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Effect of micronutrients and plant growth regulators on quality parameters of guava (*Psidium guajava* L.) cv. Allahabad Safeda in semi-arid regions of Rajasthan

Suman Kumari Yadav, S Mukherjee and DK Sarolia

Abstract
A field experiment was conducted at IHITC, Jaipur during two consecutive years *i.e.* 2018-19 and 2019-20. Higher yield and good quality is the priority of guava producer to fetch high income. The effect of foliar application of micronutrients (Zn, B and Fe; each at 0.2 and 0.4%) and plant growth regulators (NAA at 50 & 100 ppm and CCC at 500 & 1000 ppm) on quality (TSS, Titratable acidity, ascorbic acid, total sugar, reducing sugar, non-reducing sugar, sugar acid ratio and specific gravity) of guava cv. Allahabad Safeda was investigated. The increasing level of micronutrients and plant growth regulators significantly increased the guava fruit quality. Combined foliar application of 0.4%H_3BO_3 with 100 ppm NAA gave best results as compared to other combinations.

Keywords: Guava, micronutrients, PGRs, yield and quality

Introduction
Guava belongs to the botanical family Myrtaceae and classified under genus *Psidium* which contains about 150 species but only *Psidium guajava* has been exploited commercially. It is native of Tropical America and introduced in India in 17th century by Portuguese. Guava is also known as "Apple of the Tropics" and "Poor man's Apple". It is highly delicious and nutritious fruit which is commercially grown throughout tropical and sub-tropical regions of India.

Guava fruit type is berry and it may be round and ovoid or pear shaped. Guava is climacteric fruit with short shelf life due to their rapid rate of ripening (Akamine and Goo, 1979; Brown and Wills, 1983) [4, 10]. Guava fruits are rich source of vitamin-C (2 to 5 times more than fresh orange juice) and pectin (a polysaccharide substance) (Agnihotri and Bhullar, 1962) [3]. It ranks third in vitamin-C content (260 mg/100 g) after Barbados cherry and *Aonla* (Phandis, 1970 and Rathore, 1979) [26, 32]. The ripe fruits contain 12.3-26.3% dry matter, 77.9-86.9% moisture, 0.511% ash, 0.10-0.70% crude fat, 0.82-1.45% crude protein and 2.0-7.2% crude fiber. The fruit is also rich in minerals like phosphorus, calcium, iron as well as vitamins like Niacin, Pantothenic acid, Thiamine, Riboflavin and vitamin-A (Mitra and Bose, 2001) [23].

Guava fruits are fourth most important fruit in terms of area and production after mango, banana and citrus (Ray, 2012) [33]. In sub-tropical climate, there are three distinct periods of growth and fruiting that are *Ambe bahar* (February to March flowering and fruit ripens in July-August), *Mrig bahar* (flowering in June to July and fruit ripens in October to December) and *Haste bahar* (flowering in October to November and fruit ripens in February to April) (Shukla *et al.*, 2008) [21].

Micronutrients play a vital role in growth and development of plants besides being improving the quality of the produce. Guava plant responses well to Zn, B, Fe, K and Mo applications (Arora and Singh, 1970 and 1972; Singh and Chhonkar, 1983) [5, 36]. The responses of guava plants to these nutrients may vary from region to region and pocket to pocket.

The foliar application of micronutrients and growth regulators play a vital role in improving the quality of fruits and more effective for rapid recovery of plants. Foliar application of different micronutrients also increased the growth, yield and quality parameters in guava (Balakrishnan, 2000; Yadav *et al.*, 2011; Priyaawasthi and Shantlal, 2009 and Trivedi *et al.*, 2012) [8, 28, 41, 44]. Guava suffers severely from deficiency of micronutrients specially boron which reduces the quality of fruits and hinder the development of fruits. Fruits will not grow into a big size even those reaching a fair size do not ripen properly and become hard with brown corky skin and cracking.

The plant growth regulators (PGRs) act as messengers and needed in small quantity at low concentration. Yadav (2002) [45] studied that by the spray of PGRs the physical, chemical and yield parameters of guava fruit were improved.
Plant growth regulators like- auxins, gibberellins and cycocel have been extensively used for improving the quality of fruits. By the application of NAA, TSS and Ascorbic acid content of fruits were increased and acidity was reduced. NAA reduced the number of seed of fruits. It also induced heavier fruiting and promotes flowering (Kumar *et al.*, 2013) [17].
The foliar spray of cycocel also affects the acidity, ascorbic acid, TSS, sugar content and yield of fruits (Garasiya *et al.*, 2013) [14].
Moreover, PGRs help in minimizing flower and fruit drop and also cadre to quality fruit production as sole or in combination with micro-nutrients.
In present era, the consumers are becoming more and more health conscious and ready to pay more for quality fruits. Today, due to increased demand for quality produce the interest of growers in production of high quality fruits is increasing.

