The Effect of Foliar Application of Zinc, Potassium, and Boron on Fruit Set and Retention in Kinnow Mandarin

ABSTRACT

The study was conducted to assess the impact of foliar application of zinc (Zn), potassium (K), and boron (B) on the yield and quality of 'Kinnow' mandarin during 2023-2024 at the experimental orchard of the Department of Horticulture, CCS Haryana Agricultural University, Hisar. The aim was to address declining yields and fruit drop percentage due to improper nutrient management. The foliar treatments included zinc sulfate ($ZnSO_4$), potassium sulfate (K_2SO_4), and boric acid, either alone or in combination, applied to 10-year-old Kinnow plants. Key parameters measured included flowering time, fruit set, fruit retention, fruit drop, fruit size, and number of flowers per twig. The results indicated that the combined treatment of zinc sulfate (1.5%), potassium sulfate (0.5%), and boron (0.6%) was superior across all metrics, significantly improving vegetative growth, yield, and decline fruit drop percentage of tree. This treatment enhanced initial fruit set, fruit retention, and fruit size while reducing fruit drop or days taken for flowering. These findings suggest that proper nutrient application can significantly improve the productivity and quality of Kinnow mandarins. Zinc (Zn), boron (B), and potassium (K) are essential nutrients for fruit trees, playing critical roles in growth and fruit quality. Zinc is vital for enzyme activation, protein synthesis, and chlorophyll production, enhancing photosynthesis and reproductive success. Boron is crucial for cell wall formation, pollen tube growth, and nutrient transport, ensuring fruit set and preventing disorders like fruit cracking. Potassium regulates water balance, enzyme activity, and carbohydrate transport, contributing to larger fruit size, improved sugar content, and stress resistance. Together, these nutrients support optimal growth, fruit development, and high-quality fruit production.

Keywords: kinnow mandarin;boron;zinc;potassium;fruit drop;fruit set.

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INTRODUCTION

Citrus species are grown in the tropics and subtropics worldwide. India and Southeast Asia represent the furthest regions of the citrus genus' native range. However, the majority of commercial citrus production occurs in subtropical regions with latitudes between 20°N and 20°S, and elevations of 600–750 m above mean sea level, but less than 45°N and 35°S. According to the United Nations Conference on Trade and Development (UNCTAD), factors driving the rising citrus output include growing incomes, expanding agricultural regions, improved packaging and transportation, and customer preferences for healthier food. Citrus fruits are cultivated in four regions of India: central India (Madhya Pradesh, Maharashtra, and Gujarat); northeastern India (Meghalaya, Assam, and Sikkim); northwestern India (Punjab, Rajasthan, Haryana, and western Uttar Pradesh); and southern Indian states including Tamil Nadu, Karnataka, Andhra Pradesh, and Telangana. According to the World Citrus Organization (WCO), world citrus production reached 158.5 million metric tons in summer 2021–22. China dominates global production with 44.6 million metric tons and 28% of the total (WCO 2021–22). Haryana accounts for 24.4 thousand hectares of area under citrus cultivation with a total production of 570.88 metric tons (IndiaStat 2021–22)."King" and "Willow Leaf" (Citrus nobilis Lour × Citrus deliciosa Tenora) are the parents of the Mandarin hybrid Kinnow (Citrus reticulata Blanco). This type of mandarin is highly prized and respected in North India. Farmers in North India, especially in Punjab, Haryana, Rajasthan, and Himachal Pradesh, are dedicating increasing amounts of land to it due to its growing popularity. The Kinnow fruit has a melting deep yellowish-orange hue, a rich aromatic flavor, and an acidity of 0.75–1.2 per cent, with a TSS of 10 to 12 per cent. It is delicious and refreshing. The expanding economic relevance of the Kinnow Mandarin can be attributed to its improved agro-environmental adaptability, fragrant flavor when consumed fresh, higher output, and superior processing quality.

