Under the present investigation, an attempt was made to study the “Effect of Foliar Application of Micronutrients on Physico-chemical Characters of Guava (Psidium guajava L.) under Subtropical Conditions in the Hills.” The results of the various treatments carried out in the present investigation are discussed in this chapter in the light of the findings reported by other workers.

5.1 QUANTITATIVE CHARACTERS

5.1.1 Fruit set

The present investigation has revealed that the percentage of fruit set increased gradually in the subsequent higher concentrations of micronutrients sprays, alone or in their combinations. The highest percentage of fruit set (80.05% and 80.29%) was recorded under $Z_3$ (0.4% Zinc sulphate) treatment with an increase of 18.42% and 16.72% over control during the years 2005 and 2006, respectively. The above findings are in close conformity with the results reported by Bhatia et al. (2001), El-Sherif et al. (2000), and Kundu and Mitra (1999) in guava cv. L-49; Sharma et al. (1993 and 1991) and Singh and Chhonkar (1983) in guava cv. Allahabad Safeda.

The beneficial effect of zinc in increasing fruit set might be due to the higher availability of photosynthates. These chemicals are also associated with hormone metabolism in plants which promotes synthesis of auxin necessary for fruit set and growth (Singh et al., 2001 and Singh and Rajput, 1976).

5.1.2 Fruit development

In present investigation, the increase in growth rates during the course of fruit development was noted with all micronutrient treatments. The maximum
influence in growth rate was exhibited by $Z_3C_3B_3$ (0.4% Zinc sulphate + copper sulphate + boric acid) treatment during both the years of experimentation. The beneficial results of combined application of micronutrients could be attributed to the positive effect of these nutrients on plant metabolism. The response of boric acid treatment is in agreement with the findings of Raghava and Tiwari (1998), Kundu and Mitra (1999) and Chaitanya et al. (1997) in guava; Bramachari et al. (1997) and Mann et al. (1985) in sweet orange.

Copper and zinc is reported to influence the permeability of cell wall and thus permits more water to inter inside the cells and thereby increasing the fruit size (Babu et al., 1982).

Rapid increase in fruit size (length and diameter) under boric acid application could be attributed to its involvement in the cell division, cell elongation and higher moisture content of the fruits (Rajput et al., 1976). Boron is also known to be associated positively with the early stages of fruit development (Heinicke, 1942).

5.1.3 Fruit drop

The percentage of fruit drop was found to decrease in all the treatments and the arresting power increases along with increase in concentration of micronutrients. The minimum percentage (33.38% and 33.61%) of fruit drop was recorded when the trees were sprayed with $Z_3C_3B_3$ treatment (0.4% Zinc sulphate + copper sulphate + boric acid) being statistically at par with $Z_2C_2B_2$ (0.3% Zinc sulphate + copper sulphate + boric acid) . These reduced 29.49% and 29.08% fruit drop over control during the years 2005 and 2006, respectively. The response of zinc sulphate, copper sulphate and boric acid treatment towards control of fruit drop is in agreement with the findings of Singh and Vashishta (1997) and Singh and Alhawat (1996) in ber, Malik et al. (1999) in Kinnow and Hassan (1995) in Washington Naval Orange, Sharma et al. (1991) and Mansour

The degree of fruit drop was adversely affected by the doses supplied and the total absorption of mineral nutrients (Pandey and Sharma, 1989). Zinc application was reported to reduce the fruit drop with an increased biosynthesis of IAA in zinc treated plants (Awasthy et al., 1975). Copper is one of the important constituent of plastocynin, which is the main component of electron transport protein of photo system and thus helps in the process of photosynthesis and hence building up of carbohydrate in the plants. Regarding to the role of copper, Pelgonen (1964) has reported that it stimulates the catalase activity and there by reduces the fruit drop. Boric acid can be attributed to the indirect action of boron in auxin synthesis that delayed the formation of abscission layer during the early stages of fruit development (Skoog, 1940) and thus, helps in preventing fruit drop.

