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Effect of multi-micronutrients on fruit quality of sweet orange (*Citrus sinensis* L. osbeck) CV. Phule mosambi

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Abstract
A field experiment was conducted at the Horticultural Research Farm, College of Horticulture, Anand Agricultural University, Anand during 2024 to evaluate the effect of multi-micronutrients on the quality of sweet orange (*Citrus sinensis* L. Osbeck) cv. Phule Mosambi. The experiment, laid out in a Completely Randomized Design with nine treatments, involved different combinations of government-notified micronutrient grades from Gujarat (G-IV and G-V) and Maharashtra (G-II-MH), applied through soil and foliar methods. Among the treatments, foliar application of G-IV (Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0%) + Mo-0.1% combined with soil application of G-V (Fe-2.0%, Zn-5.0%, Cu-0.2%, B-0.5%, Mn-0.5%) under T_9 significantly enhanced fruit quality, recording the highest total soluble solids (9.22 °Brix), total sugars (7.03%), juice content (52.12%), sugar:acid ratio (20.64) and ascorbic acid (44.15 mg/100 ml), along with the lowest acidity (0.45%) and minimum rind thickness (4.07 mm). The control treatment T_1 consistently recorded the lowest values for all parameters.

Keywords: Quality, sweet orange, multi-micronutrients, *Citrus sinensis*, Phule mosambi

Introduction

Sweet orange (*Citrus sinensis* L.) is a subtropical fruit member of the rutaceae family and the aurantioideae subfamily. After mango and banana, citrus is the third-largest fruit crop cultivated in India. Both tropical and subtropical climates are often used to develop it. Sweet orange needs a dry climate and arid weather with distinct summer and winter seasons, with low rainfall. It is grown on a wide range of soil, ranging from clay to light sandy and sensitive to salt. Sweet orange is well grown on medium black, red, alluvial riverbank loamy soil of Maharashtra state and sandy loam soil of Gujarat. In Sweet Orange 100 g fruit contains 60-80% fruit juice, protein 0.8-1.4 g, fat 0.2-0.4 g, fiber 0.8 g, vitamin-A 198 I.U, 0.113 mg vitamin B_1, 0.046 mg riboflavin, 65.69 mg vitamin C, 0.2-0.8 mg iron, 0.16 mg calcium and potassium 192-201 mg. Khan *et al*., (2016) [9]. Micronutrients play a vital role in influencing the quality of sweet oranges, which are particularly sensitive to nutrient imbalances. Although required in much smaller quantities compared to primary nutrients, micronutrients are equally essential for various physiological and metabolic processes in plants (Katyal, 2004) [6]. Optimum micronutrients are the most important factor in producing high-quality fruits (Babu and Yadav, 2005; Tariq *et al*., 2007) [1, 16]. These elements include boron (B), copper (Cu), manganese (Mn), molybdenum (Mo), iron (Fe) and zinc (Zn). Despite their presence in the soil, the uptake of micronutrients can be limited due to nutrient interactions that interfere with their availability. These elements are involved in critical metabolic functions such as starch metabolism, photosynthesis, nucleic acid metabolism, chlorophyll synthesis, and protein biosynthesis, all of which are fundamental to plant development and productivity (Swietlik, 2002) [15].

Materials and Methods

The experiment was conducted on twelve-year-old trees of sweet orange planted at Horticultural Research Farm, College of Horticulture, Anand Agricultural University, Anand during 2024. It was carried out using a Completely Randomised Design with nine treatments *viz.*, T_1: Control, T_2: G-II-MH (Fe-2.5%, Zn-3.0%, Cu-1.0%, B-0.5%, Mn-1.0%, Mo-0.1%), T_3: G-IV (Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0%), T_4: G-IV (Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0%) + Mo- 0.1%, T_5: G-V (Fe-2.0%, Zn-5.0%, Cu-0.2%, B-0.5%, Mn-0.5%), T_6: G-V (Fe-2.0%, Zn-5.0%, Cu-0.2%, B-0.5%, Mn-0.5%) + Mo- 0.1%, T_7: G-V + T_2 {(G-II-MH (Fe-2.5%, Zn-3.0%, Cu-1.0%, B-0.5%, Mn-1.0%, Mo-0.1%)}, T_8: G-V + T_3 {(G-IV (Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0%) and T_9: G-V + T_4 {(G-IV (Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0%) + Mo- 0.1% repeated thrice during February to October in the year 2024. Micronutrient formulations multi-micronutrient G-II-MH and Multi-micronutrient G-IV @ 1% was applied twice as foliar spray, *i.e.* first spray in March (at flowering time) and second spray one month after the first spray and multi-micronutrient Grade-V @ 1% was given as a soil application in February. A full dose of RDF (20 kg FYM + 800:300:600 g N:P: K per plant) was given in two equal splits in the months of February and June as per the recommendation of MPKV, Rahuri.

