The available literature pertaining to the present investigation entitled “Effect of Foliar Application of Micronutrients on Physico-chemical Characters of Guava (Psidium guajava L.) under Subtropical Conditions in the Hills” has been mentioned under suitable headings in this chapter.

It is well known that the nutrients sprayed on the fruit trees for the improvement of vegetative growth, flowering, correction of deficiency symptoms and increasing the yield would invariably affect the fruit quality, like fruit size, appearance, colour, soluble solids, sugars, vitamins, taste, and self-life at maturity. Various workers have reported that nutrients definitely influence the physico-chemical characters of the fruits (Ahmad et al., 1988; Embleton et al., 1967 and 1980; Lee and Chapman, 1988). Adequate supply of micronutrients especially during the developmental phases of fruits influences the fruit quality.

**EFFECT OF MICRONUTRIENTS ON QUANTITATIVE CHARACTERS OF FRUIT**

**Effect of zinc**

Lal and Sen (2002) observed that the earliest fruit maturity (131.33 days) and the highest number of fruits (327.00 fruits/tree) were significantly affected by foliar spray of ZnSO\(_4\) and MnSO\(_4\), and soil application of urea in cultivar Allahabad Safeda in a field experiment conducted in Rajasthan. The highest yield (76.97 kg/tree) was recorded at treatment combination of 600 g N + 4 g Zn + 4 g Mn/tree, while the latest fruit maturity (172.67 days), and the lowest number of fruits (243.33 fruits/tree) and yield (41.18 kg/tree) were recorded under the control.

Bhatia et al. (2001) pointed out that the fruit weight and yield of guava cultivar L-49 increased with foliar application of ZnSO\(_4\) at 0.5, 0.75 and 1.0 per
cent, during winter season. The maximum increase in fruit weight and yield (133.0 g and 68.0 kg/tree, respectively) were recorded with 1.0 per cent ZnSO$_4$.

Shoot length, fruit set, fruit retention and yield as weight or number of fruits per tree were significantly increased with 0.5 per cent and 1.0 per cent zinc sulphate sprayed at full bloom in both the seasons on guava trees of Montakhab El-Kanater (El-Sherif et al., 2000). While, foliar application of ZnSO$_4$ at 1.0 per cent significantly increased the growth and yield of guava cultivar Lucknow-26 (Balakrishnan, 2000).

Lal et al. (2000) reported that the foliar spray of ZnSO$_4$ at 4 g per plant per year significantly increased the yield and Zn content of leaves in guava cv. Allahabad Safeda. However, it reduced significantly the Mn content of leaves. Similarly, foliar spray of MnSO$_4$ at 4 g per plant per year significantly increased the fruit yield.

Kundu and Mitra (1999) noted that the foliar spraying of ZnSO$_4$ at 0.3 per cent applied on L-49 trees markedly increased the fruit set and hastened fruit maturity.

The size of Allahabad Safeda fruits increased appreciably with zinc spray (0.5 and 1.0%). The fruits treated with 1.0 per cent ZnSO$_4$ were recorded to increase in size (Singh and Brahmachari, 1999).

Kumar et al. (1998) examined the effect of nitrogen, potassium, zinc and gibberellic acid on yield attributing characters and yield of guava cultivar Allahabad Safeda grown in an acid soil. They found that calcium ammonium nitrate (CAN) + 150 ppm GA$_3$ significantly increased the number of flowers, fruit set, fruit retention, fruit size, fruit weight and yield. Other treatments which exhibited better responses were CAN + 100 ppm GA$_3$ and CAN + 1.5 per cent ZnSO$_4$.

Chaitanya et al. (1997) recorded the maximum fruit yield of 133.82 kg per tree, fruit weight of 108.9 g, length and diameter (5.52 & 4.51 cm) when L-
49 guava trees were sprayed thrice with 0.3 per cent zinc sulphate in comparison of 0.5 per cent. While, Sharma et al. (1993) found that GA$_3$ and zinc sulphate applications significantly improved the fruit set in guava. The highest fruit set (71.96%) was obtained under 0.6 per cent ZnSO$_4$ and the lowest (69.81%) with 0.4 per cent. It was further noticed that GA$_3$ with different concentrations was superior to zinc sulphate treatment. Almost similar response of these treatments was observed in respect of fruit retention. Significant increase in length and diameter of fruits was recorded under GA$_3$ and zinc sulphate sprays. Among the ZnSO$_4$ and GA$_3$ treatments, the maximum length and diameter of fruits (6.53 cm and 7.51 cm) was obtained with 0.6 per cent ZnSO$_4$ and 200 ppm GA$_3$ (7.30 cm and 7.97 cm), respectively. The yield response with 0.6 per cent zinc sulphate was also superior to its lower concentrations.

Plants of guava cultivar Allahabad Safeda sprayed with 0.4 per cent ZnSO$_4$ before flowering, at fruit setting and 3 weeks after fruit setting produced fruits with 4.96 cm length, 5.28 cm width, 78.67 g fruit weight, and 18.17 kg fruit yield per plant. When trees were sprayed with 0.4 per cent ZnSO$_4$ in combination with urea at 2.0 per cent produced fruits with 4.79 cm length, 5.02 cm width, 70.00 g fruit weight and 18.67 kg fruit yield per tree (Ali et al., 1991).

Sharma et al. (1991) found the highest fruit set (71.96%), fruit retention (53.86%), fruit weight (165.8 g) and fruit yield (498.6 fruits weighing 82.39 kg/plant) with 0.6 per cent zinc sulphate treatment, when foliar sprays of aqueous solutions of zinc sulphate (0.2, 0.4 or 0.6%) were applied to guava cultivar Allahabad Safeda at flower initiation (mid March) and after >50% fruit set (mid May).

The doses and absorption of mineral nutrients played a vital role towards the degree of fruit drop (Pandey and Sharma, 1989). Pandey et al. (1988) noted that the size of Sardar guava fruits with respect to both length and breadth was significantly increased by foliar application of chemicals. The maximum value (6.21 cm length and 5.68 cm breadth) of both the characters was recorded under
urea + ZnSO₄ + ethrel + NAA (2.0%, 0.4%, 250 ppm and 10 ppm, respectively). Zinc alone at 0.4 per cent gave fruits of 5.28 cm length, 5.30 cm diameter, 83.63 g weight and 51.91 kg/tree, which superseded such effects of control.

