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Effect of exogenous application of micronutrients on growth and yield of Kinnow mandarin under semi-arid zone of Haryana

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Abstract
An experiment was conducted during 2014-15 to assess the performance of Kinnow mandarin to soil and foliar mode of micronutrients application. The study comprised of six treatments, *viz.*, T_1- $FeSO_4$ 42g + $MnSO_4$ 21g + $ZnSO_4$ 14g, T_2- $FeSO_4$ 84g + $MnSO_4$ 42g + $ZnSO_4$ 28g, T_3- $FeSO_4$ 126g + $MnSO_4$ 63g + $ZnSO_4$ 42g, T_4- $FeSO_4$ 168g + $MnSO_4$ 84g + $ZnSO_4$ 56g, T_5- Foliar spray of 0.5% each of $FeSO_4$, $MnSO_4$, $ZnSO_4$ + 1% Urea and T_6- Control (No micronutrients). Four treatments (T_1 to T_4) were applied through soil in four equal splits. Foliar spray was also performed four times during soil application of micronutrients. All micronutrients treated plants produced higher magnitude of growth and fruit yield over control. However, foliar application of micronutrients produced significantly higher number of fruits, fruit weight, juice content, and fruit yield (28.9 t ha^{-1}) compared to other treatments.

Keywords: Foliar application, soil drenching, micronutrients, manganese sulphate, zinc sulphate, ferrous sulphate, Kinnow

Introduction
Citrus is one of the most relevant fruit crops grown across the globe and has a tremendous social and cultural and economical influence in our society. India being the home of many citrus species, its cultivation is spread over 0.953 million hectares with the production of 11.66 million tonnes (Anonymous, 2016) [1]. Among citrus group, the Kinnow mandarin occupies a unique place in the fruit industry of India. The acreage under Kinnow cultivation is being expanded in arid and semi-arid zones due to the growing market demand in domestic and international markets. Commercially, it is grown in Punjab, Haryana, northwestern parts of Rajasthan and Uttar Pradesh. In Haryana, its production is estimated at 2.31 lakh tonnes from 17,402 hectare area (Gera, 2014) [5]. The Kinnow growers often supply the major nutrients abundantly and micro-elements are frequently overlooked since the deficiency of these elements is difficult to diagnose and often occur as hidden hunger. The micronutrients though are required in smaller amount; play a complex role in plant metabolism. The multi-micronutritional deficiency in Kinnow mandarin contributing for 'decline' like condition is widely established. The sub-optimum availability of zinc, iron and manganese in Kinnow leaves are commonly reported to cause interveinal chlorosis, leaf mottling and reduced growth of young shoots in northwestern India (Kaur *et al.*, 2015) [8]. In semi-arid states like Haryana, the physiological availability of these trace elements to plant's absorption is hindered due to soil alkalinity, lower organic matter content and competition from other nutrients, despite theoretically being present in soil at moderate to sufficient range. The beneficial effect of amelioration of zinc, iron and manganese deficiencies by both foliar and soil application have been well documented in citrus from previous studies (Ram and Bose, 2000; Babu *et al.*, 2007; Hippler *et al.*, 2015 and Kaur *et al.*, 2015) [8, 6, 13]. However, the scientists and growers even today are ambiguous about the efficacy of soil application versus foliar feeding of micronutrients as the knowledge available in comparing the mode of application of micronutrients are very limited. Keeping in the view that the micronutrients increases the productivity of Kinnow mandarin, the present experiment was undertaken to evaluate the soil application of different levels of micronutrients with foliar application.

Material and Methods
The present investigation was conducted at farmer's commercial orchard at Dhani Majra Village, Fatehabad District. The selected orchard is located at 29°50'N latitude and 75°54'E longitude at an elevation of 216.3 m above mean sea level. The seven-year-old 72 Kinnow mandarin plants budded on Jatti Khatti (*Citrus jambhiri* Lush) rootstock planted at a spacing of 6 m x 6 m were selected and divided it into 24 treatment plots with each having three plants.