5.1.4 Fruit retention

In the present investigation, it has been observed that the foliar sprays of $Z_3C_3B_3$ (0.4% Zinc sulphate + copper sulphate + boric acid) treatment on trees, at full bloom stage, gave the maximum fruit retention (66.62% and 66.39%) with an increase of 26.51% and 26.19% over control during the year 2005 and 2006, respectively, which was at par with $Z_2C_2B_2$ treatment (0.3% Zinc sulphate + copper sulphate + boric acid) during the year 2006. An increase in fruit retention was also reported by various workers with the foliar application of zinc sulphate, copper sulphate and boric acid alone or in combination, in many fruits, viz., guava (Singh and Singh, 2002; El-Sherif et al., 2000 and Sharma et al., 1993 and 1991), Kinnow (Verma et al., 1980; Malik et al., 2000 and 1999), ber (Singh and Vashishtha, 1997) and plum (Chahil et al., 1996).

Zinc, copper and boron influenced many physiological processes which resulted in increased fruit retention. The effect of C/N ratio on growth and
fruitfulness is parallel by its effect on physiological activities to check the abscission of fruits (Randhawa and Dhillon, 1964).

The zinc helps in the synthesis of triptophan which serves as precur sor for auxin synthesis (Skoog, 1940) might have retarded abscission of fruits and thereby increased fruit retention. A definite relationship between the auxin contents of the seeds and the abscission of the fruits during various stages of development has been established by Luckwill (1948). High amount of auxin appears in the seeds after fruit set coincide with the formation of endosperm may inhibit fruit drop and thereby improves the retention of fruits on the trees.

Copper might have also ushered in an increase in fruit retention as copper controls peroxidation of lipids through redox reaction and hence reduced the senescence. Boron is known to be associated positively with the early stages of fruit development, resulting in increased fruit retention (Heinicke, 1942).

5.1.5 Fruit volume

Present findings showed that the increasing concentration of micronutrients alone or in combination gave the increased fruit volume over control. The pronounced effect on the volume of fruits (103.44 ml and 103.97 ml) was recorded under Z₃ (0.4% Zinc sulphate) treatment with an increase of 42.09% and 37.78% over control, which was at par with the treatment Z₃B₃ (0.4% Zinc sulphate + boric acid) during both the years. An increase in the fruit volume on account of various micronutrient sprays was also recorded by Yadav (1998), Raghava and Tiwari (1998) and Sharma et al. (1991) in guava; Singh and Vashishtha (1997) in ber; Singh et al. (1990) in Kagzi lime; Rana and Sharma (1979) in grape and Awasthy et al. (1975) in litchi.

The foliar spray of higher concentration of zinc sulphate applied singly or in combination with boric acid, brought about a definite increase in fruit length, diameter and weight of fruits, and ultimately led to an increased fruit volume.
5.1.6 Specific gravity

Specific gravity of the fruits in all the treatments followed a gradual decreasing trend over control. The minimum specific gravity (1.10 and 1.12) of L-49 fruits was found with Z₃ (0.4% Zinc sulphate) treatment during both the years. The reduction of 12.70% and 10.40% over control was noticed under this treatment. However, trees sprayed with tap water, tended to produce fruits having higher specific gravity. The minimum specific gravity of fruits under the zinc sulphate treatment, presumably, because of the effect of the zinc on the internal quality of the fruits, which affects the weight and volume of the fruits. The specific gravity of the fruit depends on fruit density which may be affected by total seed contents of the fruit, rainfall and cultural practices.

5.1.7 Fruit size

The results of present study indicate that the combined application of zinc sulphate, copper sulphate and boric acid at higher concentration s, i.e.; Z₃C₃B₃ (0.4% Zinc sulphate + copper sulphate + boric acid) treatment at full bloom stage produced the fruits with larger size in respect of length (6.91 cm and 7.02 cm) and diameter (6.50 cm and 6.53 cm) of fruits during both the years. There was an increase of 17.72% and 15.84% in fruit length and 19.93% and 19.16% in fruit diameter over control during the years 2005 and 2006, respectively. These results are in line with Kundu and Mitra (1999); Chaitanya et al. (1997) and Sharma et al. (1993) in guava; Singh et al. (2001) in aonla; Bramachari et al. (1997) and Chandel (1987) in litchi and Mann et al. (1985) in sweet orange.