Growers in North India have focused significantly on Kinnow cultivation, dedicating extensive land, especially in Punjab, Haryana, Rajasthan, and Himachal Pradesh. Its peel can be used to extract essence and in cosmetics, while its pulp is ideal for making sweets, jams, and sauces. It is well-known that micronutrient deficiencies negatively impact fruit yield, quality, and vegetative growth. Citrus groves (small groups or clusters of trees that are planted and managed for specific purposes) in the country commonly suffer from deficiencies in zinc and boron. Zinc is crucial for plant metabolism, being involved in enzymatic reactions like hexokinase, carbohydrate synthesis, and protein production.

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Boron enhances carbohydrate breakdown into simple sugars and facilitates sugar transport through boron-sugar complexes, while improved cell permeability due to zinc and boron could regulate plant water relations. These findings align with those of previous studies on sweet orange (Sajid et al., 2010) and Khasi mandarin (Babu and Yadav, 2005).

Growers value Kinnow for its high yield, wide tolerance to various agro-climatic conditions, and exceptional fruit flavor, aroma, and processing qualities. Nutrition plays a crucial role in the health and prosperity of citrus cultivation. Citrus trees develop abnormally and yield less fruit due to inadequate nutrition. Integrated nutrition management—comprising regular nutrient application, adequate fertilization, and the use of nutrient-rich organic manures and biofertilizers—leads to excellent citrus production (Srivastava, 2012).

Kinnow mandarin is a nutrient-loving and nutrient-responsive crop. Besides the effect of macronutrients on the growth and yield of the crop, micronutrients are equally important for Kinnow fruit. Researchers have worked extensively on establishing a relationship and standardizing micronutrient applications in Kinnow mandarin. There is a particular interest in Kinnow crops as they are adaptable to a wide range of climatic aberrations, are heavy bearers, and give more production per unit area along with some other citrus crops.

Zinc and boron are critical elements in the functioning of enzymes that facilitate nitrogen and carbohydrate metabolism, respectively. This leads to an enhanced uptake of nitrogen by the plant. Additionally, zinc plays a vital role in synthesizing tryptophan, a precursor to indole acetic acid, which promotes tissue growth and development. Boron contributes to the production of phenolic compounds, which are essential for the regulation of polar auxin transport. The elevated activity of auxins results in improved vegetative growth characteristics. The findings observed in Kinnow mandarin align with the research conducted by Ullah et al. (2012).

Zinc (Zn) and boron (B) are crucial nutrients that support various physiological and biochemical processes essential for the optimal growth of citrus trees. Zinc plays a key role in enzyme activation, protein synthesis, and carbohydrate transport (Ashraf et al., 2012, 2013). It also enhances photochemical reactions in the thylakoid membranes and boosts electron transport, leading to an improved photosynthetic rate (Roach & Liszkay, 2014). Razzaq et al. (2013) reported that Zn foliar sprays positively impacted fruit yield and quality in Kinnow mandarin, sweet oranges, and grapes. Boron, on the other hand, is vital for pollen tube germination and elongation (Abd-Allah, 2006). Applications of both Zn and B have

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been shown to increase fruit set, yield, and quality in citrus trees (Ram & Bose, 2000; Asadi et al., 2005).

Fruit yield in citrus trees is influenced by various factors, including climate, geographical location, rootstock selection, soil quality, irrigation water quality, and pest and disease management. Among these, malnutrition is identified as one of the leading causes of low fruit production (Randhawa et al., 1967). Proper nutrient management is critical to ensuring optimal growth and maximizing fruit yield in citrus orchards. The application of balanced fertilizers has been shown to significantly enhance the growth, yield, and quality of various fruit crops under diverse agro-climatic conditions across the country. Studies conducted by Ram et al. (1997), Kumar et al. (1998), Ghosh (1990), and Monga et al. (2002) consistently highlight the positive impacts of appropriate nutrient management on fruit crops. These findings underscore the importance of a well-rounded fertilization approach in achieving optimal fruit production across different regions.