Material and Methods

Experimental details

The experiment was conducted for two consecutive years during May to March months of 2018-19 and 2019-20 at International Horticulture Innovation and Training Centre (IHITC), Durgapura (Jaipur).
The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications. The treatments consisted of 2 levels of each micronutrient (B, Zn and Fe, each at 0.2 and 0.4%) and 2 levels of each plant growth regulators (50 & 100 ppm NAA and 500 & 1000 ppm CCC). Thus, there were 24 treatments combinations.
The spraying of different micronutrients and plant growth regulators as per treatments was done 15 days before flowering and 20 days after fruit set at marble stage.

Observations for evaluation

Quality parameters:

Total soluble solids (TSSºB): Total soluble solids was recorded by the "Digital Refractometer" (Brix: 0.0 to 53.0%) at 20 °C temperature that is worked on the principle of refraction of light (Correction factor at 24 °C was 0.29).

Titratable Acidity (%): The acidity of pulp was determined by diluting the known volume of pulp with distilled water and titrating against standard N/10 NaOH solution using phenolphthalein as an indicator until faint pink colour appeared. The result was expressed in terms of per cent acidity of fruit pulp (A.O.A.C., 1995) [1].

$$\text{Acidity} = \frac{0.0064 \text{ X Volume of NaOH used}}{\text{Volume of sample taken}} \text{ X } 100$$

Ascorbic acid (Vit.-C) mg/100 g pulp
Ascorbic acid content of pulp was determined by using volumetric method.

Standardization: Standardization of the dye 2,6-dichlorophenol-indophenol was done by titrating it against standard ascorbic acid solution. The standard was prepared by dissolving 100 mg of pure L-Ascorbic acid in 100 ml of 3 per cent metaphosphoric acid. Then 1 ml of ascorbic acid solution (aliquot) was used for titration.
The ascorbic acid content of pulp was calculated by following formula:

$$\text{Ascorbic acid (mg/100g pulp)} = \frac{\text{Burette reading (ml) X Dye factor X Volume made up (ml)}}{\text{Aliquot (ml) X Weight of pulp (g)}} \text{ X } 100$$

Reducing sugar (%): The reducing sugar was estimated by DNS method (Miller, 1959) [22].

Estimation: Reducing sugar was estimated by using DNS reagent and Rochelle salt. Pulp (0.5ml) (100 times diluted) was added with 2.5ml D.W., 3ml DNS reagent and heated in boiling water bath, cooled and 1 ml of Rochelle salt was added. The absorbance was measured at 510 nm on spectrophotometer, model Spectronic–20. The value was plotted against a standard curve prepared from glucose. The figure was expressed on percentage basis.

Total sugar (%): Total sugar was estimated by Anthrone reagent method (Dubois *et al.*, 1951) [11].

Estimation: Total sugar content was determined by using Anthrone reagent method (Dubois *et al.*, 1951) [11]. 0.5ml of diluted pulp (100 times) was taken. 0.5 ml of diluted H_2O and 4ml Anthrone reagent was put in chilled water for 5-10 minutes and absorbance was measured at 630 nm on Spectronic-20.
The amount of sugar present in the pulp was plotted against standard curve prepared from glucose. The content was expressed on per cent basis.

Non-reducing sugar (%): The amount of non-reducing sugar was obtained by dividing the total sugar by factor 0.95 and subtracting the reducing sugar from the resultant.

Sugar/Acid ratio: Sugar/acid ratio of guava fruit pulp was calculated by dividing the total sugar content with acidity of the fruit.

Specific gravity (w/v): The specific gravity was obtained by dividing the weight of the fruit by volume of the fruit.

Statistical analysis

In order to test the significance of variation in experimental data obtained for various treatment effects, the data were statistically analysed as described by Panse and Sukhatme (1985) [25]. The critical difference was worked out for 5 per cent (0.05) level of significance.

