Effect of micronutrients foliar supplementation on the production and eminence of plum (*Prunus domestica* L.)

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ORIGINAL ARTICLE

Abstract

Poor soil fertility due to continuous depletion of micronutrients is a major problem for the production of *Prunus domestica* L. Low level of soil organic matter and calcareous parent material decrease the bioavailability of these micronutrients to plum plants. Thus, less micronutrients uptake resulted in deterioration of plum fruit quality and decreased yield. On the other hand, balance and correct combination of micronutrients used as a foliar has potential to overcome this problem. Foliar application method provides plants a chance for rapid and easy uptake of micronutrients. Therefore, the present research was carried out to select the best combination of micronutrients using foliar method. Aim of the study was to select a balanced combination of micronutrients for better production and improved quality of plum (*Prunus domestica* L., variety *Fazal manai*) fruit. Seven treatments in three replications were applied. Our results showed that the quality of fruit was significantly improved through the application of T6 micronutrients consortia. A significant increase in total soluble solids (16%), fruit yield per tree (92%) and fruit size (12%) validated the effectiveness of treatment T6 (Zn + Cu + Fe + Mn + B = 0.5% + 0.2% + 0.5% + 0.5% + 0.1%) over control. Application of treatment T6 also enhanced quality attributes, that is, juice acidity (22%), juice sugar (22%) and juice contents (16%), as compared to control. It is concluded that use of treatment T6 as a foliar application is a better approach for significant improvement in quality and yield attributes of plum in micronutrients deficient conditions.

Keywords: consortia, foliar application, zinc, iron, boron, copper, plum, quality attributes, yield

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Introduction

Plum (*Prunus domestica* L.) is a nutritious fruit, rich in vitamins and minerals. It has great economic importance and is widely grown for profit (Gregory, 1993 and Misra *et al.* 1986). Orchards of plum are cultivated in different areas of Khyber Pakhtunkhwa based on climatic conditions and variables, that is, quality of water, chill units and value of the market. However, nutritional surveys of plum orchards in Khyber Pakhtunkhwa region indicated a severe deficiency of micronutrients (Muhammad *et al.* 1995; Tariq *et al*. 2008 and Bacha *et al.* 1997).

Deficiency of micronutrients affects the production as well as quality of fruit. The soil of Peshawar, a subdivision in Khyber Pakhtunkhwa province of Pakistan, is rich in organic matter, which is a very important factor for better availability of macro and micronutrients to plants (El-Sheikha, 2016 and Burki, 2000). However, calcareous parent material causes unavailability of micronutrients to plants. So plum orchards in Peshawar produce poor quality fruit with lower yield (Zekri and Obreza, 2003). The nutritional survey report (2016–2017) and Balakrishnan *et al*. (2000) stated that micronutrient deficiency in Peshawar soil and lack of use of micronutrient fertiliser by local farmers were causing a severe nutritional deficiency in plum fruit. Furthermore, symptoms of nutritional deficiency in plants are an indication of the prevalence of micronutrient deficiency (Belkhodja *et al.* 1998; Tiwari *et al.* 2000 and Khattak and Hussain, 2007). Plum orchards with sufficient micronutrients in soil still show young yellowish leaves, indicating that the transfer of nutrients does not meet demands of the plant. Plant nutrient uptake is a serious concern in Khyber Pakhtunkhwa province of Pakistan. Peach, apricot and plum are commonly affected plants with iron (Fe) deficiency (Tariq and Rafiullah 2008–09 and Rehman, 1990). Formation of gum pockets is another common problem in plum, which is due to the deficiency of boron (B) (Shorrocks, 1984, Boaretto *et al.* 2008 and Saraswathi *et al.* 1998).

