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EXOGENOUS APPLICATION OF MACRO- AND MICRO-NUTRIENTS IMPROVES PLANT GROWTH, PRODUCTIVITY AND QUALITY OF 'PINEAPPLE' SWEET ORANGE

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Abstract

'Pineapple' sweet orange is an important citrus species being grown at commercial scale in Pakistan. Due to inadequate supply of macro along with micronutrients, its productivity and quality is not up to the required standard as compare to other citrus producing countries. Therefore, current study was designed in order to investigate the effect soil application of NPK (2500 g per plant in two splits) compound fertilizer (17:17:17) (T2) or foliar application of boric acid (0.3%) + zinc sulphate (0.6%) (T3) alone or in combination (T4) on growth, productivity and fruit quality of 'Pineapple' sweet orange. Untreated trees were kept as control (T1). Analysis of leaf mineral contents revealed that nitrogen (N), phosphorous (P), potassium (K), boron (B), and zinc (Zn) were found to increase significantly after macro and micronutrients application. Tree vegetative growth [Increase in tree height (54 cm) and tree spread (56 cm), stem girth (3.5 cm), length of flush (13.35 cm), leaf number flush^{-1} (12)], fruit yield [fruit weight (23.35 kg), fruit numbers (110.75), marketable fruit % (89.72%) per tree], fruit quality [fruit length (69.33 mm), breadth of fruit (70.06 mm), fruit weigth (211 kg), juice TSS (8.62%), TSS/Acid ratio (15.87), ascorbic acid content (31.62 mg 100g^{-1}), total phenolics (423.90 mg 100g^{-1} FW), antioxidants (92.65%) and carotenoids (1.20 µg 100g^{-1}) were significantly improved by T4 treatment. In conclusion, combine application of 2500 g NPK + boric acid (0.3%) + zinc sulphate (0.6%) significantly enhanced tree growth, production and quality of 'Pineapple' sweet orange fruit.

Key words: *Citrus sinensis* Osbeck; Fruit quality; Leaf mineral contents; Mineral nutrition; 'Pineapple'.

Introduction

Pakistan is blessed with diverse climatic conditions by nature, which are favourable for production of variety of fruit crops including citrus. Presently, citrus cultivation is ranked at number one in production (121 MT and 2.39 MT) and area (1361.4 thousand ha and 195 thousand ha) worldwide as well as in Pakistan (Anon., 2020). About 95% citrus is produced Pakistan in contributed by Punjab (Sargodha, Toba Tek Singh, Faisalabad, Sahiwal and Multan) province (Anon., 2020). Citrus industry in Pakistan is dominated (70% share) by cultivation of single citrus cv. *i.e.* 'Kinnow' mandarin (Ahmad *et al*., 2007), which suffers with various problems including monoculture, seediness, decline, glut production (Niaz *et al*., 2004). Therefore, there is need to cultivate other citrus species like sweet orange to eliminate the trend of monoculture. Hence, sweet orange has great potential, which can be used for diversification of the citrus industry in Pakistan (Nawaz *et al*., 2012).

Among sweet oranges, cv. 'Pineapple' being early to mid-season maturing can be best alternative to replace with 'Kinnow' mandarin in citrus industry of Pakistan. It exhibits pineapple-scented pulp, smooth skin, medium sized round shape, deep orange colour at ripening, and less seeds (Morton, 1987). In general, sweet oranges with very delicious taste (due to blend of sweet and acidic content), attractive appearance, rich in phytonutrients and health promoting beneftis have high demand in the world (Chel-Guerrero *et al.,* 2022; Etebu & Nwauzoma, 2014). Poor bearing, inferior fruit quality and the less productive age are difficulties faced by sweet orange growers in the country (Ahmad *et al*., 2007). For higher productivity, citrus trees require slightly acidic soil and well irrigated soil with good mineral composition (Ameer *et al.,* 2023). Poor nutrition management cause excessive leaf and flower drop, low fruit s*et al*ong with high fruit drop at multiple stages, are the root causes of low productivity (Saleem *et al*., 2008). Therefore, proper plant nutrition plays key role to improve growth, production and quality (Albrigo, 2002). Essential nutrients are categorized into two groups, micro and macronutrients. Macronutrients are relatively required by plants in large amounts such as nitrogen (N), phosphorus (P) and potassium (K); whereas, micronutrients required in low amounts to plants including boron (B), chlorine (Cl), iron (Fe), copper (Cu), manganese (Mn), molybdenum (Mo), and zinc (Zn).

