Effects of Foliar Sprays of Micronutrients on the Quantitative and Qualitative Characters of Guava cv. L-49

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Abstract—*This study was conducted at Horticultural Research Centre and department of Horticulture, HNB Garhwal University, Srinagar (Garhwal), UK, India. The experiment was carried out for two successive years 2005 and 2006 during the rainy season (Ambe Bahar) of guava cv. Lucknow-49 (Sardar Guava). The experiment consisted of 10 treatment combinations of 3 micronutrients viz., zinc sulphate, copper sulphate and boric acid at 0.2%, 0.3% and 0.4% alone and spray of plain tap water as control. The maximum fruit set and fruit volume improved fruit retention and maximum fruit yield per tree and per hectare. While, maximum fruit length and diameter, weight and minimum counts of fruits /kg was associated with boric acid at 0.4%. However, sprays of Zn 0.4% resulted into maximum TSS, total sugars, sugar acid ratio and in guava fruits, whereas, Boron at 0.4% shows maximum vitamin C and pectin content in fruits.*

1. INTRODUCTION

Concept of global village and advances in technology enable exporters to supply markets around the world with high quality product. To compete in domestic as well as foreign market requirements, quality fruit production is becoming a major objective of the day in fruit industry. The tree crops, grown under field conditions, are subjected to numerous nutrients deficiencies which influence the tree growth, tissue composition, fruit production and quality. Nutritional deficiencies are closely associated with the poor plant growth and fruit set, heavy fruit drop, inferior quality of produce and also make the tree vulnerable to diseases, pests and other disorders. Availability and uptake of nutrients by the plants is influenced by several external, internal and other factors such as climate, soil environment, i.e.; physical characters such as texture, drainage, soil moisture, temperature, aeration and soil erosion; the chemical and biological properties like soil reaction, electric conductivity, organic matter status, microbial activity and available nutrients, rate of transpiration, nutritional status of the plant, its nutritional requirement, rootstock and genotype etc.

It has been noticed that guava suffers severely from deficiency of micronutrients specially zinc and manganese which reduces the quality of fruits. However, very little work has been done on the foliar application of these nutrients in guava trees. The response of guava plant to these nutrients may vary from region to region and pocket to pocket. Most consumers would initially judge acceptability of products on their appearance, flavour, texture and perceived nutritional benefits. Each of these attributes is influenced by nutrients received by the plants. The production of good quality fruits in terms of fruit size, weight and nutritive value may be increased with the help of foliar application of micronutrients. In view of the above facts, the present study was conducted on rainy season crop (Ambe Bahar) of cultivar Lucknow-49 (Sardar Guava).

2. MATERIALS AND METHODS

The experiment was conducted at Horticultural Research Centre and Department of Horticulture, HNB Garhwal University, Srinagar (Garhwal), UK, India. Twelve year old sixty six bearing guava trees (cv. L-49) of uniform vigour maintained under similar cultural schedule were selected for the present studies. The experiment consisted of 10 treatment combinations of 3 micronutrients viz., zinc, copper and boron at 0.2%, 0.3% and 0.4% alone and spray of plain tap water as control. Aqueous solutions of zinc, copper, boron and tap water were sprayed at the time of full bloom on rainy season crop (Ambe Bahar). The experiment was laid out in Randomized Block Design (RBD). All the treatments were replicated thrice in the present experimentation. Sprays under treatment were done at full bloom stage in early morning with the help of foot sprayer @ six liters per tree to ensure the maximum absorption of nutrients through the leaves. Each tree was sprayed thoroughly in such a way as to completely drench it with the spray solution.

The percentage of fruit set and fruit drop was recorded after fifteen days of micronutrient sprays. The data on fruit development was recorded in terms of their length and diameter (cm) with the help of Vernier Caliper at an interval of fifteen days from the date of foliar sprays of micronutrients till harvesting. The data on fruit volume were recorded using water dispersal method. The specific gravity was calculated by dividing the average fruit weight with average fruit volume. Fruit size in terms of length and width were recorded with help of vernier caliper and average size was expressed in cm. The weight of fruits was measured by using electronic top pan balance (Model–z-400) and later on the average was expressed in grams. The yield was calculated on the basis of number of fruits present on the tree by multiplying it with the average weight of fruits. Calculation of fruit yield quintal per hectare was done by multiplying the yield per plant with 277. The weight of pulp and seeds was measured and later on the average was expressed in grams. Total soluble solids (TSS) were measured by hand refractometer and values are corrected at 20^0C. Acidity was determined by titrating the fruit pulp against 0.5 N/NaOH and expressed as percent malic acid. Ascorbic acid was analysed according to Rangana [19] and expressed as vitamin C mg/100 g. Similarly, soluble sugars were determined by the method of Mc Cready *et al*. [16]. The mean of two successive years (2005 and 2006) data were computed at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