Foliar application of 0.3 per cent solution of zinc sulphate increased the weight, number and yield of fruits per plant in cultivar L-49 as reported by Ghosh (1986).

Mansour and El-Sied (1985) reported that the foliar application of Zn at 0.5 or 1.0 per cent applied at full bloom in guava trees increased fruit set, reduced pre-harvest fruit drop and boosted the yield (160-373 fruits/tree) when compared to control (206-964 fruits/tree).

While studying the effects of pre-blossom foliar sprays of zinc sulphate with 0.1-0.4 per cent concentration, on the fruit size of guava cultivar Allahabad Safeda, Rajput and Chand (1976) found that fruit size was enhanced by all treatments. However, the best results were obtained under 0.3 per cent zinc sulphate.

Pre-flowering sprays of zinc sulphate at 0.1, 0.2, 0.3 or 0.4 per cent were applied to guava trees, cultivar Allahabad Safeda and it was found that all treatments, especially at the 2 higher concentrations, led to significant improvements in growth, flowering and fruiting (Rajput and Chand, 1975).

Bahadur et al. (1998) applied zinc sulphate as foliar sprays (0.25, 0.50 and 1.0%) or to the soil (0.5, 1.0 and 2.0 kg/tree) during 2nd week of October at flower bud differentiation to 26-year-old mango trees cultivar Dashehari. They found that uptake of zinc under foliar application was more rapid than that of soil applied zinc and there was a significant increase among zinc sulphate treatments with respect to fruit size, weight and yield.

According to Singh and Rajput (1976) the foliar application of 0.2, 0.4, 0.6 and 0.8 per cent zinc sulphate increased the fruit set in Chausa cultivar of mango. The fruit weight increased with the increase in concentrations and found
to be the maximum (251.32 g) under 0.8 per cent. Malik et al. (2000) also found the maximum number of fruits and yield per tree in Kinnow when sprayed with 0.5 per cent zinc sulphate.

Malik et al. (1999) recorded the minimum fruit drop and fruit retention in Kinnow trees sprayed with 0.4 per cent zinc sulphate. Foliar application of 0.75 per cent zinc sulphate was found to be more effective as compared to soil application on the yield and quality of Kinnow (Wali and Sharma, 1997).

Hassan (1995) sprayed Washington Naval Orange trees twice a year with 75 ppm Fe, 50 ppm Mn or 75 ppm Zn, alone. All micronutrient treatments (apart from 50 ppm Mn) reduced fruit drop and yield compared with control.

In Valancia Late Orange, the fruit size and yield were not affected by application of ZnSO₄ (Rodriguez et al., 1994). However, Langthasa et al. (1993) noted that the application of chelated zinc @ 0.4 per cent gave the highest number of flowers (289.33), fruit set (78.17%) and yield/tree (20.88 kg) in Blood Red Orange. Ali et al. (1992) in their experiment found that when four-year-old highly chlorotic Blood Red Orange trees growing on alkaline clay soil (pH 8.2 4) were given foliar sprays in April and July containing 39 g FeSO₄, 98 g ZnSO₄ and 39 g MnSO₄ in 20 lit. of water separately or in all possible combinations, had the greatest effect on tree growth.

Mann et al. (1985) reported the highest fruit weight (167.0 g), width (7.05 cm) and yield (344 fruits/ tree) with ZnSO₄ sprays (0.5%), in sweet orange cultivar Blood Red.

Sindhu et al. (1999) noted that zinc sulphate with 0.5 per cent concentration produced the maximum number of branches per vine, bunch weight and yield of grape cv. Perlette.

Foliar spray of ZnSO₄ at 0.4 per cent once at full bloom and again after fruit set stage in Perlette grapes was found to be the most effective among
ZnSO₄ concentrations (0.2, 0.4, and 0.6%) in increasing yield, bunch weight, and berry weight (Dhillon and Bindra, 1995).

Bacha et al. (1995) investigated the effect of foliar application of chelated iron, zinc, and manganese on yield and berry quality of Thompson Seedless and Roumy Red cultivars of grape. The results revealed that with a mixture of Fe, Zn and Mn caused non-significant and significant increase in the yield of Thompson Seedless and Roumy Red as compared to control. The foliar application of Fe, Zn and Mn was more effective exhibiting pronounced effects on the yield of berry in the second season. Furthermore, spraying vines of both cultivars with Fe, Zn and Mn gave obvious increase in size (length and diameter) and weight of berries when compared to control.

The lower concentration (0.2%) of zinc sulphate found to be more effective in improving berry set and length but weight and breadth of bunches and berries were not affected in grape cultivar Gold (Kumar et al., 1988).

Daulta et al. (1983) reported that all the concentrations (0.2, 0.4 and 0.6%) of zinc sulphate significantly improved the berry weight over the control in Beauty Seedless grape. ZnSO₄ with 0.4 and 0.6 per cent significantly increased the length and breadth of berry over control. The maximum berry weight was obtained with ZnSO₄ (0.6%), while boracic boron could not affect berry weight.

Two sprays of zinc sulphate (0.5-1.0%) at fruit setting stage in ber cultivar Seb were found suitable for fruit retention and increased yield in semi-arid regions (Singh and Vashishtha, 1997).

Singh and Ahlawat (1996) noted the maximum fruit set, length, breadth; weight, yield and the minimum fruit drop in ber cultivar Umran when trees receiving 0.5% zinc sulphate as foliar spray. Further increase in concentration of zinc sulphate decreased yield. Fruit weight and yield of ber was improved by
application of 2 per cent urea+0.8 per cent ZnSO\textsubscript{4} in comparison to other treatments (Joon \textit{et al.}, 1984).

Hasan and Chattopadhyay (1990) were successful in controlling fruit drop in litchi cultivar Bombai by using 0.5 per cent zinc. Awasthy \textit{et al.} (1975) reported that zinc sulphate spray significantly reduced fruit drop in litchi. The reduction was due to increased biosynthesis of IAA in zinc treated plants. They also reported that foliar application of zinc sulphate at 0.5, 1.0 and 1.5 per cent concentrations, considerably increased number of fruits, pulp weight and volume.

