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Effect of Foliar Spray of Zinc and Manganese on Vegetative Growth, Yield and Fruit Quality of Kinnow Mandarin (*Citrus reticulate*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In the Fruit Orchard of Guru Kashi University, Talwandi sabo, in the Southern-Western region of Punjab, the current study, named "Effect of foliar spray of Zinc and Manganese on vegetative development, yield, and fruit quality of Kinnow mandarin"(*Citrus reticulate*), was carried out from 2023 to 24, Applying a mixture of manganese and zinc sulfate to Kinnow plants that are five years old. The study employed a randomized block design with three replications. The inquiry involved the use of various treatments. T4-Zn+Mn (0.5%+0.25%), T5-Zn+ Mn (0.5%+0.35%), T6-Zn+ Mn (0.5%+0.45%), T7-Mn+ Zn (0.35%+0.4%), and T8-Mn+ Zn (0.35%+0.6%) are the groups that comprise T1-control, T2-zinc 0.5%, and T3-Mn 0.35%.The results showed that the best

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combinations for plant growth metrics, such as plant height (302 cm), mean fruit weight (182 gm), mean fruit length (7.26 cm), and mean fruit weight, were T8: 0.35%Mn+0.6%Zn and T5:0.5%Zn+0.35%Mn. diameter (9.20 cm), average fruit output per plant (482), and quality characteristics with the T5:0.5% Zn+0.35% Mn and T1 control, such as total soluble solid (11.16 Brix) and maximum acidity (1.94).The ideal concentrations of zinc sulfate (0.6% and manganese sulfate (0.35%) to boost output, enhance fruit quality, and promote kinnow vegetative growth.

Keywords: Foliar application; micronutrients; kinnow; zinc; manganese; physio-chemical attributes.

1. INTRODUCTION

The citrus genus, which is important to the Rutaceae family, is native to Southeast Asia. After bananas and mangoes, it is the third most significant agricultural product worldwide. Citrus fruits are valuable due to their high level of ascorbic acid and other beneficial nutrients. Northwest India is the largest producer of kinnow, with Punjab being the most agriculturally engaged region. This region mostly grows lemon, lime, sweet oranges, and kinnow among other citrus varieties. (Ministry of Agriculture & Farmers Welfare). The kinnow mandarin is a highly valued citrus fruit that is renowned for its amazing aroma, wonderful taste, generous volumes of juice, and great nutritional value, which includes large quantities of vitamin C, sugar, and antioxidants. In warm climates, kinnow trees can grow up to 35 feet in height and bear up to 1,000 fruits a tree [1-3]. The fruit ripens between January and February, has a peel that is easily detached, and is rich in juice (Department of Horticulture, Government of Punjab) In India, citrus fruit production is very important and highly valued. It covers a large area of 1054,000 hectares of land and produces over 13,976,000 metric tons of fruit annually. Anonymous [4] The Ministry of Agriculture & Farmers Welfare, Government of India, obtained this data from the Indian Horticulture Database maintained by the National Horticulture Board.

Dr. H.B. Frost developed the Kinnow hybrid in 1915 at the Citrus Research Centre, University of California, Riverside, USA, by crossing King (*Citrus nobilis*) with Willow Leaf (*Citrus deliciosa*) mandarins. 1935 saw the introduction of the new commercial cultivar following a 20-year trial period. Micronutrients such as manganese and zinc play a key role in regulating physiological processes and plant development through a range of enzymatic activities [5-9]. Zinc, for example, influences the synthesis of over 150 different enzymes in plants, as well as respiration, growth hormones, and auxin. It also encourages flowering and the growth of pollen tubes, which has an impact on fruit set. Together with boron, it also lessens fruit and blossom drops by shielding the abscission layer's establishment. Manganese is also beneficial to the citrus family since it raises the average weight and number of fruits produced per tree, increasing fruit yield. Additionally, the addition of manganese, copper, boron, and zinc enhances quality markers such as total soluble solids, peel thickness, and juice % [10].

