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Effect of foliar application of manganese and ferrous on vegetative growth, fruit yield and quality of mandarin (*Citrus reticulata* Blanco) cv. Kinnow

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Abstract
The results of present investigation entitled "Effect of foliar application of manganese and ferrous on vegetative growth, fruit yield and quality of mandarin (*Citrus reticulata* Blanco) *cv.* Kinnow" conducted at the School of Agricultural Sciences, G. H. Raisoni University, Dhoda Borgaon, Saikheda. Dist. Chhindwara, M. P during 2018-19. An attempt has been made to work out the effect of manganese and ferrous on vegetative growth and fruit yield *cv.* Kinnow. The highest increase in shoot length (32.83%), canopy area E-W (17.80%), canopy area N-S (35.37%), and tree height (4.97%) recorded in treatment T_9 (1.0% $MnSO_4$ + 1.0% $FeSO_4$). The maximum fruit diameter (0.23 cm & 0.17 cm), fruit weight (0.56 g), fruit volume (1.42 cc), fruit retention (0.26%), number of fruit per plant (417.33), yield plant^{-1} (56.33 kg), yield ha^{-1} (22.93 t ha^{-1}) was recorded in treatment T_8 (1.0% $MnSO_4$ + 0.5% $FeSO_4$).

Keywords: Foliar application, manganese, ferrous, vegetative growth, fruit yield, *Citrus reticulata* Blanco

Introduction
Citrus is the leading fruit crop of the world. The genus *Citrus* includes more than 162 species belonging to the order Geraniales, family Rutaceae and sub family Aurantoideae. Citrus fruits are a fair source of vitamin C and their daily consumption protects mankind from scurvy, a disease commonly associated with inadequate availability of vitamin C in the dietary foods. Citrus fruits are cultivated in India in four different zones i.e. Central India (Madhya Pradesh, Maharashtra and Gujarat), Southern India (Andhra Pradesh and Karnataka), North-Western India (Punjab, Rajasthan, Haryana and Western UP) and North-Eastern India (Meghalaya, Assam and Sikkim). These zones have different leading cultivar(s) that occupies a place of prominence in the respective area (Singh and Singh 2006) [17].

Mandarin (*Citrus reticulata* Blanco) is most common among citrus fruits grown in India. It is originated from South Eastern Asia (China). Major producing states of mandarin are Punjab, Madhya Pradesh, Andhra Pradesh, Maharashtra, Rajasthan, Assam, and Karnataka. It is grown widely in many districts of Rajasthan particularly in Jhalawar, Sriganganagar, Hanumangarh, Bhilwara, Chittorgarh, Kota and Baran (Anon. IHD, 2014) [1].

"Kinnow Mandarin" is one of the most important and finest variety of mandarin grown especially in north India. It is the first generation hybrid of king mandarin (*C. nobilis* Lour) and willow leaf mandarin (*C. deliciosa* Tenora) (Sharma *et al*., 2007) [16]. It was developed by H.B. Frost at Regional Fruit Station, California, USA. It was first introduced in India during 1959's at the Fruit Experiment Station, Punjab and Agriculture College and Research Institute, Lyallpur by S. Bhadur Lal Singh (Singh *et al*., 1978). Since then it has assumed great importance among north Indian growers and a large acreage is being brought under its cultivation particularly in Punjab, Haryana, Rajasthan and Himachal Pradesh (Khurdiya and Lotha., 1994) [10].

Foliar application of micro and macronutrient like Zn, Cu, Mn, B, Fe and K_2O has advantages over soil application because of high effectiveness, rapid plant response, convenience and elimination of toxicity symptoms brought about by excessive soil accumulation of such nutrients (Obreza *et al*., 2010) [13]. Curing micronutrient deficiencies through foliar application is a common practice in getting profitable yield and good quality fruit. Foliar spray of micronutrients has been reported to be more effective than soil application in curing deficiencies in citrus. Keeping in view, it is very important to apply micronutrients in proper amount through foliar spray to increase citrus production.

The manganese activates decarboxylase, dehydrogenase and oxidase enzymes in plants which are important in photosynthesis, nitrogen metabolism and nitrogen assimilation. It is an essential element in respiration and involved in the destruction or oxidation of indole-3-acetic acid (IAA). Iron is required in plants for synthesis of enzymes responsible for chlorophyll synthesis. It is a component of various flavo- protiens, peroxidase, catalase, cytochrome oxidase enzymes and found in ferrodoxin which precipitates in oxidation – reduction reaction e.g. NO_4^- and SO_4^{2-} reduction, N – fixation etc.

