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RESEARCH ARTICLE

Effects of nano micronutrient foliar application on physiology and yield traits of kinnow mandarin (*Citrus reticulata* Blanco)

Rohit Sharma[1], Shweta[1*], Sumedha[2] & Aryan Bhatia[1]

[1]Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara 144 411, Punjab, India
[2]Department of Entomology, BA College of Agriculture, Anand Agricultural University, Anand 388 110, Gujarat, India

*Correspondence email - shwetaguleria228@gmail.com

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Abstract

Despite the recognized importance of micronutrients in citrus production, limited research has been conducted on the synergistic effects of nano boron (nB) and nano zinc (nZn) in improving growth, yield and fruit quality of kinnow mandarin under Punjab's agro-climatic conditions. A field experiment was conducted at the Department of Horticulture, Lovely Professional University, Punjab, to evaluate the effects of foliar application of nB and nZn on the vegetative growth, productivity and qualitative traits of kinnow mandarin (*Citrus reticulata* Blanco). The study followed a randomized block design (RBD) comprising nine treatments replicated thrice, using 27 uniform, twelve-year-old trees grafted onto rough lemon (*Citrus* × *jambhiri* Lush.) rootstock. Foliar sprays were applied twice at varying concentrations. Among all treatments, T_9 [nB (60 mg/L) + nZn (200 mg/L)] significantly outperformed others in all evaluated parameters, showing the highest increment in tree height (5.94 %), canopy spread (6.06 % East-West; 6.23 % North-South), initial fruit set (53.17 %), final fruit retention (24.30 %) and ultimately yield (81.07 kg/plant). Fruit morphology and quality attributes were also significantly improved, including fruit size [length (5.92 cm) ×diameter (6.75 cm)], number of fruits (512.67), fruit weight (158.20 g), rind weight (27.85 g), weight of pulp (130.35 g) and pulp percentage (82.40 %). Additionally, notable enhancements were observed in shelf life (8.68 days), total soluble solids (11.50 °Brix), total sugars (8.97 %), reducing sugars (3.92 %) and non-reducing sugars (5.05 %). Treatments T_6 and T_8 also showed significant improvements, though they were less effective than T9. Overall, the combined foliar application of nB and nZn proved highly effective in enhancing vegetative, reproductive and postharvest quality attributes of kinnow mandarin.

Keywords: administration; foliar application; kinnow; nanoparticles; productivity

Introduction

Citrus species, classified under the family Rutaceae, are among the most widely cultivated fruit crops worldwide, grown in over 140 countries. The genus *Citrus* comprises approximately 162 species, of which the commercially significant ones are include mandarin, sweet orange, grapefruit, pummelo, acid lime and lemon. *Citrus* species exhibit ploidy levels ranging from diploid to tetraploid, with a fundamental chromosome number of nine (1). Their centre of origin is Southeast Asia and the Indian subcontinent, while commercial cultivation thrives in subtropical regions up to 750 meters above sea level. Due to their high concentrations of bioactive components such as hesperidin, naringin, ascorbic acid (vitamin C), carotenoids (notably β-cryptoxanthin and β-carotene), along with other health-promoting properties, citrus fruits are highly valued in the global fruit market (2). Among the various citrus species, mandarins-particularly the kinnow cultivar hold significant importance owing to their superior organoleptic qualities and higher consumer acceptance.

Kinnow (*C. reticulata* Blanco), a hybrid of King (*C. nobilis* Lour) × Willow leaf (*C. deliciosa* Tenora), is widely cultivated in India, especially in the northern states. With its high juice yield (50-60 %), rich aroma and desirable organoleptic traits, kinnow is often referred to as the "King of Mandarins" (3). It contains valuable bioactive compounds, including 30 mg/100 mL ascorbic acid, along with flavonoids, phenolics and antioxidants, which confer health-promoting properties and may help reduce the risk of chronic diseases such as cardiovascular disorders, cancer and diabetes (4-6).