It is evident from the present studies that the application of K produced variable results in respect of tree volume, with the maximum tree volume observed with the application of this treatment (Monga et al., 2004). Boron plays a crucial role in plant growth and fruit production by enhancing pollen germination and pollen tube elongation, which leads to increased fruit set, seed development, and overall yield. It also influences sugar composition in nectar, which attracts more pollinators, thereby improving pollination efficiency. Furthermore, boron positively impacts pollen production and viability, ensuring better fertilization and fruit formation (Mohammad et al., 2018).

The citrus processing industry generates significant waste, primarily in the form of seeds, peels, and pomace. These by-products, especially the peels and seeds, are rich in valuable phytochemicals such as polyphenols, flavonoids, antioxidants, limonoids, carotenoids, and tocopherols. These bioactive compounds can be extracted and utilized in various industries, including pharmaceuticals, food, nutraceuticals, cosmetics, and paper. Additionally, the growing demand for processed Kinnow products is driven by shifting consumer tastes, dietary habits, and preferences (Dudeja et al., 2023).

Boron, as a crucial micronutrient, plays a vital role in the growth and productivity of citrus. Boron deficiency is commonly observed in acidic, sandy soils, and those with low organic matter content. To address micronutrient deficiencies, foliar application has become a promising approach for researchers and growers. It enhances nutrient uptake, reduces

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application doses, and minimizes leaching losses. Applying micronutrients like zinc (Zn), copper (Cu), manganese (Mn), boron (B), and iron (Fe) through foliar sprays offers several benefits over soil application, including greater effectiveness, faster plant response, convenience, and prevention of toxicity caused by excessive soil accumulation (Kumari et al., 2024).

METHODOLOGY

The current study, "*Influence of foliar application of nutrients on fruit set, yield, and quality of Kinnow Mandarin*," was carried out in 2023–2024 on ten -year-old kinnow Mandarin trees at Experimental Orchard and Post-harvest Technology Laboratory of Department of Horticulture at CCS Haryana Agricultural University, Hisar. These plants were set aside specifically to collect data on various physiological and biochemical parameters. The delineation of materials and methods practiced in the present study are as follows:

Experimental site

Field trials were carried out in the Department of Horticulture, CCS Haryana Agricultural University, Hisar Experimental Orchard (29º 10' N latitudes and 75º 46' E longitudes), which is situated 215.2 m above mean sea level.

Weather and Climate

Hisar has a typical semi-arid climate, with extremely cold winters and scorching, dry summers. It is typical for the area to see highs of about 45ºC in the summer, from May to June, and lows of almost freezing in the winter, from December to January.The amount of precipitation overall and how it is distributed throughout the area are very variable. Approximately, 450 mm, or 80 per cent of the annual precipitation, falls between July and September. Due to the western disturbances, a few showers also occur between December and February.There are notable fluctuations in the precipitation, ranging from 20–30 per cent annually to 30–50% seasonally.

Treatments:

T_1 : $ZnSO_4$ (1%)

T_2 : $ZnSO_4$ (1.5%)

T_3 : Boron(0.3%)

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T_4 : Boron (0.6%)

T_5 : K_2SO_4 (0.25%)

T_6 : K_2SO_4 (0.5%)

T_7 : $ZnSO_4$ (1%) + Boron (0.3%) + K_2SO_4 (0.25%)

T_8 : $ZnSO_4$ (1%) + Boron (0.6%) + K_2SO_4 (0.5%)

T_9 : $ZnSO_4$ (1%) + Boron (0.3%) + K_2SO_4 (0.5%)

T_{10} : $ZnSO_4$ (1%) + Boron (0.6%) + K_2SO_4 (0.25%)

T_{11} : $ZnSO_4$ (1.5%) + Boron (0.3%) + K_2SO_4 (0.25%)