N is very important for citrus production and considered as pre-requisite (Dasberg *et al*., 1984). It is essential for vegetative and reproductive development of plants (Alva *et al*., 2003). It is required by fruiting plants for their numerous physiological processes, for example, cell division, growth, photosynthetic activity and the respiration (Abbas and Fares, 2009). P is basically 2nd most important macro nutrient that fulfils the requirements of plants and constitutes 0.2% of plant dry weight (Soceanu *et al*., 2009). It has been reported to involve in various enzymatic activities, sugar mobility and metabolism (Zekri & Obreza, 2013). K is vital macronutrient and particularly required by plants in higher amounts to improve colour, size and juice flavour (Tiwari, 2005). Hence, balance amount of N, P and K is key factor to obtain maximum yield with good quality fruit in citrus (Albrigo, 2002).

For deep rooted plants micronutrients like B and Zn are also very important, however, their soil application is not much effective in order to overcome their deficiencies (Embleton *et al*., 1973). Therefore, foliar application of micronutrients application is more effective in contrast to their soil application (Singh & Khan, 2012). To get complete flowering, fruit development and hormonal activities B can be a good choice. B deficient citrus plants exhibit decreased photosynthetic activity and ultimately retarded growth (Han *et al*., 2008). Zn is also very beneficial and key micronutrient. It is sufficiently required for tryptophan and which is a precursor of indole acetic acid (Tucker, 1999). It is also involved in starch metabolism and is co-factor of many enzymes (Alloway, 2008). In Pakistan most of soils are very low in available Zn, and its deficiency is very common in citrus orchards (Alloway, 2004).

For optimum growth and development of citrus, especially sweet orange it is most important that there must be optimum level of essential mineral nutrients in leaves and which can be obtained only by following the balanced nutrient application program. In order to get maximum yield with good quality fruits, it is critically important to manage micro and macronutrients application. NPK compound fertilizer along with B and Zn may influence growth, development, productivity and fruit quality. As earlier little information exists on sweet orange regarding combine effect of NPK, B and Zn application on growth and productivity. So, it was hypothesized that NPK, B and Zn application of sweet orange can improve its growth, production and fruit quality. Hence, the aim of present experiment was to investigate the impact of soil applied NPK compound fertilizer (17:17:17) along with foliar applied B + Zn on the growth (vegetative + reproductive), production and quality parameters of ‘Pineapple’ sweet orange grown under Faisalabad conditions.

Materials and Methods

Cultural conditions and treatments: This experiment was carried out at Experimental Fruit Orchard Sq. No. 9 (31°25'N; 73°09'E), Institute of Horticultural Sciences, and University of Agriculture – Faisalabad, Pakistan during the year 2016-17. Seventeen years old ‘Pineapple’ sweet orange trees budded on the ‘Rough Lemon’ (*Citrus jambhiri* Obseck) rootstock grown under homogenous conditions at 11 x 11 spacing were chosen for the study. The experiment consists of four treatments including control (T_1), application of 2500 g NPK (17:17:17) per plant in two splits (before flowering on 24th February, 2017 and at fruit set stage on 15th April, 2017) (T_2), foliar application of 0.3% boric acid and 0.6% zinc sulphate (T3) and combine application of both T1+T2 (T_4). Each treatment repeated four times. The experimental layout was in accordance to Randomized Complete Block Design (RCBD). Single tree was treated as an experimental unit. Data were recorded regarding leaf mineral contents, tree growth, productivity and fruit quality.

Determination of mineral nutrients: Leaf sampling was done twice *i.e.* before and approximately after 10 days of nutrient application to determine leaf mineral contents of the plants. Around 50 healthy and mature leaves without any deficiency and disease symptoms were collected carefully. After washing with tap water and light detergent solution, leaves were rinsed with distilled water and dried first for 48 h under shade followed by oven drying for 48 h at 65°C. Dried leaves were grinded to fine powder for further analysis. For determination of leaf macro (N, P and K) and micronutrients (Zn, Fe, Mn, Cu, B) method reported by Khan *et al*., (2015) was used; where, N, P and K were expressed % and micro nutrients as mg kg^{-1}.

Tree vegetative growth: To determine the vegetative growth, data were recorded for increase in tree height (cm), canopy spread (cm), and trunk girth (cm) by using the method outlined earlier by Razzaq *et al*., (2013).

Tree reproductive growth: Fruit set (%) was computed by dividing number of fruits to the number of flowers and multiplying by hundred. Fruit drop was measured at interval of one month on the basis of actual fruit set by calculating fruits on tagged branches. Total fruits on whole tree were calculated just before harvesting during 2nd week of December 2017. Ten fruits from each tree were harvested randomly and average weight of each fruit was measured on electrical balance. Average fruit weight was multiplied with number of total fruits to calculate the yield. On each tree, fruits comprising 6 cm or more breadth were listed in marketable category. While, fruits comprising less than 6 cm breadth were listed in unmarketable category.