Kinnow is an evergreen, thornless tree that exhibits vigorous growth and adaptability to sandy loam soils (7). Kinnow mandarin is commercially propagated through T-budding, typically grafted onto rootstocks like rough lemon, Troyer Citrange and Soh Sarkar. These rootstocks are selected for their ability to enhance drought and salinity tolerance, confer resistance to diseases such as citrus tristeza virus, regulate tree vigor and improve fruit yield and quality attributes. The plant produces solitary, synoecious flowers and its fruits are botanically classified as hesperidia, usually containing 8-20 seeds. The edible portion consists of the juicy endocarp vesicles enclosed within a smooth, peelable rind [exocarp (flavedo) and mesocarp (albedo)].

Globally, citrus is cultivated over 10.55 million hectares, with an annual yield of 169.4 million tons. India ranks as the third-largest producer of citrus, contributing about 9.26 % of global output (8). Of the 1.034 million hectares under citrus in India, mandarins occupy

0.437 million hectares, with a production of 6.075 million tons (9, 10). Punjab is a major kinnow-producing state, contributing 29 % to the national output, with an approximate annual output of 1.1 million tons cultivated across 48000 hectares. Fazilka district alone accounts for over half the state's area and production (11).

Despite its economic importance, achieving consistent yield and fruit quality in kinnow remains a challenge. Major constraints include high fruit drop rates, influenced by both biotic (rootstock, cultivar, pest and disease pressure) and abiotic (climate, site, nutritional imbalance and soil quality) factors (12, 13). Among these, micronutrient deficiencies especially boron (B) and zinc (Zn) are critical limiting factors in citrus productivity (14). Boron plays a vital role in pollen germination, fruit set, sugar translocation and cell wall integrity. It is also essential for root development, RNA synthesis and carbohydrate metabolism (15-17). Its deficiency is frequently observed in sandy and acidic soils characterized by low organic matter content. Zn is vital for enzyme activation, auxin synthesis (through tryptophan), starch metabolism, protein biosynthesis and photosynthetic parameters (18, 19). Additionally, it exhibits a reductive effect on reactive oxygen species and provides defence against metal contamination (20, 21). Zinc deficiency is widespread in citrus, especially in sandy and alkaline soils (22, 23).

Nanotechnology-based nutrient delivery systems, particularly foliar-applied nano-fertilizers, offer improved nutrient use efficiency, reduced losses and targeted delivery. Although research on the combined administration of nano-formulated B and Zn fertilizers in citrus is limited, especially in kinnow mandarin grown under Indian agro-climatic conditions. Therefore, the trial was initiated to explore the implications of the nano-formulated fertilizers on growth dynamics, crop yield and fruit quality characteristics of kinnow mandarin.

Materials and Methods

Location

The field study was conducted in 2024 at the kinnow orchard of the Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab, located at 31°22′31.83″ N latitude and 75°23′03.02″ E longitude, at an elevation of 252 m above sea level.

Climate and soil

The study area is located within the central plain zone of the agro-climatic region of Punjab, characterized by a subtropical climate with hot summers and cold winters. The southwest monsoon provides most of the rainfall between June and September. In 2024, the region received an average of 314.6 mm rainfall, which was 28 % below average, with only 5 mm in July. The average annual temperature was 23.52 °C, peaking at 33.01 °C in June and dipping to 9.92 °C in January (Fig. 1). The soil possessed sandy loam texture, slightly alkaline, rich in organic matter and well-drained, suitable for optimal kinnow growth.

Experimental design

The field investigation was carried out using a randomized block design (RBD) with 9 treatments replicated thrice, totalling 27 kinnow mandarin trees, spaced 6 m × 6 m apart, occupying a total plot size of 972 m^2. The aim of the experiment was to assess the impact of nano boron (nB) and nano zinc (nZn) applied through foliar spray at two critical stages: before flowering (1st week of March) and at the fruit set stage (3rd week of April) on plant growth and yield.

Treatment details

The study included nine treatments with varying concentrations of nano boron and nano zinc (Table 1). Each treatment was applied to

Table 1. Treatment specifications

Treatments	Treatment particulars
T_1	nB (0 mg/L) + nZn (0 mg/L) (Control)
T_2	nB (0 mg/L) + nZn (100 mg/L)
T_3	nB (0 mg/L) + nZn (200 mg/L)
T_4	nB (30 mg/L) + nZn (0 mg/L)
T_5	nB (30 mg/L) + nZn (100 mg/L)
T_6	nB (30 mg/L) + nZn (200 mg/L)
T_7	nB (60 mg/L) + nZn (0 mg/L)
T_8	nB (60 mg/L) + nZn (100 mg/L)
T_9	nB (60 mg/L) + nZn (200 mg/L)

T= Treatment, **nB**= Nano boron, **nZn**= Nano zinc.