The fruit retention per cent and yield increased successively with the increase in the dose of zinc sulphate but the best results were obtained with zinc sulphate sprays at 0.6 per cent on plum trees (Chahil \textit{et al.}, 1996). Bambal \textit{et al.} (1991) also found an increase in yield of pomegranate cultivar Ganesh with foliar spray of ZnSO\textsubscript{4} at 0.3 per cent.

**Effect of copper**

Singh and Singh (2002) reported the application of two foliar sprays of copper sulphate at 0.1, 0.2, 0.3, and 0.4 per cent to guava cultivar Allahabad Safeda trees. Copper sulphate at 0.4 per cent increased fruit set and fruit retention. The effect on the yield attributes of the rainy season crop was significant as compared to winter season. They also found that copper sprays at 0.4 per cent gave significantly higher values for fruit length (5.19 cm), diameter (5.02 cm) and weight (168.7 g) than the other treatments. The foliar application of 0.1, 0.2, 0.3 and 0.4 per cent copper significantly increased the fruit yield over the control, with highest yield of 62.63 kg/tree at 0.4 per cent copper spray.

Copper sulphate at 0.3 per cent markedly increased the fruit set and hastened fruit maturity in guava cultivars L-49 when applied as foliar spray (Kundu and Mitra, 1999).
Arora and Singh (1971) found that 0.4 per cent copper sulphate spray on guava trees improved yield and hastened fruit maturity by 10 days. Its spray at 0.2 and 0.4 per cent showed significant improvement in Allahabad Safeda with the maximum increase (3.5%) in length, (3.2%) in diameter, (12.4%) in fruit weight and cent per cent increase in yield under 0.4 per spray, whereas 2.1, 2.2, 9.7 and 92.3 per cent increase in length, diameter, fruit weight and yield, respectively, was obtained with 0.2 per cent spray.

Singh and Khan (1990) observed the fruit weight increased and fruit number decreased in mango with copper sulphate application alone.

Sharma et al. (1999) reported that the copper sulphate sprays individually resulted in significant increase in yield of lemons as compared to control. Singh and Rethy (1996) observed greatest fruit weight in Kagzi lime with the spraying of 0.5 per cent copper sulphate and 20 ppm NAA. Spraying of CuSO$_4$ (0.25 or 0.5%) in combination with 20 ppm 2, 4-D on Kinnow mandarins, reduce fruit drop significantly and improved fruit size (Singh and Mishra, 1986).

Sarkar et al. (1984) found that 0.4 per cent Cu spraying improved weight and diameter of litchi fruits. They also reported that copper at 0.2 per cent spray reduced fruit drop and hence increased fruit yield of Rose Scented litchi. Dutt (1962) also reported that spraying of Cu (3.05 g/l) increased fruit set, fruit size and yield of litchi.

Copper sulphates @ 0.2 per cent significantly improved the fruit retention and yield of plum trees (Chahil et al., 1996).

Ghanta et al. (1992) noted the foliar spray of copper increased weight and size of papaya fruit. Chattopadhyay and Gogoi (1990) also obtained higher fruit weight, fruits number and yield per plant than control in papaya following foliar spray of copper.
Effect of boron

Foliar application of $\text{H}_3\text{BO}_3$ at 0.3, 0.5 and 1.0 per cent on guava cultivar L-49 during winter season (Bhatia et al., 2001) increased the fruit weight and yield showing the maximum value of 141.0 g and 73.0 kg/tree, respectively with 1.0 per cent.

The foliar application of 0.1 per cent borax significantly increased the growth and yield of guava cultivar Lucknow-26 as compared to control (Balakrishnan, 2000).

Kundu and Mitra (1999) noted the increased fruit set and early fruit maturity with foliar spraying of boric acid at 0.1 per cent alone on guava cultivar L-49.

The size of guava fruits cultivar Allahabad Safeda increased appreciably with borax at 0.5 and 1.0 per cent. The maximum value for length (6.44 cm) and breadth (6.86 cm) of fruits were recorded with borax 1.0 per cent (Singh and Brahmachari, 1999).

Pre-harvest spray of borax with 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 per cent concentrations twice in October improved the quality of guava fruits in cultivar Sardar in terms of size and weight. The maximum fruit length (7.6 cm), diameter (6.69 cm), weight (135.85 g) and volume (138.83 ml) were recorded with 1 per cent borax and the minimum with control. However, fruit growth pattern was not influenced by borax treatments (Raghav and Tiwari, 1998).

Yadav (1998) found the best yield of quality fruits, fruit yield (67.7 kg per tree), number of fruits (686 per tree), volume of fruit (107.5 cc) after foliar application of urea (3.0%) + borax (0.15%) + NAA (10 ppm) in guava trees.

Chaitanya et al. (1997) found the maximum increase in the fruit length and diameter (5.40 & 4.90 cm), yield (138.30 kg/plant) and weight (109.93 g) in L-49 guava trees, when received borax as foliar feeding thrice at 0.3 per cent.
Spray of borax at 0.2 per cent in combination with urea at 2 per cent thrice at pre-flowering, fruit setting and 3 weeks after fruit setting in guava cultivar Allahabad Safeda produced fruits with 4.84 cm length, 5.00 cm width, 72.67 g weight and 19.08 kg fruit yield per tree (Ali et al., 1991). They also recorded higher fruit weight of 80.67 g and yield of 20.17 kg/plant with foliar feeding of borax at 0.2 per cent alone on guava cultivar Allahabad Safeda.

Spraying of borax (0.2%) proved effective in increasing the size of Sardar guava fruits, weight and yield as 5.93 cm length and 5.63 cm width, 95.25 g and 63.49 kg/tree, respectively, (Pandey et al., 1988). The fruit yield was the highest (69.45 kg/tree) with the combined application of borax + ethrel + NAA (0.2%, 250 ppm, 10 ppm, respectively). However, the spraying of urea or borax proved equally effective in this respect.

Foliar application of 0.3 per cent solution of borax resulted in larger fruit size, increase the number of fruits per plant, weight of fruit and yield of guava cultivar L-49 (Ghosh, 1986).

The results obtained by Singh et al. (1983) from the foliar spray of urea and boric acid at different concentrations singly as well as in combinations have good effects on physical characters of guava fruits cultivar L-49. The largest fruits, sizing 6.68 x 7.12 cm with 125.8 g fruit weight were produced on trees treated with 3.0 per cent urea + 0.3 per cent boric acid.