Fruit physical quality: In order to determine size of fruit, 10 fruits from each tree were randomly harvested length and breadth were determined by using Vernier Caliper and expressed as mm. Randomly selected fruits were weighed using an electrical balance and the average fruit weight was estimated. Selected fruit samples were peeled-off and juice was carefully extracted. Healthy and aborted seeds in a fruit were also counted for each experimental sample. Weight of peel (g), seed (g), juice (g), and of each composite sample was weighed by using digital weighing balance and converted into per cent. Thickness of peel was estimated by Vernier Caliper and expressed as mm. Peel to pulp ratio was also determined by diving the peel weight to weight of pulp.

Fruit biochemical quality: In order to measure the pH of fruit juice pH meter (Hanna Instruments, Mauriyius) was used. Juice TSS was measured by using digital refractrometer (ATAGO, RS-5000, Atago, Japan) and was expressed as %. Juice TA (%) was measured through titration method. TSS/Acid ratio of each composite juice sample from each replication was determined by dividing juice TSS with juice TA (%). Ascorbic acid (mg $100g^{-1}$ FW) contents in fruit juice were determined by using the method reported earlier by Khan *et al*., (2015). The method used by Khan *et al*., (2009) was used to determine sugars in fruit juice and were expressed as %. Total phenolics in 'Kinnow' mandarin were determined by the method described by Ainsworth and Gillespie (2007) with some modifications as described by Ullah *et al*., (2012), using a standard curve of gallic acid at 0.02-0.1 mg mL^{-1} concentrations. Total phenolics were calculated for each sample and expressed as GAE mg 100 mL^{-1} FW as described earlier by Nasir *et al*., (2016). Antioxidants in fruit juice were estimated by using the method used by Ullah *et al*., (2012).

Statistical analysis

Data were analyzed statistically by using Statistix 8.1. To test the overall significance of data, analysis of variance technique was used, while for comparing the differences among different treatment means, least significant difference (LSD) test at $p \leq 5\%$ was used (Steel *et al*., 1997).

Results and Discussion

Leaf mineral nutrients: Nitrogen (N) and phosphorus (P) content (%) of 'Pineapple' sweet orange leaves remained unchanged except in the trees treated with N, P and K alone (T2) or in combination with micro nutrients (T4) (Fig. 1A and B). Trees treated with combine application of N, P and K with zinc (Zn) and boron (B) exhibited about 1.5-fold and 1.6-fold increase in lead N and P level in contrast with control trees and their levels before treatment applications (Fig. 1A and B). Similarly, highest level of leaf potassium (K) about 1.44-fold higher than before application were observed in trees which were treated with T4 (Fig. 1C). However, calcium (Ca) contents in leaves of experimental trees did not show any significant increase after treatment applications (Fig. 1D). Significant increase in N, P and K level may be due to their exogenous application and synergistic relation between these nutrients. A similar increase in leaf N, P and K levels has been reported earlier by Rajaie *et al*., (2009) in lemon plants. Our findings are in accordance with Ashraf *et al*., (2010) who found that soil application of K enhanced endogenous K contents in leaves of 'Kinnow' mandarin trees.

After analysing the results shown in (Figs 1E and F), this can be clearly revealed that levels of leaf Zn and Mn were significantly reduced after the application of macro and micronutrients. However, leaf Zn contents were increased about two folds in trees treated with T_3 (0.3% boric acid + 0.6% zinc sulphate) and T_4 (2500 g NPK in two splits + 0.3% boric acid + 0.6% zinc sulphate) (Fig. 1E). Foliar application of micro nutrients alone (T3) or in combination with NPK significantly improved the leaf B contents about 1-3-fold in contrast to their level before application of treatments (Fig. 1H). This increase in the endogenous level of Zn and B contents in sweet orange leaves may be ascribed to their exogenous foliar application and also due to some synergetic relationship between N, P, and K with B and Zn. Similar, results have earlier been reported in 'Kinnow' mandarin (Khan *et al*., 2015; Razzaq *et al*., 2013; Ullah *et al*., 2012), 'Balady' mandarin (Samra *et al*., 1985), 'Valencia' orange (Sayed *et al*., 2004; Ullah *et al*., 2012) and Washington Navel' orange (Omaima & El-Metwally, 2007) trees.