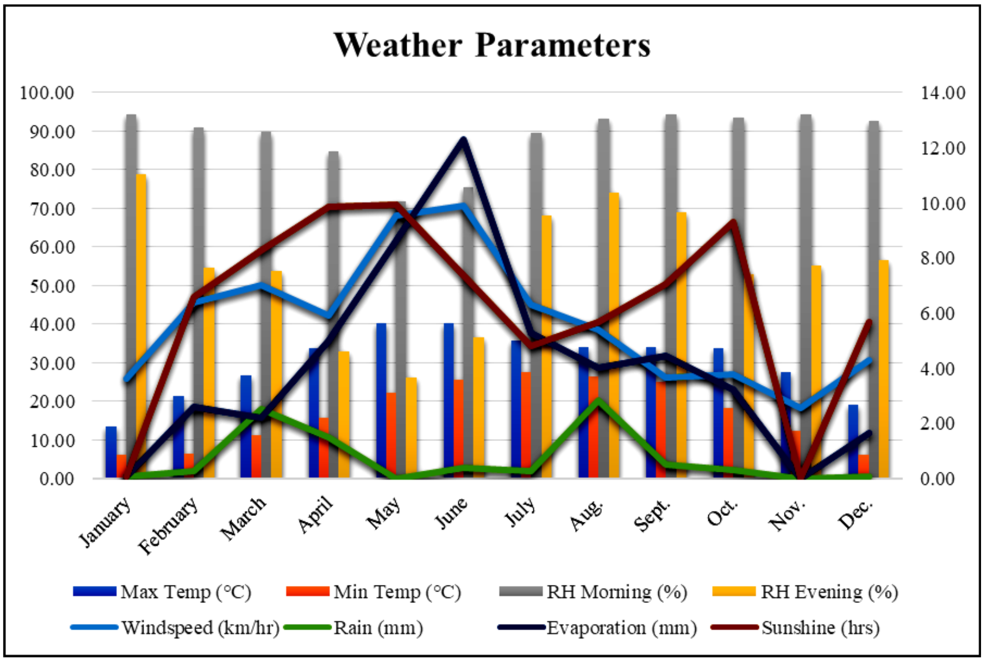

Fig. 1. Mean monthly meteorological data during the experimental season (January 2024-December 2024).

individual plants using a knapsack sprayer with 4-5 L of water per plant, early in the day under favourable weather conditions.

Methodology

The experimental site was a well-maintained 12-year-old kinnow orchard with protective windbreaks. Twenty-seven uniformly vigorous, 12-year-old kinnow plants grafted onto rough lemon (*Citrus × jambhiri*) rootstock was chosen from a north-facing block. Nano boron (B_2O_3 NPs) and nano zinc (ZnO NPs) were accurately weighed, labelled, pre-mixed in 5 L of water and diluted to the required volume before foliar application using a battery-operated knapsack sprayer under suitable conditions. Land preparation involved ploughing, harrowing, levelling and installation of drip irrigation. As per Punjab Agricultural University recommendations, 100 kg farm yard manure per plant was applied 45 days before flowering, with nitrogen (through urea) applied in two splits, phosphorus through single superphosphate and potassium by foliar spray of 1 % potassium nitrate in May-July. Weed control was done using glyphosate (1.6 mg/L) in July, avoiding tree trunks (24). Harvesting was done manually in late December 2024 using secateurs and fruits were cleaned and transported for analysis.

Growth parameters

Tree height progression (%), tree spread increment (%) [(E-W & N-S) direction], linear growth of shoot (cm), number of functional leaves/ shoot and leaf area (cm^2) were recorded.

Yield and attributing traits

Number of flowers per twigs, initial fruit set (%), final fruit drop (%), final fruit retention (%), fruit length (cm), fruit diameter (cm), total fruit count per plant, weight of individual fruits (g), yield (kg/plant), yield (t/ha), peel weight (g), peel percentage (%), pulp weight (g) and pulp percentage (%) were recorded.

