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Effect of Foliar Application of Macro and Micronutrients on Quality of Kinnow Mandarin

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Authors' contributions

This work was carried out in collaboration among all authors. The research was conceptualized by authors GSR and Reetika. The work was carried out by author Reetika under the supervision of author GSR. Data curation and statistical analysis were carried out by author Reetika. The first draft of the manuscript wrote by author Reetika and authors Komal and Pooja reviewed and edited. Author MKR managed the writing proofs and helped in drafting of the paper. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine the suitable combination of fertilizers for obtaining high quality fruits from Kinnow orchard.
Study Design: The experiment was conducted in randomized block design with three replications per treatment on Kinnow mandarin.
Place and Duration of Study: The experiment was conducted on seven years old earmarked plants at Experimental Orchard and in Post-harvest Technology Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana, India during the year 2016-17.
Methodology: The treatments comprising of 11 combinations of Urea, K_2SO_4, $ZnSO_4$, $FeSO_4$ and boric acid which were laid out in randomized block design with three replications. Seven years old uniformly grown trees spaced at 6x6 m were selected for the present study and analyzed for yield and quality parameters such astotal soluble solids (%), acidity (%), ascorbic acid (mg/100 ml juice), juice content (%), TSS to acid ratio etc.

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Results: In comparison to other fertilizers combinations, the maximum fruit yield per plant (97.83 kg/plant), juice content (49.47%), total soluble solids (9.80%), TSS to acid ratio (11.95) and ascorbic acid content (32.30mg/100ml) and minimum acidity (0.83%), rag (24.00%) and peel content (25.60%) and peel thickness (3.42 mm) were registered with foliar application of Urea 1.0% + K_2SO_4 1.0% + $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + H_3BO_3 0.2%, however, the foliar spray of Urea, K_2SO_4, $ZnSO_4$, $FeSO_4$ and boric acid had no effect on number of seeds per fruit in Kinnow mandarin. Thus it is clear from results that foliar nutrient application showed a stimulating influence on yield and quality parameters of Kinnow fruits.
Conclusion: From the research findings it can be concluded that the maximum potential of Kinnow mandarin plants in respect of fruit yield per plant, juice content, total soluble solids, TSS to acid ratio and ascorbic acid content was exploited to a maximum level and the acidity, rag and peel content and peel thickness to a minimum level with foliar application of Urea 1.0% + K_2SO_4 1.0% + $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + H_3BO_3 0.2%.

Keywords: Foliar spray; fruit quality; fruit yield; Kinnow mandarin.

1. INTRODUCTION

Kinnow is a hybrid between king mandarin (*Citrus nobilis* Lour) x willow leaf mandarin (*Citrus deliciosa* Tenora), was developed by H.B. Frost in 1915 and released in 1935 in California (USA). It was introduced to India in 1958 at the regional fruit research station, Abohar (Punjab) by Dr. J.C. Bakshi [1]. A noble introduction of this cultivar inspired the growers to extend the cultivation in adjoining areas and has become the most favorite citrus cultivar among citrus growers because of its wider adaptability and higher yields. After the implementation of national horticulture mission, there has been a tremendous increase in the area under citrus during the last decade. In India, the area under citrus is 1003 thousand hectares with 12546 thousand metric tons production and 12.5 metric ton per hectare productivity [2] and in Haryana, the area under citrus is 20.05 thousand hectares with production of 323.92 thousand metric tons and productivity 16.15 metric ton per hectare [3].

Citrus crops are relatively high nutrients-demanding [4] and highly responsive to applied nutrients in the form of fertilizers particularly the nitrogen which is critical input involved in plant metabolism growth and in different biochemical processes [5]. Enhanced yield with improved fruit quality can be obtained with the application of proper and adequate fertilizers. The deficiency or excess of any nutrient can lead to a reduction in crop yield coupled with inferior fruit quality, thus, judicious application of fertilizers (macro-nutrients) is essential for increasing the productivity as well as quality of Kinnow [6]. Micronutrients play an active role in metabolism starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity, hormone synthesis, nitrogen fixation and reduction [7]. The application of macro-nutrients particularly nitrogen, phosphorus and potassium plays an important role in yield as well as in fruit quality [8]. However, nitrogen is the key component for citrus growers, as it has more influence on tree growth, appearance and fruit quality than any other element [9]. Potassium is necessary for basic physiological functions such as formation of sugars and starch, synthesis of proteins and cell division, thus an important tool to optimize the quality of citrus fruit and juice [10]. Foliar application of micronutrients like zinc, boron and iron were much better than that of soil application because of their high efficacy, quick plant response, and easiness in application and toxicity symptoms elimination brought about by excessive soil accumulation of such nutrients [11]. Therefore, effective nutrients management in citrus, which involves finding of appropriate rate, time and method of application as well as selection of suitable combination of fertilizers, was required to get desired quality of fruits. Considering the above facts in view, the present experiment was planned to evaluate the effect of macro and micronutrients on quality parameters of Kinnow mandarin.