Easy availability of nutrients to the plants caused subsequent rapid fruit development (Singh et al., 2001). An increase in size (length and diameter) of fruits on account of zinc sulphate, copper sulphate and boric acid application could be attributed to its involvement in the cell division, cell elongation and moisture content of the fruits (Josan, 1991).
Zinc is reported to regulate the semi permeability of cell walls thus mobilizing more water into the fruits and thereby increasing the diameter of fruits (Babu et al., 1982). The permeability of cell wall was also influenced by copper. Active salt absorption, maintenance of water relation, cellular differentiation and photosynthesis, all has been suggested as a functions of boron. Being a non metal, it may only influence the functions rather than taking any active part in the system, resulting in increased fruit size in terms of length and diameter of fruits (Nijjar, 1990).

5.1.8 Fruit weight

Present findings revealed that the trees treated with combined spray of zinc sulphate, copper sulphate and boric acid @ 0.4% (Z$_3$C$_3$B$_3$) produced the heaviest fruits (120.92 g and 122.84 g) with an increase of 31.61% and 28.66% over control, during the year 2005 and 2006, respectively. The response of these nutrients is in accordance with earlier results in different fruit crops viz., Kundu and Mitra (1999), Chaitanya et al. (1997) and Ghosh (1986) in guava; Singh et al. (2001) in aonla; Chahil et al. (1996) in plum; Singh and Khan (1990) in mango; Singh et al. (1990) in Kagzi lime and Chandel (1987) in litchi.

An increase in fruit weight with combined foliar application of zinc sulphate, copper sulphate and boric acid might be due to rapid cell division and translocation of sugars resulted into higher pulp content. It could also be due to higher mobilization of food and minerals from other parts of the plants towards the developing fruits that are extremely active metabolic sink. Zinc has been reported to involve in protein synthesis (Menzel and Kirby, 1978) and maintaining higher level of auxin in various parts of the fruits, ought to have helped in increasing optimum fruit growth (Awasthy et al., 1975). Copper, due to its positive effects, has been considered necessary for the formation of carbohydrates. According to Mishra and Khan (1981), boron acts as booster to the fruit weight. Boron brings about inactivation of superfluous growth by
formation of complex compounds (Singh et al., 1983) might have resulted in bolder fruits. An increase in fruit size due to the application of zinc and boron may probably be due to the more uptake of oxygen and translocation of sugars as suggested by O’Kelly (1957).

5.1.9 Number of fruits per kg

The number of fruits/kg was significantly decreased by various sprays of micronutrients. The minimum number of fruits/kg (8.27 and 8.14) were recorded in the trees receiving Z₃C₃B₃ (0.4% Zinc sulphate + copper sulphate + boric acid) treatment at full bloom stage during both the years. Further, the decrease in foliar spray concentration of these micronutrients increases the number of fruits/kg. The total reduction over control by this treatment was 23.99% and 28.62% during the years 2005 and 2006, respectively. For instance, the positive effect of combined application of micronutrients has been reported by Singh and Khan (1990) in mango.

The reduction in the average number of fruits/kg is presumed to be due to an increase in fruit size and thereby fruit weight as micronutrients help in rapid expansion in the size of cells.

5.1.10 Fruit yield per tree

The fruit yield increased successively with the increase in the dose of combined foliar spray of zinc sulphate, copper sulphate and boric acid and gave maximum yield (171.02 kg and 173.28 kg/tree) with Z₃C₃B₃ (0.4% Zinc sulphate + copper sulphate + boric acid) treatment during both the years. The increasing percentage of fruit yield over control was recorded as 49.64% and 49.88% during the year 2005 and 2006, respectively.

An increase in yield by applying zinc, copper and boron either singly or in combinations has been reported by many workers in guava and several other fruit crops, viz., Balakrishnan (2002), Kundu and Mitra (1999), Chaitanya et al.
(1997) and Ghosh (1986) in guava; Chahil et al. (1996) in plum; Balakrishnan et al. (1996) and Bambal et al. (1991) in pomegranate and Mann et al. (1985) in sweet orange.

An increase in photosynthetic activity of leaves and consequently the yield as a result of zinc, copper and boron seems to be obvious as these nutrients involve in maintaining an optimum balance of nutrients and growth substance in the plants for better growth.