The present investigation has revealed that the percentage of fruit set increased gradually in the subsequent higher concentrations of micronutrients sprays singly. The highest percentage of fruit set (80.17%) was recorded under foliar application of 0.4% concentration of zinc sulphate with an increase of 17.57% over control (Table 1). The above findings are in close conformity with the results reported by Bhatia *et al*. [3] and El-Sherif *et al.* [8] in L-49. 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*., 23 and Singh and Rajput, 25).

The increased growth rate during the fruit development was noted with all micronutrient treatments. The maximum influence in growth rate was noticed under foliar application of 0.4% concentration of zinc sulphate and boric acid. The response of boric acid treatment is in agreement with the findings of Kundu and Mitra [12] and Chaitanya *et al*. [6] in guava. 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*., 1).

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 of fruit drop (37.91%) was recorded under foliar application of 0.4% concentration of zinc sulphate being statistically *at par* with 0.3% concentration of zinc sulphate (Table 1). These treatments reduced 19.97% and 19.46% fruit drop over control, respectively. The response of zinc sulphate treatment towards control of fruit drop is in agreement with the findings of Sharma *et al.* [21] in guava.

The foliar application of 0.4% concentration of zinc sulphate at full bloom stage, gave the maximum fruit retention (62.09%) with an increase of 15.23% over control (Table 1). Singh and Singh [26]; El-Sherif *et al.* [8] and Sharma *et al.* [21] were also reported similar findings. The zinc helps in the synthesis of triptophan which serves as precursor for auxin synthesis (Skoog, 27) 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 [15].

The pronounced effect on the volume of fruits (103.70 ml) was recorded under 0.4% concentration of zinc sulphate spray with an increase of 39.93% over control. An increase in the fruit volume with the foliar application of various micronutrients was also reported by Raghava and Tiwari [18] and Sharma *et al*. [21] in guava. The foliar application 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.

Specific gravity of the fruits in all the treatments followed a gradual decreasing trend over control. The minimum specific gravity (1.11) of L-49 fruits was found with 0.4% concentration of zinc sulphate spray. The reduction of 11.55% over control was noticed under this treatment. However, trees sprayed with tap water (control), 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.

The foliar application of boric acid at full bloom stage produced the fruits with larger size in respect of length (6.79 cm) and diameter (6.29 cm) of fruits (Table 1). There was an increase of 12.22% in fruit length and 13.35% in fruit diameter over control. These results are in line with Kundu and Mitra [12] and Chaitanya *et al*. [6] in guava. 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, 9). 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*., 1). Active salt absorption, maintenance of water relation, cellular differentiation and photosynthesis, all has been suggested as a functions of boron.

The trees treated with spray of boric acid at 0.4% concentration produced the heaviest fruits (116.92 g) with an increase of 19.87% over control (Table 1). An increase in fruit weight could 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. The number of fruits/kg was significantly decreased in all the treatment in comparison of control. The minimum number of fruits/kg (8.55) was recorded in the trees treated with 0.4% concentration of boric acid 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 19.94%. For instance, the positive effect of combined application of micronutrients has been reported by Singh and Khan [24] 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.

Table 1: Influence of foliar application of micronutrient on quantitative characters of guava cv. L-49

