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Full Length Research Paper

Effect of multi-micronutrient on yield and quality attributes of the sweet orange

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Field experiment was conducted for two successive years on sweet orange to evaluate the effect of multi-micronutrient on yield and quality attributes of sweet orange grown on Inceptisols of Aurangabad district of Maharashtra, India. The result indicates that the number of fruits per tree increased with the application of balanced dose of NPK along with multi-micronutrient from 426 to 554. Similarly, weight of fruit per tree was ranged from 72.42 kg/tree in control to 143.80 kg/tree in the treatment receiving multi-micronutrients through soil. Productivity was also enhanced from 20.06 to 39.83 t/ha due to application of multi-micronutrients along with recommended NPK. The quality of the fruits in terms of juice, TSS, fruit girth, ascorbic acid content, reducing and non-reducing sugar increased with the application of multi-micronutrient and NPK either applied through soil or fertigation, whereas, acidity of the fruit juice was found highest in untreated control as compared to balance nutrient application.

Key words: Multi-micronutrient, sweet orange, NPK, quality of fruit.

INTRODUCTION

The productivity of sweet orange in India is significantly lower than in some of the frontline citrus growing countries like Brazil, USA, Spain and Italy (30 to 35 t/ha). Similarly, the average productivity of sweet orange orchards (14.9 t/ha) is comparatively lower among the different sweet orange varieties. One of the main reasons for low sweet orange orchard productivity in the soils of Marathwada region is multiple nutrient deficiencies. The soils of this region are mostly derived from basaltic parent material and are commonly deficient in multiple nutrients, including N, P, Fe, Mn, and Zn; that is why the conventional nutrient management strategy based mainly on macronutrient application in citrus orchards has not been very successful in raising the productivity level (Srivastava et al., 2009). Relatively, small amount of micronutrient is required as compared to those of primary nutrients, but these are equally important for plant metabolism (Katyal, 2004). Even though micronutrients are present in soil, their absorption may be hindered by other nutrients by interaction between nutrients.

For instance, zinc deficiency often occurs due to heavy phosphate application. Manganese deficiency occurs especially due to over liming, heavy phosphate application and excess of iron, copper and zinc in the soil. Copper deficiency is induced by heavy liming and excessive application of nitrogen and phosphate on the yield of crops could be improved with little quantities of micronutrients applied either singly or in mixtures through soil or foliar feeding (Malewar, 2005).

Micronutrient plays many complex roles in plant nutrition and plant production, while most of micronutrients participate in the functioning of number of enzyme systems, there is considerable variation in the specific functions of the micronutrients in plant and microbial growth processes, for example, copper, iron and molybdenum are capable of acting as electron carriers in the enzyme system that bring about oxidation reduction reactions in plants. Such reactions are essential steps in photosynthesis and many other metabolic processes. Zinc and manganese functions in many enzyme systems as bridges to connect the enzyme with the substrate upon which it is meant to act (Rajaie et al., 2009). Under various application techniques and their effects on Indian

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Table 1. Initial physico-chemical properties and fertility status of experimental soil in 2006.

Soil characteristics	Unit	2006
Physical properties		
Field capacity (%)	%	51.88
Water holding capacity (%)	%	73.07
Clay	%	52.98
Free $CaCO_3$	%	8.78
Texture	-	Clay
Chemical composition		
pH	-	7.9
EC	dSm^{-1}	0.23
Organic carbon	g kg^{-1}	5.7
Nutrient status		
Available N	mg kg^{-1}	38.0
Available P_2O_5	mg kg^{-1}	7.00
Available K_2O	mg kg^{-1}	250.0
Exchangeable Ca	mg kg^{-1}	4391
Exchangeable Mg	mg kg^{-1}	1051
Available S	mg kg^{-1}	16.0
DTPA Fe	mg kg^{-1}	7.05
DTPA Zn	mg kg^{-1}	2.10
DTPA Mn	mg kg^{-1}	11.03
DTPA Cu	mg kg^{-1}	4.01
Available B	mg kg^{-1}	0.35
Available Mo	mg kg^{-1}	0.12

conditions, no systematic work was carried out on the role of multi-micronutrient in sweet orange and qualitative as well as quantitative production. Hence, this present investigation was planned to evaluate the effect of multi-micronutrient along with major nutrients on yield and some quality parameters of sweet orange.