Foliar application of micronutrients could be a better alternative to soil application, since the application of these nutrients to soil may be beyond reach to the deep root system of orchards trees (Ziogas *et al*. 2020, Bibi *et al.* 2019, Ahmad *et al.* 2018 and Hipps and Davies, 2001). Additionally, the foliar application is more valuable because of quick reaction, recovery of nutrient deficiency (Muradi and Godara, 2020 and Samant *et al.* 2008) and its effectiveness because of boron, manganese (Mn), copper (Cu), Fe and zinc (Zn). However, some indigenous studies have suggested the recommended dose and time of foliar application of micronutrients. Saini *et al*. (2019), Zia *et al.* (2006) and Stampar *et al.* (2006) have observed positive effects of foliar application of micronutrients just before flowering and preferably after fruit harvest. Foliar application before flowering is best because application of micronutrients enhances flower formation, fruit set, promotes ripening of fruit and improves fruit quality (Dhillon and Bindra, 1995; Farid *et al*. 2007 and Sharma *et al.* 1999). In addition, it also increases fruit firmness and shelf life (Deepa *et al*. 2008 and Samar *et al.* 2007).

So far, scientists have documented a large number of works regarding the use of combination of macro- and micronutrients in different fruits. Limited updated literature is available on improvement in yield and quality attributes (total soluble solids [TSS], fruit juice acidity and sugar contents) of plum plants by using micronutrients consortia in calcareous soils. Novelty of the present study is the selection of best micronutrients combination as consortia to fulfill the micronutrients' requirement of plum fruit cultivated in calcareous soils. We hypothesised that foliar application of micronutrients consortia could be beneficial to plum plant especially grown in calcareous soil. In the light of our nutritional survey done on the predominant value of micronutrients in plum trees of Peshawar locality, current study would help in the management of micronutrients of plum orchards in calcareous soils.

Methodology

Experimental design

The research was carried out on 14 years old plum (*Fazal manani* variety) plants orchard at *Tarnab* Peshawar. For this study, statistical design, randomised complete block (RCBD) with three replications, was used.

Soil characterisation

Soil samples were collected from the plum orchard, air-dried, grinded and then sieved with 2-mm mesh sieve. The important physico-chemical characteristics of the soil determined includes texture (Gee and Budr, 1982), lime (Cottenie, 1980), pH (McLean, 1982), electrical conductivity (EC) (Rhoades, 1982) and organic matter (Nelson and Sommers, 1982). Characterisation of plum orchard's soil (Table 1) showed that textural class of soil was silty clay loam, alkaline in reaction, non-saline and slightly calcareous in nature. The organic matter was found to be medium. Hot water-soluble boron (Sillanpaa, 1982) was assessed by spectrophotometer, while AB-DTPA soil extractable of Cu, Mn, Zn and Fe (Soltanpour, 1985) was analysed by atomic absorption spectrophotometer. Pre-experiment characterisation revealed that the concentration of B, Zn and Fe was highly deficient in the soil of research field (Table 1).

Table 1. Physical and chemical properties of the research field.

Properties	Units	Values
Sand	%	20.0
Silt	%	52.0
Clay	%	28.0
Textural class	–	Silty clay loam
$pH_{(1:5)}$	–	7.95
$E.C._{(1:5)}$	dS m^{-1}	0.32
Organic matter	%	1.07
Lime	%	11.4
AB-DTPA Zn	ppm	0.49
AB-DTPA Cu	ppm	1.71
AB-DTPA Fe	ppm	0.37
AB-DTPA Mn_e	ppm	2.59
Hot water-soluble B	ppm	0.48

Treatment plan

The following six treatments were applied in three replications: T1 = control (without foliar spray); T2 = Zn (0.5%) applied as $ZnSO_4$; T3 = Zn + Cu (0.5% + 0.25%) applied as $ZnSO_4$ and $CuSO_4$; T4 = Zn + Cu + Fe (0.5% + 0.25% + 0.5%) applied as $ZnSO_4$ + $CuSO_4$ + $FeSO_4$; T5 = Zn + Cu + Fe + Mn (0.5% + 0.25% + 0.5% + 0.5%) applied as $ZnSO_4$ + $CuSO_4$ + $FeSO_4$ + $MnSO_4$, and T6 = Zn + Cu + Fe + Mn + B (0.5% + 0.2% + 0.5% + 0.5% + 0.1%) applied as $ZnSO_4$ + $CuSO_4$ + $FeSO_4$ + $MnSO_4$ + $Na_2B_4O_7.10H_2O$.