Vegetative growth: Irrespective to the treatments applied, increase in tree height, canopy spread and stem girth of experimental 'Pineapple' sweet orange trees significantly improved in contrast to untreated control trees (Fig. 2). Highest increase in tree height, canopy spread, and stem girth was observed in the trees treated with T4 (combine application of 2500 g NPK in two splits + 0.3% boric acid + 0.6% zinc sulphate) (Fig. 2). These result clearly indicated that both macro micro nutrients paly very important role in the vegetative growth of 'Pineapple' sweet orange trees as with their combine application, experimental trees exhibited better tree growth, compared to their application alone. Similarly, the results regarding other vegetative parameters including flush length, leaves per flush, leaf length, leaf width and leaf size were significantly improved with application of macro and micronutrients and remained highest in T4 as compared to untreated control trees (Table 1). This increase in the vegetative growth of trees with macro and micro nutrients may be due to the increase in their endogenous level (Fig. 1). In addition, these nutrients are also involved in various activities of photosynthetic enzymes, which consequently help to improve the overall tree growth (Alloway, 2008), as earlier it has been observed that lower food reserves due to reduced level of photosynthesis cause reduction in citrus tree growth (Alloway, 2008; Ashraf *et al*., 2010). Similarly, soil application of macro nutrients and foliar application micronutrients had been reported to increase vegetative growth of mandarin and sweet orange fruits (Ashraf *et al*., 2010; Dawood *et al*., 2001; Khan *et al*., 2015; Nasir *et al*., 2018).

Reproductive growth: Application of macro and micronutrients showed significant improvement in reproductive parameters of the experimental trees. Trees treated with combine application of 2500 g NPK in two splits + 0.3% boric acid + 0.6% zinc sulphate (T_4) exhibited lowest fruit drop (%), and highest numbers of fruits per tree, yield per plant (kg), marketable and unmarketable fruits (%) as compared to untreated control fruit (Table 2). Highest level of fruit drop was recoded in control trees. The significant increase in reproductive growth of 'Pineapple' sweet orange trees by combine application of macro and micronutrient indicated that essential mineral elements play important role in the productivity of citrus fruit. Combine treatment caused about 1.25-fold reduction in fruit drop as compared to untreated control fruit which consequently increased the yield. This can further be ascribed that increase in the fruit retention on the tree consequently increased over all yield and marketable fruit (%). Similar results have been reported by Khan *et al*., (2015) where foliar application of B and Zn significantly increased marketable yield of 'Kinnow' mandarin fruit. Increase in yield has also been found earlier in mandarin (Razzaq *et al*., 2013; Ullah *et al*., 2012) and sweet orange (Ismail, 1994) through application of Zn or B.