2. MATERIALS AND METHODS

The experiment was conducted on seven years old earmarked plants during the year 2016-17 at Experimental Orchard and in Post-harvest Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar to study the effect of Urea, K_2SO_4, $ZnSO_4$, $FeSO_4$ and boric acid on quality parameters of Kinnow mandarin. The orchard, which is situated at

Table 1. List of treatments comprising foliar fertilization along with their concentration

Sr. no.	Treatments	Concentration of fertilizers for foliar application
1	T_1	Urea 1.0%
2	T_2	Urea 1.5%
3	T_3	Urea 1.0% + K_2SO_4 1.0%
4	T_4	Urea 1.5% + K_2SO_4 1.5%
5	T_5	Urea 1.0% + K_2SO_4 1.0% + $ZnSO_4$ 0.5%
6	T_6	Urea 1.5% + K_2SO_4 1.5% + $ZnSO_4$ 0.75%
7	T_7	Urea 1.0% + K_2SO_4 1.0% + $ZnSO_4$ 0.5% + $FeSO_4$ 0.5%
8	T_8	Urea 1.5% + K_2SO_4 1.5% + $ZnSO_4$ 0.75% + $FeSO_4$ 1.0%
9	T_9	Urea 1.0% + K_2SO_4 1.0% + $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + boric acid 0.2%
10	T_{10}	Urea 1.5% + K_2SO_4 1.5% + $ZnSO_4$ 0.75% + $FeSO_4$1.0% + boric acid 0.4%
11	T_{11}	Control (Water spray)

215.2 m above mean sea level with coordinates of 29º10' N latitude and 75º46' E longitudes, has a typical semi-arid climate with hot and dry summer and extremely cold winter. The total rainfall as well as its distribution in the region is subjected to large variations. The soil was sandy loam, low in organic carbon (0.7%), low in available nitrogen (67.3 ppm) and medium in phosphorus (5.6 ppm) and high in available potassium (267.3 ppm) with soil pH (7.8) and EC (0.32 dSm^{-1}). The experiment comprised of eleven fertilizer treatments (Table 1) in different combinations *viz*., Control (water spray), Urea (1.0 and 1.5%), K_2SO_4 (1.0 and 1.5%), $ZnSO_4$ (0.5 and 0.75%), $FeSO_4$ (0.5 and 1.0%) and boric acid (0.2 and 0.4%). They were laid out in randomized block design with three replications comprising eleven trees in one replication or single row. Seven years old uniformly grown trees spaced at 6x6 m were earmarked in February 2016 for collecting the data on quality parameters. The nutrients were applied through foliar spray with help of Knap sack sprayer at two different times (first spray in last week of April and second in last week of July). The plants were kept under uniform orchard management practices during the study, where all the cultural practices were carried out as per the package of practices (FYM 100 kg, Urea 1.5 kg, SSP 2 kg and MOP 175 g /tree). The observations were recorded on fruit yield, number of fruit seeds per fruit, juice content (%), peel content (%), rag content (%), peel thickness (mm), total soluble solids (%), titratable acidity (%), TSS to acid ratio and ascorbic acid (mg/100 ml of juice). Peel thickness was measured with the help of Vernier caliper and the chemical analysis of fruit was done as per the methods given in official methods of analysis by Association of official analytical chemists (AOAC) [12]. The recorded data were subjected to statistical analysis with Critical difference (CD) at 5% by using one factorial Randomized Block Design (RBD) analysis with OP Stat, CCS HAU Hisar software [13].