Results

Effect of treatments on quality parameters

Foliar application of micronutrients and plant growth regulators significantly affected the quality parameters of guava *viz.*, TSS (ºBrix), Acidity (%), Ascorbic acid content (Vit.-C)mg/100 g pulp, Total sugars (%), Reducing sugar (%), Non-reducing sugar (%), sugar acid ratio and specific gravity (w/v).
It is evident from data presented in Table 1 the maximum TSS (ºBrix) and minimum acidity (%) content was recorded with treatment M_4 (0.4%H_3BO_3) during both the years and in

pooled analysis *i.e.* 11.88, 11.89 and 11.88ºB, respectively. In respect to PGRs application treatment P_2 (100 ppm NAA) gave maximum and treatment P_4 (1000 ppm CCC) gave minimum TSS (ºBrix) content during both the year and in pooled analysis i.e. 11.55, 11.59 and 11.57, and 10.88, 10.91 and 10.90ºB, respectively. Minimum acidity was obtained with treatment P_2 (100 ppm NAA) during both the years and in pooled analysis *i.e.* 0.42, 0.45 and 0.44, respectively. Maximum TSS, total sugars and ascorbic acid content were observed in guava with the foliar application of B. It might be due to the direct role of boron in photosynthetic activity of plant and in sugar activity. TSS increased by the application of NAA due to the conversion of complex substances into simple ones, which enhanced the metabolic activity in fruits (Rajput *et al.*, 1977 and Ram *et al.*, 2005) [30, 31].

The minimum acidity was obtained with NAA because it (acids) might be converted into sugars and their derivatives by glycolytic pathways or respiration or both. A consistent decrease in acidity and increase in sugars resulted into increase in sugar acid ratio (Agnihotri *et al.*, 2012) [2]. NAA also increased the ascorbic acid content and reduced the acidity of guava fruit (Kher *et al.*, 2005) [16]. Minimum acidity in guava was reported with 100 ppm NAA (Mitra *et al.*, 1982 and Singh *et al.*, 2010) [24, 38].

Table 1: Effect of micronutrients and plant growth regulators on TSS (^{0}B) and acidity (%)

Treatments	TSS (^{0}B)			Acidity (%)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Micronutrients						
M_1 ($ZnSO_4$@0.2%)	10.76	10.88	10.82	0.52	0.53	0.52
M_2 ($ZnSO_4$@0.4%)	11.86	11.87	11.86	0.41	0.51	0.46
M_3 (H_3BO_3@0.2%)	11.04	11.04	11.04	0.48	0.47	0.47
M_4 (H_3BO_3@0.4%)	11.88	11.89	11.88	0.39	0.40	0.40
M_5 ($FeSO_4$@0.2%)	10.60	10.65	10.62	0.52	0.53	0.53
M_6 ($FeSO_4$@0.4%)	11.14	11.14	11.14	0.47	0.47	0.47
SEm±	0.24	0.25	0.17	0.01	0.01	0.01
CD (p=0.05)	0.69	0.72	0.47	0.03	0.03	0.02
PGRs						
P_1 (NAA@ 50 ppm)	11.51	11.55	11.53	0.44	0.45	0.45
P_2 (NAA @ 100 ppm)	11.55	11.59	11.57	0.42	0.45	0.44
P_3 (CCC @ 500 ppm)	10.91	10.93	10.92	0.49	0.51	0.50
P_4 (CCC @1000 ppm)	10.88	10.91	10.90	0.51	0.53	0.52
SEm±	0.20	0.21	0.14	0.01	0.01	0.01
CD (p=0.05)	0.56	0.59	0.39	0.02	0.03	0.02
CV (%)	5.18	5.84	5.51	7.77	8.72	7.96

The data on ascorbic acid content (mg/100 g) and sugar acid ratio of guava fruit as affected by foliar application of micronutrients and plant growth regulators are presented in Table 2. The maximum ascorbic acid content (value during both the years and in pooled analysis,*i.e.* 234.30, 237.05 and 235.68 mg/100 g fruit pulp) and Maximum sugar acid ratio (16.17, 16.32 and 16.25 during both the years and in pooled analysis) was recorded with treatment M_4 (0.4%H_3BO_3). In respect to PGRs application, it was confirmed that maximum ascorbic acid and Maximum sugar acid ratio was obtained with the treatment P_2 (100 ppm NAA) during both the years and in pooled analysis. Boron (0.4%) effectively increased the ascorbic acid in guava fruit (Kundu and Mitra, 1999, Lal and Sen, 2001 and Singh *et al.*, 2004) [19, 20, 37]. Fe played a key role in carbohydrate metabolism and fruit quality (Dongre *et al.*, 2000) [12]. NAA and CCC increased the value of quality parameters in guava (Prajapati and Singh, 2018) [27] and sapota (Bhujbal *et al.*, 2012) [9]. Arshad and Ali (2016) [6] recorded maximum TSS, minimum acidity and maximum vitamin-C with Zn (0.5%) application in guava. This finding also satisfied with the findings of Awasthi and Lal (2009) [7] and Yadav*et al.*, (2011) [44] in guava. Activation of ascorbic acid synthesis in guava fruit is also an important work of boron. This finding also satisfied with the findings of Goswami *et al.* (2014) [15] and Yadav *et al.* (2018) [43] in guava.