Ments	Fruit set (%)	Fruit drop (%)	Fruit retention (%)	Fruit volume (ml)	Specific gravity (%)	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits/kg	Fruit yield/tree (kg)	Fruit yield/ha (q)
Zn (0.2%)	79.37	38.28	61.72	94.33	1.15	6.41	5.76	108.21	9.25	131.58	364.47
Zn (0.3%)	79.82	38.15	61.85	97.14	1.14	6.49	5.90	110.26	9.07	135.31	374.81
Zn (0.4%)	**80.17**	**37.91**	**62.09**	**103.70**	**1.11**	6.70	6.17	114.88	8.71	148.08	410.36
Cu (0.2%)	78.61	41.73	58.27	84.53	1.24	6.25	5.62	105.12	9.52	122.35	338.90
Cu (0.3%)	78.78	41.36	58.64	86.61	1.23	6.30	5.64	106.11	9.43	126.18	349.52
Cu (0.4%)	79.19	41.26	58.91	94.39	1.20	6.62	6.08	113.23	8.83	140.35	388.76
B (0.2%)	73.27	39.28	60.72	93.06	1.18	6.50	5.88	110.20	9.08	135.77	376.07
B (0.3%)	73.51	38.98	61.02	97.67	1.16	6.62	6.05	113.01	8.85	140.03	387.14
B (0.4%)	74.19	38.77	61.23	101.65	1.15	**6.79**	**6.29**	**116.92**	**8.55**	**150.02**	**415.55**
Control	**68.19**	**47.37**	**52.63**	**74.07**	**1.26**	**5.96**	**5.45**	**93.68**	**10.68**	**114.95**	**318.41**
S Em. ±	**0.281**	**0.152**	**0.154**	**0.507**	**0.005**	**0.031**	**0.049**	**0.612**	**0.052**	**0.907**	**2.489**
CD at 5%	**0.512**	**0.277**	**0.280**	**0.923**	**0.009**	**0.056**	**0.090**	**1.114**	**0.095**	**1.651**	**4.530**

The fruit yield increased successively with the increase in the dose of foliar spray of boric acid and gave maximum yield (150.02 kg/tree) with 0.4% concentration of zinc sulphate spray (Table 1). The increasing percentage of fruit yield over control was recorded as 23.37%. An increase in yield by foliar application of zinc, copper and boron either singly or in combinations has been reported by Balakrishnan [2] and Kundu and Mitra [12], in guava.

Present findings showed that the 0.4% concentration of boric acid spray gave significantly higher fruit yield/ha (415.55 q/ha) compared to control (Table 1). The increase in fruit yield/ha was to the tune of 30.45% over control. Kundu and Mitra, [12] and Chaitanya, [5] have also reported an increase in fruit yield positively with foliar application of minor elements. 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.

As regards to the effect of different micronutrients on fruit quality, it was found that foliar feeding of micronutrients showed significant impact on TSS, acidity, total sugars and sugar acid ratio content of fruits. The highest total soluble solids (11.78^0 Brix) were noted in the 0.4% concentration of Zinc sulphate treatment, which gave the 19.45% increase over control (Table 2). 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 [11] suggested that foliar application of $ZnSO_4$ increased the TSS contents by increasing photosynthetic activity of the plants resulting into the production of more sugars.

All the treatments showed a general decline of fruit acidity with the concentration of increased micronutrients. The lowest acid of fruit 0.400% was recorded with the spray of 0.4% zinc sulphate. The maximum reduction in acid content (27.89%) was also obtained under 0.4% zinc sulphate treatment (Table 2). Lal and Sen [13] reported that the foliar application of zinc sulphate reduced the acid content in guava fruits. 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, 10). 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.

Foliar application of zinc sulphate alone at the higher concentration enhances the total sugar contents of the fruits and maximum sugar/acid ratio (15.90) in comparison to other nutrients and their combinations. The present findings show that the 0.4% concentration of zinc sulphate treatment gave the significantly higher total sugars (6.36%) in guava fruits as compared to all other treatments. The increase in total sugars under this treatment was to the tune of the 29.82% over the control (Table 2). It is in agreement with the findings of Singh and Brahmachari [22] and Kundu and Mitra [12] in guava. 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 (Skoog, 27).

Table 2: Effect of foliar application of micronutrients on qualitative characters of guava cv. L-49