T_{12} : $ZnSO_4$ (1.5%) + Boron (0.3%) + K_2SO_4 (0.5%)

T_{13} : $ZnSO_4$ (1.5%) + Boron (0.6%) +K_2SO_4(0.25%)

T_{14} : $ZnSO_4$ (1.5%) + Boron (0.6%) + K_2SO_4 (0.5%)

T_{15} : Control (No application)

Treatments details

Crop	:	Kinnow Mandarin
Number of treatments	:	Fifteen (15)
Time of foliar application	:	First week of March
		Last week of April
Replications	:	Three per treatment (3)
Experimental Design	:	Randomized Block Design

Observations recorded

Growth parameters

1. Days taken for flowering
2. Numbers of flowers per twig
3. Initial fruit set (%)
4. Final fruit retention(%)
5. Leaf chlorophyll content (mg/g)
6. Fruit drop (%)

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Days taken for flowering

Number of days were counted for flower initiation from each tree and averaged.

Number of flowers per twig

Four twigs were selected from the tree in each direction, and the number of blooms on each twig was counted and averaged.

Initial fruit set (%)

To determine the initial fruit set, the total number of flowers on tagged twigs was subtracted from the number of fruits set in the initial stage.The following calculation can be used to determine the initial fruit set percentage:

$$\text{Initial fruit set (\%)} = \frac{\text{Initial fruit set}}{\text{Total number of flowers}} \times 100$$

Final Fruit retention (%)

The quantity of initial fruit set was subtracted from the total number of mature fruits to determine the percentage of fruit retention. The following calculation was used to determine the percentage of fruit retention:

$$\text{Final Fruit retention (\%)} = \frac{\text{Retained mature fruits}}{\text{Initial fruit set}} \times 100$$

Leaf chlorophyll content

A method developed by Hiscox and Israelstam (1979) was used for the estimation of chlorophyll. Samples of leaves were collected in the month of October and then washed and the chlorophyll content was measured by using spectrophotometer. One hundred mg of leaf tissue was placed in test tubes, then 5 ml dimethyl sulphoxide (DMSO) was added into it and kept overnight so that chlorophyll could be extracted into fluid and the tissue became chlorophyll free. A 3 ml aliquot of chlorophyll extract was transferred to a cuvette and the absorbance values were recorded at 645 and 663 nm against a blank (DMSO) by using a spectrophotometer. The chlorophyll contents were calculated by using the following equations:

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$$\text{chlorophyll a} = \frac{(12.3\times A665)-(0.86\times A645)}{a\times \text{wt. of tissue}\times 1000}\times \text{volume of DMSO}$$

$$\text{Chlorophyll b} = \frac{(19.3\times A645)-(3.6\times A665)}{a\times \text{wt. of tissue}\times 1000}\times \text{volume of DMSO}$$

Where, a=path length

Total chlorophyll= chlorophyll a+ chlorophyll b

Fruit drop (%)

The fruit drop was assessed by deducting the number of fruits kept in July from the total number of fruits counted in the first four stages of four tagged branches. The following calculation can be used to determine the percentage fruit drop:

$$\text{Fruit drop (\%)} = \frac{\text{Initial fruit set - Retained fruits in month of July}}{\text{Initial fruit set}} \times 100$$

RESULTS AND DISCUSSION

The data recorded for different parameters like fruit set and fruit retention from lab experiment directed on Influence of foliar application of nutrients on fruit set,yield and quality of kinnow Mandarin were incorporated, tabulated and analyzed according to the standard procedures as per the experimental design and other statistical methods. The data so acquired have been thoroughly analyzed,interpreted,explained and presented in this chapter under the following headings:

Effect of foliar application of different nutrients on days taken for flowering and number of flowers per twig