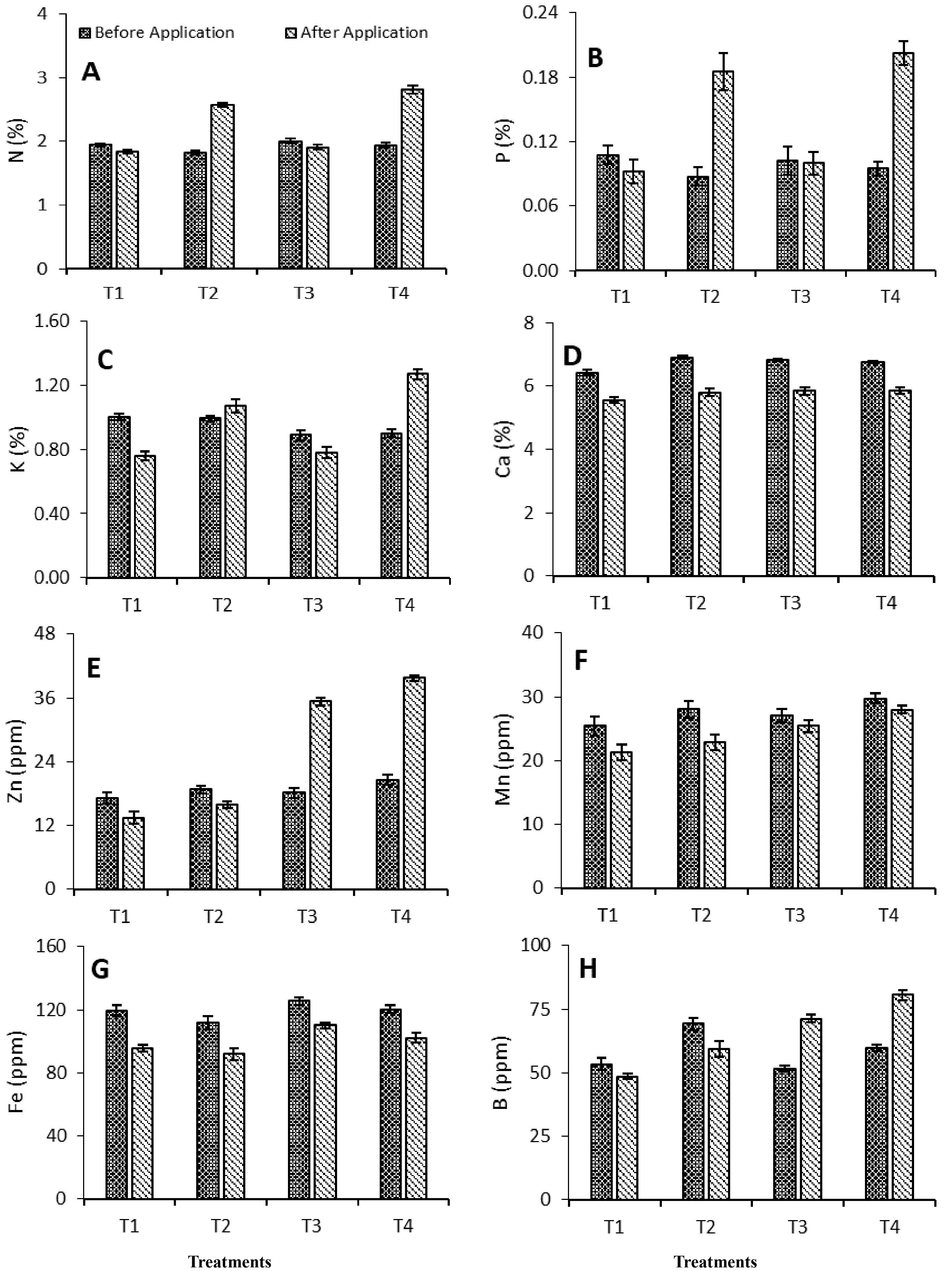

Fig. 1. Effect of macro and micronutrients on N (a), P (b), K (c), Ca (d), Zn (e), Mn (f), Fe (g) and B (h) contents of 'Pineapple' sweet orange leaves. Vertical bars represent ± SE of means. T1 = Control, T2 = 2500 g NPK (two splits) before flowering, T3 = Boric acid (0.3%) + zinc sulphate (0.6%) spray at the fruit setting stage, T4 = 2500 g NPK (two splits) + boric acid (0.3%) + zinc sulphate (0.6%) (before flowering + at fruit setting stage). n = 4 replications.

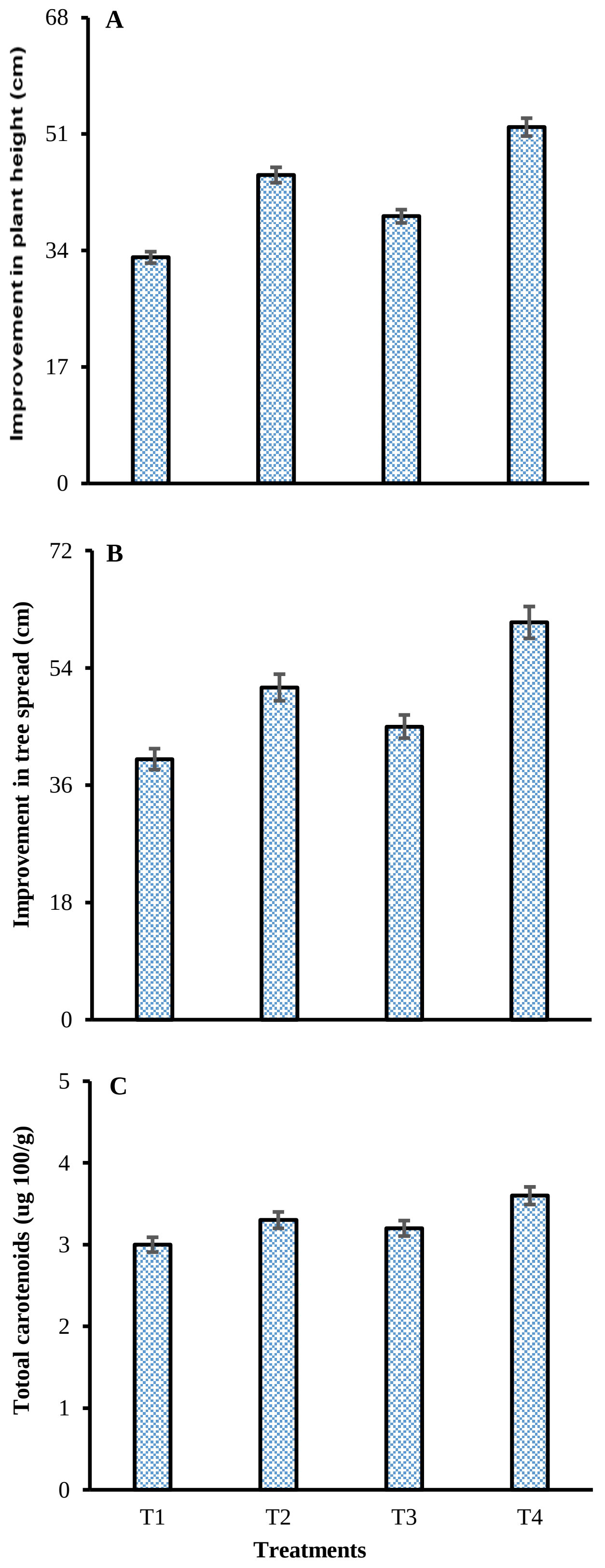

Fig. 2. Effect of macro and micronutrients on plant height (a), tree spread (b) and stem length (c) of 'Pineapple' sweet orange leaves. Vertical bars represent ± SE of means. T1 = control, T2 = 2500 g NPK (two splits) before flowering, T3 = boric acid (0.3%) + zinc sulphate (0.6%) spray at the fruit setting stage, T4 = 2500 g NPK (two splits) + boric acid (0.3%) + zinc sulphate (0.6%) (Before flowering + at fruit setting stage). n = 4 replications.

