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Effect of foliar application of boric acid on fruit quality and yield traits of mango

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Abstract: Imbalance uptake of boron disturbs the process of pollination that eventually decrease the flowering, fruit setting and yield. Its deficiency also deteriorates the quality of fruit by increasing fruit acidity. Therefore, source, balanced application, method of application and optimum uptake of B is an important aspect and need keen scientific attention. So, a field study was conducted with the hypothesis that foliar application of B would be an effective technique to improve the yield and quality of Mango cv. Summer Bahisht (SB) Chaunsa. The source of B was boric acid (BA) applied twice as foliar spray i.e., 0, 0.1, 0.2 and 0.3%. Results confirmed that as compared to control, a significant improvement in fruit weight at ripening and harvesting stages (36.9%), fruit length (21.9%), fruit width (10.1%), flower (22.1%) and fruit terminals m^{-2} (40.0%) confirmed the effectiveness of T_4 (BA= 0.3%). A significant improvement in average yield (78.6%) validated the efficacious functioning of boric acid (0.3%). In conclusion, boric acid is an important and effective source of B to improve the quality and yield of Mango cv. SB Chaunsa. Similarly, BA (0.3%) is a better option than 0.2 and 0.1% BA to improve the quality and yield of mango.

1. Introduction

Mango (*Mangifera indica* L.) belongs to the genus *Mangifera* and family *Anacardiaceae* which has 74 genera and 600 species (Mitchell and Mori, 1987; Tian *et al.,* 2010). It is known as 'King of Fruits' due to its sweetness, fragrance and nutritional status (Sharma and Singh, 2009). Mango is becoming popular in the western countries and it is originated from Indian sub-continent (Yadav and Singh, 2017). However, in recent years, the productivity of Mango has been reduced due to deficiency of micronutrients especially boron (B) and other environmental stresses (Saran and Kumar, 2011; Adak *et al.,* 2017; Ahmad *et al.,* 2018).

Boron deficiency is quite common after zinc micronutrient especially in arid and semi-arid regions (Zhang *et al.,* 2015). The deficiency of B is ubiquitous in acidic sandy, alkaline soils and sandy soils (Camacho-Cristóbal *et al.,* 2018). Boron deficiency is one of the key factors for a reduction in the yield of fruit crops (Davarpanah *et al.,* 2016; Karlidag *et al.,* 2017). Its deficiency symptoms show their effect on younger plant parts, while toxic effects are on older parts of plants (Fernández-Escobar *et al.,* 2016). The deficiency of B in mango plant results in deformed leaves hooked and pre-matured dieback of inflorescence, loss of apical dominance, death of apical bud, swelling at internode and retorted growth (Litz, 2009).

Contemporary agricultural practices include the additional supply of fertilizers that enhanced the growth of plants and resulted in an improvement of yield (Barker and Pilbeam, 2006). Micronutrients especially B plays an indispensable role in the growth and development of fruit trees (Davarpanah *et al.,* 2016). Mango fruit drop before maturity is a common issue in most of the mango growing areas (Murti *et al.,* 2008). On the other hand, the potential of foliar application of B has been well documented as an effective amendment for the improvement in mango fruit formation (Saran and Kumar, 2011). Boron is intrinsic for fruit trees in forming higher germinating pollen and elongated pollen tube which sets fruit (El-Sheikh *et al.,* 2007). It is also indirectly involved in the activation of plant hormones and dehydrogenase enzyme (Marschner, 2012). Boron has low adsorption capacity and leaches at a high rate in soil (Raja *et al.,* 2005).

Foliar application of fertilizers is more convenient and effective as compared to soil application (Fernández *et al.,* 2013). It has been observed that foliar application of fertilizers moreover confers quick response and alleviate the deficiency symptoms leading to fruitful returns (Obreza *et al.,* 2010). Scientists have also documented that foliar application of B at different rates enhance mango fruit setting panicle^{-1}, fruit weight and volume (Zhong and Dong, 2000; Bibi *et al.,* 2019). Therefore, the current study was conducted with the aim to examine the effectiveness of the various application of boric acid as a source of B on growth and yield of mango. It is hypothesized that foliar application of boric acid as a source of B would be an effective technique for improvement in growth and yield of mango.

2. Materials and Methods

Experimental site

The study was planned to evaluate the influence of foliar applied boron on yield and quality of mango cultivar Summer Bahisht Chaunsa during the year 2016-17 at experimental mango orchard near Bahauddin Zakariya University, Multan (Fig. 1). Fifteen to twenty years old mango trees were selected for the experimental purpose. The study was carried out in accordance with RCBD design (Randomized Complete Block Design) with four treatments and four replications.