Treatments	TSS (^{0}Brix)	Acidity (%)	Total sugars (%)	Sugar/acid ratio	Vitamin C (mg/100 g)	Pulp weight (g)	Seed weight (g)	Pulp/seed ratio	Pectin (%)
Zn (0.2%)	10.75	0.431	5.60	13.00	148.54	106.18	2.03	52.38	1.037
Zn (0.3%)	11.31	0.419	5.88	14.05	153.45	108.23	2.03	53.35	1.163
Zn (0.4%)	**11.78**	**0.400**	**6.36**	**15.91**	156.60	112.86	**2.02**	**55.94**	1.218
Cu (0.2%)	10.45	0.449	5.30	11.81	156.06	103.02	2.10	49.11	0.828
Cu (0.3%)	10.68	0.445	5.59	12.56	162.60	104.02	2.09	49.72	0.848
Cu (0.4%)	10.87	0.443	5.75	12.98	166.07	111.12	**2.11**	52.78	0.952
B (0.2%)	10.72	0.434	5.56	12.81	165.42	108.14	2.06	52.48	1.243
B (0.3%)	11.04	0.431	5.67	13.14	168.81	110.97	2.03	54.60	1.426
B (0.4%)	11.42	0.420	5.88	13.99	**173.56**	**114.90**	2.03	54.60	**1.650**
Control	**9.85**	**0.554**	**4.89**	**8.83**	**143.27**	**91.62**	2.06	**44.58**	**0.625**
S Em. ±	**0.021**	**0.003**	**0.033**	**0.143**	**0.480**	**0.619**	**0.025**	**0.888**	**0.007**
CD at 5%	**0.039**	**0.005**	**0.059**	**0.260**	**0.874**	**1.126**	**0.045**	**1.617**	**0.012**

Sprays of micronutrients significantly influence the pectin content of L-49 guava fruits. It was observed that the pectin content increased with the increase in the concentration of micronutrients sprays from 0.2% to 0.4%. Boric acid treatment at 0.4% concentration was proved superior (1.650%) in pectin content with an increase of 163.96% over control (Table 2). Pandey *et al*. [17] also reported an improvement in pectin content of guava fruits by foliar application 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, 14). 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, 28).

Vitamin C content of the fruits was increased with the increased in the concentration of micronutrient application 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 (173.56 mg per 100 g) was noted under 0.4% concentration of boric acid treatment with 21.22% increase over control (Table 2). Singh and Brahmachari [22] in guava and Singh *et al.* [23] in aonla also found an increase in vitamin C content of fruits with boron spray. 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, 20).

The maximum pulp weight (114.90 g) in L-49 guava fruits was obtained with the spray of 0.4% concentration of boric acid with an increase of 20.26% over control (Table 2). Brahmachari and Kumar [4] also reported increase in pulp weight of fruits with the foliar application of micronutrients in litchi and ber, respectively. 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 (Dugger, 7).

REFERENCES

[1] Babu, R. S. H., Rajput, C. B. S. and Rath, S., "Effect of zinc, 2, 4-D and GA_3 in Kagzi lime (*Citrus aurantifolia*) IV. Fruit quality", *Haryana J. Hort. Sci.,* **11, 1,** 1982, pp. 59-65.

[2] Balakrishnan, K., "Foliar spray of zinc, iron, boron and magnesium on vegetative growth, yield and quality of guava", *Annals of Plant Physio.*, **14, 2,** 2000, pp. 151-53.

[3] Bhatia, S. K., Yadav, S.; Ahlawat, V. P. and Dahiya, S. S., "Effect of foliar application of nutrients on the yield and fruit quality of winter season guava cv. L-49", *Haryana J. Hort. Sci*., **30, 1-2,** 2001, pp. 6-7.

[4] Brahmachari, V.S., Kumar, R., "Effect of foliar sprays of mineral nutrients on fruit set, retention and cracking of litchi (*Litchi chinensis* Sonn.) fruits", *Haryana J Hort Sci.,* 26, 3-4, 1997, pp. 177-80.

[5] Chaitanya, C. G., **"**Effect of foliar sprays of zinc and boron on yield and post harvest quality of guava fruits *(Psidium guajava)* cv. L-49", Thesis, M.Sc. (Hort.), Submitted to G.B.P.U.A. & T., Pantnagar (Nainital), 1984.

[6] Chaitanya, C. G., Kumar, G., Raina, B. L. and Muthoo, A. K., "Effect of foliar application of zinc and boron on yield and quality of guava cv. Lucknow-49 (Sardar)", *Haryana J. Hort. Sci*., **26, 1-2,** 1997, pp. 78-80.

[7] Duggar, W.M., "Boron in Plant Metabolism, Encyclopedia of plant physiology" *Springer-verlag*, 15, B, 1983.

[8] El-Sherif, A. A., Saeed, W. T. and Nouman, V. F., "Effect of foliar application of potassium and zinc on behaviour of

Montakhab El-Kanater guava trees", *Bulletin of Faculty of Agriculture,* Univ. of Cairo, **51, 1,** 2000, pp. 73-84.