MATERIALS AND METHODS

Site description

This research was conducted at farmer's field, Pimpri Raja village, Aurangabad (17° 35′ to 20° 40′ North latitude and 74° 40′ to 78° 15′ East longitude), Maharashtra, India. The climate of Aurangabad is moderately warm and dry. It has 550 to 750 mm average rainfall but during experimental period it was noticed up to 972 mm and the temperature were 11 to 39°C. The Vertisol under study area was formed from the weathering of trap rock, rich in iron, copper and magnesia. According to Vaidya and Joshi (1972), soils are brown black with non-calcareous to highly calcareous (free $CaCO_3$ ranges from 1.2 to 15%). The experimental soil was clay 52.98 per cent in texture with alkaline pH (7.9), having medium content of organic carbon and low in available nitrogen and phosphorus but high in potassium, calcium and magnesium. The available sulphur and all the micronutrients except boron are up to adequate level. Boron was below the critical limit (Table 1).

Experimental treatments

The experiment was planned in 15 years old sweet orange orchard in completely randomized block design with six replications and 5 treatments in the farmer's field. Each replication consists of 3 plants per treatment. The various treatments used in the study include: T_1- FYM 6952 kg ha^{-1} per year, T_2- NPK through soil (160.2:55.4:110.8 kg ha^{-1}) per year, T_3- NPK (20:20:20 (Nelfmel) water soluble fertilizer 83.1 kg ha^{-1} per year through fertigation, T_4- NPK (160.2, 55.4, 110.8 kg ha^{-1} per year) + Boracol (BSF-11) 83.1 kg ha^{-1} per year through soil and T_5- NPK [20:20:20 (Nelfmel)] water soluble fertilizer 83.1 kg ha^{-1} per year) through fertigation. However, Boracol and Kiecite-CTR were used as sources of multi-micronutrient for soil and fertigation application, respectively. In fertigation fields, treatments were applied in three splits as NPK 27.7, 27.7 and 27.7 kg ha^{-1} and micronutrient water soluble 13.85, 13.85 and 13.85 ha^{-1} per year in the month of January, March and July, respectively. The fertilizer applications were carried out at flowering, fruit setting and fruit development stages of production period. The data on yield attributes like number of fruits per tree and weight of fruits per tree and fruit quality parameters like juice percentage, acidity and TSS content were recorded at harvest. All plant protection and intercultural operations were done whenever necessary. The fruit harvesting was done in the first week of November as usual.

Statistical analysis

The obtained data was analyzed for statistical significance as per Panse and Sukhatme (1985) using computer programme (MAUSTAT) developed by MAU Parbhani.

RESULTS AND DISCUSSION

The data with respect of fruit quantity parameters like number of fruits per tree, weight of fruit per tree and productivity per hectare as influenced by use of multi-micronutrient are presented in Table 2. During two years of trial (2007 and 2008), Treatment T_4 (NPK + Boracol BSF11) through soil showed significantly superior values of number of fruits per tree (554 and 553), weight of fruit per tree (132.90 and 143.80 kg) and simultaneously productivity per hectare (36.81 and 39.83 t/ha) over (T_1) FYM 25 kg ha^{-1}, (T_2) NPK only, (T_3) NPK water soluble and at par with treatment T_5 [NPK WS + Kiecite DF (CTR)] water soluble multi micronutrient mixture through fertigation. Increase in number of fruit per tree in T4 (NPK + Boracol-11) applied with multi-micronutrient that is, Boracol BSF-11 along with recommended dose of NPK and T_5 [NPK + Kiecite DF (TR)] might have supplied all the micronutrients along with major nutrients which might have helped the crop to increase in chlorophyll content of leaves, photosynthetic efficiency, translocation of metabolites from the source to sink as and when needed by the crop and it may be responsible for retaining more number of fruits, increase in weight of fruit and productivity as compared to T_2 and T_3 where only NPK were added. The findings of the present investigation are supported by earlier work of Muhammad and Manzoor (2010).