Riordon [11] and Shkolnik [12] identified growth regulation, cell division, preservation of membrane structure, nucleic acid metabolism, protein biosynthesis, and sexual fertilization as the primary physiological roles of zinc. It is engaged in the process of plant respiration and regulates the synthesis of chlorophyll and the redox potential in plant cells. In addition to serving as an enzyme cofactor, zinc is necessary for the synthesis and upkeep of the molecular structures of numerous vital cell components, including the ribosome. It's present in 59 enzymes, which cover nearly all enzyme groups. They claimed that compared to other trace metals, zinc's metabolic functions are the most apparent [13-15]. The part zinc plays in the Krebs cycle's operation. The cultivar has extreme variability in all fruit characteristics which is undesirable for fresh fruit export. Twelve lots of good looking, healthy clean fresh fruits were taken from different locations [16-19]. The characteristics studied were fruit and peel weight, fruit volume, diameter, height, number of segments, seed shapes, total seeds, aborted seeds, seed embryony, juice pH and juice Brix. Hussain J et al. (2008) Fruit variability in Kinnow mandarin (*Citrus reticulata*).

2. METHODS AND MATERIALS

The faculty of agriculture at Guru Kashi University in Talwandi Sabo conducted the current study on the "Effect of foliar spray of Zinc and Manganese on vegetative development, yield, and fruit quality of Kinnow mandarin" (*Citrus reticulate*). The following lists the materials and techniques employed.

2.1 Experimental Site and Climate Condition

The investigation was conducted from March 2023 to 24 at the Guru Kashi University's Talwandi Sabo research orchard in Bathinda, Punjab. Bathinda is on the southern Punjabi Sutlej-Ganga plain, near the Rajasthani Thar Desert, and is located between 29°-33' and 30°-36' North latitude and 74°-38' and 75°-46' East longitude. The monsoon season, which begins in the first two weeks of July and produces an average of 293.8 mm of rainfall, begins in the area, which sees intense summer heat and harsh winter cold. Talwandi Sabo has an undulating topography, sandy to loam sand soil, and insufficient underground water. The in vitro work was carried out in the university, Department of Horticulture laboratory. However the fieldwork was completed in the Guru Kashi University experimental orchard.

2.2 Analysis of Soil Samples for Basic Properties

The sandy loam texture and high pH of the soil caused an annual micronutrient shortage in the Kinnow orchard. In this case, we arbitrarily chose twelve plants from your divided trial orchard. Determining the proportion of zinc and manganese that are easily accessible in the orchard soil is the main objective of soil sampling. In order to evaluate the fundamental features and micronutrient availability of the orchard, six samples were taken from 0 to 150 cm in the first orchard and the same in the second. Once all of the orchard samples were gathered, the samples were sent to the KVK Center for examination of the basic properties and available micronutrients in the soil.We used the International Pipette Method to examine and evaluate the mechanical properties of the soil. Using an Elico glass electrode pH meter and a solubridge conductivity meter, we determined the pH and electrical conductivity of 1:2 soil water solutions. We applied the Walkley and Black fast titration method to calculate the organic carbon concentration. Jackson, Merwin, and Peech's approach was utilized to determine available potassium, while Olsen et al.'s method was utilized to extract available phosphorus. Table 1 displays a profile of the soil's physical and chemical properties.

2.3 Plant Growth Characteristics

Following each treatment application, ten randomly selected plants from each Treatment were taken, and the following measurements were noted. The fruit retention percentage (%), tree height, flower count per branch, and rootstock and scion diameters.

2.4 Physical Characteristics

At the end of the experiment, every physical feature was measured, including the fruit's equatorial shape, diameter, number of seeds per fruit, pulp and peel weights, fruit weight, and juice percentage based on treatment.

2.5 Chemical Characteristics

2.5.1 Total soluble solids [TSS]

We took ten randomly chosen fruit samples from each experimental treatment. We measured the total soluble solids content of the juice using a electronic refractor meter. When a small amount of juice was applied to the prism that was facing

Table 1. Basic soil properties of experimental area from soil depth of 0-5 and 120-150cm

