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EFFECT OF NANO AND CHELATED MICRONUTRIENTS ON THE GROWTH AND YIELD OF MANGO CV. ALPHONSO

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ABSTRACT

A field experiment was conducted during 2025–2026 at the Main Horticultural Research and Extension Centre, University of Horticultural Sciences, Bagalkot, Karnataka, to evaluate the influence of foliar applied nano and chelated micronutrients on growth and yield of mango cv. Alphonso. The experiment comprised nine treatments in a Randomized Complete Block Design with three replications. Treatments included nano zinc, nano copper and chelated zinc, copper, magnesium and calcium, applied at four crop stages: one month before flowering, flowering, peanut and marble stages. Nano zinc at 20, 40, 60 and 20 ppm (T_2) recorded the highest values for several major growth and reproductive attributes. It recorded the highest fruiting shoot length (23.83 cm) and diameter (8.82 mm), chlorophyll content (42.57 SPAD), leaf area (98.57 cm^2), number of fruiting shoots (94.76 $tree^{-1}$), panicles (59.25 $tree^{-1}$), fruits per panicle at harvest (4.08), fruit length (9.54 cm), diameter (8.52 cm) and fruit weight (285.00 g). T_2 produced highest yield 36.75 kg $tree^{-1}$ compared with 26.95 kg $tree^{-1}$ in the control according to the treatment-wise results table. The findings indicate that appropriately timed foliar nano-zinc application can improve vegetative growth, flowering, fruit set, fruit development and yield of Alphonso mango under the experimental conditions.

***Key words*:** Alphonso mango, nano zinc, nano copper, chelated micronutrients, foliar application, fruit set, yield

Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical and subtropical fruit crops and is widely valued for its flavour, aroma, taste, attractive colour and nutritional importance. In India, mango occupies an important position in fruit production and trade, with major production occurring in Uttar Pradesh, Andhra Pradesh, Bihar, Karnataka and Gujarat. The 2024–25 horticultural statistics cited in the thesis report an estimated mango area of 2.39 million ha and production of 22.84 million tonnes in India, while Karnataka accounted for about 139.64 thousand ha and 1,479.70 thousand tonnes of production (Anon., 2025).

Alphonso is a premium mango cultivar characterized by attractive colour, distinctive aroma, smooth non-fibrous pulp and high consumer preference. Productivity of mango is influenced by vegetative growth, flowering, fruit set, fruit retention, fruit development and nutrient status. Micronutrients are required in relatively small quantities but are involved in enzyme activation, chlorophyll formation, hormone metabolism, reproductive development and carbohydrate transformation. Zinc, in particular, is associated with auxin metabolism, enzyme activity, chlorophyll synthesis and physiological processes that influence flowering and fruit development (Bahadur *et al*., 1998; Kumar *et al*., 2017a).

Nanofertilizers have attracted attention because their small particle size and high surface area may facilitate

Table 1. Important growth parameters of mango cv. Alphonso as influenced by foliar application of nano and chelated micronutrients.

Treatment*	Length of fruiting shoot(cm)	Diameter of fruiting shoot (mm)	Chlorophyll (SPAD value)	Leaf area (cm^2)	Specific leaf area (cm^2/g)
T_1 - Nano Zn 10,20,30,10 ppm	22.10	8.15	39.03	92.84	118.62
T_2 - Nano Zn 20,40,60,20 ppm	23.83	8.82	42.57	98.57	114.38
T_3 - Nano Cu 5, 10,15,5 ppm	20.41	7.46	36.73	83.45	124.76
T_4 - Nano Cu 10,20,30,10 ppm	21.35	7.86	35.63	81.62	126.18
T_5 - Chelated Zn 0.02%,0.03%,0.05%,0.02%	20.08	8.02	39.5	90.18	119.84
T_6 - Chelated Cu 0.02%,0.03%,0.05%,0.02%	21.03	7.12	30.73	75.36	130.54
T_7 - Chelated Mg 0.02%,0.03%,0.05%,0.02%	19.17	7.53	35.6	84.92	123.08
T_8 - Chelated Ca 0.02%,0.03%,0.05%,0.02%	22.84	8.42	40.5	93.46	117.46
T_9 – Control	17.20	6.42	31.03	72.84	133.82
S.Em±	0.39	0.17	0.50	1.62	2.08
CD at 5 %	1.18	0.52	1.51	4.89	6.28
CV	3.23	3.80	2.35	3.27	2.92
Note: All treatments are imposed by foliar application at four different stages*					