Tariq et al. (2007) also observed that application of

Table 2. Fruit quantity parameters of sweet orange as influenced by multi-micronutrient applications.

Treatment		Number of fruits/tree		Weight of fruit/tree		Productivity t/ha	
		2007	2008	2007	2008	2007	2008
T_1	FYM at a rate of 25 kg/tree/year	433	426	73.61	72.42	20.38	20.06
T_2	NPK bulk RDF	477	475	90.63	90.42	25.10	24.99
T_3	NPK water soluble grade	496	490	99.20	99.00	27.47	27.42
T_4	NPK bulk RDF+ Boracol BSF11 (multi-micronutrient)	554	553	132.90	143.80	36.81	39.83
T_5	NPK water soluble+ Keicite DF (multi-micronutrient) WS	538	547	129.10	131.30	35.76	36.37
S.E.±		13.0	18.5	3.91	4.62	3.70	3.75
C.D. at 5%		38.4	54.5	11.40	13.65	10.07	11.17

RDF = Recommended dose of NPK fertilizers; S.E. = standard error; C.D. = critical differences and WS = water soluble.

micronutrients lead to more number of fruits in sweet orange and yield were increased significantly. Ghosh and Basra (2000) also reported highest number of fruits in sweet orange due to combined application of micronutrients along with NPK.

Effect of multi-micronutrient on quality parameters of fruit

Fruit girth

Fruit girth was increased in multi-micronutrient applied treatments during first year of experimentation (2007) in T_4 (26 cm), T_5 (24 cm) and minimum at T_1 (20 cm). During 2008 the fruit girth was found highest in T_4 followed by T_5 which was significantly superior over T_1 (FYM). Abo-El-Komsan et al. (2003) found that the best results with regard to yield and fruit quality were obtained due to spraying balady orange trees four times with a mixture containing NPK + Mg + S at 0.5% + Zn, Fe, Mn at 0.05% + citric acid at 1000 mg kg^{-1}. The findings are in agreement with Ingle et al. (2002) in acid lime. The plants treated with micronutrient specially zinc increased the size/volume/girth of fruits as it regulates the semi-permeability of cell wall which mobilizes more water into fruits thereby increasing size of fruits in kagzi lime (Babu et al., 1982).

Juice content

During two years of the experiment, it was observed that juice content in the sweet orange was ranged from 33.29 to 57.80%. Juice content was increased in treatment T_4, followed by T_5 and decreased in T_1 with significant differences; T_2, T_3, T_4 and T_5 were found statistically at par with each other in terms of juice content in fruit and superior over control T_1 (FYM). Application of multi-micronutrients along with NPK might have improved tree health and this could be the main reason for increase in juice content. It has been reported by various researchers that balanced nutrition considerably increased the juice content in the fruits of healthy trees. The results obtained in this present study confirm the findings of many earlier researchers (Ghosh and Basra, 2000; Kulkarni, 2004) in sweet orange. The results are in similar line as those of Devi et al. (1997) who found that juice content of sweet orange fruits was significantly increased when the plants were supplied with soil application of $ZnSO_4$, $FeSO_4$ and $MnSO_4$ at 50 g/tree and combined foliar spray of the micronutrient at 0.5% concentration.