Table 2: Effect of micronutrients and plant growth regulators on Ascorbic acid (mg/100 g pulp) and sugar/acid ratio

Treatments	Ascorbic acid (mg/100 g pulp)			Sugar/acid ratio		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Micronutrients						
M_1 ($ZnSO_4$@0.2%)	205.91	208.65	207.28	14.82	14.91	14.87
M_2 ($ZnSO_4$@0.4%)	232.19	235.90	234.05	16.13	16.28	16.21
M_3 (H_3BO_3@0.2%)	225.51	228.15	226.83	15.48	15.60	15.54
M_4 (H_3BO_3@0.4%)	234.30	237.05	235.68	16.17	16.32	16.25
M_5 ($FeSO_4$@0.2%)	204.28	207.33	205.80	14.64	14.76	14.70
M_6 ($FeSO_4$@0.4%)	226.50	228.31	227.41	15.61	15.72	15.67
SEm±	5.21	5.64	3.70	0.33	0.36	0.24
CD (p=0.05)	14.84	16.13	10.40	0.95	1.03	0.67
PGRs						
P_1 (NAA@50 ppm)	230.64	232.69	231.67	15.84	15.96	15.90
P_2 (NAA @100 ppm)	234.85	236.84	235.84	16.15	16.29	16.22
P_3 (CCC@500 ppm)	211.67	214.75	213.21	15.05	15.15	15.10
P_4 (CCC@1000 ppm)	208.64	212.65	210.65	14.86	15.01	14.94
SEm±	4.26	4.61	3.02	0.27	0.29	0.19
CD (p=0.05)	12.11	13.17	8.49	0.78	0.84	0.54
CV (%)	8.15	8.72	8.14	7.49	8.00	7.47

Data presented in Table 3 explicit that different micronutrients had non- significant effect on specific gravity (w/v) in guava fruit. Maximum specific gravity in guava fruit recorded under treatment M_4 during both the years and in pooled analysis *i.e.* 0.98, 0.99 & 0.99, respectively. PGRs also played a non-significant role on specific gravity of guava fruit. Maximum (0.99, 0.99 & 0.99) and minimum (0.95, 0.96 & 0.96) specific gravity was found out with treatment P_2 and P_4 during both the years and in pooled analysis, respectively. Waskela *et al.* (2013) [42] also observed that Zn is most effective to get the maximum value of specific gravity, ascorbic acid content and sugar acid ratio, and minimum acidity in guava (Arshad and Ali , 2016 and Zagade *et al.*, 2017) [6, 47].

Table 3: Effect of micronutrients and plant growth regulators on specific gravity (w/v)

Treatments	Specific gravity (w/v)		
	2018-19	2019-20	Pooled
Micronutrients			
M_1 ($ZnSO_4$@0.2%)	0.96	0.967	0.96
M_2 ($ZnSO_4$@0.4%)	0.98	0.99	0.98
M_3 (H_3BO_3@0.2%)	0.97	0.97	0.97
M_4 (H_3BO_3@0.4%)	0.98	0.99	0.99
M_5 ($FeSO_4$@0.2%)	0.96	0.96	0.96
M_6 ($FeSO_4$@0.4%)	0.97	0.98	0.98
SEm±	0.021	0.022	0.015
CD (p=0.05)	NS	NS	NS
PGRs			
P_1 (NAA@50 ppm)	0.97	0.98	0.98
P_2 (NAA @100 ppm)	0.99	0.99	0.99
P_3 (CCC@500 ppm)	0.96	0.97	0.97
P_4 (CCC@1000 ppm)	0.95	0.96	0.96
SEm±	0.017	0.018	0.013
CD (p=0.05)	NS	NS	NS
CV (%)	7.58	7.95	7.77