Treatment of zinc, copper and boron influences the fruit set, fruit retention, growth and development of fruits resulted into the more number of large size fruits to reach the stage of harvest. An increase in fruit weight and consequently the yield by spraying with combined application of zinc, copper and boron might be due to the accumulation of dry matter in the fruits, rapid cell division and elongation.

5.1.11 Fruit yield per hectare

Micronutrients are known to accelerate the metabolic activities of plants, thereby mobilizing the yields and other potentialities of plants (Chaitanya, 1984). Present findings showed that \( \text{Zn}_3\text{Cu}_3\text{B}_3 \) (0.4\% Zinc sulphate + copper sulphate + boric acid) treatment gave significantly higher fruit yield/ha (473.72 and 479.97 q/ha) compared to \( \text{C}_0 \) (control) during both the years. The increase in fruit yield/ha was to the tune of 49.64\% and 49.88\% over control during the years 2005 and 2006, respectively. Various workers have reported an increase in yield of different fruit crops positively with minor elements’ sprays, viz., guava (Kundu and Mitra, 1999, and Chaitanya, 1984) and litchi (Chandel, 1987). The yield attribute shows a positive correlation with the number of fruits/kg and yield/tree and these were jointly contributing the yield of fruits per hectare, to produce final outcome.
5.2 QUALITATIVE CHARACTERS

5.2.1 Total soluble solids (TSS)

As regards to the effect of different micronutrients on fruit quality, it was found that foliar feeding of micronutrients showed significant impact on TSS content of fruits. The highest total soluble solids (11.68\textsuperscript{0}Brix and 11.87\textsuperscript{0}Brix) was noted in the Z\textsubscript{3} (0.4\% Zinc sulphate) treatment which gave the 19.67\% and 19.30\% increase over control during the years 2005 and 2006, respectively.


The effectiveness of the application depends on the ability of the micronutrients to penetrate through the leaf cuticle into the mesophyll cells and thus eliciting a particular response. It is an established fact that zinc is credited with definite role in the hydrolysis of complex polysaccharides into simple sugars, synthesis of metabolites and rapid translocation of photosynthetic products and minerals from other parts of the plants to developing fruits. Kumar and Bhushan (1980) suggested that foliar application of ZnSO\textsubscript{4} increased the TSS contents by increasing photosynthetic activity of the plants resulting into the production of more sugars.

5.2.2 Acid content

The fruits of all the treatments showed a general decline of acidity as the concentration of micronutrients increased. The lowest percentage (0.395\% and 0.404\%) of acid was recorded with the spray of Z\textsubscript{3} (0.4\% Zinc sulphate) treatment. The maximum reduction in acid content (28.57\% and 27.21\%) was obtained under Z\textsubscript{3} treatment (0.4\% Zinc sulphate) during both the years. The results are in agreement with the findings of previous workers who found that...

The acid under the influence of chemicals might have either been rapidly converted into sugars and their derivatives by the reactions involving reversal of glycolytic pathway (Ruffner et al., 1975) or might be used in respiration or both.

Being a major substrate of respiration, the decline in the malic acid during fruit ripening might be the results of an increase in membrane permeability which allows acids to be stored in the respiring cells (Kliewer, 1971). The downwards trend in the levels of organic acids was also possibly due to dilution effect with the increase in volume of fruits in these treatments.

5.2.3 Total sugars

The spraying of zinc sulphate alone at the higher concentration enhances the total sugar contents of the fruits in comparison to other nutrients and their combinations. The present findings show that Z₃ (0.4% Zinc sulphate) treatment gave the significantly higher total sugars (6.31% and 6.40%) in guava fruits as compared to all other treatments during both the years. The increase in total sugars under this treatment was to the tune of 29.83% and 29.82% over the control during both the years 2005 and 2006, respectively. It is in agreement with the findings of Das et al. (2001), Singh and Brahmachari (1999), Kundu and Mitra (1999), Chaitanya et al. (1997) and Singh and Chhonker (1983) in guava, and Kumar and Pathak (1992) grape.