Total soluble solids (TSS)

In this trial, TSS ranged from 9.0 to 10.3 Brix°C showed a maximum with T_5 followed by T_4 and the lowest was observed in control (T_1). The treatments T_4 and T_5 were statistically at par to each other. Similar trend was also found during second year of experiment. This increase in T.S.S. was due to increase in photosynthesis activity (Kulkarni, 2004). Similar observations were recorded by Ghosh and Basra (2000) and highest TSS in sweet orange with foliar application of $ZnSO_4$ + Borax was noted.

Ascorbic acid

During both years of experimentation, ascorbic acid was noted to the tune of 46.10 to 58.01 mg/100 ml juice and found highest in T_4 followed by T_5. There was a slight increase in ascorbic acid content with statistical difference.

Table 3. Fruit quality parameters of sweet orange as influenced by multi-micronutrient applications.

Treatment		Fruit girth (cm)		Juice (%)		Total soluble solids (%)		Ascorbic acid content (mg/ 100 ml)		Reducing sugar (%)		Non-reducing sugar (%)		Acidity (%)	
		2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
T_1	FYM at 25 kg/tree/year	20	19	33.29	32.04	9.0	10.0	48.05	46.10	1.6	1.6	8.6	8.7	1.0	0.99
T_2	NPK bulk RDF	23	24	51.00	50.16	9.1	10.1	52.35	51.30	1.7	1.7	9.0	9.3	0.98	0.97
T_3	NPK water soluble grade	22	25	45.71	47.60	9.7	10.9	53.00	52.10	1.7	1.8	9.2	9.6	0.95	0.94
T_4	NPK bulk RDF+Boracol BSF11 (multi-micronutrient)	26	27	57.80	55.40	10.1	11.3	57.77	58.01	2.2	2.5	9.8	10.4	0.86	0.80
T_5	N PK water soluble+ Keicite DF (multi-micronutrient)	24	25	52.78	54.16	10.3	11.2	56.30	57.17	2.0	2.3	10.1	10.2	0.87	0.86
S.E.±		1.03	0.98	3.66	2.72	0.44	0.54	0.32	2.96	0.15	0.19	0.16	0.45	0.107	0.12
C.D. at 5%		3.09	2.85	10.80	8.01	1.23	1.58	0.96	8.74	0.45	0.57	0.48	1.34	NS	NS

RDF = Recommended dose of NPK fertilizers, S.E. = standard error, C.D. = critical differences and WS = water soluble.

Ascorbic acid content was increased by all the various fertilizer treatments. Higher levels of sugar due to micronutrient application including boron might be the possible cause behind increase in ascorbic acid content which is synthesized from sugar (Mengel and Kirkby, 1987). Similar findings were reported by many researchers (Devi et al., 1997; Ghosh and Basra, 2000; Kulkarni, 2004) in sweet orange.

Reducing sugar /non-reducing sugar content

During both years, reducing sugar was found to be the highest in T_4 followed by T_5 and lowest in T_1. The variation of reducing sugar content across treatments was significant and T_4 was superior to T_1, T_2 and T_3 and at par with T_5. Non-reducing sugar content ranged from 8.6 to 10.1%, maximum content was observed in treatment T_5, followed by T_4 and minimum was in control (T_1).

Similar observations were recorded during second year where non-reducing sugar content varied from 8.7 to 10.4% in sweet orange juice. Multi-micronutrient application resulted in a significant increase in reducing, non-reducing and total sugars in the sweet orange fruits. These multi-micronutrient treatments comprised of boron and zinc application along with other micronutrients, which have an important role in sugar metabolism.

These results are supported by the findings of Dixit et al. (1977), who found increase in sugar content of juice in kinnow mandarin fruits due to foliar sprays of $ZnSO_4$+ $FeSO_4$.Similar results were recorded by Kulkarni (2004) and it recorded the highest sugar content in juice of sweet orange fruits with the foliar application of $ZnSO_4$ (0.5%) + $FeSO_4$ (0.4%) + Borax (0.2%).