Quality traits

Fruit firmness (kgf/cm^2), storage-associated physiological mass loss (%), shelf life of the fruits (days), TSS (°Brix), total acidity (%), TSS-acidity ratio, total sugars (%), reducing sugars (%) and non-reducing sugars (%) were analysed.

Data analysis

Data on biometric growth, yield and fruit quality traits were collected as per the scheduled observations. Recorded data was tabulated across three replicates for each treatment. Data was tabulated using Microsoft Excel. The generated data underwent statistical evaluation through ANOVA (analysis of variance), analysed by using the statistical software OP STAT, using one-factor analysis to test the significance of treatments with level of significance used ($p \leq 0.05$).

Results and Discussion

Growth parameters

Foliar supplementation of nB and nZn application had a significant influence on the vegetative growth characteristics of kinnow mandarin (Table 2). Trees supplemented with treatment T_9[nB (60 mg/L) + nZn (200 mg/L)] before flowering and at fruit set stage exhibited a maximum increase in tree height percentage of 5.94 %, which was statistically at par with treatment T_6(5.92 %) at $p \leq 0.05$. Maximum tree spread (6.06 % and 6.23 %) in the E-W and N-S directions which was also at par with T_6 (5.98 % and 6.19 %). Shoot length (102.00 cm) was highest under T_9,followed by T_6(100.00 cm) and T_3 (99.03 cm). Similarly, the number of leaves per shoot (48.27) was highest under T_9, followed by T_6(46.03) and T_3(43.00), while leaf area (18.67 cm^2) was also greater under T_9, followed by T_6 (18.10 cm^2) and T_3 (17.83 cm^2). In contrast, control plants showed the minimum variation in all traits.

The significant increase in growth parameters with higher concentrations of nB and nZn is likely associated with their role in promoting key physiological processes. Zn promotes endogenous production of indole-3-acetic acid, a phytohormone known to promote cell elongation and stimulates meristematic activity. It also supports chlorophyll formation, thereby improving photosynthesis. B contributes to cell wall development and facilitates carbohydrate transport, ensuring energy supply to developing tissues. These functions collectively lead to vigorous vertical growth, wider canopy spread, active shoot growth, increased functional leaf count per shoot and larger leaf area. The present finding are highly consistent with those reported by several researchers, who also observed a synergistic effect of Zn and B on tree height and canopy spread in kinnow (25-28). Enhanced shoot elongation and a greater number of physiologically active leaves per shoot in kinnow and pomegranate have also been documented (25, 29). In addition, increased leaf area in both crops under foliar application of Zn and B has been reported (28, 29).

Yield and attributing traits

Foliar supplementation of nB and nZn had a prominent impact on the yield and attributing traits of kinnow mandarin (Table 3 & 4; Fig. 2). Trees treated with treatment T_9 [nB (60 mg/L) + nZn (200 mg/L)] through foliar spraying before flowering and at the fruit set stage showed the greatest improvement in number of flowers/twigs (72.00) which was statistically at par with treatment T_8 (71.00); initial

Table 2. Effect of nano boron and nano zinc on the growth parameters of kinnow

Treatments	Tree height increment (%)	Tree spread increment E-W (%)	Tree spread increment N-S (%)	Shoot length (cm)	Number of functional leaves/shoot (no.)	Leaf area (cm^2)
T_1	4.36	4.41	4.62	96.77	30.23	15.07
T_2	4.79	5.12	5.36	97.63	38.07	16.50
T_3	5.69	5.78	5.99	99.03	43.00	17.83
T_4	4.52	4.67	4.95	97.13	33.23	15.40
T_5	5.17	5.63	5.85	98.53	39.97	17.07
T_6	5.92	5.98	6.19	100.00	46.03	18.10
T_7	4.60	4.87	5.17	97.27	35.00	16.20
T_8	5.47	5.71	5.92	98.67	44.11	17.50
T_9	5.94	6.06	6.23	102.00	48.27	18.67
SE(m)	0.08	0.09	0.09	0.47	0.70	0.14
C.D.	0.23	0.26	0.28	1.42	2.11	0.43

T = Treatment, **SE(m)**= Standard error of the mean, **C.D.**= Critical difference.