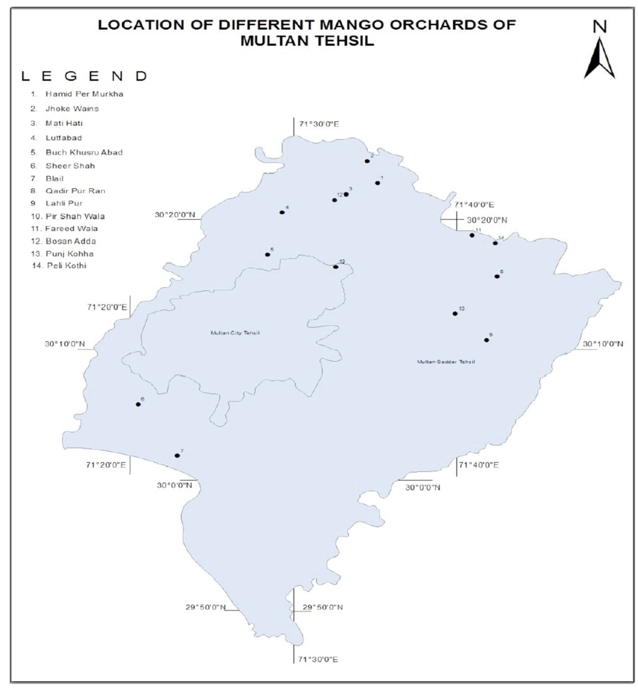

Fig. 1 - GPS locations of area.

Treatment plan

There were four different levels of boric acid (BA) i.e., T_1 (control) = no boric acid, T_2 = 0.1% BA, T_3 = 0.2% BA and T_4 = 0.3% BA which were applied as foliar application. Each tree was taken as one replica of each treatment (consist of four trees). All treatments were applied twice in a year i.e., firstly at inflorescence stage and secondly at the marble stage (pea size of fruit).

Physio-chemical analysis

Soil sampling. The data regarding physio-chemical composition was recorded at harvest stage on ripened fruit. Composite soil samples (0-30 cm) were collected from experimental mango orchard. This depth for soil sampling was selected because the majority of mango feeding roots are present in the depth of 0-30 cm.

Sample preparation. Soil samples were initially air dried, after that grinded and finally sieved through 2 mm sieve in the laboratory of Department of Soil

Science, Faculty of Agricultural Sciences and Technology Bahauddin Zakariya University Multan, Pakistan for determination of different physio-chemical characteristics of the soil.

Soil characterization. For determination of soil texture, hydrometer method was used (Bouyoucos, 1962). Soil pH and electrical conductivity (EC) was assessed by using JENWAY 3510 pH and BANTE DDS-12DW Microprocessor EC meter (Abid *et al.,* 2017). Soil cation exchange capacity (CEC) was calculated according to Richards (1954) and Rhoades (1982). For determination of soil organic matter (SOM) Walkley Black method was followed (Jackson, 1975). Olsen *et al.* (1954) method was adopted for the analysis of soil available P while for soil extractable K Rowell (1994) method was used. Calcium Carbonate (lime) was determined according to Allison *et al.* (1965). All characteristics of the soil are provided in Table 1.

Boron determination in soil and leaves

Leaves samples for B determination were collected twice during 2016-17. Samples were collected prior to foliar application of boric acid and after spraying the mango orchard. Boron (B) concentration from soil was assessed by HCl extraction as described by Ponnamperuma *et al.* (1981), while for leaves samples method of Gaines and Mitchell (1979) was followed.

Growth and yield attributes

Different mango parameters were recorded by selecting 15 panicles and labelled on each tree prior to measurements in an experimental mango garden. Flower terminal m^{-2}, fruit terminal m^{-2}, total number of flowers per panicles was observed with respect to each treatment and average was computed among all the treatments. The total number of flowers from the selected panicles (in case of each tree) was calculated to calculate the average one. Fruit weight (FW) after harvest and ripening was measured by selecting 15 fruits from each treatment.

Yield of fruits

The average yield $tree^{-1}$ was assessed at the time of harvest by weighing out all fruits of tree regarding each treatment and their average was calculated by multiplying average fruit weight with total number of fruits. Fruit weight after harvest was noted soon after harvesting when fruit was not ripen. When the fruit was ripened, again the weight of fruit was noted and referred to as fruit weight after ripening.

Maturity days

Maturity days were recorded by estimation of days from flowering period to harvest stage.

Length and diameter of fruits

Fruit length and diameter were assessed by digital Vernier Caliper after randomly selecting 5 fruits from each treatment.

Total soluble solids

The total soluble solid percentage was calculated by using a digital refractometer as described by AOAC (2005).

Acidity of fruits

The acidity of mango was estimated followed by the method as proposed in Souza et al (2015), one drop (mango juice) was retained on the mirror regarding digital refractometer and reading was observed in case of Brix on the screen.

Sugar contents

Total sugar contents were recorded according to the titrimetric method as described by Raganna (1986). The method proposed by Rusk (1961) was used to estimate the vitamin C content from the juice of mango pulp. Pulp recovery (%) was determined by the following formula

$$\text{Pulp recovery} = (\text{Peel weight} - \text{stone weight} / \text{Fruit weight}) \times 100$$

Statistical Analysis

For statistical analysis standard statistical procedure was adopted (Steel *et al.,* 1997). The significance of treatments was analyzed through analysis of variance (ANOVA). Tukey's test was applied at $p \leq 0.05$ for comparison of treatments by using statistical software "Statistix 8.1".