Materials and methods

The present investigation, "Effect of foliar application of manganese and ferrous on vegetative growth, fruit yield and quality of mandarin (Citrus reticulata Blanco) cv. kinnow" was conduted at Department of Agronomy, School of Agricultural Sciences, G. H. Raisoni University, Saikheda, Chhindwara, (M.P). The experiment was laid out in square design with nine treatments comprising of Manganese sulphate and Ferrous sulphate with the different concentration having treatments T1 Control (water spray), T2 (0.5% Manganese sulphate), T3 (1.0% Manganese sulphate), T4 (0.5% Ferrous sulphate), T5 (1.0% Manganese sulphate), T6 (0.5% MnSO4 + 0.5% FeSO4), T7 (0.5% MnSO4 + 1.0% FeSO4), T8 (1.0% MnSO4 + 0.5% FeSO4), T9 (1.0% MnSO4 + 1.0% FeSO4).

The field experiment was completed with three replications and crop was fertilized and irrigated as per treatment schedule. Variety Kinnow was sown at a spacing of 5 m x 5 m. Periodical observations were taken up with different growth stages. The experimental data on observations were statistically analyzed by adopting the procedure of Panse and Sukhatme7. The critical difference was calculated at five per cent probability level to draw statistical calculations.

Result and Discussion

Effect of foliar application of manganese and ferrous

Vegetative growth attributes

The foliar application of manganese and ferrous significantly influence the growth attributes such as shoot length (cm), canopy area (m^2), stem girth (cm) and tree height (m) in mandarin *cv.* kinnow. The highest increase in shoot length (32.83%), canopy area E-W (17.80%), canopy area N-S (35.37%), and tree height (4.97%) recorded in treatment T_9 (1.0% $MnSO_4$ + 1.0% $FeSO_4$) over the treatment T_1 (control). The stem girth was not significantly influenced by Mn and Fe. It might be due to that manganese and ferrous are major contributor to various biological systems including photosynthesis, respiration, and nitrogen assimilation. Further, involvement of Mn as activates decarboxylase, dehydrogenase and oxidase enzymes in plants which are important in photosynthesis, nitrogen metabolism and nitrogen assimilation. The greater production of photosynthesis increase the vegetative growth attributes of plant. It is an essential element in respiration and involved in the destruction or oxidation of indole-3-acetic acid (IAA). In case of ferrous, it is required in plants for synthesis of enzymes responsible for chlorophyll synthesis. It is a component of various flavo-protiens, peroxidase, catalase, cytochrome oxidase enzymes and found in ferrodoxin which precipitates in oxidation – reduction reaction e.g. NO_4^- and SO_4^{2-} reduction, N – fixation etc. These activities are responsible for increase in vegetative growth attributes in plants. Results depicted are similar to those achieved by El-Saida (2001) [6] in Washington navel orange, Ingle *et al.* (2002) [9] in acid lime, Sarolia *et al.* (2007) [15] in guava.

Yield attributes

There were positive effect of spraying of manganese and ferrous on yield attributes *viz.*, fruit diameter (equatorial & polar), fruit weight, fruit volume, fruit retention, number of fruits per plant, yield per plant and per ha (Table 1). The maximum fruit diameter (0.23 cm & 0.17 cm), fruit weight (0.56 g), fruit volume (1.42 cc), fruit retention (0.26%), number of fruit per plant (417.33), yield plant^{-1} (56.33 kg), yield ha^{-1} (22.93 t ha^{-1}) was recorded in treatment T_8 (1.0% $MnSO_4$ + 0.5% $FeSO_4$) closely followed by T_9 over the treatment T_1 (control).

Manganese increases the fruit diameter (Equatorial & Polar), fruit weight and fruit volume. It might be due to role of Mn in photosynthesis and greater production of assimilates. Ferrous sulphate mediated increase in fruit diameter (Equatorial & Polar), fruit weight and fruit volume because of improved chlorophyll content of kinnow leaves that in turn might have increased the photosynthetic efficiency and greater production of assimilates. The greater production of photosynthesis and their translocation to economic sinks may be the reason of improved yield character.

The similar findings were also reported by Bambal *et al.* (1991) [3] in pomegranate *cv.* Ganesh, Ghosh and Besra (2000) [8] in sweet orange *cv.* Mosambi, Ram and Bose (2000) [14] in mandarin, Sourour (2000) in orange, El-sheikh *et al.* (2007) [7] in Florida prince and Desert red peach trees.