Soil properties	Soil depth (cm)		Reference
	Orchard 1st	Orchard 2nd	
Soil texture	Sandy loam	Sandy loam	Jackson [20]
PH	7.9	8.3	Jackson [20]
EC	0.71	0.47	Jackson [20]
OC	0.33	0.24	Walkley and Black (1934)
Available P (%)	39.3	30.4	Olsen et al. [21]
Available K (%)	109.6	125.8	Merwin and Peech [22]
DTPA–Extractable Zn (mg kg^{-1})	5.91	0.58	Lindsay and Norvell [23,24]
DTPA–Extractable Mn (mg kg^{-1})	0.21	0.14	Lindsay and Norvell [23,24]
DTPA–Extractable Fe (mg kg^{-1})	0.1	1.5	Lindsay and Norvell [23,24]
DTPA–Extractable S (mg kg^{-1})	16.8	21.6	D.R. Leckyer (1972)
DTPA–Extractable Cu (mg kg^{-1})	0.9	0.68	D.R. Leckyer (1972)

the light source, the measured value was shown. It was necessary to thoroughly clean the prism with distilled water for each subsequent reading.

2.5.2 Total titratable acidity

Ten randomly selected fruit samples from each experimental condition made up the total. Ten milliliters of the freshly extracted juice were collected, and then 100 milliliters of pure water were added to bring the volume up to 100 milliliters. The next step was to use phenolphthalein as an indicator and titrate a ten milliliter sample against N/10 NAOH. The final point was when a light pink color emerged. It was necessary to average these readings in order to calculate total acids, or the percent acidity of citric acid. Acidity = $N \times V \times M / S \times 10$

2.5.3 Fruit characteristics

Ten arbitrary samples were chosen at random from each experimental unit during the picking period in order to measure the average weight (g), diameter (cm), and length (cm) of individual fruits. For picking, the overall fruit yield during the harvesting time was defined as the total fruit yield/plant (kg).

2.5.4 Experimental design and statistical analysis

The study employed a five-year-old, uniformly sized kinnow mandarin orchard with eight treatments. A total of 64 experimental trees were used in the investigation, which was conducted using a randomized complete block design (R.C.B.) with three replicates. The mean of any two treatments was compared using the standard error of mean (SEm) and critical difference (CD) Gomez & Gomez [25].

3. RESULTS AND DISCUSSION

3.1 Vegetative Characteristics

The results of the application of Zn + Mn treatments at several concentrations are shown in Table 2, wherein the number of flowers per branch plant, rootstock and scion diameter, and plant height all significantly improved. Nevertheless, out of all the treatments, applying a T80.35%Mn+0.6%Mn micronutrient therapy had the greatest beneficial impact on the plant's height, scion and rootstock diameters, and number of flowers per branch. The second-best course of action was T50.5%Zn+0.35%Mn. The least amount of improvement was observed when T2 zinc (0.5%) and T3Mn (0.35%) were used at its lowest quantities. Conversely, the Kinnow plants (T1control) that were treated with ground water had the lowest values for the aforementioned attributes. These findings were consistent during investigation seasons. Some related resulted obtained by Chahil and Singh [26] also reported that the annual increment in tree height was significantly higher (25.62 cm) with application of 350 ppm Plano fix (NAA) as compared with control (17.07 cm).Thorat et al [27] Effect of soil and foliar application of zinc on growth and yield parameters of sweet orange var. Nucellar (Citrus sinensis L. Osbeck) foliar application with Zinc sulphate (0.50%) for highest tree height and canopy volume. Kachotet al. [28] Integrated nutrient management in rainy-season groundnut (Arachis hypogaea). The treatment group T1, as the control, resulted in the smallest fruit length of 4.20 cm, followed by treatment T2 with 0.5% Zn, which exhibited a fruit length of 6.24 cm. Babu G H V R and Lavania ML [29] Vegetative growth and nutritional studies as influenced by auxins and gibberellic acid and their effect on fruit yield in lemon. Application of 2,4-D and 2,4,5-T at concentrations ranging from 5 to 20 mg l^{-1} to 5-year-old 'Pant Lemon-1' (Citrus limon Burm) trees reduced the vegetative growth in terms of height, spread, shoot length, number and size of the leaves in the autumn flush. Tagad SS et al. [30]. Effect of foliar application of plant growth regulators and micronutrients on growth and yield parameters of acid lime (*Citrus aurantifolia* L.) cv. Sai Sarbati. Among all the treatments, T_{11} GA_3 (50 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%) recorded maximum increase in plant height (0.25 m), plant spread East-West spread (3.74 m), North-South spread (3.54 m) and minimum days required for initiation of new vegetative flush (17.00 days), flower initiation after vegetative flush (14.00 days) and harvesting (144.00 days). While among all treatments, (T_{11}), GA3 (50 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%) recorded maximum number of fruits/tree (148.00 fruits/tree), fruit weight (43.33 g), fruit volume (41.30 ml), yield (6.41 kg/tree), fruit set (51.20%), number of flower/shoot (18.57) and minimum fruit drop (35.20%). Ram RA et al. [31] Mishra AA et al. [32] Monga et al. [33] the increase in Zn content was more when spraying of Zn was conducted alone rather than in combination with Fe and Mn. Fruit yield, juice content, and total soluble solids were maximum under zinc sulfate (0.3%) treatment. Acidity decreased in all treatments compared to the control.