Table 3. Effect of nano boron and nano zinc on yield and attributing traits of kinnow

Treatments	Number of flowers/ twig (no.)	Initial fruit set (%)	Final fruit drop (%)	Final fruit retention (%)	Fruit length (cm)	Fruit diameter (cm)	Number of fruits / plant (no.)
T_1	65.00	46.50	81.83	18.17	5.21	6.06	459.33
T_2	66.00	47.67	80.60	19.40	5.50	6.26	467.00
T_3	66.30	48.20	79.30	20.70	5.76	6.60	470.00
T_4	67.60	48.97	78.88	21.12	5.33	6.10	480.00
T_5	68.30	49.90	78.00	22.00	5.55	6.39	485.67
T_6	69.00	50.30	77.43	22.57	5.83	6.66	489.67
T_7	70.30	51.70	76.80	23.20	5.40	6.16	500.67
T_8	71.00	52.53	76.00	24.00	5.65	6.47	505.33
T_9	72.00	53.17	75.70	24.30	5.92	6.75	512.67
SE(m)	0.95	0.72	0.44	0.44	0.06	0.09	6.02
C.D.	2.86	2.17	1.32	1.32	0.17	0.26	18.19

T= Treatment, **SE(m)**= Standard error of the mean, **C.D**.= Critical difference.

Table 4. Effect of nano boron and nano zinc on yield contributing parameters of kinnow

Treatment notation	Fruit weight (g)	Yield (kg/ plant)	Yield (t/ha)	Peel weight (g)	Peel percentage (%)	Pulp weight (g)	Pulp percentage (%)
T_1	133.15	61.13	17.00	25.30	19.01	107.85	80.99
T_2	140.12	65.40	18.17	26.03	18.58	114.09	81.42
T_3	151.99	71.43	19.87	27.25	17.93	124.74	82.07
T_4	134.98	64.77	18.00	25.50	18.89	109.48	81.11
T_5	143.21	69.63	19.33	26.61	18.58	116.60	81.42
T_6	155.30	76.10	21.13	27.50	17.71	127.80	82.29
T_7	136.15	68.23	18.93	25.60	18.80	110.55	81.20
T_8	146.97	74.30	20.63	26.95	18.34	120.02	81.66
T_9	158.20	81.07	22.50	27.85	17.60	130.35	82.40
SE(m)	1.18	1.06	0.29	0.17	0.09	1.04	0.083
C.D.	3.58	3.20	0.88	0.53	0.26	3.14	0.25

T= Treatment, **SE(m)**= Standard error of the mean, **C.D**.= Critical difference.

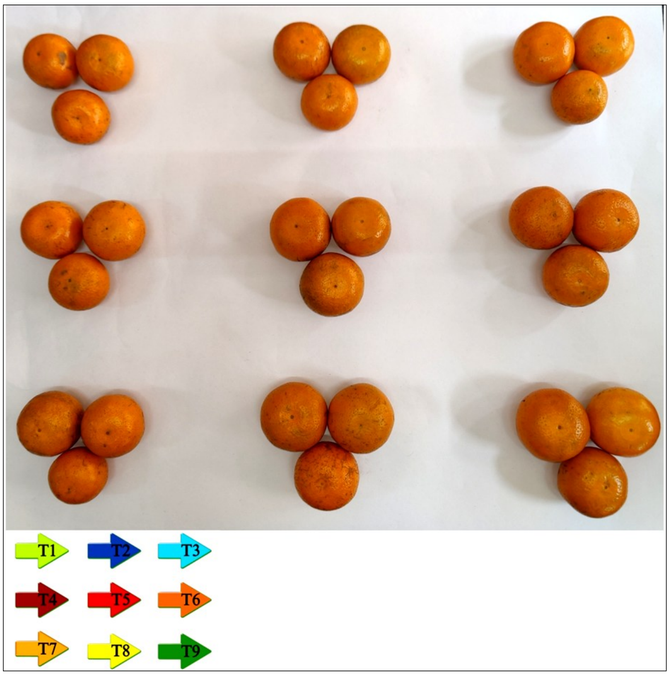

Fig. 2. Demonstrating the differences in fruits among various treatments.

fruit set (53.17 %) which was at par with T_8 (52.53 %) and T_7 (51.70 %); final fruit drop (least- 75.70 %) which was at par with T8 (76.00 %) and T_7 (76.80 %); final fruit retention (maximum- 24.30 %) which was statistically at par with T_8 (24.00 %) and T_7 (23.20 %); fruit length (5.92 cm) which was statistically comparable to T_6 (5.83 cm) and T_3 (5.76 cm); fruit diameter (6.75 cm) which exhibited similar performance to T_6(6.66 cm) and T_3 (6.60 cm); fruit count per plant (512.67) which was statistically comparable to T_8 (505.33) and T_7 (500.67) as depicted in Table 3.