Rajput and Chand (1976) observed the effects of pre-blossom foliar sprays of boric acid at 0.1 - 0.4 per cent, on the fruit size of guava cultivar Allahabad Safeda and reported that fruit size was enhanced by all treatments. However, with 0.4 per cent boric acid the results obtained were the best.

The effects of the boron sprays were particularly marked when pre-flowering sprays of boric acid at 0.1, 0.2, 0.3 or 0.4 per cent concentrations were applied to Allahabad Safeda (Rajput and Chand, 1975). They found that all the
treatments, especially with two higher concentrations, led to significant improvements in growth, flowering and fruiting.

Spraying guava trees with 0.1 and 0.2 per cent B as boric acid increased the extension of the terminal shoot, the number of leaves and the leaf-area/shoot. These also hastened fruit ripening by 7 and 11 days and increased the yield by 82 and 73 per cent, respectively. 0.1 per cent boric acid improved the size of the fruits (Arora and Singh, 1972).

Rai and Tiwari (1988) while working on orange (Citrus reticulata Blanco) observed that foliar spray of 0.6 per cent borax was most effective in increasing fruit set, reducing fruit drop and increasing yield/tree.

Brahmachari and Kumar (1997) reported that spray of borax 0.4 per cent was the most effective in enhancing the fruit set and retaining more number of fruits in litchi. Bramachari et al. (1997) also studied the effectiveness of borax (0.4% or 0.8%) as foliar spray on yield of litchi cultivar Purbi. Fruit set, size and weight of fruits were the highest with 0.4 per cent borax.

Upreti and Kumar (1996) found that borax was most effective in reducing fruit drop in Rose Scented litchi. They reported a fruit drop of 75 -76 per cent only by using borax (0.5% and 1.0%) as foliar sprays as against 92.4 per cent fruit drop in control. Hasan and Chattopadhyay (1990) were successful in controlling fruit drop in litchi cv. Bombay by using 0.5 per cent borax.

Xu et al. (1984) reported a considerable increase in fruit set and reduction in fruit drop when litchi trees were sprayed with 0.4 per cent boron solution. Pujari and Shyamal (1977) reported that boron alone at 0.5 per cent reduced the fruit drop in litchi upto 66 per cent.

Boric acid (0.05%) once at full bloom and again after fruit set stage, improved the yield of Perlette grapes compared to boric acid 0.1 and 0.2 per cent (Dhillon and Bindra, 1995).
Jindal et al. (1982) treated some girdled vines with 0.2 per cent boric acid at bloom or non girdled vines were sprayed once (at bloom) or twice (at bloom and a week later). Fruit set (58.5%), berry retention (363/bunch) and yield (9.7 kg/vine) were highest in girdled vines, whereas berry drop (58.5%) and panicle drying (24.4%) were lowest in girdled and sprayed vines. The yield in control was 2.95 kg/vine.

Rana and Sharma (1979) found increase in weight and volume of individual grape berries as well as each cluster when grape vines were sprayed with boron at 0.025 per cent and 0.05 per cent concentrations. They also reported significant increase in yield over control when boron was applied to grapevines. Yamdagni et al. (1979) observed that foliar application of boric acid one week before full bloom and at full bloom, advanced berry maturity by 6 or 7 days and there was slight increase in berry weight of grape.

The maximum fruit size (length and breadth), pulp per cent and pulp - stone ratio were found with 1.0 per cent borax application in ber cv. Umran (Singh et al., 2001).

Two sprays of borax (0.5%) at fruit setting stage in ber cultivar Seb was found suitable for fruit retention and increased yield in semi -arid regions (Singh and Vashishthha, 1997).

Foliar application of boric acid (0.2%) improved the rind and fruit colour, average fruit weight, percentage of grain and reduction in percentage of peel in pomegranate fruits (Bambal et al., 1991).

**Effect of combined spray of zinc, copper and boron**

Kundu and Mitra (1999) noted that among different combinations of micronutrients applied on guava cultivars L -49, CuSO$_4$ + ZnSO$_4$ (both at 0.3%) exhibited the highest fruit set (78.75%) while foliar spray of ZnSO$_4$ + H$_3$BO$_3$ (0.3 + 0.1%) advanced early fruit maturity. Sharma et al. (1999) reported that the
copper sprays in combination with zinc resulted in significant increase in yield of lemons as compared to control.

Combination of ZnSO₄ + MnSO₄ (0.5 + 0.4%) produced fruits with the maximum length (6.96 cm) in sweet orange cultivar Blood Red as reported by Mann et al. (1985). Whereas, Manchanda et al. (1972) recorded the minimum fruit fall with foliar spray of ZnSO₄ + CuSO₄ (0.5 + 0.4%) in sweet orange.

Combination of zinc sulphate and copper sulphate as 0.3 + 0.2 and 0.6 + 0.2 per cent increased the fruit retention, fruit weight and yield of plum fruit with successive increase in the concentration of zinc (Chahil et al., 1996).

The combination of all the micronutrients, ZnSO₄ at 0.25 per cent + FeSO₄ at 0.25 per cent + MgSO₄ at 0.25 per cent + borax at 0.1 per cent, resulted in the highest fruit yield (70.15 kg/tree) in guava cv. Lucknow-26 as compared to control (Balakrishnan, 2000).

An increase in the fruit length and diameter (6.02 & 5.30 cm), yield (144.22 kg/plant) and weight (120.0 g) in L-49 guava trees were recorded the maximum when zinc sulphate and borax spray made combined thrice each at 0.3 per cent as compared to Zinc sulphate + Borax at 0.5 + 0.5, 0.5 + 0.3, and 0.3 + 0.5 per cent (Chaitanya et al., 1997).

Borax in combination with zinc sulphate and magnesium sulphate increased the average fruit weight by about 9.0 per cent compared to control in guava cultivar L-49 (Ghosh, 1986). It also increased the number of fruits (150.0) and fruit yield (26.1 kg) per plant.

Chandel (1987) reported fruits of maximum size and weight, and an increase of 29 per cent yield in litchi cultivar Rose Scented, when the trees were sprayed with a combination of borox at 0.2 and zinc sulphate at 0.5 per cent.

While studying the effect of growth substances in combination with minor elements for controlling fruit drop Verma et al. (1980) reported that the
combined spray of zinc and boron showed 84.22 per cent fruit drop control in litchi.