Table 2. Effect of micronutrient zinc and manganese of different treatment combinations in kinnow mandarin

Treatments	Diameter		Tree height	Number of Flower Per Branch	Fruit equatorial	Fruit diameter	Fruit weight	NO. of seeds per fruit	Juice percentage (%)	Total soluble solid (Brix)	Total tiltable acidity (%)	Fruit retention (%)	Fruit yield per plant
	Rootstock	Scion											
T1-control	97	20.2	242	40.66	4.2	4.13	112	124	35.2	5.36	1.94	15.20	253
T2-zinc 0.5%	101	21.9	277	52	6.24	8.46	142	133	37.6	9.43	1.28	17.20	392
T3-Mn 0.35%	104	22.2	278	55.66	6.4	8.2	148	132	38.6	11.53	1.61	19.20	452
T4-Zn+Mn (0.5%+0.25%)	105.3	23.2	282	59.33	6.24	8.3	152	134	40.06	11.16	1.57	16.20	461
T5-Zn+Mn (0.5%+0.35%)	112	25.03	290.3	64.66	6.8	8.8	171	142	42.6	11.16	1.8	22.20	476
T6-Zn+Mn (0.5%+0.45%)	110	24.2	290	62	6.7	9	168	138	40.4	9.36	1.09	23.40	472
T7-Mn+Zn (0.35%+0.4%)	117	25.2	295.6	64	6.4	8.6	172	142	42.4	9.73	1.53	25.23	469
T8-Mn+Zn (0.35%+0.6%)	120.6	26.2	302	68.66	7.26	9.2	182	150	43.81	9.86	1.24	28.20	482
SE(m)	0.71	0.1	1.13	0.79	0.09	0.1	0.87	1.26	0.09	0.22	0.01	0.10	0.40
CD (5%)	2.18	0.31	3.46	2.42	0.3	0.31	2.68	3.87	0.29	0.67	0.03	0.31	1.24

3.2 Fruit Characteristics

The size and weight of Kinnow fruits are significantly impacted by the administration of micronutrient sprays containing zinc and manganese, as shown by the data in Table 2. The findings show that, when these compounds were sprayed at any concentration, the fruits' length, diameter, weight, juice %, pulp and peel weight, total soluble solid, and acidity were all considerably increased in comparison to the control treatment. To sum up, Kinnow's size and weight were greatly increased by the zinc and manganese spray micronutrients. The greatest findings for fruit diameter, length, average weight, peel and pulp weight, juice percentage, TSS, and acidity were also found in T8 0.35%Mn+0.6%Mn. Plants treated with 0.35% Mn + 0.4% Mn (T7) came next and the suggested doses of 0.5% Zn + 0.45% Mn (T6), T5 0.5% Zn + 0.35% Mn. The lowest beneficial effect was observed with T2 zinc 0.5% and T3 Mn 0.35%. In contrast, the data for the above-mentioned features were lowest in the control plants. These findings are consistent with previous studies by Maheswarappa et al. [34]. Influence of organic manures on yield of arrowroot, soil physio-chemical and biological properties when grown as inter crop in coconut garden. The enhanced fruit length could be attributed to the improved availability of nutrients, the physical condition of the soil, and the activity of enzymes. Similar results have been documented in strawberry by Yadav [35], as well as in papaya by Srivastava [36] and Ravishankeret al. [37], showing a strong correlation between increased fruit length and factors such as dry matter content, the synthesis of various growth regulators, nitrogen fixers, and their translocation, as indicated by Awasthiet al. (1990). Asharf et al. (2023) According to the experiment result increase in fruit diameter, citric acid, Zn content in leaf and fruit quality were all markedly enhanced by integrated fertilization strategy Partap et al.(2017) also recorded that the foliar application of zinc (3gm) and boron (2gm) led to increased weight of fruit per plant and vitamin c content. Choudhary et al. (2021) sprays of zinc and iron improve the quality attributes of kinnow, the treatments of (0.75% ZnSO4 + 0.75% FeSO4) produced the fruits with the most seeds per fruit. Bhargava and Dhaudar [38], Firake and Deolankar [39] conducted research on pomegranate, all support the findings of the current study. Malik et al. [40] Efficiency of exogenous zinc sulfate application reduced fruit drop and improved antioxidant activity of 'Kinnow'mandarin fruit found comparable outcomes through foliar application of Zinc sulfate (0.6%), leading to increased total soluble solids (9.5 brix). Yadav et al. [41] Aulakh et al. (2022).

