the plant.

Leaf mineral analysis is widely accepted as a reliable indicator of the nutritional status of perennial fruit crops because leaves represent the principal sites of photosynthesis and nutrient accumulation. Quantitative estimation of inorganic constituents in leaves provides valuable information on nutrient availability, physiological status, and nutrient requirements during different stages of crop growth. Such information is essential for developing balanced fertilizer management practices and improving fruit quality and productivity (Sharma, et al., 2019).

Therefore, the present investigation was undertaken to determine the inorganic mineral composition of acid-digested leaf samples collected from Alphonso mango trees growing in Ratnagiri and Devgad during both vegetative and reproductive phases. The study focused on the estimation of major and micronutrients, namely sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), phosphorus (P), and zinc (Zn), with the objective of understanding their seasonal variations and evaluating their possible contribution to the superior fruit quality

traditionally associated with Devgad Alphonso mangoes.

Materials and Method

Inorganic constituents were determined in acid digested samples. A known weight of oven dried samples was digested in a mixture of HNO_3 and perchloric acid. The acid digest was filtered through Whatman No. 1 paper and the volume was adjusted. The clean extract of the sample was then used to determine inorganic constituents. By using flame photometer Na^+, K^+ and Ca^{2+} were determined. By using Atomic Absorption Spectrophotometer Mg^{2+}, Mn^{2+}, Fe^{3+}, Zn^{2+} were analysed and P^{5+} was analysed colorimetrically.

Results and Discussion

The mineral composition of Alphonso mango leaves differed considerably between the vegetative and reproductive stages in both Ratnagiri and Devgad orchards (figure 1), indicating stage-specific nutrient redistribution associated with flowering, fruit set, and fruit development. Mineral nutrients play vital roles in physiological processes such as photosynthesis, carbohydrate metabolism, enzyme activation, osmotic regulation, flowering, fruit development, and stress tolerance. The present observations are consistent with recent studies demonstrating that nutrient accumulation and translocation vary significantly according to the phenological stage of mango trees.