Table 1 - Pre-experimental characteristics of soil

Textural class	Depth (cm)	pH	ECe (dS m^{-1})	SAR (mmol $L^{-1})^{1/2}$	$CaCO_3$ (%)	Organic matter (%)	Boron concentration in soil (mg kg^{-1})	Boron concentration in leaves (mg kg^{-1})	Phosphorus in soil (mg kg^{-1})	Potassium in soil (mg kg^{-1})
Loam	0-30	8.4	2.04	2.3	6	0.31	0.36	20.49	13	218

3. Results

Fruit weight

Effect of various foliar application rates of boric acid remained significant ($p \leq 0.05$) for fruit weight at ripening and harvesting stages. No significant change in fruit weight was observed at ripening and harvest stages among control T_3 and T_2. However, the application of T_4 was significantly better as compared to control for fruit weight at ripening and harvesting stages (Table 2). The maximum increase of 36.9% in fruit weight was noted where T_4 was applied as compared to control at ripening and harvesting stages.

Fruit length and width

Effect of various foliar application rates of boric acid remained significant ($p \leq 0.05$) for fruit length and width. Application of T_2, T_3 and T_4 were statistically alike to each other but performed significantly better as compared to control for fruit length and width. The maximum increase of 21.9 and 10.1% in fruit length and width was noted respectively where T_4 was applied as compared to control.

Average yield

Effect of various foliar application rates of boric acid remained significant ($p \leq 0.05$) for average yield. Application of T_3 and T_2 did not differ significantly for the average yield of mango fruit as compared to control. However, the application of T_4 was significantly better as compared to control for average yield (Table 2). The maximum increase of 7.86% in average yield was noted where T_4 was applied as compared to control.

Peel and stone weight

Effect of various foliar application rates of boric acid was significant ($p \leq 0.05$) for stone and peel yield. Application of T_3 and T_2 did not differ significantly for stone and peel weight of mango fruit as compared to control. However, the application of T_4 significantly decreased stone and peel yield as compared to control (Table 2). The maximum decrease of 22.2 and 15.0% in peel and stone yield was noted where T_4 was applied as compared to T_3 and T_2 respectively.

Flower and fruit terminal m^{-2}

Effect of various foliar application rates of boric acid was significant ($p \leq 0.05$) for flower and fruit terminals m^{-2}. It was observed that T_4 and T_2 did not differ significantly but differed significantly better as compared to control for flower terminals m^{-2}. Application of T_3 also performed significantly better for flower terminals m^{-2} as compared to control (Table 3). For fruit terminals, m^{-2} T_3 and T_4 were statistically alike to each other but differed significantly as compared to control. Application of T_4 also differed significantly better for fruit terminals m^{-2} as compared to control (Table 3). The maximum increase of 22.1 and 40.0% in flower and fruit terminals m^{-2} was noted respectively where T_4 was applied as compared to control.

Total number of flowers, male and hermaphrodite flower

Effect of various foliar application rates of boric acid was significant ($p \leq 0.05$) for total number of flowers,

Table 2 - Effect of various levels of boric acid on yield attributes of mango

Treatments	Fruit weight after ripening (g)	Fruit weight after harvest (g)	Fruit length (cm)	Fruit width (cm)	Average yield (kg tree^{-1})	Peel weight (g)	Stone weight (g)
T_1 (control)	250.72 b	270.93 b	10.46 b	5.74 b	132.25 b	40.48 ab	51.18 ab
T_2 0.1% boric acid	281.62 b	301.74 ab	11.82 a	6.10 a	135.75 b	47.20 a	58.30 a
T_3 0.2 % boric acid	304.29 ab	334.28 ab	12.01 a	6.11 a	138.43 ab	47.72 a	51.27 ab
T_4 0.3 % boric acid	343.34 a	371.16 a	12.75 a	6.32 a	142.65 a	37.15 b	49.53 c

Mean values followed by the different letter in the same column are statistically different ($p \leq 0.05$).

Table 3 - Effect of various levels of boric acid on flowering related attributes of mango

Treatments	Flower terminal m^{-2}	Fruit terminal m^{-2}	Total number of flowers panicle^{-1}	Male flower (%)	Hermaphrodite flowers (%)	Maturity days
T_1 (control)	21.50 c	7.32 c	895.43 c	548.475 b	346.525 ab	195 b
T_2 0.1% boric acid	25.08 ab	8.75 b	933.54 b	618.45 ab	314.55 b	197 a
T_3 0.2 % boric acid	24.25 b	9.25 a	1017.5 a	633.225 ab	384.275 a	196 b
T_4 0.3 % boric acid	26.25 a	10.25 a	1001.75 a	672.525 a	329.225 b	198 a

Mean values followed by the different letter in the same column are statistically different ($p \leq 0.05$).

male and hermaphrodite flower. Application of T_3 and T_4 did not differ significantly with each other but remained significant for total number of flowers in mango as compared to control (Table 3). However, the application of T_2 also significantly improved total number of flowers in mango as compared to control. In the case of male flowers, only T_4 remained significantly better from control (Table 3). For hermaphrodite flowers, application of T3 remained significantly better as compared to control. The maximum increase of 11.9, 22.6, and 22.2% in total number of flowers, male and hermaphrodite flower was noted where T_4, T_4 and T_3 were applied as compared to control, control and T_2 respectively.