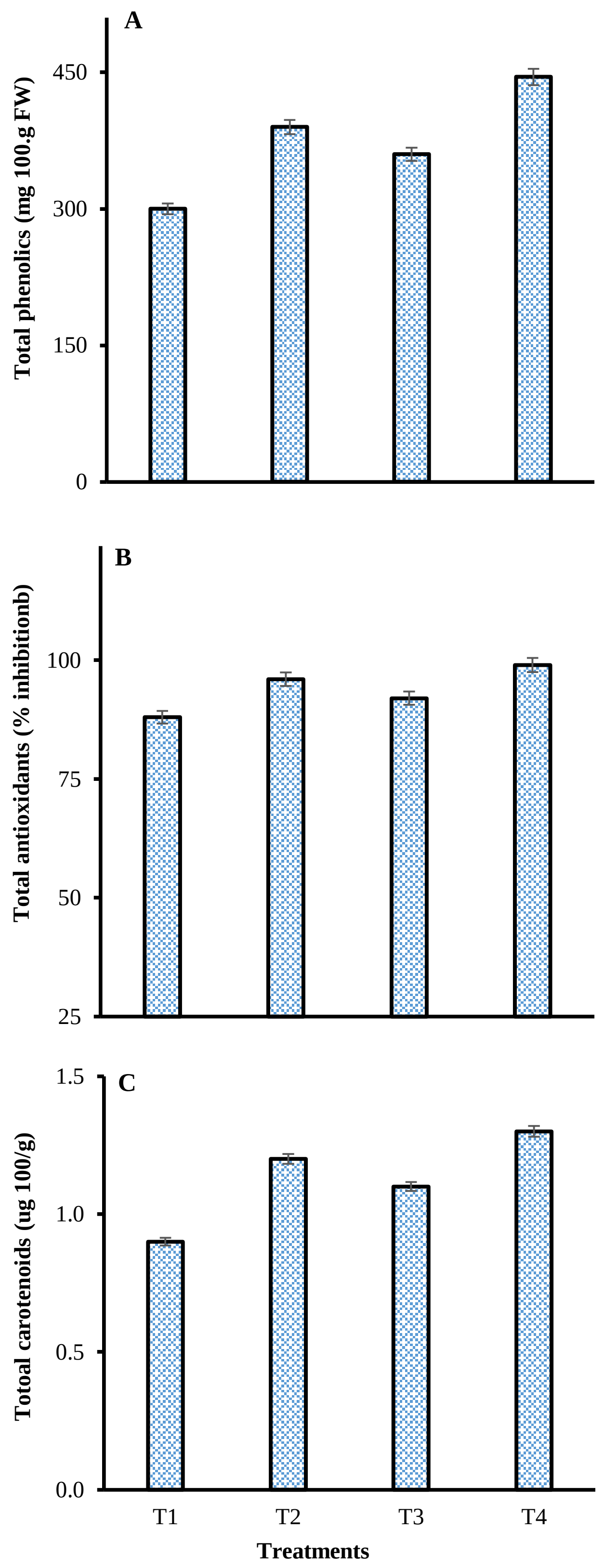

Fig. 3. Effect of macro and micronutrients on total phenolics (a), total antioxidants (b) and total carotenoids (c) of 'Pineapple' sweet orange leaves. Vertical bars represent ± SE of means. T1 = Control, T2 = 2500 g NPK (two splits) before flowering, T3 = Boric acid (0.3%) + zinc sulphate (0.6%) spray at the fruit setting stage, T4 = 2500 g NPK (two splits) + boric acid (0.3%) + inc sulphate (0.6%) (before flowering + at fruit setting stage). n = 4 replication.

Table 3. Effect of macro and micronutrients application on physical quality of 'Pineapple' sweet orange fruit.