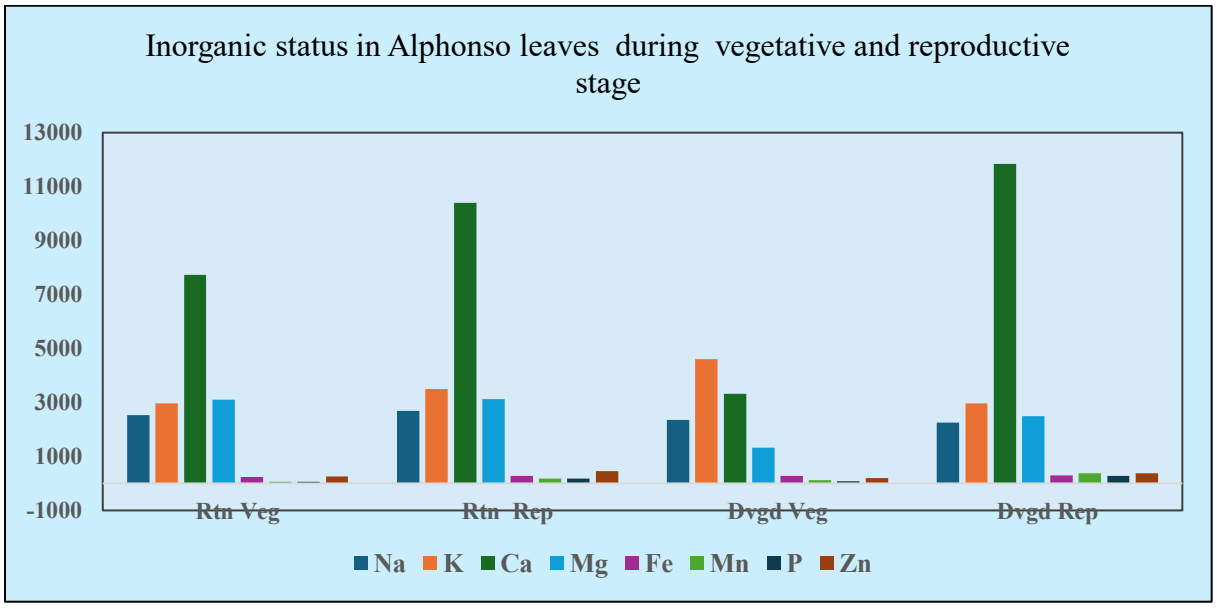


Figure 1: Inorganic status in Alphonso leaves during vegetative and reproductive stage

Sodium (Na)

The sodium concentration increased slightly from **2540 ppm to 2690 ppm** in Ratnagiri during the reproductive stage, whereas Devgad showed a slight decrease from **2345 ppm to 2260 ppm**. Sodium is not considered an essential nutrient for mango; however, it contributes to osmotic regulation and may partially substitute potassium under certain conditions. The relatively lower Na concentration in Devgad leaves during reproduction suggests greater ionic selectivity and efficient nutrient regulation, preventing sodium toxicity and maintaining better physiological activity. Several recent studies have reported that maintaining low foliar sodium enhances photosynthetic efficiency and improves fruit quality in perennial fruit crops, particularly under coastal conditions (Kumar *et al.,* 2018; Singh *et al.,* 2021). Efficient exclusion of sodium has also been associated with higher productivity and better nutrient use efficiency in mango orchards (Patel *et al.,* 2020).

Potassium (K)

Potassium exhibited contrasting patterns between the two locations. In Ratnagiri, K increased from **2960 ppm** during vegetative growth to **3505 ppm** during reproduction, whereas Devgad showed a decline from **4600 ppm** to **2960 ppm**. Potassium is recognized as one of the most important nutrients regulating stomatal movement, carbohydrate translocation, enzyme activation, and fruit quality. The increase in Ratnagiri indicates enhanced potassium mobilization during flowering and fruit development. Conversely, the reduction in Devgad reproductive leaves likely reflects translocation of potassium from leaves to developing fruits, which act as strong physiological sinks.

Recent investigations have shown that potassium demand increases markedly during flowering and fruit enlargement because of its role in sugar transport, fruit colour development, pulp quality, and shelf life. High potassium nutrition has been associated with increased fruit size, total soluble solids (TSS), and improved market quality of mango fruits (Sharma *et al.,* 2019; Rani *et al.,* 2022). Foliar potassium application has also been shown to enhance flowering intensity and fruit retention in Alphonso mango (Kumar *et al.,* 2020).

Calcium (Ca)

Calcium increased substantially during reproduction in both regions, rising from **7720 ppm to 10405 ppm** in Ratnagiri and from **3325 ppm to 11840 ppm** in Devgad. Calcium is structurally important for cell wall stability, membrane integrity, pollen tube growth, and fruit firmness. The remarkably higher calcium concentration observed in Devgad during the reproductive stage indicates greater calcium accumulation associated with active fruit development.

Recent research confirms that calcium enhances fruit firmness, reduces physiological disorders, minimizes post-harvest losses, and improves storage quality in mango. Increased calcium during reproductive growth has been correlated with better fruit retention and reduced incidence of fruit cracking (Singh *et al.,* 2023; Prasad *et al.,* 2021). Calcium also functions as a secondary messenger regulating numerous developmental and stress-response pathways (Thor, 2019).

Magnesium (Mg)

Magnesium remained almost constant in Ratnagiri (**3110–3120 ppm**) but increased considerably in Devgad from **1325 ppm** to **2500 ppm** during reproduction. Magnesium is the central atom of chlorophyll and is essential for ATP formation, carbohydrate metabolism, and photosynthetic carbon fixation.