Maturity days

Effect of various foliar application rates of boric acid was significant ($p \leq 0.05$) for fruit maturity days. Application of T_2 and T_4 remained statistically alike to each other but remained significantly better as compared to control for maturity days. No significant change was noted among T_3 and control for maturity days. The maximum increase of 1.51% in maturity days was noted where T4 was applied as compared to control.

Acidity and boron concentration

The foliar application was effective in case of quality traits of mango. It was observed that with the application of boric acid treatments acidity of fruit was decreased. Minimum acidity was noted in T_3 treatment while T_2 and T_4 treated plots exhibited the same response for the acidity of fruit (Fig. 2). The pulp recovery, vitamin C, total soluble solids and total sugar contents tend to increase with an increasing application rate of foliar boric acid (0.3% boric acid) (Fig. 3).

Boron concentration in leaves

Foliar application of B was found effective in term of improvement in leaves B concentration (Fig. 4). Higher application of foliar B 0.3% (T_4) enhanced the B concentration in leaves as compared to T_1. Lowest B concentration was noted in T_1. No significant change was noted among T_4 and T_3 for B concentration in leaves. Similarly, T3 and T2 were statistically alike to each other for B concentration in leaves.

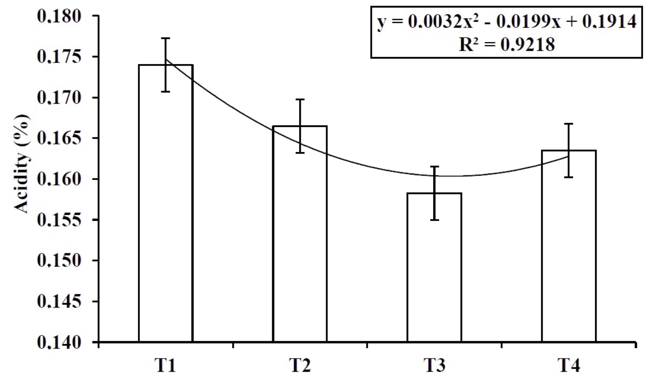

Fig. 2 - Effect various levels of boric acid on acidity of mango fruit.

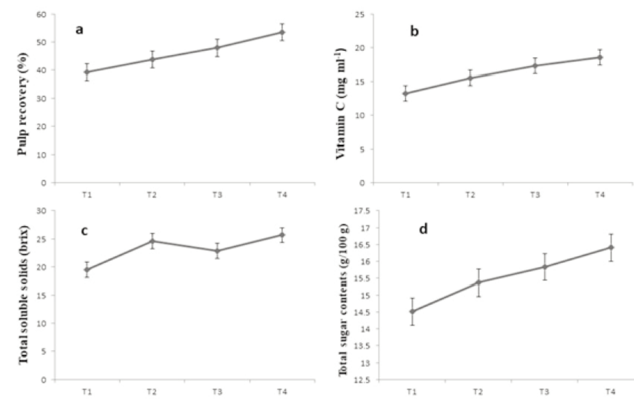

Fig. 3 - Effect of various levels of boric acid on pulp recovery, vitamin C, total soluble solids and total sugar contents in mango fruits

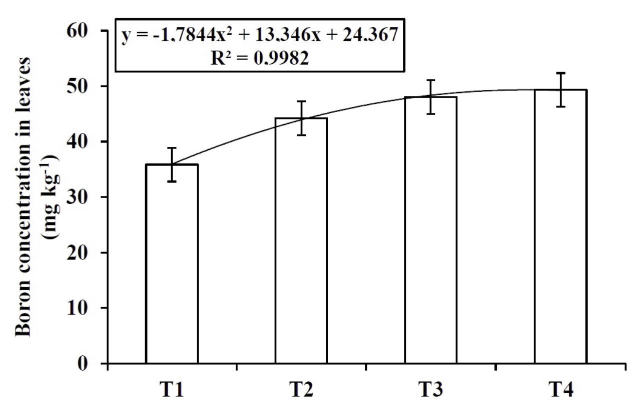

Fig. 4 - Effect of various levels of boric acid on boron concentration in mango leaves.