The data proposed in Table 1 describe the effect of application of different combinations of zinc sulphate,boric acid and potassium sulphate on number of flowers per twig tagged in each direction of Kinnow mandarin plant.The number off lower staged per twig was significantly affected by the treatments.The maximum number of flowers tagged per twig(75 flowers) was observed in treatmentT_{14}-Zinc sulphate (1.5%)+Boric acid (0.6%)+Potassium sulphate (0.5%) which was found at par with treatment T_7 : $ZnSO_4$ (1%) + Boron (0.3%) + K_2SO_4 (0.25%)*i.e.*, 73.33 flowers per twig and treatment T_{12} : $ZnSO_4$ (1.5%) + Boron (0.3%) + K_2SO_4 (0.5%)*i.e.*, 73.00 flowers per twig while the minimum number of flowers tagged

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per twig was recorded intreatmentT_{15} control.

The maximum days taken for flowering were recorded in treatment T_{15}- control (23.67)and the minimum days taken for flowering were obtained from thetreatmentT_{14} *i.e.*, Zinc sulphate (1.5%)+Boric acid (0.6%)+Potassium sulphate (0.5%), however, was found at par with treatment T_7 : $ZnSO_4$ (1%) + Boron (0.3%) + K_2SO_4 (0.25%)*i.e.*, 20 days and T_{12} : $ZnSO_4$ (1.5%) + Boron (0.3%) + K_2SO_4 (0.5%)*i.e.*, 20 days.

Table 1: Effect of foliar application of different of nutrients on days taken for flowering and number of flowers per twig in Kinnow mandarin

Treatments	**Days taken for flowering**	**Number of flowers per twig**
T_1:$ZnSO_4$(1%)	19.67	69.00
T_2: $ZnSO_4$(1.5%)	22.00	70.33
T_3: Boron(0.3%)	21.00	68.00
T_4:Boron(0.6%)	20.33	69.33
T_5: K_2SO_4(0.25%)	21.00	72.00
T_6: K_2SO_4(0.5%)	22.00	68.00
T_7: $ZnSO_4$(1%) + Boron(0.3%) + K_2SO_4(0.25%)	20.00	73.33
T_8: $ZnSO_4$(1%) + Boron(0.6%) + K_2SO_4(0.5%)	20.67	71.00
T_9: $ZnSO_4$(1%) + Boron(0.3%) + K_2SO_4(0.5%)	20.00	70.00
T_{10}: $ZnSO_4$(1%) + Boron(0.6%) + K_2SO_4(0.25%)	20.33	71.00
T_{11}: $ZnSO_4$(1.5%) + Boron(0.3%) + K_2SO_4(0.25%)	19.00	70.00
T_{12}: $ZnSO_4$(1.5%) + Boron(0.3%) + K_2SO_4(0.5%)	20.00	73.00
T_{13}: $ZnSO_4$(1.5%) + Boron(0.6%) + K_2SO_4(0.25%)	19.00	71.00
T_{14}: $ZnSO_4$(1.5%) + Boron(0.6%) + K_2SO_4(0.5%)	18.67	75.00
T15:Control (no application)	23.67	67.33
C.D. at 5% level of significance	**1.78**	**2.68**

A research study was conducted in 2019 under the PM-AMP (Prime Minister Agriculture Modernization Project), Project Implementation Unit, Citrus Zone, in Dailekh, Nepal, during the spring season. The study aimed to investigate the effects of foliar micronutrient application on the flowering and fruit setting of mandarin (Citrus reticulata Blanco). This