The higher magnesium accumulation in Devgad reproductive leaves suggests greater photosynthetic activity required to support fruit growth. Recent studies have demonstrated that magnesium deficiency reduces chlorophyll content, photosynthetic efficiency, and assimilate transport, ultimately affecting fruit yield and quality (Verbruggen & Hermans, 2018; Cakmak & Yazici, 2022). Adequate magnesium nutrition during flowering improves carbohydrate availability for developing fruits.

Iron (Fe)

Iron concentration increased from **246 ppm to 274 ppm** in Ratnagiri and from **278 ppm to 296 ppm** in Devgad during reproduction. Iron is indispensable for chlorophyll synthesis, electron transport, respiration, and several oxidation-reduction reactions. The comparatively higher iron concentration in Devgad suggests better nutritional status supporting enhanced photosynthetic activity during reproductive growth.

Recent investigations indicate that adequate iron nutrition enhances chlorophyll biosynthesis, photosystem stability, and antioxidant enzyme activities, thereby

improving reproductive performance in fruit crops (Kobayashi *et al.,* 2019; Briat *et al.,* 2021). Iron deficiency during flowering often results in poor fruit set and reduced yield.

Manganese (Mn)

Manganese exhibited nearly a three-fold increase during reproduction, increasing from **60 ppm to 180 ppm** in Ratnagiri and from **125 ppm to 375 ppm** in Devgad. Manganese functions as an essential cofactor for the oxygen-evolving complex of photosystem II and activates several enzymes involved in nitrogen metabolism and antioxidant defence.

The significantly higher manganese concentration in Devgad may contribute to improved photosynthetic efficiency and reproductive development. Recent studies have emphasized the role of manganese in enhancing pollen viability, protecting plants from oxidative stress, and improving fruit productivity (Schmidt *et al.,* 2019; Millaleo *et al.,* 2020).

Phosphorus (P)

Phosphorus showed the greatest proportional increase during reproductive growth. Ratnagiri increased from **65 mg 100 g^{-1}** to **180 mg 100 g^{-1}**, while Devgad increased from **85 mg 100 g^{-1}** to **280 mg 100 g^{-1}**. Phosphorus is fundamental for ATP production, nucleic acid synthesis, membrane phospholipids, flowering, and fruit development.

The markedly higher phosphorus concentration in Devgad indicates greater metabolic activity and energy availability during reproductive growth. Recent reports confirm that phosphorus enhances flowering, fruit set, root activity, and sugar accumulation in mango and other tropical fruit crops (Liu *et al.,* 2020; Kumar *et al.,* 2022). Phosphorus also promotes efficient assimilate translocation towards developing fruits.

Zinc (Zn)

Zinc increased markedly during reproduction, rising from **255 ppm to 460 ppm** in Ratnagiri and from **195 ppm to 370 ppm** in Devgad. Zinc participates in auxin biosynthesis, protein synthesis, membrane stabilization, and activation of numerous enzymes regulating reproductive development.

The higher zinc concentration during flowering and fruit development indicates increased metabolic demand associated with reproductive growth. Recent studies have demonstrated that zinc nutrition improves

flowering, fruit retention, pollen viability, enzyme activity, and fruit quality in mango (Hasanuzzaman *et al*., 2020; Rani *et al.,* 2022). Foliar zinc application has also been reported to increase fruit yield and improve nutrient balance in Alphonso orchards.

Conclusion

Overall, the reproductive stage was characterized by greater accumulation of calcium, phosphorus, zinc, iron, and manganese, reflecting increased metabolic requirements during flowering and fruit development. Devgad orchards generally exhibited higher reproductive concentrations of Ca, Mg, Fe, Mn, and P, whereas Ratnagiri retained relatively higher potassium and zinc concentrations during reproduction. These regional differences likely reflect variations in soil fertility, nutrient availability, environmental conditions, and nutrient translocation efficiency. The enhanced accumulation of reproductive nutrients in Devgad may explain the superior fruit quality, early flowering, and better market value traditionally associated with Alphonso mangoes from this region.

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