4. Discussion and Conclusions

The current study depicted the beneficial role of foliar application of boric acid as a source of B for improving mango yield and quality traits. Similarly, the effective role of foliar application has been reported previously (Anees *et al.,* 2011; Singh *et al.,* 2017; Ahmad *et al.,* 2018; Oldoni *et al.,* 2018). Our results are in accordance with Silva *et al.* (2014) that supply of boron is intrinsic to enhance the length and diameter of mango fruit with foliar application. Moreover, it was revealed that boron is less mobile in the plant, therefore, it piles up in older plant leaves and becomes unable for the sturdy growth of fruit development (Oldoni *et al.,* 2018). Contrarily foliar application was reported to supplement boron supply to the growing plant organs which ultimately enhanced mango fruit diameter (Bhatt *et al.,* 2012). It was further strengthened by the findings of Singh *et al.* (2017) that B application increases fruit size due to the better mobilization of food material from production sites to storage organs and rapidly fruit development. It was noted that foliar application was significantly effective for improvement in mango fruit weight. Our results were inlined with findings of Dutta (2004). The possible reason behind the increase in fruit weight might be due to increased cell expansion and cell division. Moreover, boron contribution in hormonal metabolism and boron is a key player in the rapid mobilization of sugar and water in fruits (Haq *et al.,* 2013). Increase in yield after boron application was correlated to an increase in carbohydrates metabolism (Perica *et al.,* 2001 a). The higher yield was also associated with the greater number of flower formation due to boron absorption and they also set a greater number of fruits (Usenik and Stampar, 2007; Sarrwy *et al.,* 2012). The similar result regarding an increase in fruit yield was also reported in almond (Nyomora *et al.,* 1999), Kinnow (Ullah *et al.,* 2012), guava (Rawat *et al.,* 2010), persimmon (Khayyat *et al.,* 2007) and peach (Ali *et al.,* 2014). Mango flowering is influenced by physiological events taking place throughout the course of its growth. We observed that improvement in flowering is due to the synthesis of flower promoters synthesized in leaves and their translocation to sprouts via phloem (Ramírez and Davenport, 2012). Foliar application increases bud formation by the synthesis of essential hormones and metabolite translocation to the bud of the tree (Usenik and Stampar, 2002). Perica *et al.* (2001 b) reported the similar findings that boron foliar spays resulted in a higher percentage of perfect flowers. It was well acknowledged that boron concentration obtained higher in pollen grains and flowers as compared to leaves. This improved flowering is due to the readily available boron required for reproductive organs (Dell and Huang, 1997; Blevins and Lukaszewski, 1998). Therefore, these results are in agreement with other fruits, where boron concentration at bud initiation, reproductive tissues, flowers and fruits were favourable (Nyomora *et al.,* 1999). It was well documented the role of boron application considerably enhanced the emerging flowers and fruits (Perica *et al.,* 2001 b). Mango quality traits were improved due to boron application was reported (Ahmad *et al.,* 2018). Increase in sugar contents due to boron was also reported from earlier studies (Hassan, 2000; Shaaban, 2010). It is due to the development of storage and accumulation in sugar content with the conversion of polysaccharide and starch into simple sugar (Kahlon and Uppal, 2005). It is evident that boron is responsible for declining acidity of fruit (Baiea *et al.,* 2015). This result was further supported by (Anees *et al.,* 2011; Sarker and Rahim, 2012; El-Razek *et al.,* 2013). Other quality traits improvement reports were found accordingly with our results (Bhatt *et al.,* 2012; Haq *et al.,* 2013). The higher rate of boron accumulation in leaves is due to the direct absorption by the leaves (Khan *et al.,* 2012). Foliar application increased boron concentration with higher application rate (Perica *et al.,* 2001 b). This result was endorsed by previous studies in olive (Hegazi *et al.,* 2018), apricot (Karlidag *et al.,* 2017) and strawberry (Kitir *et al.,* 2018).

It was concluded that foliar application of boric acid is an effective source to alleviate B deficiency in mango trees. In addition, the application of boric acid also improves the yield and fruit quality of mango. Furthermore, increasing application rate 0 to 0.3% was concluded fruitful for the overall yield and quality traits. However, more investigations are yet recommended to introduce exact application rate of boric acid to alleviate boron deficiency or its toxicity in mango trees.

References

ABID M., DANISH S., ZAFAR-UL-HYE M., SHAABAN M., IQBAL M.M., REHIM A., QAYYUM M.F., NAQQASH M.N., 2017 - *Biochar increased photosynthetic and accessory pigments in tomato (*Solanum lycopersicum *L.) plants by reducing cadmium concentration under various irrigation waters.* - Environ. Sci. Pollut. R., 24(27): 22111-22118.

ADAK T., KUMAR K., SINGH V.K., 2017 - *Micronutrient management for mango and guava orchards: farmers' perspective*. - Tropical Plant Res., 4(1): 180-182.

AHMAD I., BIBI F., BAKHSH A., ULLAH H., DANISH S., REHMAN A.U., 2018 - *Assessment of various levels of potassium citrate and sucrose along with boric acid on quality and yield of Sufaid Chaunsa.* - Int. J. Biosci., 13(1): 188-195.