Fertiliser application

Nitrogen (N), phosphorus (P) and potash (K), 150, 100 and 100 kg ha^{-1}, respectively, were applied under the canopy of each tree. The reserved area was 65 cm around each tree where basal dose was applied and irrigated. The nutrients were applied twice within 20 days interval, as the leaves and fruit developed at the start of spring season. Application of primary micronutrients was done to all experimental trees at recommended basal doses. Foliar sprays were applied twice during the growth season. Foliar sprays were applied in March–April 2017.

Solution preparation of foliar supplementation

For this research work, solution of foliar supplementation was prepared from the commercial micronutrients available in the market. These micronutrients were applied by using their chemical formulas. To supplement micronutrients as a foliar application, first the canopy of each tree was completely witted with water assuming the total volume on whole tree.

Analysis of fruit quality attributes

In this research work, different chemical properties were checked according to the method described by the Association of Official Analytical Chemists (AOAC; 1990); these were sugars (reducing, non-reducing), pH of fruit juice, acidity and TSS. Before and after inversion with invertase, polarimetric method was used to determine the sugars in plum fruit, pH meter was used for the pH of fruit juice, volume of juice were calculated by a cylinder, TSS of fruit was calculated by refractometer, and acidity by titration of a 25-mL aliquot of juice using 0.25 N NaOH to an end point of pH by an autotitrator. While fruit size was calculated using vernier caliper, volume of the plum fruit was calculated using eight plum fruit selected randomly by water displacement method (Maurer and Taylor, 1999, Wer and LiuWengeng 1998 and Sing *et al.* (2005).

Statistical analyses

The overall data of this experiment were analysed statistically using analysis of variance (ANOVA). Difference between the treatments were evaluated at $p \leq 0.05$ by Fisher's least significant difference (LSD) test of significance (Steel *et al.* 1997) using Origin software (OriginPro version 2020b, Origin Lab Cooperation, Northampton, MA, USA) and SPSS (version 20).

Results and Discussion

Fruit number

Application of treatments significantly affects the number of fruit per plant (NFPT) (Figure 1A). Treatment T6 differed significantly from control for NFPT in *Prunus domestica* L fruit. No significant change in NFPT was noted where treatments T2, T3, T4 and T5 were applied over control (Figure 1B). Pearson's correlation showed that a significant positive correlation existed between NFPT, yield of fruit per tree (YFPT) and juice contents (JC) (Figure 8). Maximum increase of 40.94% in NFPT was noted in T6 treatment over control. These results are in line with the earlier works of Arvind and Ganesh (1996) and Sharma *et al*. (1991).

Fruit size

Effect of treatments was significant on fruit size (FS). Results showed that application of T6 treatment was significant as compared to control for improving fruit size (Figure 2A). No significant change in fruit size was noted where treatments T2, T3, T4 and T5 were applied over