Acidity

The data presented in Table 3 on the fruit quality parameters indicated during first year (2007), acidity varied from 0.86 to 1.0%. Maximum acidity was observed in only FYM treated plants (T_1) followed by T_2 and T_3 treatment and minimum in multi-micronutrient treated trees that is, in T_4 and T_5. There were no-significant differences among these treatments. Similar trend was observed in second year of trial for juice acidity that is, showing maximum acidity in T_1 followed by T_2 and T_3. Whereas, T_4 and T_5 showing minimum juice acidity. The decreased acidity in micronutrient treated fruit juice might be due to their utilization in respiration and rapid metabolic transformation of

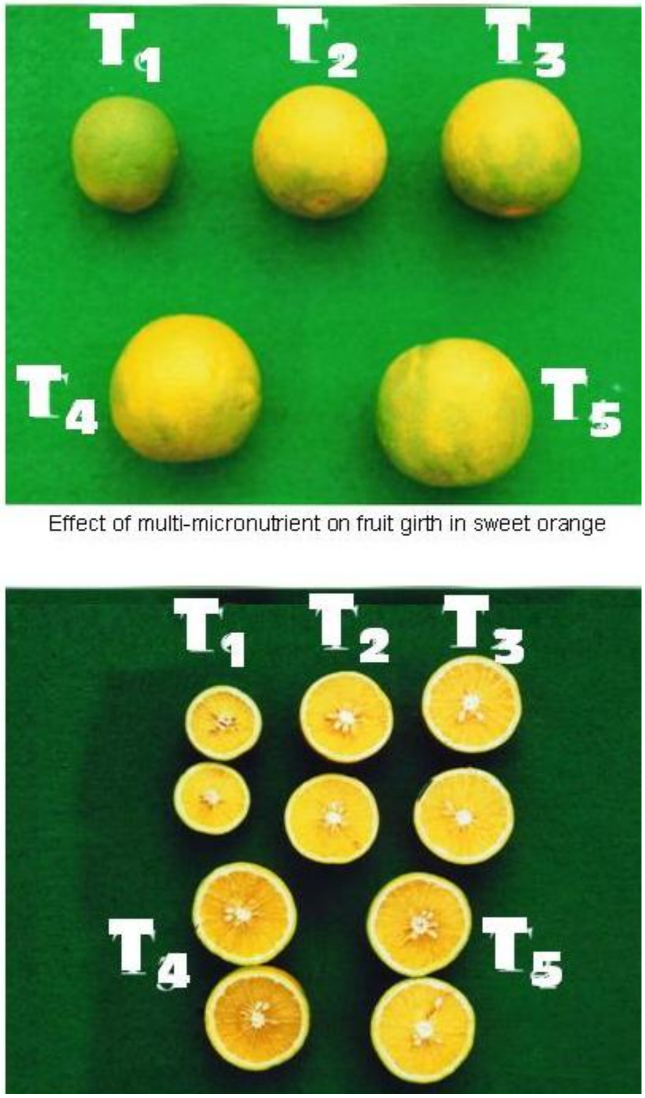

Figure 1. Fruit girth of sweet orange as influenced by different treatments {T_1- FYM at 25 kg/tree/year , T_2- NPK bulk RDF, T_3- NPK water soluble grade, T_4- NPK bulk RDF+Boracol BSF11 (multi-micronutrient) and T_5- N PK water soluble+Keicite DF (multi-micronutrient)}.

organic acids into sugars (Brahmahachari et al., 1997). The results obtained in this present investigation were in agreement with those of Devi et al. (1997) in sweet orange (Figure 1). Similar results were also reported by Deolankar and Firke (2001) in banana and by Singh et al. (2003) in pomegranate and Patil and Hiwarale (2004) in acid lime.

Conclusions

On the basis of the aforementioned research results, it can be concluded that sweet orange growers of the region should apply multi-micronutrients along with recommended dose of NPK either through soil and foliar spray to their sweet orange trees to recover the trees from noticed deficiency for healthy growth of trees and could achieve a good yield with excellent fruit quality.

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