3.3 Yield Attributes

As indicated by the data gathered from various combinations of therapies in the Table 2. Based on the total impact of micronutrient application, T8 (0.35% Mn + 0.6% Zn) generated the highest number of fruits per plant (482). In addition, T5 (0.5% Zn + 0.35% Mn) produced 476 fruits per plant, indicating a high fruit production rate. Conversely, the control group (T1) yielded the fewest fruits—253 fruits per plant. Furthermore, the T2, T3, and T4 treatments exhibited moderate fruit yields: 392, 452, and 461 fruits per plant, respectively. T8 and T5 show noticeably higher yields than the other treatments, indicating that vitamin delivery has a substantial impact on fruit output. The study's findings indicate that T1, the control group, experienced the lowest fruit retention percentage (15.20%) in relation to the other treatments. However, T8, which received a 0.35%Mn+0.6%Zn treatment, had the highest fruit retention rate, at 28.20 percent. Contrasting T4 0.5%Zn+0.25%Mn to the other treatments, the best outcome was 16.20%) had the lowest fruit retention percentage (15.20%) in relation to the other treatments. However, T8, which received a 0.35%Mn+0.6%Zn treatment, had the highest fruit retention rate, at 28.20 percent. Comparing T4 0.5%Zn+0.25%Mn to the other treatments, the best outcome was 16.20%).This shows that while the control group had the lowest retention, the application of various therapies, in particular T_8 had a substantial impact on fruit retention %. Similar studies reveled by Nazir et al., [42]. Additionally, the findings of Shivakumar [43] in papaya. The control treatment (T1) yielded the minimum number of fruits per plant at 253.99, followed by Treatment T2 with 392.84 fruits per plant when applying 0.5% zinc. Kohale et al. [44] achieved a maximum number of fruits per plant at 417.33 and a yield of 56.33 kg per plant with the application of 1.0% MNSO4. Additionally, in a study by Nirmaljit et al. [45] Kinnow mandarin achieved a maximum fruit yield of 862 fruits per tree when a foliar combination of 1000 ppm zinc and 1000 ppm manganese was utilized. Similarly, Nazir et al. [42] found that a foliar application of 0.5% FeSO4 resulted in the highest number of fruits per plant, with 0.5% ZnSO4 ranking as the second most effective treatment. Kaushik et al. [46] also found that a combination of 0.2% boric acid and 0.5% zinc sulfate decreased fruit retention percentage and enhanced fruit quality. Zoremtluangi J et al. [47] foliar application Zn+Cu+B (T_{13}) shows maximum fruit set%, yiled, numbers of fruits per plants, stem girth. Bhatnagar et al [48] Yadav I et al. [49].

4. CONCLUSION

The study's conclusions imply that zinc and manganese are advantageous for the growth of Kinnow. The application of 0.5% Zn + 0.35% Mn (T5) and 0.35% Mn + 0.6% Zn (T8) and (T7) 0.35%Mn +0.4%Zn have significantly higher results in vegetative growth, physio-chemical attributes and yield of Kinnow mandarin as compared with other treatments and control, particular clearly showed the greatest benefits in Kinnow fruit development, yield, and quality. These findings unequivocally confirm that zinc and manganese have the ability to improve Kinnow orchards' overall performance and this will help others as well as farmers in future.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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