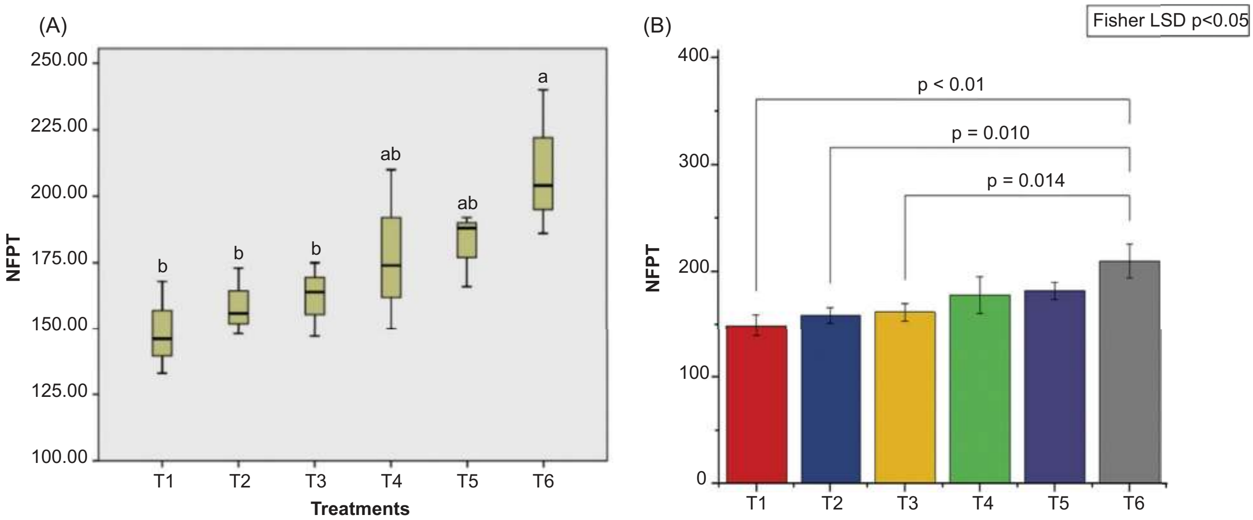

Figure 1. Effect of treatments on number of fruit per plant (NFPT) of *Prunus domestica* L. Different letters show significant difference compared with Fisher's LSD, p ≤ 0.05.

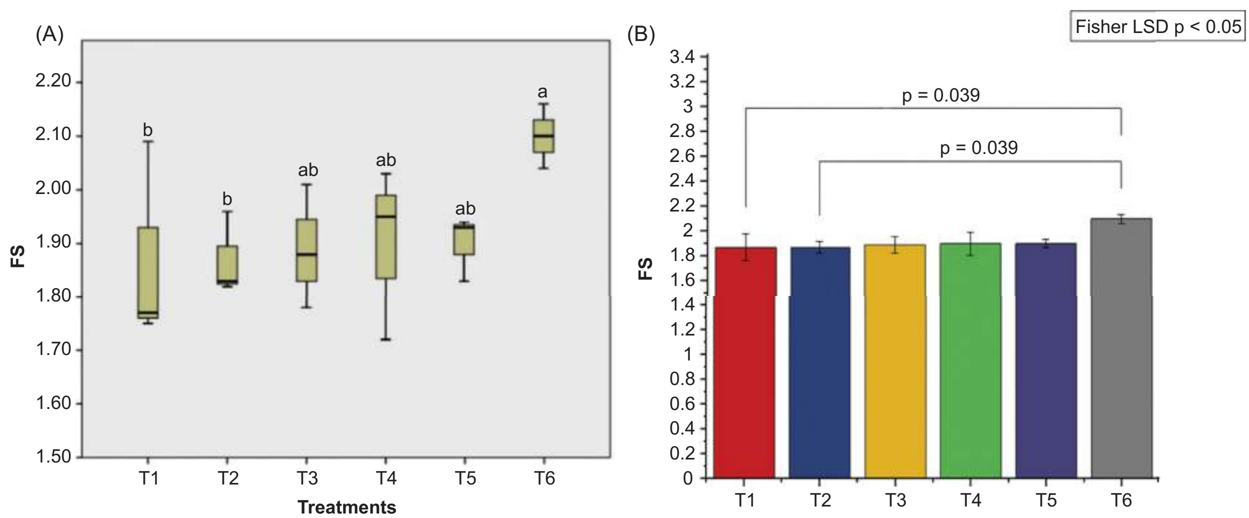

Figure 2. Effect of treatments on fruit size (cm) of *Prunus domestica* L. Different letters show significant difference compared with Fisher's LSD, p ≤ 0.05. FS, Fruit size.

control (Figure 2B). Pearson's correlation showed that a significant positive correlation existed between FS, juice sugar contents (JSu) and JC (Figure 8). Maximum increase of 12.30% in fruit size was noted in T6 treatment as compared to control. The results were in line with that of Arvind and Ganesh (1996). Moreover, results also indicated that probably boron was transferred to fruit, thereby correcting the deficiency symptoms, as fruit size increased in leaves that had received boron as a foliar supplementation. Similarly, Shorrocks (1984) found in his research work that deficiency of boron was suspected based on leaf symptoms and should be confirmed by fruit symptoms.