AHMAD I., BIBI F., ULLAH H., MUNIR T., 2018 - *Mango fruit yield and critical quality parameters respond to foliar and soil applications of Zinc and Boron*. - Plants, 7(4): 97.

ALI A., PERVEEN S., SHAH S.N.M., ZHANG Z., WAHID F., SHAH M., BIBI S., MAJID A., 2014 - *Effect of foliar application of micronutrients on fruit quality of peach*. - Am.

J. Plant Sci., 5(09): 1258-1264.

ALLISON L., BOLLEN W.B., MOODIE C.D., 1965 - *Total carbon,* pp.1346-1366. - In: BLACK C.A., D.D. EVANS, L.E. ENSMINGER, J.L. WHITE, and F.E. CLARCK (eds.) *Methods of soil analysis. Part 2. Chemical and microbiological properties.* The American Society of Agronomy, Madison, WI, USA, pp. 1572.

ANEES M., TAHIR F.M., SHAHZAD J., MAHMOOD N., 2011 - *Effect of foliar application of micronutrients on the quality of mango (*Mangifera indica *L.) cv. Dusehri fruit*. - Mycopathologia, 9(1): 25-28.

AOAC, 2005 - *Official Methods of Analysis.* - The Association of Official Analytical Chemists, 18th ed., Gaithersburg, MD, USA.

BAIEA M.H.M., EL-BADAWY H.E.M., EL-GIOUSHY S.F., 2015 - *Effect of potassium, zinc and boron on growth, yield and fruit quality of Keitt mango trees*. - Res. J. Pharmaceutical Bio. Chem. Sci., 6(4): 800-812.

BARKER A.V., PILBEAM D.J., 2015 - *Handbook of plant nutrition.* - CRC Press, Boca Raton, FL, USA, pp. 773.

BHATT A., MISHRA N.K., MISHRA D.S., SINGH C.P., 2012 - *Foliar application of potassium, calcium, zinc and boron enhanced yield, quality and shelf life of mango*. - Hort. Flora Res. Spectrum, 1(4): 300-305.

BIBI F., AHMAD I., BAKHSH A., KIRAN S., DANISH S., ULLAH H., REHMAN A. U., 2019 - *Effect of foliar application of boron with calcium and potassium on quality and yield of mango cv. Summer Bahisht (SB) Chaunsa*. - Open Agri., 4: 98-106.

BLEVINS D.G., LUKASZEWSKI K.M., 1998 - *Boron in plant structure and function*. - Annu. Rev. Plant Physiol. Plant Mol. Biol., 49: 481-500.

BOUYOUCOS G.J., 1962 - *Hydrometer method improved for making particle size analyses of soils 1*. - Agron. J., 54(5): 464-465.

CAMACHO-CRISTÓBAL J.J., NAVARRO-GOCHICOA M.T., REXACH J., GONZÁLEZ-FONTES A., HERRERA-RODRÍGUEZ M.B., 2018 - *Plant response to boron deficiency and boron use efficiency in crop plants,* pp. 109-121. - In: HOSSAIN M.A., T. KAMIYA, D.J. BURRITT, L.S. PHAN TRAN, and T. FUJIWARA (eds.) *Plant micronutrient use efficiency. Molecular and genomic perspectives in crop plants*. Academic Press, London, UK, pp. 324.

DAVARPANAH S., TEHRANIFAR A., DAVARYNEJAD G., ABADÍA J., KHORASANI R., 2016 - *Effects of foliar applications of zinc and boron nano-fertilizers on pomegranate (*Punica granatum *cv. Ardestani) fruit yield and quality*. - Sci. Hortic., 210: 57-64.

DELL B., HUANG L., 1997 - *Physiological response of plants to low boron*. - Plant Soil, 193: 103-120.

DUTTA P., 2004 - *Effect of foliar application on panicle growth, fruit retention and physicochemical characters of mango cv. Himsagar*. - Ind. J. Hort., 61(30): 265-266.

EL-RAZEK E.E.A., ABD-ALLAH A.S.E., SALEH M.M.S., 2013 - *Foliar spray of some nutrient elements and antioxidants for improving yield and fruit quality of Hindi mango trees*. - Middle East J. Sci. Res., 14(10): 1257-1262.

EL-SHEIKH M.H., KHAFGY S.A.A., ZAIED S.S., 2007 - *Effect of foliar application with some micronutrients on leaf mineral content, yield and fruit quality of Floridaprince desert red peach trees*. - J. Agric. Biol. Sci., 3: 309-315.

FERNÁNDEZ V., SOTIROPOULOS T., BROWN P.H., 2013 - *Foliar fertilization. Scientific principles and field practices*. - International Fertilizer Industry Association, Paris, France, pp. 140.

FERNÁNDEZ-ESCOBAR R., GUERREIRO M., BENLLOCH M., BENLLOCH-GONZÁLEZ M., 2016 - *Symptoms of nutrient deficiencies in young olive trees and leaf nutrient concentration at which such symptoms appear*. - Sci. Hortic., 209: 279-285.