Treatments	Fruit length (mm)	Fruit width (mm)	Fruit wt. (g)	Juice wt. (g)	Juice wt. (%)	Rag wt. (g)	Rag wt. (%)	Peel wt. (g)	Peel wt. (%)	Peel: pulp (Ratio)	Peel thickness (mm)	Total seeds (No.)	Healthy seeds (No.)	Abort seeds (No.)	Seed wt. (g)
T1	61.5b	63.2b	178.5b	54.5c	30.5b	48.2c	26.9c	59.6c	33.3a	1.23a	3.4b	6.0	3.3b	2.8a	0.66
T2	65.5ab	68.9a	205.7a	63.4a	30.7ab	62.3a	30.2a	65.3b	31.6b	1.04c	3.5b	6.5	4.8ab	1.8b	0.68
T3	65.4ab	68.7a	199a	58.6b	29.4c	53.8b	27.0c	62.9bc	31.6b	1.2b	3.7ab	7.0	5.5a	1.5b	0.67
T4	69.3a	70.1a	211a	66.5a	31.47a	61.5a	29.1b	70.6a	33.4a	1.2b	3.9a	7.3	6.0a	1.3b	0.71
LSD $p \leq 0.05$	4.46	3.81	12.11	3.81	0.93	2.79	0.52	4.61	1.16	0.04	0.31	NS	1.53	0.93	NS

NS = Non-significant, n = 4 replications. T1 = Control, T2 = 2500 g NPK (two splits) before flowering, T3 = Boric acid (0.3%) + zinc s ulphate (0.6%) spray at the fruit setting stage, T4 = 2500 g NPK (two splits) + boric acid (0.3%) + zinc sulphate (0.6%) (before flowering + at fruit setting stages). Wt. = Weight

Table 4. Effect of macro and micronutrients application on physico-chemical quality of 'Pineapple' sweet orange fruit.

Treatments	TSS (°Brix)	TA (%)	TSS/TA (Ratio)	Ascorbic acid (mg $100g^{-1}$)	pH	Reducing sugars (%)	Total sugars (%)	Non-reducing sugars (%)
T1	8.05 b	0.61 a	13.05 c	26.3 c	4.02	2.37 b	6.46 ab	3.71
T2	8.45 a	0.57 bc	14.7 ab	28.92 b	4.11	2.55 ab	6.39 ab	3.76
T3	8.5 a	0.59 ab	14.36 bc	30.31 ab	4.08	2.42 b	6.34 b	3.76
T4	8.62 a	0.54 c	15.87 a	31.62 a	4.05	2.75 a	6.71 a	3.77
LSD ($p \leq 0.05$)	0.31	0.04	1.42	1.95	NS	0.24	0.32	NS

NS = Non-significant, n = 4 replications. T1 = Control, T2 = 2500 g NPK (two splits) before flowering, T3 = Boric acid (0.3%) + Zinc s ulphate (0.6%) spray at the fruit setting stage, T4 = 2500 g NPK (two splits) + Boric acid (0.3%) + Zinc sulphate (0.6%) (before flowering + at fruit setting stages)

Fruit physical quality: Most of the fruit physical quality attributes including fruit length, fruit width, fruit weight, juice weight, rag weight, peel weight, peel thickness and healthy seeds of 'Pineapple' sweet orange was significantly influenced by T_4 (2500 g NPK in two splits + 0.3% boric acid + 0.6% zinc sulphate), as compare to control. While fruit peel to pulp ratio and number of aborted seeds was more in untreated fruits (Table 3). The improvement in length of fruit may be due to key role of potassium in enlargement of cell. Similar type of results was achieved by Sarrwy (2012) who found increment in fruit length of 'Balady' mandarin through combine application of K and Zn. Results also support Tariq *et al*., (2007) who mentioned that size of sweet orange fruit increased with application of B and Zn. B and Zn is involved in maintenance of protein synthesis, photosynthesis and sugar transport. Our results were also confirm the earlier findings of Batu *et al*., (1984) who indicates that diameter of fruit can be increased through B and Zn application. Increase in fruit weight is ascribed to the influence of macro and micronutrient on fruit cell division and enlargement (Mishra *et al*., 2003; Ashraf *et al*., 2010). Nutrients also play an important role in healthy seeds production. Similarly, earlier Saleem *et al*., (2008) also reported that overall seed health of sweet orange fruit was improved application of supplemental N. N tends to increase the rag weight of 'Kinnow' mandarin. It may be due to the fact that N enhances the metabolic efficiency *i.e.* growth of plants; and ultimately improves the overall weight of fruit (Garhwal *et al*., 2014). Percentage of juice is linked with size of fruit which can be achieved by balanced nutrition. Earlier Mostafa and Saleh (2006) who indicated that higher weight of juice was attained through N along with P and K_2O in 'Kinnow' mandarin. Moreover, 75 kg of K_2O in combination with N and P per ha in return improves juice percentage significantly (Ashraf *et al*., 2012). Inadequate nutrient management results in production of thin peeled fruit. N and K is involved in cell division and growth; hence, improves peel thickness of citrus (Omaima & El-Metwally, 2007).