The perceptible increase in sugar contents through the foliar feeding of zinc sulphate might be due to the active synthesis of triptophan in the presence of zinc, the precursor of auxin, which in turn causes an increase in the rate of chlorophyll synthesis which ultimately accelerates the photosynthetic activity. Zinc also helps in enzymatic reactions like transformation of carbohydrate.
Foliar spray of micronutrients increased the sweetness of fruits, which was due to more intensive transformation of starch into sugars and its translocation into the fruits (Rusko, 1968). The low acid in fruits clearly suggested that they were sweeter in taste.

5.2.4 Sugar-acid ratio

The effects of micronutrients when sprayed singly or in combination were found promising. In the present findings, the trees treated with Z₃ (0.4% Zinc sulphate) treatment resulted into the maximum sugar/acid ratio (15.97 and 15.84). There was 82.10% and 78.79% increase in sugar/acid ratio over the control during the years 2005 and 2006, respectively. The present findings are also supported from the work of Lal and Sen (2001), Kundu and Mitra (1999) in guava and Singh et al. (1989) in ber.

Due to an increase in total sugars and decrease in acid contents, there was also an increase in the sugar/acid ratio. Response of zinc sulphate application towards the sugar/acid ratio was in accordance with the increase in the total sugars and decrease in acidity of fruits with the higher concentration of zinc sulphate.

5.2.5 Pectin

Sprays of micronutrients either singly or in combination significantly influence the pectin content of L-49 guava fruits. It is observed that the pectin content was increased with the increase in the concentration of micronutrients sprays from 0.2% to 0.4%. As a result, B₃ (0.4% Boric acid) treatment proved superior (1.643% and 1.656%) in pectin content with an increase of 166.72% and 161.20% over control, during the years 2005 and 2006, respectively. Pandey et al. (1988), Singh and Chhonker (1983) and Rajput and Chand (1976) also suggested an improvement in pectin content of guava fruits by foliar sprays of boron.
Boron has been found to be associated with plant system in various ways and increased the production of cellulose and pectin in the fruits, might be the possible reason of increased pectin contents in the fruits (Lee and Kim, 1991). Boron increased the pectin contents in the fruits as it facilitates the process of translocation of photosynthates from leaves to the young fruits, which are partly used for the synthesis of pectic substances (Whiting, 1970). Synthesis of pectic substances in the cells is due to the physiological role of boron; Winfield (1945) also reported a relationship between boron and pectic substances in plants.

5.2.6 Vitamin C

The increase in vitamin C content of the fruits was increased as the concentration of micronutrient spray increased in all the treatments. An appreciable increase in vitamin C content was recorded in the fruits of boric acid treated trees. The maximum content of vitamin C (172.95 mg and 174.16 mg per 100 g) was noted under B₃ (0.4% Boric acid) treatment with 24.27% and 18.17% increase over control during the years 2005 and 2006, respectively. Singh and Brahmachari (1999), Pandey et al. (1988), Ghosh (1986), Singh and Chhonker (1983) and Rajput and Chand (1976) in guava; Singh et al. (2001) in aonla; Singh et al. (1989) and Shukla (1985) in ber; Josan et al. (1995) in lemon, were also found such beneficial effect of boron in increasing the vitamin C content.

A notable characteristic of boron has been found to affect the photosynthesis of plants (Lal and Patil, 1948). Movchan and Soboroikova (1972) reported that boron enhances nitrogen uptake and thus facilitates the process of photosynthesis, which ultimately led to the accumulation of carbohydrate and helped in increasing the sugar contents of the fruits. It also stimulates the functioning of number of enzymes in the physiological processes which probably caused an increase in ascorbic acid contents of the fruits. The higher ascorbic acid (vitamin C) levels during early stages of fruit growth may be
attributed to adequate supply of hexose sugars via photosynthetic activity (Sharma, 1984).

5.2.7 Pulp weight

The present investigation revealed that all the micronutrient sprays were found significant over control. The Z₃C₃B₃ (0.4% Zinc sulphate + copper sulphate + boric acid) treatment produced the maximum pulp weight with 118.81 g and 120.75 g in L-49 guava fruits with an increase of 32.25% and 29.27% over control during the years 2005 and 2006, respectively. The above finding is in close conformity with the investigation of Brahmachari and Kumar (1997) in litchi and Singh et al. (2001) in ber fruits.