Foliar spray of 0.25 per cent each of ZnSO$_4$, FeSO$_4$ and MnSO$_4$ combined with 0.15 per cent boric acid significantly increased the yield from 18.5 kg/plant under control to 26.37 kg/plant in pomegranate cultivar Ganesh (Balakrishan et al., 1996).

Among the foliar feeding combinations of zinc sulphate, boric acid, iron sulphate and manganese sulphate (0.3, 0.2, 0.4 and 0.3%, respectively) in various, Fe + B + Mn + Zn combination was found promising in increasing the yield of pomegranate tree, followed by B + Zn combination (Bambal et al., 1991).

Effect of foliar application of nutrients on fruits of guava cultivar L-49 was studied by Kundu and Mitra (1999) and reported that the maximum increase in weight and size (length & diameter) of fruits was recorded under the combined spraying of CuSO$_4$ + Boric acid + ZnSO$_4$ (0.3 + 0.1 + 0.3%). A combination of these micronutrients was also found effective in increasing the yield (54.65 kg), fruit weight (149.20 g) and size (6.30 x 6.75 cm).

Copper application in combination with boron or zinc increased the fruit weight and decreased fruit number in mango (Singh and Khan, 1990).

Singh et al. (1990) conducted a trial to study the effect of Zn, B and Cu on 15 year old trees of Kagzi lime. The plants were sprayed twice a year in middle of August and beginning of September with ZnSO$_4$, CuSO$_4$ and borax at 0.3 per cent alone and mixture of all three micronutrients. They recorded highest number of fruits per twig (7.0), weight of fruit (55.26 g), length (5.40 cm), width (4.81 cm) and volume (248 cm$^3$) with the mixture of zinc, boron and copper treatment.

Combined spray of ZnSO$_4$, borax and CuSO$_4$ significantly improved the size and weight of fruits when foliar feeding of 0.5 per cent ZnSO$_4$, 0.2 per cent
borax and 0.4 per cent CuSO\textsubscript{4} were conducted on aonla cultivar Francis (Singh et al., 2001).

**EFFECT OF MICRONUTRIENTS ON QUALITATIVE CHARACTERS OF FRUIT**

**Effect of zinc**

The total soluble solids, ascorbic acid, reducing sugars, non reducing sugars, total sugars and pectin, TSS acid ratio and pH in fruits of guava cultivar Allahabad Safeda linearly increased with 0, 2 and 4 g Zn SO\textsubscript{4} and MnSO\textsubscript{4} per plant in a field experiment, whereas acidity decreased with increasing rates of ZnSO\textsubscript{4} and MnSO\textsubscript{4} (Lal and Sen, 2001).

Bhatia et al. (2001) reported an increase in quality of guava fruits cultivar L-49 with foliar application of ZnSO\textsubscript{4} at 0.5, 0.75 and 1.0 per cent during winter season. The total soluble solids, sugars and ascorbic acid were increased with the increasing concentrations of ZnSO\textsubscript{4}, however, decreased trend in acidity per cent was observed with increasing concentration of ZnSO\textsubscript{4}.

Spraying aqueous solution of zinc sulphate 0.5 or 1.0 per cent at 25-27 days after fruit set concentrations increased the total, reducing, and non reducing sugar contents of guava fruits cultivar Allahabad Safeda (Das et al., 2001). Greater increases, however, were recorded for 1.0 per cent concentration. The improvement in fruit sweetness due to zinc sulphate started 15 days after spraying when the fruits were in the early developmental stage. El-Sherif et al. (2000) also found improved fruit quality with 0.5 per cent and 1.0 per cent zinc sulphate sprays at full bloom on guava plants.

The increase in TSS (11.75 ⁰Brix), total sugars (8.42%) and sugar/acid ratio (33.69) of guava cultivar L-49 fruits and decline in fruit acidity (0.24%) were highest with zinc sulphate at 0.3 per cent, followed by boric acid at 0.1 per cent (Kundu and Mitra, 1999).
TSS and sugar content were enhanced markedly by the foliar application of zinc sulphate in guava fruits cultivar Allahabad Safeda (Singh and Brahmachari, 1999). The ascorbic acid content of the fruit pulp also increased greatly with the 1.0 per cent of zinc sulphate.

The total soluble solid contents of L-49 guava fruits were found to increase under the influence of zinc sulphate sprays at 0.3 and 0.5 per cent (Chaitanya et al., 1997). Lower concentration of zinc sulphate was found to be significantly superior to the higher concentration in enhancing the TSS content, carbohydrates, starch, sugar, sugar acid ratio and vitamin C contents in guava fruits. Total acidity of fruit was also found to decrease with the foliar sprays of zinc.

Foliar sprays of aqueous solutions of zinc sulphate (0.2, 0.4 or 0.6%) applied to guava cultivar Allahabad Safeda at flower initiation (mid March) and after >50% fruit set (mid May) gave the highest fruit TSS (11.25%) and the lowest acidity (0.36%) with the 0.6 per cent zinc sulphate treatment (Sharma et al., 1991).

In Sardar guava, the foliar application of ZnSO₄ (0.4%) proved effective with respect to TSS (10.29%), total sugars (6.80%) and pectin content (0.65%). The acidity content of fruits under ZnSO₄ application was found lower than control treatment (Pandey et al., 1988).

Application of ZnSO₄ at 0.3 per cent produced the fruits with 8.6° Brix TSS, 6.63 per cent total sugars which was more than the control in guava cultivar L-49 (Ghosh, 1986), however, reduction in acidity was observed.

Zinc sulphate when supplied alone at 0.4 per cent as foliar spray on guava cultivar Allahabad Safeda gave maximum TSS, reducing and non-reducing sugars, ascorbic acid and pectin (Singh and Chhonkar, 1983).

The effect of pre-blossom foliar sprays of zinc sulphate, at 0.1-0.4 per cent, on guava fruits cultivar Allahabad Safeda was observed by Rajput and
Chand (1976), of which 0.3 per cent zinc sulphate was more effective. Total soluble solids, total sugars, vitamin C and pectin contents were also enhanced but fruit acidity was markedly reduced.