GAINES T.P., MITCHELL G.A., 1979 - *Boron determination in plant tissue by the azomethine-H method*. - Commun. Soil. Sci. Plant Anal., 10: 1099-1108.

HAQ I., RAB A., SAJID M., 2013 - *Foliar application of calcium chloride and borax enhance the fruit quality of litchi cultivars.* - J. Anim. Plant. Sci, 23(5): 1385-1390.

HEGAZI E.S., EL-MOTAIUM R.A., YEHIA T.A., HASHIM M.E., 2018 - *Effect of foliar boron application on boron, chlorophyll, phenol, sugars and hormones concentration of olive (*Olea europaea *L.) buds, leaves, and fruits*. - J. Plant Nutr., 41(6): 749-765.

JACKSON M.L., 1975 - *Soil chemical analysis. Advanced Course*. - University of Wisconsin, College of Agriculture, Department of Soils, Madison, WI, USA, pp. 894.

KAHLON P.S., UPPAL R.S., 2005 - *Effect of post-harvest treatments on shelf life of mango cv. Chausa*. - Haryana J. Hort. Sci., 34(1/2): 51.

KARLIDAG H., ESITKEN A., TURAN M., ATAY S., 2017 - *The effects of autumn foliar applications of boron and urea on flower quality, yield, boron and nitrogen reserves of apricot*. - J. Plant Nutr., 40(19): 2721-2727.

KHAN R., GURMANI A.H., GURMANI A.R., ZIA M.S., 2006 - *Effect of boron application on rice yield under wheat rice system*. - Int. J. Agric. Biol., 8: 805-808.

KHAYYAT M., TAFAZOLI E., ESHGHI S., RAJAEE S., 2007 - *Effect of nitrogen, boron, potassium and zinc sprays on yield and fruit quality of date palm*. - Am. Eurasian J. Agric. Environ. Sci., 2: 289-296.

KITIR N., GUNES A., TURAN M., YILDIRIM E., TOPCUOGLU B., TURKER M., OZLU E., KARAMAN M.R., FIRILDAK G., 2018 - *Bio-boron fertilizer applications affect amino acid and organic acid content and physiological properties of strawberry plant*. - Erwerbs-Obstbau, 61: 129-137.

LITZ R.E., 2009 - *The Mango 2nd edition. Botany, production and uses.* - CABI, Wallingford, Oxfordshire, UK, pp. 680.

MARSCHNER H., 2012 - *Mineral nutrition of higher plants*. - Academic Press, London, UK, pp. 651.

MURTI G.S., UPRETI K.K., JAYARAM H.L., 2008 - *Fruit drop in mango cv. Alphonso: Changes in ethylene production and ACC content*. - Ind. J. Hort., 65(1): 97-99.

NYOMORA A.M.S., BROWN P.H., KRUEGER B., 1999 - *Rate and time of boron application increase almond productivity and tissue boron concentration*. - HortScience, 34: 242-245.

OBREZA T.A., ZEKRI M., HANLON E.A., MORGAN K., SCHUMANN A., ROUSE R., 2010 - *Soil and leaf tissue testing for commercial citrus production*. *SL253.04*, pp. 1-10. - UF/IFAS Extension Service, University of Florida, FL, USA.

OLDONI F.C.A., LIMA A.M.N., CAVALCANTE Í.H.L., SOUSA K.D.S.M.D., CARNEIRO M.A., CARVALHO I.R.B.D., 2018 - *Boron fertilizing management on fruit production and quality of mango cv. Palmer in semiarid*. - Rev. Bras. Frutic., 40(3).

OLSEN S.R., 1954 - *Estimation of available phosphorus in soils by extraction with sodium bicarboante (no. 939)*. - US Dept. of Agriculture.

PERICA S., BELLALOUI N., GREVE C., HU H., BROWN P.H., 2001 a - *Boron transport and soluble carbohydrate concentrations in olive*. - J. Amer. Soc. Hort. Sci., 126: 291-296.

PERICA S., BROWN P.H., CONNELL J.H., NYOMORA A.M.S., DORDAS C., HU H., STANGOULIS J., 2001 b - *Foliar boron application improves flower fertility and fruit set of olive.* - HortScience, 36(4): 714-716.

PONNAMPERUMA F.N., CAYTON M.T., LANTIN R.S., 1981 - *Dilute hydrochloric acid as an extractant for available zinc, copper and boron in rice soils*. - Plant and Soil, 61(3): 297-310.

RAJA M.E., KUMAR S.C.A., RAJU S.Y., 2005 - *Boron deficiency in mango (*Mangifera indica *L.): a cause delineation study in acidic soils of Maharashtra, India*. - Soil Sci. Plant Nutr., 51(5): 751-754.

RAMÍREZ F., DAVENPORT T.L., 2010 - *Mango (*Mangifera indica *L.) flowering physiology*. - Sci. Hortic., 126(1): 65-72.