Zinc sulphate, copper sulphate and boric acid in combination increase the fruit pulp. The increase in pulp percentage might be due to more absorption of water and food substances and increased volume of intercellular spaces in the pulp (Sarkar et al., 1984). The increase may be due to enhanced synthesis of metabolites, increased absorption of water and mobilization of sugars and minerals in the expended cells and intercellular spaces of the mesocarp.

Boron either singly or in combination also helped in maximum increase in pulp by accelerating the transportation of photosynthates from leaf to the developing fruits (Gauch and Dugger, 1953; Mitche ll et al., 1953 and Dugger, 1983).

5.2.8 Seed weight

The present studies have shown that the lowest seed weight (2.02 g) was recorded under Z₃ (0.4% Zinc sulphate), B₂ (0.3% Boric acid) and B₃ (0.4% Boric acid) treatments during the year 2005 while during the year 2006, the lowest weight of seed (2.02 g) was recorded under Z₃ (0.4% Zinc sulphate) treatment only. Though, the foliar sprays of micronutrients gave a slight seed weight differences in favour of the zinc and boron treated trees, but the average
weight of seeds extracted was not increased significantly by foliar sprays of these micronutrients. The reduction in seed content by zinc and boron treatments shows parthenocarpic effects to some extent.

5.2.9 Pulp-seed ratio

Present studies have shown that the spray of micronutrients singly or in combination influences the proportion of fruit pulp and seed in the fruits of L -49 guava. The highest pulp/seed ratio (56.39) was noticed under $Z_3C_3B_3$ (0.4% Zinc sulphate + copper sulphate + boric acid) treatment with an increase of 28.04% which was at par with $Z_3$ (0.4% Zinc sulphate), $B_2$ (0.3% Boric acid), $B_3$ (0.4% Boric acid), $Z_2B_2$ (0.3% Zinc sulphate + boric acid), $Z_3B_3$ (0.4% Zinc sulphate + boric acid) and $Z_2C_2B_2$ (0.3% Zinc sulphate + copper sulphate + boric acid) treatments during the years 2005.

During the year 2006, the highest pulp/seed ratio (57.76) was noticed under $Z_3C_3B_3$ (0.4% Zinc sulphate + copper sulphate + boric acid) treatment with an increase of 28.01% which was at par with $Z_3$ (0.4% Zinc sulphate), $B_2$ (0.3% Boric acid), $Z_2B_2$ (0.3% Zinc sulphate + boric acid), $Z_3B_3$ (0.4% Zinc sulphate + boric acid) and $Z_2C_2B_2$ (0.3% Zinc sulphate + copper sulphate + boric acid) treatments. The results of the present study are in line with the findings of Singh et al. (2001) in ber fruits.

Due to the increase in pulp weight, there was also an increase in the pulp/seed ratio of the fruits. Response of combined application of zinc sulphate, copper sulphate and boric acid produced the pulp/seed ratio was found parallel to those of pulp weight and seed weight of fruits under these treatments.

5.2.10 Moisture content

Although, no significant differences were found with micronutrient sprays on the moisture percentage of the fruits, the trees treated with $Z_3C_3B_3$ (0.4% Zinc sulphate + copper sulphate + boric acid) treatment produced the fruits having
maximum moisture content (83.63%) during the year 2005, while during the year 2006, the highest percentage of moisture (83.07%) was obtained in the fruits taken from the trees sprayed with C1 (0.2% Copper sulphate) treatment. Malik et al. (2000) reported that moisture content in citrus fruits increased with the zinc application. The variation in moisture content in the fruits may be due to the plot variability, position of plants and various external and internal factors prevailing there (Singh and Singh, 1977).

5.2.11 Shape and flesh colour

With the approach of maturation, the most obvious change which takes place in the fruits is the degradation of chlorophyll and is accompanied by the biosynthesis of one or more pigments usually either anthocynins or carotenoids which are localized within the vacuole and chloroplast, contribute to the sensory qualities of the fruits. The shape and flesh colour of fruits were not affected by foliar application of micronutrients consisting zinc sulphate, copper sulphate and boric acid individually or in combination.