3. RESULTS AND DISCUSSION

3.1 Physical Parameters

The significantly highest fruit yield per plant (Table 2) was obtained from treatment T_9, which was closely followed by the treatment T_7 and lowest from control treatment. Spray of boron at fruit set stage is helpful for enhanced levels of fruit yield of Kinnow [14]. The enhanced yield with foliar application of micronutrients might be attributed to their effects on balancing the nutritional status and in increasing the chlorophyll content of leaves, photosynthetic efficiency and translocation of metabolites from source to the sink as and when required. It was reported that zinc plays an important role in starch metabolism and acts as co-factor for many enzymes, affecting photosynthesis, nucleic acid metabolism and protein biosynthesis [15]. These microelements are credited for their definite role in synthesis of chlorophyll, photolysis of water during photosynthesis and synthesis of auxin [16]. It has been reported that application of urea in combinations with B and Zn resulted in higher fruit yield and better physico-chemical characteristics rather than application of any of these alone [17].

The significantly maximum juice content in fruits of Kinnow mandarin was registered with treatment T_9 (Table 2), which was closely followed by T_5, T_6, T_7, T_8 and T_{10}. The juice content was found minimum in fruits of control treatment. The increase in juice content in fruits might be attributed to the fact that potassium might have regulated the water relations in plants along with production of large fruits with bigger

juice vesicles. The results of present investigation are in agreement with the findings of researchers who reported that the juice content in Khasi mandarin increased with the spray of zinc on plants [18]. Another team of workers found that foliar application of Zn + K increased juice content in fruits of Kinnow mandarin [19] and who observed maximum juice content in Kinnow fruits taken from the plants sprayed with a mixture of micro nutrients ($FeSO_4$, $ZnSO_4$ and $MnSO_4$) along with urea 1% [20].

The minimum rag and peel thickness was recorded with treatment T_9 (Table 2), while the fruits of control plants showed maximum rag and peel thickness. The minimum peel content was observed in fruits of treatment T_{10} (Table 2), while the fruits of control plants showed maximum peel content. The results of present study are contrary to the findings of scientists who reported that zinc spray increased the peel thickness in Washington Navel oranges [21]. However, the minimum rag and peel content and peel thickness in Kinnow mandarin with foliar application of treatment T_9 might be due to the fact that inclusion of urea, ferrous sulphate and boric acid might have counteracted the effect of zinc and potassium, which have been shown to increase peel thickness and peel content in previous paper of Eman et al. [21]. However, the results of present investigation correspond to the findings of Khan *et al.* (2015) who reported lower peel content in Kinnow mandarin with the application of $ZnSO_4$ 0.5% + H_3BO_3 0.3%. The results of present study also coincide with the findings of researcher who reported that the maximum amount of pulp content is found in aonla with spray of born, zinc and copper. The foliar application of micronutrients made rapid synthesis of metabolites particularly carbohydrates and their translocation to fruits, causing relatively higher pulp content. In addition, higher pulp content, which leads to increase in juice content might be due to the accelerated rate of metabolites diversion from source to sink [22].

The number of seeds per fruit was not influenced by foliar supplementation of nutrients (Table 3). The results of present study agree with the findings of scientists who stated that the number of seeds per fruit was not significantly affected by foliar application of different nutrients [23]. However, the results of present study are contrary to the findings of workers who reported lower number of seeds per fruit with the application of $ZnSO_4$ 0.5% + H_3BO_3 0.3% [24].

3.2 Chemical Parameters

The total soluble solids and TSS to acid ratio were recorded maximum in fruits harvested from plants of treatment T_9, while the minimum TSS and TSS to acid ratio were found in fruits of control plants (Table 3). The increased TSS due to the spray of nutrients combination might be due to the increased photosynthesis activity [25], translocation of sugars from source to sink and conversion of complex form of sugars (polysaccharides) to simple sugars (glucose and fructose) in fruits [21] due to the increased activities of enzymes by zinc and potassium. The results of present study are supported by the findings of investigators who reported the highest total soluble solids in Kinnow mandarin with foliar application of GA_3 15 ppm along with zinc 0.5% and boron 0.1% [26]. Researchers stated that Kinnow mandarin fruits had the highest total soluble solids with foliar application of Zn + B on plants [27]. Scientists reported that the highest total soluble solids in Kinnow mandarin fruits as compared to the fruits of control plants with foliar application of 0.2% boric acid [14]. Researchers recorded the maximum total soluble solids in fruits taken from the plants supplied with Urea + $ZnSO_4$ + 2,4-D [28]. The findings of present experiment in respect of TSS to acid ratio are supported by scholars who observed the maximum TSS to acid ratio in fruits taken from the plants sprayed with Salicylic acid (SA) + Zn + K and 2,4-D [29]. Scientists also found an improvement in TSS to acid ratio with the application of K in combination with micronutrients in Washington Navel orange [30]. However, some workers suggested same improvement in TSS to acid ratio with the application of 1000 ppm Zn + 1000 ppm Mn [31].