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research explored how different micronutrient treatments could impact the reproductive processes of mandarin trees, such as flower production, pollen viability, and fruit set, which are critical for optimizing yield and quality in citrus cultivation. The number of days to flowering and fruit set did not show significant variation across different treatments. On average, the first flowering occurred 45.05 days after the initial spraying, with the range spanning from 43.50 days (for 0.04% boron) to 46 days (control). Similarly, the average time to the first fruit set after the second spraying was 7.55 days, varying between 6.50 days (for 0.04% boron) and 9 days (control). The characteristics of the spring flush are primarily influenced by the combined effects of climate, flower induction, and bud sprouting. However, variations can arise due to additional environmental factors and the impact of cultural practices (Jahn, 1973) .The flowering of mandarin was significantly affected by the foliar application of micronutrients, recorded at 44 days after spraying (DAS). The average number of flowers per branch was 155.7. The highest number of flowers per branch was observed with a 0.15% zinc (Zn) spray, producing 252.50 flowers. This result was statistically similar to the treatment with 0.05% Zn + 0.02% boron (B), which yielded 182.50 flowers, and 0.1% Zn + 0.04% B, which resulted in 158.75 flowers per branch. In contrast, the control group showed the lowest flower count, with only 46.25 flowers per branch.

Effect of foliar application of different nutrients on initial fruit set and percent final fruit retention

Different chemical treatments significantly affected percent initial fruit set in Kinnow mandarin as shown in table 2. Minimum number of percent initial fruit set (49.00%) was recorded withT_1*i.e.*, Zinc sulphate (1%)and T_{11}-Zinc sulphate (1.5%)+Boric acid (0.3%)+Potassium sulphate (0.25%). Maximum number of fruit set (50.33%) was observed in T_{14}- Zinc sulphate (1.5%)+Boric acid (0.6%)+Potassium sulphate (0.5%) was found superior.The perusal data given in Table 2 revealed that the different treatments considerably affected final fruit retention.The maximum retention (24.67%) was observed in T_{14}- Zinc sulphate (1.5%)+Boric acid (0.6%)+Potassium sulphate (0.5%)and the minimum was observed in T_{15} – control *i.e.*18.67%.

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Table 2: Effect of foliar application of different nutrients on initial fruit set percent and final fruit retention in Kinnow mandarin

Treatments	**Initial fruit set (%)**	**Final fruit retention (%)**
T_1:$ZnSO_4$ (1%)	47.00	19.33
T_2: $ZnSO_4$ (1.5%)	48.00	20.67
T_3: Boron(0.3%)	47.67	20.67
T_4: Boron (0.6%)	47.00	22.67
T_5: K_2SO_4 (0.25%)	48.67	20.67
T_6: K_2SO_4 (0.5%)	47.33	21.67
T_7: $ZnSO_4$ (1%) + Boron (0.3%) + K_2SO_4 (0.25%)	47.00	22.67
T_8: $ZnSO_4$ (1%) + Boron (0.6%) + K_2SO_4 (0.5%)	47.67	23.00
T_9: $ZnSO_4$ (1%) + Boron (0.3%) + K_2SO_4 (0.5%)	48.00	22.33
T_{10}: $ZnSO_4$ (1%) + Boron (0.6%) + K_2SO_4 (0.25%)	48.33	22.00
T_{11}: $ZnSO_4$ (1.5%) + Boron (0.3%) + K_2SO_4 (0.25%)	47.00	24.00
T_{12}: $ZnSO_4$ (1.5%) + Boron (0.3%) + K_2SO_4 (0.5%)	47.33	22.67
T_{13}: $ZnSO_4$ (1.5%) + Boron (0.6%) + K_2SO_4 (0.25%)	47.67	23.67
T_{14}: $ZnSO_4$ (1.5%) + Boron (0.6%) + K_2SO_4 (0.5%)	50.33	24.67
T15: Control (no application)	48.33	18.67
C.D. at 5% level of significance	**1.34**	**1.09**

Kumar et al. (2019)reported that a 0.25% $ZnSO_4$ treatment resulted in the highest initial fruit set percentage, while 2,4-D at 15 ppm produced the lowest initial fruit set. Furthermore, the application of 2,4-D at 20 ppm had a positive impact by reducing June and pre-harvest fruit drop, increasing final fruit retention, and improving the number of fruits per plant, thus enhancing overall fruit yield. Gurjar et al. (2018) noted that the foliar application of 0.2% boric acid combined with 0.5% zinc sulfate during the fruit set and peach size stages (T9) in Kinnow mandarin resulted in the highest fruit retention (71.77%) and the maximum number of fruits per plant (486.24). In contrast, the control group had significantly lower values. The

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reduction in fruit drop was likely a key factor contributing to this enhanced fruit retention and yield.