Bahadur et al. (1998) applied zinc sulphate as a foliar spray (0.25, 0.50 and 1.0%) or to the soil (0.5, 1.0 and 2.0 kg/tree) during flower bud differentiation to 26 year old mango cultivar Dashehari. They found that uptake of foliar spray of zinc was more rapid than that of soil applied zinc. However, fruit acid and sugar contents were not significantly affected by any of the methods of application.

In mango cv. Fazli, an increase in TSS, reducing and non-reducing sugar contents and a decrease in acidity content was observed by Banik et al. (1997), following zinc application.

The foliar application of 0.2, 0.4, 0.6 and 0.8 per cent zinc sulphate on mango cultivar Chausa increased the TSS contents, and the maximum TSS was recorded with 0.8 per cent. Similar results were found in ascorbic acid contents and reducing and non-reducing sugars of the fruits (Singh and Rajput, 1976).

Trees sprayed with 1.0 and 0.8 per cent zinc sulphate showed the maximum total soluble solids in Kinnow fruits (Malik et al., 2000). Ascorbic acid contents, however, decreased with foliar spray of zinc sulphate as compared to control.

In lemons, foliar application of Zn significantly increased the juice content in fruits with higher TSS, sugars, ascorbic acid and appreciable reduction in titratable acidity (Sharma et al., 1999).

In Washington Naval Orange trees, most of the fruit quality parameters were enhanced with the foliar spray of Zn at 75 ppm (Hassan, 1995). Vitamin C contents and TSS of juice increased, while acidity decreased with ZnSO₄ at 0.5 per cent on Mosambi sweet orange (Desai et al., 1991).
Langthasa and Bhattacharyya (1991) reported that the highest juice (59.49 cc) content, TSS (5.19%), ascorbic acid (60.12 mg/100 ml), total sugars (1.18%) and reducing sugars (0.95%) of fruit were observed with 0.4 per cent chelated zinc sulphate spray in Assam lemon. The beneficial effect on fruit quality with the highest rate (3 or 4%) of application of both zinc sources, i.e., chelated and non-chelated zinc sulphate was also noted.

Foliar spray of 1.0 per cent ZnSO$_4$ significantly increased the total soluble solids, total sugars, reducing sugar and pH of litchi fruit juice with considerable reduction in acidity (Hasan and Jana, 2000). Sinha et al. (1999) also found that the quality of litchi was improved by the application of Zn.

Kumar et al. (1995) sprayed litchi cultivar Purbi trees with zinc sulphate at 0.6, 0.8 and 1.0 per cent just after fruit set and again a fortnight later and found that spraying with 1.0 per cent zinc sulphate produced the best chemical composition in terms of TSS content, sugar/acid ratio and ascorbic acid content.

Awasthy et al. (1975) found an increased TSS and decreased total acidity in fruits by foliar sprays of zinc on litchi trees. An increase in total sugars, ascorbic acid content and sugar acid ratio was also observed in litchi with the foliar application of ZnSO$_4$ (Hoda et al., 1975). A higher TSS and total sugar contents together with lower acidity in litchi was associated with Zn foliar application (Dutt, 1962).

The total soluble solids of grape fruits cultivar Perlette increased with foliar spray of zinc sulphate and the maximum was reported in vines receiving 0.5 per cent zinc sulphate, whereas acidity decreased with an increase in the concentrations of zinc sulphate (Sindhu et al., 1999). Foliar spray at 0.2, 0.4, 0.6 per cent of ZnSO$_4$ and 0.5 per cent boric acid once at full bloom and again after fruit set stage, improved the quality of Perlette grapes considerably (Dhillon and Bindra, 1995). The percentage of TSS in the berries of Thompson Seedless and Roumy Red grape was increased, while the percentage of acidity was decreased.
only in berries of Roumy Red with a combined foliar application of chelated iron, zinc and manganese (Bacha et al., 1995).

The quality of berries in grape cultivar Perlette with regards to the highest TSS and sugars were obtained with 0.2 per cent ZnSO$_4$ and the lowest acidity with 0.4 per cent ZnSO$_4$ (Kumar and Pathak, 1992). Makhiza and Chandra (1992) reported that foliar application of ZnSO$_4$ at 0.3 per cent improved the quality of perlette grapes in terms of TSS, acidity, and TSS/acid ratio.

The TSS contents in foliar spray of zinc sulphate (0.2, 0.4 and 0.6%) were significantly improved as compared to control in Beauty Seedless grape (Daulta et al., 1983).

Kamble and Desai (1995) reported that foliar application of ZnSO$_4$, increased fruit weight and total soluble solids, sugars and vitamin C contents of ber cv Karaka, compared with control.

Foliar application of 1.5 and 0.5 per cent zinc sulphate increased total soluble solids and ascorbic acid of ber fruits (Singh and Ahlawlat, 1995). Total sugars, TSS, acidity, ascorbic acid and TSS/ac id ratio were improved in ber fruits by zinc sulphate aqueous spray (Singh et al., 1989). These parameters reached maximum when zinc sulphate (0.5%) was sprayed along with NAA (50 ppm).

**Effect of copper**

Copper sulphate sprays at 0.1, 0.2, 0.3 and 0.4 per cent, slightly increased the total soluble solids of the guava fruits cultivar Allahabad Safeda. The highest reducing sugars (4.11%) and pectin content (0.80%) of fruits was recorded with copper at 0.4 per cent (Singh and Singh, 2002).

Guava cultivar Allahabad Safeda was sprayed with copper sulphate at 0.2 and 0.4 per cent showed reduction in fruit acidity with the maximum decrease of 15.6 per cent under 0.4 per cent spray (Arora and Singh, 1971). They found fruits with the maximum increase in reducing and non-reducing sugars, increase
in vitamin C contents of fruits (14.1, 14.7 and 10.3%, respectively) under 0.4 per cent copper spray. Almost a similar trend was also recorded in pectin content of fruits with the maximum increase (20.9%) under 0.4 per cent; however, 0.4 per cent spray resulted in 11.6 per cent increase in TSS over control.

In lemons, foliar application of Cu significantly increased the juice content in fruits with higher TSS, sugars, ascorbic acid and appreciable reduction in titratable acidity (Sharma et al., 1999). Foliar application of CuSO₄ at 0.25% on Mosambi sweet orange revealed the significant increase in quality of fruits. Vitamin C contents and TSS of juice increased, while acidity decreased (Desai et al., 1991).