The maximum total sugars (%) and reducing sugars (%) were recorded with treatment M_4 during both the years and in pooled analysis *i.e.* 7.82, 7.88 and 7.85; 4.85, 4.90 and 4.88, respectively, in respect to micronutrients application. While in respect to PGRs application maximum (7.89, 7.93 and 7.91; 4.71, 4.73 and 4.72 in 2018-19, 2019-20 and in pooled analysis, respectively) total sugars (%) and reducing sugars (%) content were obtained with treatment P_2 (100 ppm NAA). It was recorded that maximum non-reducing sugar found out with treatment M_6 (0.4% $FeSO_4$) and treatment P_2 (100 ppm NAA). Higher percentage of sugars (Total sugar, reducing sugars and non-reducing sugars) might be due to efficient translocation of phytosynthates to the fruits by regulation of boric acid (Singh and Brahmachari, 1999 and El-Sherif *et al*., 2000) [39, 13]. The boron treatment might hasten the process of ripening during which degradation of acid might have occurred and helped in preventing the excessive polymerization of sugars and accumulation of more sugars in the cell of plants. Due to the influence of boron, acids easily converted into sugars and their derivatives by the reaction involving the reversal of glycolytic path way or might have been used in respiration (Trivedi *et al.*, 2012) [41]. Total sugars and reducing sugars increased by the use of NAA might be due to the faster hydrolysis of starch into simple sugars and their mobilization during the fruit development (Yadav *et al.*, 2001 and Kumar *et al.*, 2010) [46, 18]. NAA also prevented the excessive polymerizations of sugars and helped in accumulations of more sugars in the cell of plants (Sharma and Tiwari, 2015) [34].

Table 4: Effect of micronutrients and plant growth regulators on total sugars (%), reducing sugar (%) and non-reducing sugar (%) content

Treatments	Total sugars content (%)			Reducing sugar content (%)			Non-reducing content (%)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Micronutrients									
M_1 ($ZnSO_4$@0.2%)	7.04	7.08	7.06	4.26	4.26	4.26	3.15	3.19	3.17
M_2 ($ZnSO_4$@0.4%)	7.79	7.86	7.83	4.82	4.88	4.85	3.39	3.39	3.39
M_3 (H_3BO_3@0.2%)	7.58	7.64	7.61	4.54	4.56	4.55	3.45	3.48	3.46
M_4 (H_3BO_3@0.4%)	7.82	7.88	7.85	4.85	4.90	4.88	3.40	3.38	3.39
M_5 ($FeSO_4$@0.2%)	6.98	7.03	7.01	4.23	4.24	4.24	3.10	3.16	3.13
M_6 ($FeSO_4$@0.4%)	7.61	7.66	7.64	4.55	4.58	4.56	3.47	3.48	3.47
SEm±	0.15	0.16	0.11	0.09	0.10	0.07	0.07	0.07	0.05
CD (p=0.05)	0.43	0.47	0.30	0.26	0.29	0.19	0.21	0.19	0.14
PGRs									
P_1 (NAA@50 ppm)	7.75	7.81	7.78	4.65	4.68	4.67	3.51	3.54	3.52
P_2 (NAA @100 ppm)	7.89	7.93	7.91	4.71	4.73	4.72	3.60	3.62	3.61
P_3 (CCC@500 ppm)	7.15	7.19	7.17	4.42	4.45	4.44	3.11	3.12	3.11
P_4 (CCC@1000 ppm)	7.11	7.16	7.14	4.39	4.43	4.41	3.09	3.11	3.10
SEm±	0.12	0.13	0.09	0.08	0.08	0.05	0.06	0.05	0.04
CD (p=0.05)	0.35	0.38	0.25	0.21	0.24	0.15	0.17	0.15	0.11
CV (%)	7.03	7.54	7.03	7.02	7.79	7.15	7.77	6.74	7.06

Conclusion

In the present investigation, the effect of micronutrients with PGRs on quality parameters was estimated. The results revealed that micronutrients and PGRs both have the ability to enhance the TSS, sugars, ascorbic acid content, sugar acid ratio and specific gravity. In respect of quality parameters i.e. TSS (ºB), Acidity (%), Ascorbic acid content (mg/100 g pulp), Total sugars (%), Reducing sugar (%), Non-reducing sugar (%), sugar acid ratio and specific gravity (w/v) of guava fruits, treatment 0.4% H_3BO_3 (M_4) and 100 ppm NAA (P_2), solely recorded better results over rest of the treatments.

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