Effect of foliar application of different nutrients on fruit drop (%)in Kinnow mandarin

The effect of different nutrients was significantly seen in case of fruit drop as given inTable 3.The observations pertaining in Table 3 was evaluated and it is evident from data that the different nutrients affected significantly.

Fruit drop was significantly affected by the treatments applied.The data pertaining in Table 3 were evaluated and the maximum fruit drop was observed in T_{15}*i.e.*,control, (52.34 %) which was nearly equal toT_4*i.e.*, Boric acid (0.6%), (51.78%), and T_5*i.e.*, Potassium sulphate (0.25%) (50.21%).Minimum fruit drop was observed in T_{12} *i.e.*,Zinc sulphate (1.5%)+Boric acid (0.3%)+Potassium sulphate (0.5%),(41.68%) which was statistically at par with T_{14}*i.e.*,Zinc sulphate (1.5%)+Boric acid (0.6%)+Potassium sulphate (0.5%),(42.44%). The experiments conducted in Dhankuta, Nepal, during 2019 and 2020 evaluated the impact of foliar application of gibberellic acid (GA3), 2,4-D, and micronutrients on fruit drop and fruit set. The treatment of GA3 + 2,4-D + micronutrients significantly reduced fruit drop in June (63.9%), July (65.9%), and September (20.8%) compared to the control (77.6%, 80.4%, and 41.5%, respectively). The highest bloom fruit set (6.1%) was achieved with GA3 20ppm + NAA 50ppm, while the control had 4.6%. Based on these findings, a combined foliar application of gibberellic acid, 2,4-D, and micronutrients is recommended for improving fruit set, retention, and yield of mandarin. The study highlighted the effectiveness of these treatments in enhancing overall fruit production (Puneet al.,2023).

Table 3: Effect of foliar application of different nutrients on fruit drop(%) of Kinnow mandarin

Treatments	**Fruit drop (%)**
T_1:$ZnSO_4$ (1%)	50.05
T_2: $ZnSO_4$ (1.5%)	51.46
T_3: Boron(0.3%)	49.73
T_4: Boron (0.6%)	51.78
T_5: K_2SO_4 (0.25%)	50.21

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T_6: K_2SO_4 (0.5%)	50.10
T_7: $ZnSO_4$ (1%) + Boron (0.3%) + K_2SO_4 (0.25%)	48.68
T_8: $ZnSO_4$ (1%) + Boron (0.6%) + K_2SO_4 (0.5%)	43.84
T_9: $ZnSO_4$ (1%) + Boron (0.3%) + K_2SO_4 (0.5%)	42.84
T_{10}: $ZnSO_4$ (1%) + Boron (0.6%) + K_2SO_4 (0.25%)	46.35
T_{11}: $ZnSO_4$ (1.5%) + Boron (0.3%) + K_2SO_4 (0.25%)	47.68
T_{12}: $ZnSO_4$ (1.5%) + Boron (0.3%) + K_2SO_4 (0.5%)	41.68
T_{13}: $ZnSO_4$ (1.5%) + Boron (0.6%) + K_2SO_4 (0.25%)	45.94
T_{14}: $ZnSO_4$ (1.5%) + Boron (0.6%) + K_2SO_4 (0.5%)	42.44
T15: Control (no application)	52.34
C.D. at 5% level of significance	**0.82**

Ashraf et al. (2013)conducted experiments in citrus orchards, revealing that foliar applications of 2,4-D, salicylic acid (SA), zinc (Zn), potassium (K), and their combinations significantly reduced fruit drop. The most notable reduction in fruit drop was observed in trees treated with a combination of 2,4-D + Zn + K, followed by treatments of SA + Zn + K, 2,4-D alone, K + Zn, and SA alone. In contrast, trees treated with distilled water exhibited the highest fruit drop, with variations in results depending on the orchard site. The findings emphasize that Kinnow fruit drop poses a major challenge for citrus growers, but proper combinations of growth regulators and nutrients can greatly improve both yield and quality (Doberman & Fairhurst, 2000;.Saleem et al., 2005).