Increase in fruit retention and fruit number might be due to reduction in the fruit drop (data not presented). Manganese is involved with photosynthesis, efficient use of N, protein metabolism and enzyme activation. Iron acts as a catalyst in oxidation/reduction reactions, involved in respiration, photosynthesis and the reduction of nitrate and sulfate. It is also a cofactor in many enzymes. These are leads to more fruit retention. Similarly the present results were supported by the findings obtained by Ghosh and Besra (2000) [8] found that zinc + boron + iron resulted in highest fruit retention (78.6%) and fruit plant^{-1} (205) in sweet orange cv. Mosambi. Mn is required in the process of photosynthesis (Mengel and Kirkby, 1987) [12] and Fe plays a key role in several enzyme-systems, in which haeme or haemin is the prosthetic group (Khurshid *et al*., 2008) [11].

The foliar spray of manganese and ferrous showed better response in improving the yield plant^{-1} and estimated yield ha^{-1}. The increase in yield is obviously due to the consolidated effect of increased size and weight of fruits caused by foliar spray of manganese and ferrous. Moreover, increased fruit set and reduced fruit drop as a result of spray of Mn and Fe could give higher number of fruits and consequently the yield. It is in conformity with the findings of Balakrishnan *et al.* (1996) [2] in pomegranate, Devi *et al.* (1997) [4] in satgudi orange, Ebeed *et al.* (2001) [5] in mango, Ingle *et al.* (2002) [9] in acid lime, Singh and Maurya (2004) [18] in mango.

Table 1: Effect of manganese and ferrous on vegetative growth and yield attributes

Treatments	Shoot Length (cm)	Canopy area (m) (E-W)	Canopy area (m) (N-S)	Stem girth (cm)	Stem girth (cm)	Fruit Diameter (cm)		Fruit weight (g)	Fruit volue (cc)	Fruit retentin (%)	Fruits per plant	Yield Per plant (kg)	Estimated yield (t/ha)
	After treatmet	After treatment	After treatment	After treatment	After treatment	Equatoril	Polar						
T_1 Control (water spray)	31.93	20.80	41.77	3.20	6.10	0.07	0.25	0.75	1.75	0.31	413.33	57.67	25.83
T_2 (0.5% Manganese sulphate)	31.40	24.27	41.63	3.83	5.90	0.07	0.27	0.80	1.83	0.48	414.67	57.33	29.54
T_3 (1.0% Manganese sulphate)	32.57	18.20	39.97	3.70	6.17	0.08	0.25	0.90	1.81	0.51	417.33	57.67	34.40
T_4 (0.5% Ferrous sulphate)	32.47	20.03	37.07	3.37	5.27	0.07	0.20	0.74	1.73	0.35	417.00	55.67	25.27
T_5 (1.0% Manganese sulphate)	31.90	17.57	40.67	3.23	5.70	0.08	0.22	0.78	1.65	0.35	418.67	56.33	23.17
T_6 (0.5% $MnSO_4$ + 0.5% $FeSO_4$)	32.73	20.03	37.47	3.50	5.83	0.28	0.23	0.88	1.74	0.45	414.00	55.67	24.97
T_7 (0.5% $MnSO_4$ + 1.0% $FeSO_4$)	31.67	16.23	34.17	3.27	4.53	0.07	0.17	0.55	1.33	0.29	413.00	58.00	19.17
T_8 (1.0% $MnSO_4$ + 0.5% $FeSO_4$)	31.83	20.10	36.33	3.20	4.77	0.08	0.17	0.56	1.42	0.26	417.33	56.33	22.93
T_9 (1.0% $MnSO_4$ + 1.0% $FeSO_4$)	32.83	17.80	35.37	3.77	4.97	0.07	0.22	0.63	1.58	0.33	414.67	58.00	21.83
F	20.57	35.42	47.41	1.32	209.22	0.98	36.23	53.56	25.08	21.01	1.99	0.68	44.16
SEm±	0.70245	0.5592	0.5776	0.2151	0.0591	0.0989	0.0086	0.0245	0.0486	0.0266	2.05	1.66	0.9545
CD	1.2263	0.9763	0.1008	0.3755	0.1031	0.1726	0.0150	0.0427	0.0085	0.0464	3.5793	2.8983	1.1224
CV%	2.62	3.52	1.85	7.63	1.32	126.24	4.77	4.10	3.61	8.90	0.6049	3.56	4.63
C x R	6.15	116.3	302.97	15.59	1,554.69	0.73	206.96	412.48	170.11	124.54	15.52	5.3	307.48

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