Treatments were allocated in randomized block design (RBD) with four replications in each treatment. The soil of the experimental orchard was slightly alkaline in pH, medium in organic carbon, available phosphorus and available potash content and low in available nitrogen as per the soil test rating chart given by Antil *et al.,* (2002) [2]. The study was comprised of six treatments viz., T_1- $FeSO_4$ 42 g + $MnSO_4$ 21 g + $ZnSO_4$ 14 g, T_2- $FeSO_4$ 84 g + $MnSO_4$ 42 g + $ZnSO_4$ 28 g, T_3- $FeSO_4$ 126 g + $MnSO_4$ 63 g + $ZnSO_4$ 42 g, T_4- $FeSO_4$ 168 g + $MnSO_4$ 84 g + $ZnSO_4$ 56 g, T_5- Foliar spray of 0.5% each of $FeSO_4$, $MnSO_4$, $ZnSO_4$ + 1% Urea and T_6- Control (No micronutrients). For soil application (T_1 to T_4), different dose of micronutrients were dissolved in water and applied as a soil drench beyond a 30 cm radius from the trunk. For foliar application (T_5), spray solutions were prepared by thoroughly dissolving in appropriate quantity of water. In control treatment (T_6) no micronutrients were used. Soil treatments were given in four equal splits during March, April, August and September months in both the years. Foliar spray (T_5) was also carried out during same time. The recommended standard package of practices and plant protection measures were adopted in both the experiments to keep the plants in good health. The observations were recorded from nine representative plants in each treatment. Growth parameters were observed during start of the experiment and after harvest. The plant height was recorded from the base of trunk to the tip of the terminal extension growth with the help of pre-marked bamboo pole. The stem girth was measured with the help of measuring tape at a point marked above 15 cm from the ground level, whereas, the plant spread was recorded by measuring the canopy spread in east-west and north-south directions using a pre-marked bamboo pole. The average of both North-South and East-West spread was taken as total spread of the trees. The average annual increment in each growth parameter was recorded and expressed as centimetre increase. The fruit and yield data were recorded at harvesting season. Statistical analysis of mean data collected on various parameters during the study was performed using randomized block design as per the methods suggested by Panse and Sukhatme (1967) using OPSTAT statistical software package (Sheoran *et al.,* 1998) [15].

Results and Discussion

The data on effect of different levels of micronutrients on growth parameters is presented in Table 1. All micronutrients treated plants. Significantly higher annual increase in plant height (39.1 cm), stem girth (5.71 cm) and plant spread (34.3 cm) were recorded with the foliar spray of 0.5% each of $FeSO_4$, $MnSO_4$, $ZnSO_4$ + 1% Urea, which was statistically at par with soil application of $FeSO_4$ 126 g + $MnSO_4$ 63 g + $ZnSO_4$ 42 g (36.8 cm) The minimum vegetative growth of the plants were observed under control. The higher stimulation of vegetative growth of the plants with the foliar application of micronutrients over soil application and control treatment may be ascribed to the enhanced leaf uptake of micronutrients with foliar application. These micro-elements are credited for their definite role in synthesis of chlorophyll molecules, photolysis of water during photosynthesis and synthesis of auxin (Quiñones *et al.,* 2012,) [11]. The similar growth responses in citrus due to foliar application of micronutrients were earlier documented by Rathore and Chandra (2003) [14] and Madarakhandi *et al.,* (2014) [9]. Increased level of micronutrients application through soil, increased the plant growth to certain level (from T_1 to T_3), further increase in micronutrient application (T_4) decreased the vegetative growth of the plants.