Effect of foliar application of different nutrients on Leaf chlorophyll content

The data revealing the effect of foliar application of different nutrients on leaf chlorophyll content are shown in table 4. The observations pertaining to leaf chlorophyll content in leaves are shown in table 4. It was evident that the different nutrients affected significantly. The maximum leaf chlorophyll content was recorded in T_{14}*i.e.*, Zinc sulphate (1.5%) + Boric acid (0.6%) + Potassium sulphate (0.5%) and minimum was observed in T_{15}*i.e.*, control (1.24).

Table 4: Effect of foliar application of different nutrients on leaf chlorophyll content (mg/g) of Kinnow Mandarin

Treatments	**eaf chlorophyll content (mg/g)**
T_1:$ZnSO_4$ (1%)	1.37
T_2: $ZnSO_4$ (1.5%)	1.41

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T_3: Boron(0.3%)	1.46
T_4: Boron (0.6%)	1.73
T_5: K_2SO_4 (0.25%)	1.88
T_6: K_2SO_4 (0.5%)	1.67
T_7: $ZnSO_4$ (1%) + Boron (0.3%) + K_2SO_4 (0.25%)	1.68
T_8: $ZnSO_4$ (1%) + Boron (0.6%) + K_2SO_4 (0.5%)	1.87
T_9: $ZnSO_4$ (1%) + Boron (0.3%) + K_2SO_4 (0.5%)	1.99
T_{10}: $ZnSO_4$ (1%) + Boron (0.6%) + K_2SO_4 (0.25%)	1.76
T_{11}: $ZnSO_4$ (1.5%) + Boron (0.3%) + K_2SO_4 (0.25%)	1.94
T_{12}: $ZnSO_4$ (1.5%) + Boron (0.3%) + K_2SO_4 (0.5%)	2.16
T_{13}: $ZnSO_4$ (1.5%) + Boron (0.6%) + K_2SO_4 (0.25%)	2.05
T_{14}: $ZnSO_4$ (1.5%) + Boron (0.6%) + K_2SO_4 (0.5%)	2.19
T15: Control (no application)	1.24
C.D. at 5% level of significance	**0.02**

Ilyas et al. (2015) found that foliar application of micronutrients like zinc (Zn), copper (Cu), and boron (B) had a significant impact on carotenoid content, the chlorophyll a/b ratio, and total chlorophyll (Chlt) in Kinnow mandarin. The highest pigment concentrations were achieved with 0.3% zinc treatment. However, as copper levels increased, a gradual decline in these pigment values was noted. Treatments with boric acid showed varying effects, with the highest concentrations of carotenoids, Chlt, and the Chla/Chlb ratio occurring at 0.2%, 0.1%, and 0.3% boric acid, respectively, during the fruit set stages.

CONCLUSION

In conclusion, foliar applications of micronutrients such as zinc, boron, and potassium have been shown to significantly improve fruit set, flower production, and overall yield in Kinnow mandarin. Studies indicate that treatments combining zinc sulfate (1.5%), boric acid (0.6%), and potassium sulfate (0.5%) result in the highest fruit retention, minimal fruit drop, and increased chlorophyll content. Treatment T14 (Zinc 1.5% + Boron 0.6% + Potassium 0.5%) consistently outperformed others, highlighting its effectiveness in enhancing citrus productivity while reducing fruit drop and improving plant health.

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