nutrient absorption and influence plant physiological responses. Foliar application of nano-zinc has been reported to improve nutrient uptake, physiological activity and growth, while nano-micronutrients have been investigated in several fruit crops for their potential to improve productivity and quality (Qureshi *et al.*, 2018). Chelated micronutrients provide nutrients in stable complexes and may improve their availability and reduce fixation, particularly where conventional nutrient forms have limited availability. Previous studies on mango and other fruit crops have reported beneficial responses to foliar micronutrient application, including improvements in vegetative growth, flowering, fruit set and yield.

Considering the potential of nano and chelated nutrient formulations and the need for efficient micronutrient management in mango, the present investigation was undertaken to evaluate their effect on growth and yield of mango cv. Alphonso and to identify a suitable foliar nutrient treatment under the conditions of the experiment.

Materials and Methods

Experimental site and design

The experiment was conducted during 2025–2026 at the Main Horticultural Research and Extension Centre (MHREC), University of Horticultural Sciences, Bagalkot, Karnataka (16°10' N, 75°42' E; 542 m above mean sea level), in the Northern Dry Zone (Zone III) of Karnataka. The experiment was laid out in a randomized complete block design (RCBD) with nine treatments and three replications. Eleven-year-old Alphonso mango trees planted at a spacing of 30 ft were used. Each treatment plot in each replication comprised three trees, giving a total of 81 experimental trees.

Treatment details and application

Treatment	Micronutrient source	Concentrations at four sprays
T_1	Nano Zn	10, 20, 30 and 10 ppm
T_2	Nano Zn	20, 40, 60 and 20 ppm
T_3	Nano Cu	5, 10, 15 and 5 ppm
T_4	Nano Cu	10, 20, 30 and 10 ppm
T_5	Chelated Zn	0.02, 0.03, 0.05 and 0.02%
T_6	Chelated Cu	0.02, 0.03, 0.05 and 0.02%
T_7	Chelated Mg	0.02, 0.03, 0.05 and 0.02%
T_8	Chelated Ca	0.02, 0.03, 0.05 and 0.02%
T_9	Control	No micronutrient treatment

Each treatment was imposed by foliar application at four stages: one month before flowering, flowering stage, peanut stage and marble stage respectively.

Crop management

All trees received the recommended manures and fertilizers, comprising 25 tonnes of FYM and 1:1:1.5 kg N:P:K per plant, as described in the thesis. Drip irrigation was provided once or twice a week according to soil moisture, maintaining approximately 50 per cent field capacity; irrigation was stopped about 15–20 days before harvest. Weeds, pests and diseases were managed using standard field practices. At harvest, five fruits were randomly selected from each experimental tree for fruit observations and laboratory analyses.

Observations

Growth observations included fruiting shoot length and diameter, chlorophyll content measured using a SPAD-

Table 2: Flowering and panicle characteristics of mango cv. Alphonso as influenced by foliar application of nano and chelated micronutrients.

Treatment*	NFST	NPPT	NFHP
T_1 – Nano Zn 10,20,30,10 ppm	86.32	56.35	3.58
T_2 – Nano Zn 20,40,60,20 ppm	94.76	59.25	4.08
T_3 – Nano Cu 5, 10,15,5 ppm	77.84	53.35	3.18
T_4 – Nano Cu 10,20,30,10 ppm	82.41	55.00	3.34
T_5 – Chelated Zn 0.02%,0.03%, 0.05%,0.02%	84.10	55.45	3.46
T_6 – Chelated Cu 0.02%,0.03%, 0.05%,0.02%	73.28	51.95	2.96
T_7 – Chelated Mg 0.02%,0.03%, 0.05%,0.02%	79.54	53.80	3.12
T_8 – Chelated Ca 0.02%,0.03%, 0.05%,0.02%	88.60	56.95	3.76
T_9 – Control	67.99	50.75	2.48
S.Em±	2.18	3.31	0.11
CD at 5 %	6.54	9.94	0.34
CV	4.62	10.47	5.72

NFST: Number of fruiting shoots per tree; NPPT: No. of panicles per tree; NFHP: No. of fruits at harvest per panicle
Note: All treatments are imposed by foliar application at four different stages*

502 meter after treatment, leaf area, specific leaf weight and specific leaf area. Yield attributes included the number of fruiting shoots and panicles per tree and the number of fruits per panicle at harvest. Yield was recorded as kg tree^{-1}. Fruit dimensions were measured using vernier calipers, and fruit and pulp weights were recorded using an electronic balance, as described in the thesis.