[9] Josan, J. S., "Studies on the fruit cracking in lemon (*Citrus limon*)", Ph D. Thesis submitted to Punjab Agril. Univ., Ludhiana, 1991.

[10] Kliewer, W.M., "The effect of day temperature and light intensity on concentration of malic and tartaric acids in *Vitis vinifera", J Amer Soc Hort Sci*., 97, 1971, pp. 372.

[11] Kumar, S., Bhusan, S., "Effect of zinc, manganese and boron applications on quality of Thompson Seedless grapes", *Punjab Hort J* ., 20, 1980, pp. 62-65.

[12] Kundu, S. and Mitra, S. K., "Response of guava to foliar spray of copper, boron and zinc", *Ind. Agriculturist*, **43**, **1-2,** 1999, pp. 49-54.

[13] Lal, G, Sen, N.L., "Effect of N, Zn and Mn fertilization on fruit quality of guava (*Psidium guajava* L.) cv. Allahabad Safeda", *Haryana J Hort Sci*., 30, 3-4, 2001, pp. 209-10.

[14] Lee, SS, Kim, KR., "Studies on the internal browning of apple fruits caused excessive boron application", *J Korean Soc Hort Sci*., 32, 1, 1991, pp. 43-51.

[15] Luckwill, L. C., "The hormone content of the seed in relation to endosperm and fruit drop in apple" *J. Hort. Sci.*, **24,** 1948, pp. 32-44.

[16] Mc, Cready RM, Guggot, J, Silvaiera, V, Owen, HS., "Determination of starch and amylase in vegetables" *Ana Chem.,* 22, 1950, pp. 1156-58.

[17] Pandey, DK, Pathak, RA, Pathak, RK., "Studies in foliar application of nutrients and plant growth regulators in Sardar guava (*Psidium guajava* L.) 1, Effect on yield and fruit quality", *Ind J Hort.,* 45, 3-4, 1988, pp. 197-02.

[18] Raghav, M. and Tiwari, J. P., "Effect of boron on growth, quality and shelf-life of fruits of guava (*Psidium guajava* L.) cv. Sardar", *Prog. Hort*., **30, 1-2,** 1998, pp. 68-72.

[19] Rangana, S., "Handbook of Analysis and Quality Control for Fruit and Vegetable Products (IInd *ed*.)", Tata McGraw-Hill Publishing Company Ltd, New Delhi, 2004.

[20] Sharma AK., "Studies on biochemical changes associated with growth development of peach", *Prog Hort*., 16, 1984, pp. 234.

[21] Sharma, R. K., Kumar, R. and Thakur, S., "Effect of foliar feeding of potassium, calcium and zinc on yield and quality of guava", *Ind. J. Hort*., **48, 4,** 1991, pp. 312-14

[22] Singh, UP, Brahmachari, VS., "Effect of potassium, zinc, boron and molybdenum on the physico-chemical composition of guava (*Psidium guajava* L.) cv. Allahabad Safeda", *Orissa J Hort*., 27, 2, 1999, pp. 62-65.

[23] Singh, H. K., Srivastava, A. K., Dwivedi, R. and Kumar, P., "Effect of foliar feeding of micronutrients on plant growth, fruit quality, yield and internal fruit necrosis of aonla (*Emblica officinalis*)", *Prog. Hort*., **33, 1,** 2001, pp. 80-83.

[24] Singh, K. and Khan, A., "Effect of fertilization on yield and quality of mango fruits cv. Dashehari", *Prog. Hort*., **22, 1-4,** 1990, pp. 44-50.

[25] Singh, R. R. and Rajput, C. B. S., "Effect of various concentrations of zinc on vegetative growth characters, flowering, fruiting and physico-chemical composition of fruits in mango (*Mangifera indica* L.) cv. Chausa", *Haryana J. Hort. Sci.,* **5, 1-2,** 1976, pp. 10-14.

[26] Singh, S. P. and Singh, A., "Effect of copper sprays on fruit development, yield and quality of 'Allahabad Safeda' guava (*Psidium guajava* L.)", *Prog. Hort*., **34, 2,** 2002, 260-62.

[27] Skoog, F., "Zinc- Auxin in plant growth Ibid. 27: 239", *Hort. Abst.*, **11,** 1940, pp. 332.

[28] Whiting, G. C., "Sugars In*:* The Biochemistry of Fruits and their Products (Vol. I). Hulme A.C., (eds)", Academic press, London. 1970.