The perusal of data presented in Table 2 states that significantly maximum fruit diameter (7.63 cm) and fruit weight (212.3 g) was observed with foliar spray of 0.5% each of $FeSO_4$, $MnSO_4$, $ZnSO_4$ + 1% Urea, which was statistically at par with soil drenching of $FeSO_4$ 168 g + $MnSO_4$ 84 g + $ZnSO_4$ 56 g (T_3). The highest juice fruit juice content was exhibited with foliar spray of 0.5% each of $FeSO_4$, $MnSO_4$, $ZnSO_4$ + 1% Urea (47.0%), being statistically at par with soil application of $FeSO_4$ 126 g + $MnSO_4$ 63 g + $ZnSO_4$ 42 g (46.3%) and $FeSO_4$ 168 g + $MnSO_4$ 84 g + $ZnSO_4$ 56 g (46.1%). The analogous findings were reported by Ram and Bose (1994) [12] in sweet orange.

The treatment that was effective in higher promotion of vegetative growth of plants (T_5) produced maximum number of fruits (479.2) and greater fruit yield (28.3 t ha^{-1}). The reason behind improvement in fruit yield may be due to improved reproductive capacity of plants *viz.,* maximum number of flowers, fruit set and fruit retention as a consequence of synthesis of more growth promoting substances (auxins & gibberellines) and less abscisic acid due to enhanced absorption and translocation of micronutrients when applied as a foliar spray (Bahadur *et al.,* 1998 and Kaur *et al.,* 2016) [4, 7]. The foliar micronutrients application (T_5) was found to be better than conventional method of application (T_1 to T_4) and control (T_6). Other studies have also showed the superior performance due to foliar application of micronutrients (Bahadur *et al.,* 1998, and Ram and Bose, 1994) [4, 12].

In conclusion, all the micronutrients treated plants produced higher magnitude of growth and fruit yield. However, foliar application of 0.5% each of $FeSO_4$, $MnSO_4$, $ZnSO_4$ + 1% Urea found effective in enhancing the fruit yield over soil application of micronutrients in Kinnow mandarin.

Table 1: Effect of different micronutrient levels on growth parameters

Treatment Details		Increase in plant height (cm)	Increase in stem girth (cm)	Increase in plant spread (cm)
T_1	$FeSO_4$ 42 g + $MnSO_4$ 21 g + $ZnSO_4$ 14 g	31.4	4.92	27.1
T_2	$FeSO_4$ 84 g + $MnSO_4$ 42 g + $ZnSO_4$ 28 g	34.1	5.39	29.4
T_3	$FeSO_4$ 126 g + $MnSO_4$ 63 g + $ZnSO_4$ 42 g	36.8	5.61	31.7
T_4	$FeSO_4$ 168 g + $MnSO_4$ 84 g + $ZnSO_4$ 56 g	34.9	5.43	30.7
T_5	Foliar spray of 0.5% each of $FeSO_4$, $MnSO_4$, $ZnSO_4$ + 1% Urea	39.1	5.71	34.3
T_6	Control (No micronutrients)	26.4	4.32	23.2
	CD at 5%	4.5	0.24	4.6

Table 2: Effect of different micronutrient levels on fruit and yield parameters

Treatment Details		Fruit weight (g)	Fruit diameter (cm)	Juice content (%)	Number of fruits per plant	Fruit yield (t ha^{-1})
T_1	$FeSO_4$ 42 g + $MnSO_4$ 21 g + $ZnSO_4$ 14 g	185.6	7.07	44.6	431.3	22.3
T_2	$FeSO_4$ 84 g + $MnSO_4$ 42 g + $ZnSO_4$ 28 g	204.9	7.30	45.5	454.3	25.9
T_3	$FeSO_4$ 126 g + $MnSO_4$ 63 g + $ZnSO_4$ 42 g	210.3	7.46	46.3	469.4	27.4
T_4	$FeSO_4$ 168 g + $MnSO_4$ 84 g + $ZnSO_4$ 56 g	207.4	7.37	46.1	458.0	26.4
T_5	Foliar spray of 0.5% each of $FeSO_4$, $MnSO_4$, $ZnSO_4$ + 1% Urea	212.2	7.63	47.0	479.2	28.3
T_6	Control (No micronutrients)	173.5	6.79	42.5	395.1	19.0
	CD at 5%	4.4	0.17	1.7	13.8	7.7

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