Results and Discussion

Table 1: Effect of multi-micronutrients on quality parameters of sweet orange

Sr. No.	Treatment Details	TSS (°Brix)	Acidity (%)	Total sugar (%)	Sugar: acid ratio	Juice (%)	Ascorbic acid (mg /100ml)	Total chlorophyll (mg/100 g)	Rind thickness (mm)
T_1	Control	7.53	0.56	5.97	13.25	41.68	38.30	125.04	5.13
T_2	G-II-MH (Fe-2.5%, Zn-3.0%, Cu-1.0%, B-0.5%, Mn-1.0%, Mo-0.1%)	8.03	0.48	6.62	16.67	47.04	41.08	144.82	4.30
T_3	G-IV (Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0%)	7.65	0.53	6.08	14.35	42.87	39.70	186.37	5.03
T_4	G-IV (Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0%) + Mo- 0.1%	7.63	0.54	6.36	14.14	42.30	40.18	176.60	4.47
T_5	G-V (Fe-2.0%, Zn-5.0%, Cu-0.2%, B-0.5%, Mn-0.5%)	7.78	0.51	6.20	15.27	43.62	39.88	146.56	4.67
T_6	G-V (Fe-2.0%, Zn-5.0%, Cu-0.2%, B-0.5%, Mn-0.5%) + Mo 0.1%	7.82	0.50	6.42	15.74	45.02	40.29	148.47	4.63
T_7	G-V + T_2 {(G-II-MH (Fe-2.5%, Zn-3.0%, Cu-1.0%, B-0.5%, Mn-1.0%, Mo-0.1%)}	8.87	0.49	6.67	18.05	49.24	43.00	199.25	4.40
T_8	G-V + T_3 {(G-IV (Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0%)}	9.07	0.47	6.82	19.17	51.01	43.63	201.29	4.33
T_9	G-V + T_4 {(G-IV (Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0%) + Mo- 0.1%}	9.22	0.45	7.03	20.64	52.12	44.15	206.67	4.07
	S.Em ±	0.10	0.01	0.16	0.47	1.10	0.76	3.18	0.13
	CD (P=0.05)	0.30	0.03	0.46	1.39	3.26	2.26	9.45	0.38
	CV%	2.13	3.55	4.19	4.95	4.13	3.21	3.23	4.87

Effect of multi-micronutrients on quality parameters

Total soluble solids (°Brix)

The perusal of data (Table 1) revealed that among the various multi-micronutrient treatments, T_9: G-V + T_4 {(G-IV: Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0% + Mo-0.1%)} recorded the highest total soluble solids (TSS) content (9.22 °Brix), followed by T_8 (9.07 °Brix) and T_2 (8.95 °Brix), while the lowest TSS value (7.53 °Brix) was observed under the control treatment T_1. The significant increase in TSS under T_9 may be attributed to the synergistic action of micronutrients such as Fe, Zn, Cu, B, Mn, and Mo, which are known to influence sugar metabolism and translocation. Zinc and manganese enhance the activity of enzymes involved in carbohydrate metabolism, while boron plays a critical role in sugar transport and partitioning towards the developing fruit. These findings corroborate the earlier reports of Saha *et al*. (2020) [13], Ghosh and Besra (2000) [5], Kazi *et al*. (2012) [8], and Pawar *et al.* (2022) [12] in sweet orange

Acidity (%)

The perusal of data (Table 1) indicated that among the different treatments, T_9: G-V + T_4 {(G-IV: Fe-4.0%, Zn-6.0%, Cu-0.5%, B-0.5%, Mn-1.0% + Mo-0.1%)} recorded the lowest acidity content (0.45%), followed by T_8 (0.47%) and T_2 (0.48%), whereas the highest acidity (0.56%) was observed in the control treatment T_1. The notable reduction in acidity under T_9 may be attributed to the synergistic effect of essential micronutrients such as Fe, Zn, Cu, B, Mn, and Mo, which are known to enhance enzymatic activity, sugar metabolism and organic acid utilization in fruit tissues. These findings are in agreement with the earlier reports of Singh *et al.* (2018) [14] and Pawar *et al.* (2022) [12] in sweet orange.

Total sugar (%)

The total sugar content of sweet orange cv. Phule Mosambi as influenced by various multi-micronutrient treatments, is presented in Table 1. The results indicated statistically significant differences among treatments. The maximum total sugar content (7.03%) was recorded under treatment T_9 [G-V + G-IV + Mo], followed by T_8 (6.82%), T_7 (6.67%) and T_2 (6.62%) while minimum was observed in control T_1 at 5.97%. Zinc and manganese help activate key enzymes involved in sugar formation, while boron supports sugar movement to fruits through the phloem. These findings are in agreement with the earlier reports of Ghosh and Besra (2000) [5] and Singh *et al.* (2018) [14] in sweet orange.