Singh and Mishra (1986) reported that spraying of CuSO₄ (0.25 or 0.5%) in combination with 20 ppm 2, 4-D on Kinnow mandarins, improved juice percentage and quality of fruits.

Sarkar et al. (1984) found that 0.4 per cent Cu spraying improved pulp contents of litchi fruits with improved total sugars and TSS in juice. Dutt (1962) also observed higher TSS and total sugar contents as well as lower acidity in litchi, following Cu foliar application.

Ghanta et al. (1992) reported that foliar spray of copper increased fruit TSS, total sugars and ascorbic acid contents in papaya.

An increase in juice content of pummelo fruits (Dutt, 1962) and sugar contents of grape (Pecznik and Merei, 1962) has been reported due to copper sulphate spray.

**Effect of boron**

Among the concentrations of H₃BO₃ @ 0.3, 0.5 and 1.0 per cent foliar application on guava fruits cultivar L-49 during winter season, Bhatia et al.
(2001) found the highest total soluble solids (13.9%), acidity (0.41%), ascorbic acid (185 mg/100 g) and sugars (7.37%) with 1.0 per cent H$_3$BO$_3$.

Singh and Brahmachari (1999) found that the TSS and sugar content in guava fruits cultivar Allahabad Safeda were enhanced markedly by the foliar application of borax. A considerable increase in ascorbic acid content of the fruit pulp was also recorded with the 1.0 per cent of borax.

Pre-harvest foliar spray of borax at 0.6-1.0 per cent twice in October improved the quality of Sardar guava fruits in terms of TSS (11.40% with 0.8%), ascorbic acid (279.09 mg/100 g pulp with 1.0%) and acidity, while the applications of 0.2 or 0.4 per cent borax improved the shelf-life of fruits. The minimum acidity (0.32%) was recorded in the fruits treated with 0.2 per cent borax and the maximum (0.51%) in control (Raghav and Tiwari, 1998).

Yadav (1998) recorded the highest ascorbic acid content (192.1 mg per 100 g) in guava fruits when trees were treated with combined spray of urea (3%) + borax (0.15%) + NAA (10 ppm).

Chaitanya et al. (1997) recorded the maximum total soluble solid, carbohydrates, starch, total sugars, sugar/acid ratio and ascorbic acid contents of L-49 guava fruits under 0.3 per cent borax spray, whereas, total acidity of the fruits was found to decrease with the foliar sprays of borax.

Borax with 0.2 per cent spray on guava plants cultivar Allahabad Safeda accumulated the maximum quantity of ascorbic acid (219.67 mg/100 g), TSS (11.33%) and total sugars (8.09%) in fruits as compared to ZnSO$_4$ at 0.4% (Ali et al., 1991).

In Sardar guava, the foliar application of borax (0.2%) proved equally effective with respect to TSS (10.33%), total sugars (6.83%) and pectin content (0.85%). Reduction in acidity content of fruits was observed with borax treatments. The plants treated with borax produced the maximum ascorbic acid contents (201.05 mg/100 g) in fruits (Pandey et al., 1988).
Treatment with borax at 0.3 per cent on guava cultivar Allahabad Safeda showed 8.6°Brix TSS, 6.63 per cent total sugars and 0.28 per cent acidity compared to 8.4°Brix, 6.52 and 0.29 per cent, respectively, in control (Ghosh, 1986).

The best results with regards to TSS, acid, reducing and non-reducing sugars, ascorbic acid and pectin were obtained with the application of boric acid at 0.2 per cent as foliar spray alone on guava cultivar Allahabad Safeda (Singh and Chhonkar, 1983).

The best quality fruits with 14.4 per cent, 8.2 per cent and 204.35 mg/100 g TSS, total sugars and ascorbic acid, respectively, were recorded in guava cultivar L-49 when treated with 3 per cent urea + 0.3 per cent boric acid, while the highest acidity (0.48%) was found under control (Singh et al., 1983).

The foliar sprays of boric acid at 0.1-0.4 per cent enhanced the total soluble solids, total sugars, vitamin C and pectin contents of guava fruits cultivar Allahabad Safeda and markedly reduced the fruit acidity (Rajput and Chand, 1976), in which 0.4 per cent boric acid was found more effective.

Boron as boric acid at 0.1 per cent improved the chemical composition of the fruits when guava trees sprayed with 0.1 and 0.2 per cent boric acid (Arora and Singh, 1972).

Haggag et al. (1995) reported that foliar application of boric acid in mango cultivar Hindi Be-Sinnara at 500-1250 ppm at the late bud swelling stage significantly increased the percentage of hermaphrodite flowers, TSS, TSS/acid ratio and total sugar contents. Fruit acidity was increased, but not significantly, while ascorbic acid content was significantly reduced compared with control. The most effective boric acid concentration was 750 ppm.

Singh et al. (1989) applied boric acid at 0, 500, 1000, 2000, 3000, 4000 or 5000 ppm on mango trees cultivar Dashehari at late bud swelling stage. Treatments significantly increased vegetative growth, length and breadth of the
panicle, fruit retention, TSS content, TSS/acid ratio and total sugar contents of the fruits, compared with the control. Application of boric acid above 3000 ppm inhibited the percentage of hermaphrodite flowers and application above 4000 ppm reduced the weight, length and breadth of the fruits and the pulp/stone ratio. The ascorbic acid content of the fruits was significantly reduced in all the treatments, compared with the control. Most of the desirable effects were achieved with 3000 ppm.

Rajput et al. (1976) reported that foliar application of boric acid at different concentrations to the mango cultivar Langra significantly improved growth, flowering, fruiting and fruit quality. The highest values for most of the quality characters were obtained at 0.8 per cent boric acid treatment.

Josan et al. (1995) noted that spray of borax at 0.25, 0.5, 0.75 and 1.0 per cent influences the TSS, acidity and ascorbic acid contents of the lemon fruits. The maximum TSS and acidity (7.5 and 5.48%, respectively) were found in 1.0 per cent borax, while borax at 0.75 per cent resulted in the maximum ascorbic acid content (50.2 mg/100 ml juice).

Boric acid at 25 or 50 mg/l it on Dancy Tangerine mandarin plants three times from September until harvest in January increase d fruit pulp, juice, sugars and ascorbic acid and reduced peel, rag, total acidity and starch content (Singh and Singh, 1981).