Maximum fruit weight (158.20 g) under T_9 which was statistically at par with T_6 (155.30 g), while yield per plant (81.07 kg/ plant) showed comparable performance to T_6(76.10 kg/plant) and T_8 (74.30 kg/plant). The overall yield t/ha (22.50 t/ha) was also statistically at par with T_6(21.13 t/ha) and T_8 (20.63 t/ha). Peel weight (27.85 g) was statistically comparable to T_6(27.50 g), while peel percentage (least-17.60 %) was statistically at par with T_6(17.71 %). Pulp weight (130.35 g) was statistically at par with T_6(127.80 g) and pulp percentage (82.40 %) was statistically similar to T_6(82.29 %) as presented in Table 4.

The significant increment in yield and attributing traits with higher concentrations of nB and nZn may be ascribed to their critical functions in boosting pollen viability, fertilization success, hormonal regulation of floral initiation and improving fruit set, fruit physical parameters and overall yield. Zn supports reproductive and physical growth by stimulating auxin production, cell division and expansion, enzyme activity, synthesizing proteins and stabilizing the hormonal balance.

Meanwhile, B supports effective pollination, pollen germination and pollen tube elongation. It also reinforces cell wall synthesis and integrity through pectin cross-linking, while aiding in carbohydrate transport, distribution and fruit development without any disorders. Collectively, these functions promote healthy plant reproduction, physical growth and improved overall yield values. The above findings corroborate the outcomes documented by previous studies, concluded that B and Zn significantly improved the flower count and initial fruit set in kinnow plants (30, 31). Furthermore, a reduction in final fruit drop and an increase in final fruit retention in kinnow were noted (31). Several researchers reported improved fruit length and diameter in citrus species under

Zn and B application (26-28, 32). In addition, the highest fruit count per plant and fruit weight in kinnow were observed (26, 28). A significant increase in yield per plant and overall yield per hectare in kinnow was also recorded (26, 28, 33). One study reported an increase in peel weight, a significant reduction in peel percentage and enhanced pulp weight and pulp percentage in kinnow (32). Similar improvements in pulp weight and pulp percentage were also reported in litchi and mango (34, 35).

Quality parameters

Foliar treatment with nB and nZn significantly improved the fruit quality parameters of kinnow mandarin (Table 5). Trees supplemented with treatment T_9[nB (60 mg/L) + nZn (200 mg/L)] prior to flowering and during the fruit set stage demonstrated the highest enhancement in fruit firmness (2.80 kgf/cm^2) which was statistically at par with T_6 (2.75 kg/cm^2); physiological weight loss during storage (least- 4.35 %) which was statistically at par with T_6 (4.49 %); shelf life of the fruits (8.68 days) followed by T_6 (8.48 days); TSS (11.50 °Brix) which was at par with T_6(11.43 °Brix); total acidity (least- 0.83 %); TSS- acidity ratio (maximum of - 13.82) which was at par with T_6 (13.66), T3 (13.45) and T_8 (13.26); total sugars (8.97 %) which was at par with T_6(8.90 %); reducing sugars (3.92 %) which was at par with T_6 (3.89 %) and non-reducing sugars (5.05 %) which was statistically similar to T_6 (5.01 %).