Sugar: acid ratio

The sugar: acid ratio of sweet orange cv. Phule Mosambi as influenced by different multi-micronutrient treatments is presented in Table 1. The results revealed statistically significant variation among treatments. The highest sugar: acid ratio (20.64) was recorded in treatment T_9 [G-V + G-IV + Mo], whereas lowest in control T_1 at 13.25. The increase in sugar: acid ratio is attributed to the combined effect of micronutrients like Fe, Zn, B, Cu, Mn, and Mo, which enhance sugar synthesis and reduce acid accumulation. The high sugar: acid ratio in T_9 indicates better carbon assimilation and acid metabolism, contributing to improved fruit sweetness and maturity. These findings are in agreement with the earlier reports of Kaur *et al*. (2015) [7] in mandarin.

Juice (%)

The data pertaining to juice content (%) of sweet orange as influenced by different multi-micronutrient treatments are presented in Table 1. Significant variation was observed among treatments, indicating substantial role of combined micronutrient application in enhancing juice content. The highest juice percentage (52.12%) was recorded in treatment T_9 (G-V + G-IV + Mo), followed by T_8 (51.01%) and T_7 (49.24%), while lowest juice content (41.68%) was observed in control T_1. The significant increase in juice content under T_9 is likely due to the synergistic role of micronutrients such as Zn, Fe, B, Cu, Mn, and Mo, which enhance photosynthesis, carbohydrate accumulation and membrane permeability, leading to better juice synthesis and retention within fruit tissues. Similar findings were reported by Singh *et al.* (2018) [14] and Bekele and Abera (2017) [2] in sweet orange.

Ascorbic acid (mg/100 ml juice)

The ascorbic acid content in sweet orange juice was significantly influenced by various multi-micronutrient treatments in Table 1. The highest ascorbic acid content (44.15 mg/100 ml juice) was recorded in treatment T_9 (G-V + G-IV + Mo) followed by T_8 (43.63 mg/100 ml) and T_7 (43.00 mg/100 ml), whereas lowest value (38.30 mg/100 ml) was observed in control T_1. The increase in ascorbic acid under T_9 can be attributed to the combined effect of Zn, Fe, B, Cu, Mn, and Mo, which enhance photosynthesis, respiration, and antioxidant enzyme activity—key pathways in ascorbic acid biosynthesis. These findings are in agreement with the earlier reports of Nandita *et al.* (2022) [11] and Bhalerao *et al.* (2020) [3] in sweet orange.

Chlorophyll (mg/100 g)

The chlorophyll content in sweet orange leaves was significantly influenced by different multi-micronutrient treatments (Table 1). The highest chlorophyll concentration (206.67 mg/100 g) was recorded under treatment T_9 (G-V + G-IV + Mo), followed by T_8 (201.29 mg/100 g) and T_7 (199.25 mg/100 g) whereas lowest was observed in the control T_1 (125.04 mg/100 g). The increase in chlorophyll content under T_9 can be attributed to the complementary and cumulative roles of Fe, Zn, Mn, Cu, B, and Mo in chloroplast development, enzymatic activation and nutrient metabolism. Iron (Fe) is a core component of ferredoxin and cytochromes, essential for chlorophyll biosynthesis and photosynthetic electron transport. These results align with those of Chaurasia *et al.* (2021) [4] in sweet orange.

Rind thickness (mm)

The data in Table 1 indicate significant variation in rind thickness due to different multi-micronutrient treatments. Minimum rind thickness (4.07 mm) was observed in treatment T_9 (G-V + G-IV + Mo) and it was found at par with treatments T_2 (4.30 mm), T_8 (4.33 mm) and T_7 (4.40 mm). maximum rind thickness (5.13 mm) was recorded in control T_1. Reduction in rind thickness in T_9 may be attributed to the balanced and combined application of Zn, Fe, B, Mn, Cu, and Mo which improved internal tissue development and cell wall plasticity favoring pulp formation over peel growth. According to Meena *et al.* (2016) [10] in mandarin.

Conclusion

From the foregoing investigation, it can be concluded that the application of 1% multi-micronutrient Gujarat government notified grade-V (Fe-2.0%, Zn-5.0%, Cu-0.2%, B-0.5%, Mn-0.5%) soil application in February and 1% spraying of grade- IV (Fe-4.0%, Zn-6%, Cu-0.5%, B-0.5%, Mn-1.0%) + Mo 0.1% in march (at flowering time) and one month after first spray along with RDF (20 kg FYM + 800:300:600 g N:P: K per plant) was found effective in improving fruit quality.

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