RANGANNA S., 1986 - *Handbook of analysis and quality control for fruit and vegetable products*. - Tata McGraw-Hill, New Delhi, India, pp. 1112.

RAWAT V.R.Y.T.J., TOMAR Y.K., RAWAT J.M.S., 2010 - *Influence of foliar application of micronutrients on the fruit quality of guava cv. Lucknow-49*. - J. Hill Agri., 1(1): 75-78.

RHOADES J.D., 1982 - *Cation exchange capacity*. pp. 149-157. - In: PAGE A.L., R.H. MILLER, and D.R. KEENEY (eds.) *Methods of soil analysis, Agron. No. 9, Part 2: Chemical and microbiological properties*. - American Society of Agronomy, Madison, WI, USA, pp.1143.

RICHARDS L.A., 1954 - *Diagnosis and improvement of saline and alkali soils*. - USDA Agric. Handbook 60, Washington DC, USA, pp. 160.

ROWELL D.L., 1994 - *Soil Science. Methods and application* - Longman Scientific & Technical, London, UK, pp. 368.

RUSK J.A., 1961 - *Chemical methods for analysis of fruits and vegetables*. - Canadian Department of Agriculture, Research Station Summerland, Canada, Publ. n. 1154.

SARAN P.L., KUMAR R., 2011 - *Boron deficiency disorders in mango (*Mangifera indica*): field screening, nutrient composition and amelioration by boron application*. - Ind. J. Agri. Sci., 81(6): 506-510.

SARKER B.C., RAHIM M.A., 2012 - *Effects of doses and splits of fertilizer application on harvesting time, yield and quality of mango cv. amrapali*. - Bangladesh J. Agri. Res., 37(2): 279-293.

SARRWY S.M.A., GADALLA E.G., MOSTAFA E.A.M., 2012 - *Effect of calcium nitrate and boric acid sprays on fruit set, yield and fruit quality of cv. Amhat date palm*. - World J. Agric. Sci., 8: 506-515.

SHAABAN M.M., 2010 - *Role of boron in plant nutrition and human health*. - Am. J. Plant Physiol., 5(5): 224.240.

SHARMA R.R., SINGH R., 2009 - *The fruit pitting disorder-A physiological anomaly in mango (Mangifera indica L.) due to deficiency of calcium and boron.* - Sci. Hortic., 119(4): 388-391.

SILVA DE A.C., DE SOUZA A.P., LEONEL S., DE SOUZA M.E., RAMOS D.P., TANAKA A.A., 2014 - *Growth and flowering of five mango cultivar under subtropics conditions of Brazil.* - Am. J. Plant Sci., 5(03): 393-402.

SINGH S., PAREKH N.S., PATEL H.R., KORE P.N., VASARA R.P., 2017 - *Effect of soil and foliar application of multi micronutrients on fruit yield and physical parameters of fruit of mango (*Mangifera indica *L.) var. Amrapali*. - Int. J. Curr. Microbiol. App. Sci., 6(12): 3495-3499.

SOUZA M.P., VAZ A.F., CERQUEIRA M.A., TEXEIRA J.A., VICENTE A.A., CARNEIRO-DA-CUNHA M.G., 2015 - *Effect of an edible nano multilayer coating by electrostatic self-assembly on the shelf life of fresh-cut mangoes*. - Food Bioprocess Technol., 8: 647-654.

STEEL R.G.D., TORRIE J.H., DICKEY D.A., 1997 - *Principles and procedures of statistics: a biometrical approach, 3rd ed*. - McGraw-Hill Co., New York, USA, pp. 633.

TIAN S.P., LIU J., ZHANG C.F., MENG X.H., 2010 - *Quality properties of harvested mango fruits and regulating technologies,* pp. 49-54. - In: SIVAKUMAR D. (ed.) *New trends in postharvest management of Fresh Produce II. Fresh Produce 4 (Special Issue 1).* Kagawa ken: Global Science Books, pp. 127.

ULLAH S., KHAN A.S., MALIK A.U., AFZAL I., SHAHID M., RAZZAQ K., 2012 - *Foliar application of boron influences the leaf mineral status, vegetative and reproductive growth, yield and fruit quality of 'Kinnow'mandarin (*Citrus reticulata *Blanco.).* - J. Plant Nutr., 35(13): 2067-2079.

USENIK V., STAMPAR F., 2007 - *Effect of late season boron spray on boron accumulation and fruit set of 'Summit' and 'Hedelfinger' sweet cherry (*Prunus avium *L.).* - Acta Agric. Slov., 89: 51-58.

YADAV D., SINGH S.P., 2017 - *Mango: History origin and distribution.* - J. Pharmacogn. Phytochem., 6(6): 1257-1262.

ZHANG Y., HU C., TAN Q., NIE Z., ZHENG C., GUI H., SUN X., ZHAO X., 2015 - *Soil application of boron and zinc influence fruit yield and quality of satsuma mandarin in acidic soils*. - Agronomy J., 107(1): 1-8.