Statistical analysis

Data were subjected to analysis of variance appropriate for a randomized complete block design. The procedure described by Cochran and Cox (1957) was followed. Treatment means were compared using the critical difference (CD) at the 5% level when the F-test was significant.

Results and Discussion

Growth parameters

Nano and chelated micronutrient treatments influenced the growth attributes of Alphonso mango. T_2 (nano-Zn at 20, 40, 60 and 20 ppm) recorded the highest fruiting shoot length (23.83 cm) and diameter (8.82 mm), whereas the control recorded 17.20 cm and 6.42 mm, respectively. The response under T_2 may be associated with improved zinc availability and utilization. Zinc is involved in enzyme activation and auxin metabolism and may support cell division and elongation, thereby contributing to shoot growth. The thesis discussion also relates the response to the high surface area and potentially improved absorption associated with nano-sized zinc (Tarafdar, 2013; Kumar *et al.*, 2017).

Chlorophyll content was highest under T_2 (42.57 SPAD), followed by T_8 (40.50) and T_5 (39.50); the control recorded 31.03 SPAD. Adequate zinc nutrition can support chlorophyll formation and photosynthetic activity, potentially contributing to assimilate production. Physiological responses to zinc oxide nanoparticles have also been reported in tomato (Raliya *et al.*, 2015). T_2 produced the largest leaf area (98.57 cm²). Specific leaf area was lowest under T_2 (114.38 cm² g^{-1}) and highest in the control (133.82 cm² g^{-1}), suggesting treatment-related differences in leaf thickness or dry-matter allocation.

Flowering and yield attributes

T_2 recorded the highest number of fruiting shoots

Table 3: Important fruit physical parameters of mango cv. Alphonso as influenced by foliar application of nano and chelated micronutrients.

Treatment*	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Pulp Weight (g)	Pulp to peel ratio
T_1 – Nano Zn 10,20,30,10 ppm	8.87	7.93	241.67	194.37	9.55
T_2 – Nano Zn 20,40,60,20 ppm	9.54	8.52	285.00	229.27	8.64
T_3 – Nano Cu 5, 10,15,5 ppm	8.39	7.93	228.33	190.13	9.35
T_4 – Nano Cu 10,20,30,10 ppm	7.98	7.63	193.33	147.5	6.98
T_5 – Chelated Zn 0.02%,0.03%,0.05%,0.02%	8.21	7.77	201.67	159.83	7.39
T_6 – Chelated Cu 0.02%,0.03%,0.05%,0.02%	8.36	7.68	200.00	161.27	8.75
T_7 – Chelated Mg 0.02%,0.03%,0.05%,0.02%	9.07	8.15	238.33	191.6	8.93
T_8 – Chelated Ca 0.02%,0.03%,0.05%,0.02%	8.93	8.07	210.00	170.8	9.12
T_9 – Control	8.38	6.37	163.33	117.83	5.61
S.Em±	0.22	0.14	10.59	10.26	0.38
CD at 5 %	0.68	0.44	31.74	30.75	1.15
CV	4.54	3.31	8.41	10.23	8.03

Note: All treatments are imposed by foliar application at four different stages*

Table 4: Fruit yield of mango cv. Alphonso as influenced by foliar application of nano and chelated micronutrients.

Treatment*	Yield (kg/ tree)
T_1 - Nano Zn 10,20,30,10 ppm	34.80
T_2 - Nano Zn 20,40,60,20 ppm	36.75
T_3 - Nano Cu 5, 10,15,5 ppm	31.73
T_4 - Nano Cu 10,20,30,10 ppm	33.60
T_5 - Chelated Zn 0.02%,0.03%,0.05%,0.02%	32.40
T_6 - Chelated Cu 0.02%,0.03%,0.05%,0.02%	27.02
T_7 - Chelated Mg 0.02%,0.03%,0.05%,0.02%	25.35
T_8 - Chelated Ca 0.02%,0.03%,0.05%,0.02%	29.26
T_9 – Control	26.95
S.Em±	0.84
CD at 5 %	2.54
CV	4.71
Note: All treatments are imposed by foliar application at four different stages*	

(94.76 tree^{-1}), compared with 67.99 tree^{-1} in the control. It also recorded the highest number of panicles per tree (59.25), while the control recorded 50.75. These responses may be associated with the roles of zinc in enzyme activity and hormone metabolism. Positive responses to micronutrient application in mango have also been reported by El-Razek *et al*., (2013) and Kheir *et al*., (2021).