Fruit yield per tree

Application of treatments significantly affects the fruit yield per tree. Treatments T5 and T6 remained significant over control (Figure 3A) for improving YFPT in *Prunus domestica* L. No significant change in YFPT was noted where treatments T2, T3 and T4 were applied over control (Figure 3B). Pearson's correlation showed that a significant positive correlation existed between YFPT, JSu and JC (Figure 8). Maximum increase of 92.22% in YFPT was noted in T6 treatment over control. The combination of boron in spray mixture increases significantly the production of plum, as the number and size of fruit also

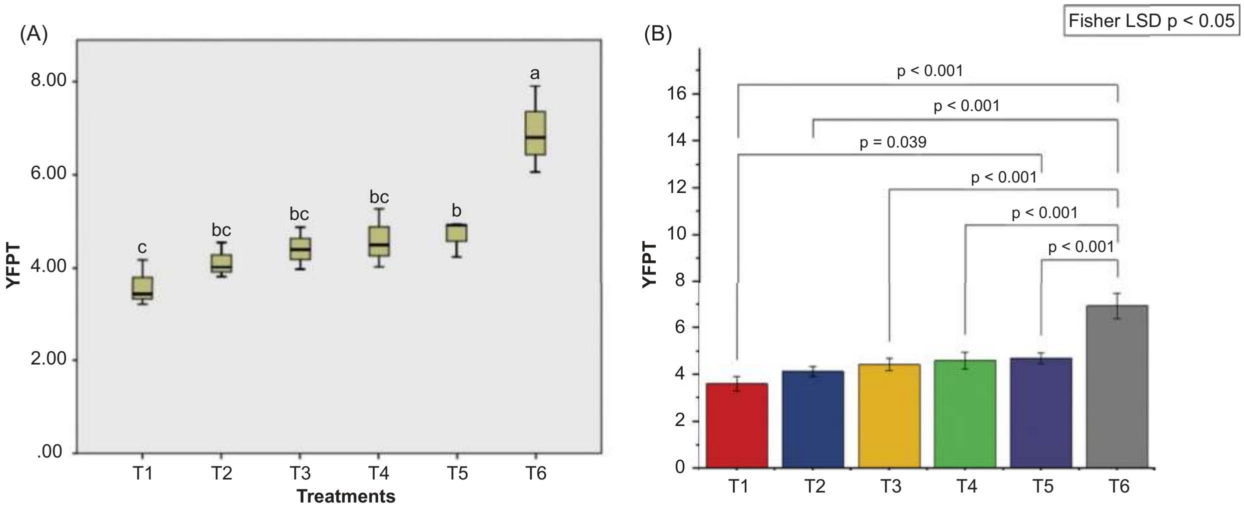

Figure 3. Effect of treatments on fruit yield (kg plant^{-1}) of *Prunus domestica* L. Different letters show significant difference compared with Fisher's LSD, p ≤ 0.05.

increased significantly with such a combination, which results in more production. Similar results were found by Dhillon and Bindra (1995), Upreti et al (1996) and Bose *et al.* (1994). As was found by Garcia *et al.* (1984) that fruit let drop decreases with increased concentration of Mn and Zn in plant leaves, while a significant increase in formation of flowers increases fruit numbers, fruit weight and size of fruit only because of the foliar supplementation of boron content (Farid *et al*. 2007). However, the lower yield of plum fruit not only depends on nutritional requirements but also on many other factors. In general, yield of plum fruit was very low in the experimental year of 2009 throughout the Peshawar valley. Probably the chilling requirements of plum orchards were not fulfilled in this year (personnel communications with plum growers), resulting in lower or no yield in the Peshawar valley.

Total soluble solid

Application of treatments significantly affects TSS. Treatment T4 differed significantly from control for TSS in *Prunus domestica* L. fruit (Figure 4A). No significant change in TSS was noted where treatments T2, T3, T5 and T6 were applied over control (Figure 4B). Pearson's correlation showed that no significant correlation existed between TSS and any other attribute (Figure 8). Maximum increase of 15.74% in fruit size was noted in T4 treatment over control. The results are in line with that of Dhillon and Bindra (1995) and Arora *et al.* (1992). Micronutrients increase the TSS of plum fruit, beside it also depends on the agronomic practices of plum orchards. As McGlasson *et al.* (2004) have reported that the highest TSS levels were achieved in stone fruit