The higher acidity is contrary to the good quality of Kinnow fruits. The quality of Kinnow mandarin fruits in terms of acidity was observed minimum (Table 3) in fruits taken from the plants sprayed with treatment T_9 and the maximum in control treatment. The decreased acidity in fruit juice because of nutrients spray might be due to the metabolic transformation of organic acids into sugars and rapid utilization of organic acids in respiration [32]. The results of present study support the findings of scientists who reported the minimum acidity in fruit juice of plants supplied with balanced nutrition as compared to acidity in fruit juice of unsprayed sweet orange plants [33].

Table 2. Effect of foliar fertilizer application on fruit yield per plant (kg), juice, rag and peel content (%) of Kinnow mandarin fruit

Treatments	Fruit yield per plant (kg)	Content (%)			Peel thickness (mm)
		Juice	Rag	Peel	
T_1	81.51	47.18	25.03	27.79	3.70
T_2	80.17	47.07	25.16	27.77	3.77
T_3	90.95	48.12	25.12	26.76	3.58
T_4	85.11	47.50	24.93	27.57	3.69
T_5	92.73	48.72	24.63	26.65	3.50
T_6	89.64	48.40	25.35	26.25	3.67
T_7	95.93	49.07	24.46	26.47	3.48
T_8	89.67	48.76	25.32	25.92	3.61
T_9	97.83	49.47	24.00	26.53	3.42
T_{10}	90.58	48.90	25.50	25.60	3.57
T_{11}	78.15	45.80	25.98	28.22	3.85
CD at 5%	1.9	1.3	1.0	0.93	0.1

Table 3. Effect of foliar fertilizer application on peel thickness (mm), number of seeds per fruit, TSS (%), acidity (%), TSS to acid ratio and ascorbic acid (mg/100 ml) in Kinnow mandarin fruit

Treatments	Number of seeds per fruit	TSS (%)	Acidity (%)	TSS to acid ratio	Ascorbic acid (mg/100 ml juice)
T_1	22.17	9.2	0.87	10.57	30.07
T_2	21.94	8.9	0.92	9.67	30.10
T_3	19.11	9.4	0.83	11.33	31.20
T_4	21.83	9.6	0.85	11.29	30.13
T_5	18.78	9.6	0.83	11.57	31.17
T_6	19.89	9.4	0.85	11.06	31.07
T_7	19.00	9.7	0.87	11.15	31.73
T_8	21.50	9.6	0.91	10.55	31.08
T_9	18.61	9.8	0.83	11.95	32.30
T_{10}	20.89	9.6	0.86	11.16	31.30
T_{11}	22.50	8.8	0.93	9.46	29.65
CD at 5%	NS	0.1	0.02	-	1.08

All the fertilizer treatments significantly increased the ascorbic acid content (Table 3) in Kinnow mandarin fruits to the highest amount when the plants were sprayed with treatment T_9, whilethe lowest amount was recorded in fruits of plants kept under control. Zinc sprays significantly increased fruit yield and fruit quality including ascorbic acid content in Kinnow mandarin since it plays an active role in auxins biosynthesis [34]. Zinc plays an active role in the synthesis of auxins and increased synthesis of auxins has been reported to increase the accumulation of ascorbic acid content in Kinnow mandarin [35]. The increased ascorbic acid content with foliar application of potassium might be related with improved sugar metabolism [19]. The results of present study are in confirmation with the findings of researchers who recorded the highest ascorbic acid content in juice of fruits obtained from the plants sprayed with 2,4-D + Zn + K or SA + Zn + K [29]. Scientists also noted the maximum ascorbic acid content (25.54 and 24.96 mg/100 ml juice) in fruits taken from the plants sprayed with KNO_3 2% + 2,4-D 10 ppm and KNO_3 2% + $ZnSO_4$ 0.5% [23].

4. CONCLUSION

From the research findings it can be concluded that the maximum potential of Kinnow mandarin plants in respect of fruit yield per plant, juice content, total soluble solids, TSS to acid ratio and ascorbic acid content was exploited to a maximum level and the acidity, rag and peel content and peel thickness to a minimum level with foliar application of Urea 1.0% + K_2SO_4 1.0% + $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + H_3BO_3 0.2%.These findings of the experiment will be useful for the scientists and Kinnow growers to improve the quality of Kinnow mandarin by spraying the macro- and micro-nutrients.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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