The significant increase in quality traits with higher concentrations of nB and nZn can be attributed to their role in strengthening the cell wall, enhancing membrane integrity, enzymatic activity and sugar synthesis and translocation. Zinc activates antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT) and ascorbate peroxidase (APX). These enzymes help stabilize membranes against oxidative stress. B, on other hand, improves pectin cross-linking, which increases cell wall rigidity. This reduces water loss and delays fruit senescence. As a result, fruit firmness in preserved, weight loss during storage is reduced and shelf life is increased. Zinc is involved in the synthesis of growth hormones, a vital component of enzymes like carbonic anhydrase that perform a dynamic role in chlorophyll synthesis, which boosts photosynthetic activity, thereby increasing sugar accumulation in fruits. Dehydrogenase enzyme involved in respiration facilitates the oxidation of organic acids, contributing to the decline in fruit acidity (36, 37). Concurrently, boron enhanced the translocation of assimilates and regulates organic acid levels, thus maintaining the acid-sugar balance essential for desirable flavour development. These outcomes are in agreement with the observations made by researchers who reported notable improvements in fruit firmness of pomegranate and Timor mango following the application of nano boron and nano zinc particles (38, 39). A significant decrease in physiological weight loss of sweet orange and papaya was also observed (40, 41). Additionally, a significant increase in the shelf life of citrus was recorded (40, 42). Significant improvement in TSS value and a slight reduction in acidity level of kinnow mandarin were noted (27, 28, 32, 33). Moreover, a significant increase in the TSS-acidity ratio in kinnow and lemon was reported (33, 43). Finally, significant enhancement in total sugars, reducing sugars and non-reducing sugar levels with micronutrient supplementation was also documented (32, 33).

Table 5. Effect of nano boron and nano zinc on quality parameters of kinnow

Treatments	Fruit firmness (kg/cm^2)	Physiological weight loss during storage (%)	Shelf life of the fruits (days)	TSS (Brix)	Total acidity (%)	TSS - acidity ratio	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
T_1	2.40	5.96	7.00	10.50	0.86	12.14	7.22	3.08	4.14
T_2	2.52	5.15	7.47	11.03	0.85	12.91	7.95	3.31	4.64
T_3	2.65	4.63	8.23	11.33	0.84	13.45	8.62	3.75	4.87
T_4	2.45	5.58	7.21	10.60	0.86	12.34	7.52	3.15	4.37
T_5	2.55	4.97	7.70	11.07	0.85	13.05	8.15	3.42	4.73
T_6	2.75	4.49	8.48	11.43	0.84	13.66	8.90	3.89	5.01
T_7	2.48	5.41	7.33	10.80	0.86	12.62	7.76	3.23	4.53
T_8	2.60	4.84	7.93	11.20	0.85	13.26	8.21	3.56	4.65
T_9	2.80	4.35	8.68	11.50	0.83	13.82	8.97	3.92	5.05
SE(m)	0.03	0.06	0.15	0.10	0.01	0.20	0.10	0.04	0.07
C.D.	0.10	0.19	0.46	0.31	0.02	0.61	0.30	0.13	0.21

T = Treatment, **SE(m)**= Standard error of the mean, **C.D.**= Critical difference.

Conclusion

Foliar application of nano boron (60 mg/L) and nano zinc (200 mg/L) applied twice - once at pre-flowering (early March) and again at fruit set (late April). This treatment led to substantial improvement in vegetative growth, yield and fruit quality parameters of mature kinnow trees under Punjab's agro-climatic conditions. Treatment T_9 showed significant improvement in vegetative traits, fruit set and fruit retention, which contributed to superior yield. It also improved fruit firmness, TSS and shelf life, while minimising physiological weight loss. Treatments T_6 and T_8 also performed comparably well in terms of vegetative development, productivity and overall quality attributes. Overall, the coupled use of nano B and Zn proved to be highly effective for enhancing productivity and post-harvest quality in kinnow cultivation. Future research directions may include evaluating the long-term effects of repeated nano nutrient applications on soil health and microbial activity, optimizing dosage and timing for different citrus cultivars, exploring the interaction of nano micronutrients with other essential elements and assessing their economic feasibility and environmental safety under diverse agro-climatic conditions.

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Authors' contributions

RS contributed to experimentation, investigation, data analysis, interpretation and writing of original draft. S[1] provided critical guidance in designing the experimental framework and supervised the overall execution of the research. She also contributed to the interpretation of results and refinement of the manuscript. S^2 helped in providing assistance in data analysis. AB provided help during course of experimentation. All authors read and approved final version of the manuscript. (S^1 stands for Shweta and S^2 stands for Sumedha).

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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