Bramachari et al. (1997) evaluated the effectiveness of borax (0.4% or 0.8%) as foliar spray on quality of litchi fruits cv Purbi. Fruit TSS, sugars and ascorbic acid were highest with 0.4 per cent borax. Acidity was reduced by all the treatments, but it was the lowest with 0.4 per cent borax.

The total soluble solids, ascorbic acid, reducing and total sugars of litchi fruits increased with the application of 0.4 per cent borax, however, acidity reduced considerably (Brahmachari and Kumar, 1997).
Kumar and Bhusan (1980) observed increased TSS and decreased acidity content in Thompson Seedless grapes by spraying boron on vines.

An increase in sugar content with 0.1 per cent boron spray during flowering and again during berry development in grape has been observed by Mesheheryakor and Alekhina (1977).

Ravel and Leela (1975) observed reduced acidity contents in grapes as a result of boron sprays (0.2 or 0.4%) at weekly intervals starting from pre blossom stage.

Kamble and Desai (1995) observed that boric acid at 0.1 or 0.2 per cent increased total soluble solids, sugars and vitamin C contents as compared to control, while studying the effects of micronutrients on fruit quality of ber cv Karaka. Fruit colour was also improved by boric acid, i.e., from greenish yellow to golden yellow.

Singh et al. (1989) found that the sprays of boric acid improved total sugars, TSS, acidity and TSS/acidity ratio in ber fruits. These parameters improved to the maximum when boric acid (0.03%) was sprayed along with NAA (50 ppm).

**Effect of combined spray of zinc, copper and boron**

Mann et al. (1985) reported that the foliar spray of ZnSO₄ + FeSO₄ (0.5 + 0.4%) gave the highest TSS (8.3%), whereas ZnSO₄ + CuSO₄ (0.5 + 0.4%) spray showed the lowest acidity (0.61%) in fruit juice of sweet orange cultivar Blood Red.

The maximum total soluble solid contents (7.9%), vitamin C (48 mg/100 g of fruit) and acidity (0.63%) were found with ZnSO₄ + CuSO₄ (0.5 + 0.4%) foliar spray on sweet orange (Manchanda et al., 1972).

Combined spray of ZnSO₄, borax and CuSO₄ significantly improved the quality of fruits, viz., TSS, acidity, ascorbic acid contents when foliar feeding of
0.5 per cent ZnSO₄, 0.2 per cent borax and 0.4 per cent CuSO₄ were conducted on aonla cultivar Francis (Singh et al., 2001).

Zinc sulphate and copper sulphate when applied in combination as foliar spray increased the TSS and acidity of plum fruits and recorded maximum with the zinc sulphate at 0.3 per cent and copper sulphate at 0.2 per cent (Chahil et al., 1996).

The combined spray of ZnSO₄ at 0.25 per cent + FeSO₄ at 0.25 per cent + MgSO₄ at 0.25 per cent + borax at 0.1 per cent on guava cultivar L ucknow-26, resulted in highest total soluble solids (14.15 degrees Brix), total sugars (10.28%), ascorbic acid content (160.08 mg/100 g) as compared to the control (Balakrishnan, 2000). The control treatment had the highest acidity percentage (0.75%), while the above combination gave the lowest (0.56%).

The combined spray of zinc sulphate and borax both at 0.3% resulted in the maximum carbohydrates (7.81%), starch (2.24%), total sugars (5.57%), TSS (12.10 ⁰Brix), sugar/acid ratio (18.08) and vitamin C (135.0 mg/100 g) in L - 49 guava fruits in comparison to combined application of zinc sulphate and borax both at 0.5 per cent, 0.3 + 0.5 per cent, 0.5 + 0.3 per cent, respectively (Chaitanya et al., 1997).

In guava cultivar L-49, among the four nutrients, viz., ZnSO₄, borax MgSO₄ and MnSO₄, the effect of borax with zinc sulphate and magnesium sulphate on TSS and total sugars was more pronounced as compared to others, whereas acidity was more in the control (Ghosh, 1986).

Effect of combined foliar spray of zinc sulphate and boric acid increased the TSS, non-reducing sugars, reducing sugars, ascorbic acid, pectin and acidity of guava cultivar Allahabad Safeda as compared to combined spray of zinc sulphate, boric acid and ammonium molibdate at 0.2, 0.4 and 0.0005 per cent, respectively (Singh and Chhonkar, 1983).
Banik et al. (1997) studied the effect of foliar application of Zn, Fe and B with urea in mango cv. Fazli. All the micronutrients significantly influenced the growth, flowering, fruiting and fruit quality particularly at higher application rates. Application of boron at the higher rate (0.4% B + 1% urea) promoted vegetative growth as indicated by plant height, trunk girth and spread of the young plants. Fruit quality in terms of TSS (20.40 °Brix) and total sugar content (14.92%) was enhanced markedly by the application of B at 0.4 per cent (+ 1% urea) to young mango plants.

Trees of the *Zyzyphus mauritiana* cultivar Pewandi were sprayed by Singh et al. (1989) with boron, zinc and NAA either alone or in combination. The best results with regard to fruit total sugars, TSS, acidity, TSS /acid ratio and ascorbic acid were obtained by spraying with 0.03 per cent boric acid + 0.05 per cent ZnSO₄ + 50 ppm NAA.

Foliar spray of 0.25 per cent each of ZnSO₄, FeSO₄ and MnSO₄ combined with 0.15 per cent boric acid in pomegranate cultivar Ganesh significantly increased the juice content from 65.6 to 74.8 per cent. Fruit acidity was not influenced by micronutrients. The highest TSS (17.35 °Brix) was obtained by applying ZnSO₄ at 0.4 per cent combined with boric acid at 0.2 per cent (Balakrishan et al., 1996).

Foliar application of boric acid + zinc sulphate increased the fruit TSS of pomegranate when ZnSO₄, H₃BO₃, FeSO₄ and MnSO₄ (0.3, 0.2, 0.4 and 0.3%, respectively) were applied in various combinations (Bambal et al., 1991).

Kundu and Mitra (1999) found the highest ascorbic acid (166.65 mg/100 g pulp) content in guava cultivar L-49 with combined spray of copper sulphate at 0.3 per cent, boric acid at 0.1 per cent and zinc sulphate at 0.3 per cent.