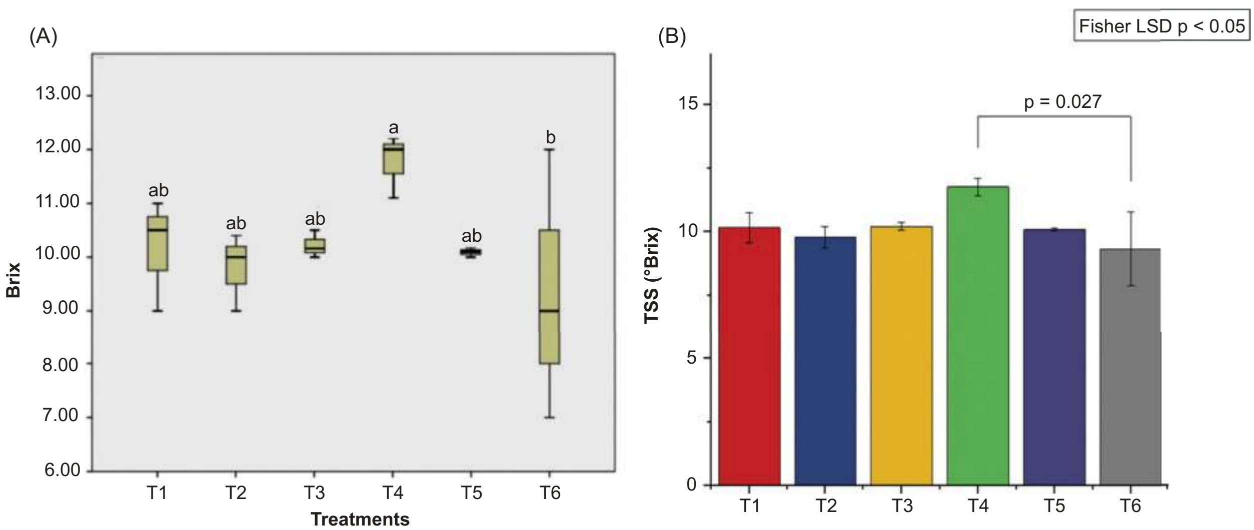

Figure 4. Effect of treatments on total soluble solids (Brix) of *Prunus domestica* L. Different letters show significant difference compared with Fisher's LSD, p ≤ 0.05.

by leaving these to ripen and completing its shelf life on trees. Similarly, water requirement and its irrigation scheduling (Boland *et al.* 1993), distribution of light in the canopy of trees (Day, 1997; George *et al.* 1994) and all other processes change the level of sugar and TSS of plum fruit.

Juice acidity

Application of treatments significantly affects juice acidity (JA). Treatments T6 and T5 differed significantly from control for JA in *Prunus domestica* L. fruit (Figure 5A). No significant change in JA was noted where treatments T2, T3 and T4 were applied over control for JA (Figure 5B). Maximum increase of 21.74% in JA was noted in treatments T6 and T5 over control for JA. Ram and Bose (2000), Abadia *et al*. (2000) and Tariq *et al*. (2007) have described non-significant differences in the acidity of mandarin juice and sweet orange juice, respectively, with the foliar sprays of micronutrients. This is not a good evidence that the acidity of plum fruit was increased. The results are contrary to those reported in literature for various plum cultivars (Družić *et al*. 2007 and Saatci and Mur (2000); perhaps this was due to improper maturity of fruit at harvest, or may be the test plum variety genetically contains high percentage of acidity.

Juice sugar

Application of treatments significantly affects the juice sugar contents (JSu) of fruit. Treatment T6 differed significantly from control for JSu in *Prunus domestica* L. fruit (Figure 6A). No significant change in JSu was noted where treatments T2, T3, T4 and T5 were applied over control (Figure 6B). Maximum increase of 21.60% in JSu was noted in T6 treatment over control. These results are consistent with the research experiment of Arvind and Ganesh (1996), who reported that percentage sugar was significantly increased due to applied boron as a foliar spray.