Fruit biochemical quality: Highest juice TSS (8.62 °Brix), TSS/TA (15.87), ascorbic acid (31.62 mg $100g^{-1}$ FW), reducing sugars (2.75%) and total sugars (6.71%), total phenolics (423.90 mg $100g^{-1}$ FW), total antioxidants (92.65% inhibition), and total carotenoids (1.20 μg $100g^{-1}$) were found in fruits of trees treated with combine application of 2500 g NPK (two splits) and micronutrients (0.3% boric acid + 0.6% zinc sulphate); while, highest juice TA (0.61%) was found in fruits of untreated trees (Table 4 and Fig. 3). Whereas pH and non-reducing sugars contents of fruit juice did not exhibit any significant change after application of macro and micronutrients. This increase in TSS of 'Pineapple' fruit juice might be due to the effect of mineral elements such as P, K and Zn on various enzymatic activities that are responsible for protein, sugar and acids metabolism (Srivastava & Gupta, 1996). Similarly, Dawood *et al*., (2001) also observed that foliar spray of Zn enhanced the SSC significantly in 'Balady' mandarin. Total soluble sugar (TSS) content was recorded highest and superior than untreated control treatment in the mandarin trees supplied with NPK (300:125:200) compound fertilizer (Nasreen *et al*., 2013). Similarly, earlier it has been observed that 'Kinnow' mandarin trees treated with 125 kg P and K produced fruit with maximum TSS (Ashraf *et al*., 2010). Moreover, Ashraf *et al*., (2010) also observed that K foliar spray in combination with Zn enhanced TSS of 'Kinnow' mandarin. Application of P and K to citrus trees help to keep the endogenous level of these minerals under optimum limits which consequently maintains TA of fruit. help to increase (Alva *et al*., 2006; Quaggio *et al*., 2006). Our results also confirm the findings of Mann *et al*., (1985) who found that micronutrients application enhance ascorbic acid contents of citrus. Earlier, exogenous foliar application of of B to 'Kinnow' mandarin tree significantly enhanced the total phenolics and total antioxidants levels of their fruit after harvest (Ullah *et al.,* 2012). Similalry, sufficient amount of N in combination of K has been found to improve the carotenoids contents in citrus fruit (Ashraf *et al.,* 2010).

Table 1. Effect of macro and micronutrients application on vegetative growth of 'Pineapple' sweet orange.

Treatments	Flush length (cm)	Leaves per flush	Leaf length (cm)	Leaf width (cm)	Leaf size (cm^2)
T1	9.8 c	7.25 c	5.7 c	2.52 c	8.32 b
T2	13 ab	9.25 bc	6.4 b	2.83 b	9.32 ab
T3	11 bc	10 ab	6.5 ab	2.82 b	9.3 ab
T4	13.35 a	12 a	6.95 a	3.03 a	10 a
LSD ($P \leq 0.05$)	2.15	2.18	0.53	0.09	1.02

n = 4 replications. T1 = Control, T2 = 2500 g NPK (two splits) before flowering, T3 = Boric acid (0.3%) + Zinc sulphate (0.6%) spray at the fruit setting stage, T4 = 2500 g NPK (two splits) + Boric acid (0.3%) + Zinc sulphate (0.6%) (Before flowering + at fruit setting stages)

Table 2. Effect of macro and micronutrients application on reproductive growth of 'Pineapple' sweet orange.

Treatments	Fruit set (%)	Fruit drop (%)	No. of fruits per tree	Yield/ tree (kg)	Marketable fruits (%)	Unmarketable fruits (%)
T1	83.25 b	84 a	80.5 d	14.34 d	85.92 b	14.07 a
T2	88.67 a	72.32 b	100.5 b	20.72 b	88.57 a	11.42 b
T3	85.75 ab	70.05 bc	88.75 c	17.69 c	87.32 ab	12.67 ab
T4	87.95 a	67.62 c	110.75 a	23.35 a	89.72 a	10.27 b
LSD ($p \leq 0.05$)	3.26	2.85	7.58	2.35	2.49	2.49

n = 4 replications. T1 = Control, T2 = 2500 g NPK (two splits) before flowering, T3 = Boric acid (0.3%) + Zinc sulphate (0.6%) spray at the fruit setting stage, T4 = 2500 g NPK (two splits) + Boric acid (0.3%) + Zinc sulphate (0.6%) (Before flowering + at fruit setting stages)

Conclusion

From the studies presented above, it can be concluded that application of 2500g NPK (17:17:17) compound fertilizer (in two splits) along with 0.3% boric acid and 0.6% zinc sulphate per plant can be used effectively to improve status of leaf mineral nutrients, vegetative growth, reproductive growth and quality of 'Pineapple' sweet orange fruit.

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