Fruit size and yield

T_2 recorded the highest fruit length (9.54 cm), diameter (8.52 cm) and weight (285.00 g). The corresponding control values were 8.38 cm, 6.37 cm and 163.33 g, respectively. Pulp weight was highest under T_2 (229.27 g), whereas the control recorded 117.83 g. The greater fruit size and pulp accumulation under T_2 may be associated with improved assimilate production and nutrient utilization. Similar improvements in fruit growth following foliar micronutrient application have been reported in mango (Bahadur *et al*., 1998; El-Razek *et al*., 2013).

Fruit yield varied among treatments. T_2 recorded the highest yield (36.75 kg tree^{-1}), followed by T_1 (34.80 kg tree^{-1}) and T_4 (33.60 kg tree^{-1}). The control recorded 26.95 kg tree^{-1} in the treatment-wise yield table. The higher yield under T_2 coincided with its higher values for fruiting shoots, panicles, fruits per panicle and fruit weight. Similar benefits of nano-zinc and foliar micronutrient application have been reported in the literature (Qureshi *et al*., 2018; Raliya *et al*., 2015; Aziz *et al*., 2024).

Economic response

Treatment-wise economics were estimated using a mango fruit price of Rs. 100 kg^{-1}. T_2 recorded the highest gross returns (Rs. 4,54,000 ha^{-1}), net returns (Rs. 3,34,500 ha^{-1}) and B:C ratio (3.80). The corresponding values for the control were Rs. 3,10,000 ha^{-1}, Rs. 1,92,500 ha^{-1} and 2.65, respectively. Thus, the yield response under T_2 was accompanied by higher economic returns under the price assumptions used in the experiment.

Conclusion

Under the conditions of the present experiment at MHREC, UHS Bagalkot, foliar application of nano and chelated micronutrients influenced vegetative growth, flowering, fruit development and yield of mango cv. Alphonso. T_2 (nano-Zn at 20, 40, 60 and 20 ppm, applied one month before flowering and at flowering, peanut and marble stages, respectively) recorded the highest values for several major growth and yield attributes, including fruiting shoot length (23.83 cm), shoot diameter (8.82 mm), chlorophyll content (42.57 SPAD), leaf area (98.57 cm^2), fruiting shoots (94.76 tree^{-1}), panicles (59.25 tree^{-1}), fruits per panicle at harvest (4.08), fruit weight (285.00 g) and yield (36.75 kg tree^{-1}). It also recorded the highest economic returns and B:C ratio (3.80) under the price assumptions used. These findings indicate the potential of appropriately timed foliar nano-zinc application to improve growth and productivity of Alphonso mango. Multi-season and multi-location validation is required before broader recommendations can be made.

Table 5: Economic Response.

Treatment*	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B: C ratio
T_1 - Nano Zn 10,20,30,10 ppm	1,18,500	4,36,000	3,17,500	3.68
T_2 - Nano Zn 20,40,60,20 ppm	1,19,500	4,54,000	3,34,500	3.80
T_3 - Nano Cu 5, 10,15,5 ppm	1,18,000	3,92,000	2,74,000	3.32
T_4 - Nano Cu 10,20,30,10 ppm	1,18,800	4,15,000	2,96,200	3.49
T_5 - Chelated Zn 0.02%,0.03%,0.05%,0.02%	1,17,800	4,00,000	2,82,200	3.40
T_6 - Chelated Cu 0.02%,0.03%,0.05%,0.02%	1,17,200	3,33,000	2,15,800	2.84
T_7 - Chelated Mg 0.02%,0.03%,0.05%,0.02%	1,17,500	3,12,000	1,94,500	2.66
T_8 - Chelated Ca 0.02%,0.03%,0.05%,0.02%	1,17,600	3,60,000	2,42,400	3.06
T_9 – Control	1,17,000	3,10,000	1,92,500	2.65

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