Juice content

Application of treatments significantly affects juice contents (JC). Treatment T6 differed significantly from control for JC in *Prunus domestica* L. fruit (Figure 7A). No significant change in JC was noted where treatments T2, T3, T4 and T5 were applied over control (Figure 7B). Maximum increase of 15.61% in JC was noted in T6 treatment over control. Similarly, its concentration increased due to the addition of boron with other micronutrients, also reported by Ram and Bose (2000) and Awasthi and Upadhayay (1996). The overall results indicated that the foliar supplementation of micronutrients have inconstant effects on the percentage of juice in plum fruit. The TSS, fruit acidity, juice pH and non-reducing sugar level were found non-significant by the foliar supplementation of micronutrients. The same trend was found by Mann *et al.* (1985), who reported that citrus fruit quality was found non-significant by foliar supplementation of micronutrients. While other parameters, like percentage of juice and reducing sugar, were significantly affected by foliar supplementation of micronutrients, these results demonstrated that the entire nutrient had a different role on the quality of plum fruit under experimental conditions .

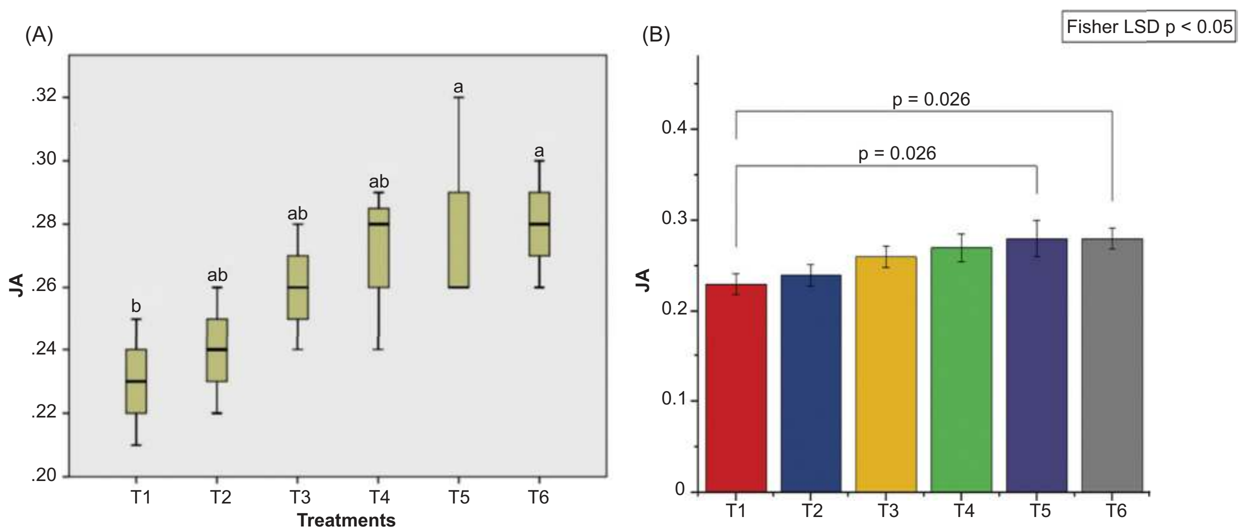

Figure 5. Effect of treatments on juice acidity (JA) of *Prunus domestica* L. Different letters show significant difference compared with Fisher's LSD, p ≤ 0.05.

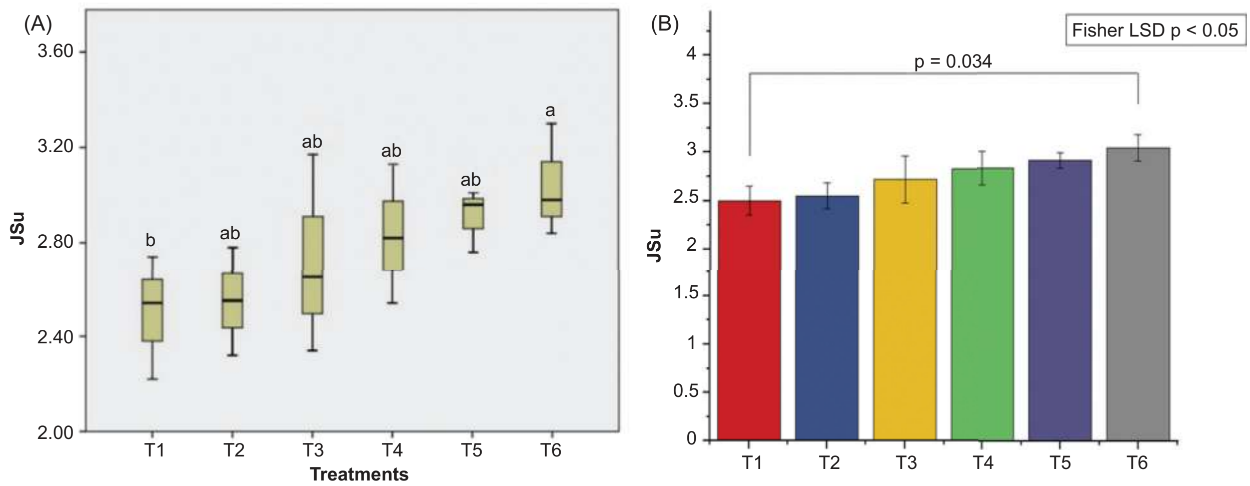

Figure 6. Effect of treatments on juice sugar content (JSu) of *Prunus domestica* L. Different letters show significant difference compared with Fisher's LSD, $p \leq 0.05$.

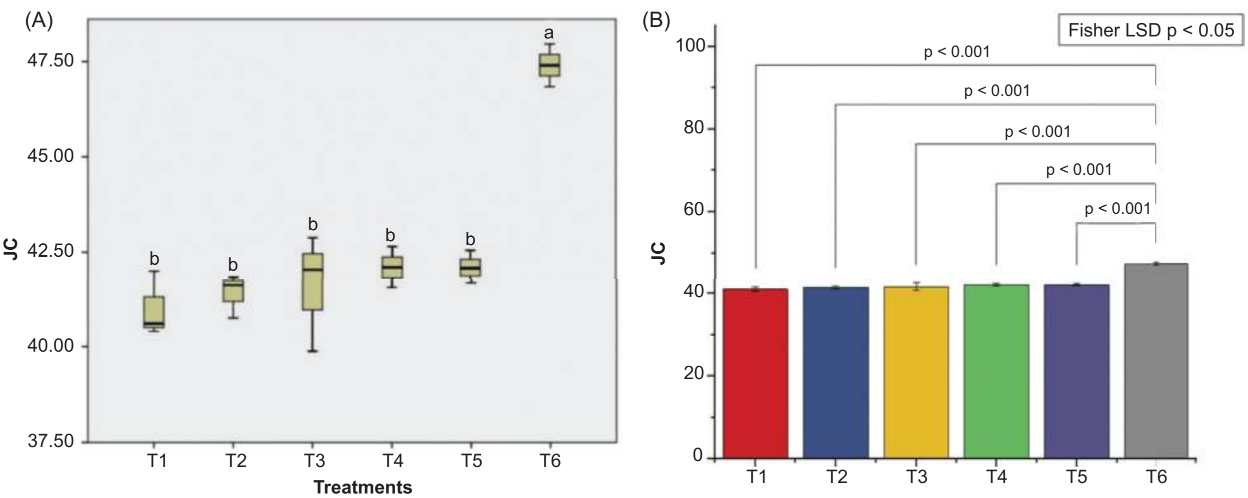

Figure 7. Effect of treatments on juice content (%) of *Prunus domestica* L. Different letters show significant difference compared with Fisher's LSD, $p \leq 0.05$. JC, juice content.

Conclusion

In conclusion, application of treatment T6 (Zn 0.5% + Cu 0.2% + Fe 0.5% + Mn 0.5% + B 0.1%) has potential to improve yield attributes of plum, that is, fruit production, and number, size and volume of fruit, especially in calcareous soils. Foliar application of micronutrients consortia (Zn 0.5% + Cu 0.2% + Fe 0.5% + Mn 0.5% + B 0.1%) is an efficacious method to improve the quality indices of plum fruit in calcareous soils. However, more investigations are suggested at field levels to investigate more efficacious and balance use of micronutrients consortia for improving quality and yield attributes in plum fruit.

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