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Studies on effect of pre harvest sprays of plant growth regulators and micronutrients on yield and economics of guava (*Psidium guajava* L.) cv. Lucknow-49

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Abstract
The study was conducted on the effects of plant growth regulators (SA@100ppm, GA_3@100ppm, NAA@200ppm) and micronutrients ($ZnSO_4$ + Boric acid, $ZnSO_4$ + Boric acid + $CuSO_4$, $ZnSO_4$ + Boric acid +$MgSO_4$, $ZnSO_4$ + Boric acid + $CuSO_4$ + $MgSO_4$ each at 0.4%) on yield and economics in fifteen year old guava cv. L-49 under randomized block design with factorial concept at FRS, Sangareddy, SKLTSHU, Telangana. In interaction effects, NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% has recorded significantly maximum fruit yield per tree (116.92kg/tree), yield per hectare (46.77t/ha), fruit weight (187.07g), However, Maximum fruit length (7.69cm) and fruit diameter (7.53cm) were observed with GA_3@100ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$@0.4% + $MgSO_4$ @0.4%. Maximum B:C ratio (5.07) was recorded in NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $MgSO_4$ @0.4%. NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% was superior in improving the yield and economics of guava cv. Lucknow-49.

Keywords: PGRs, guava, micronutrients, yield, economics

Introduction
Guava (*Psidium guajava* L.) the apple of the tropics, is one of the most popular fruits grown in tropical, sub-tropical and some parts of arid regions of India. The fruit belongs to the family Myrtaceae. It is a rich and cheap source of vitamin C and pectin (Agnihotri *et al*. 1962) [2]. Due to hardy nature of plant it can withstand adverse climatic conditions and grows under a wide range of soil types from sandy loam to clay loam (Dhaliwal and Singla 2002) [10]. Guava is a prolific bearer and highly remunerative even without much care. Therefore, it is an ideal fruit crop in terms of yield, nutritional security as well as in economic boost.
Guava comes to flowering three times a year in South India, *viz*., ambe bahar (February-March), mrig bahar (June-July) and hasth bahar (October-November) seasons and two times a year in South India (Samson, 1980) [36]. In mild tropical or subtropical climates, flowering and fruiting occurs continuously throughout the year, if water and temperatures are not the limiting factors (Rathore and Singh, 1974) [34].
The use of plant growth regulators has resulted in some outstanding achievements in several fruit crops with respect to growth, yield and quality. The yield parameters like average fruit weight, number of fruits per tree and yield per tree are increased by the spray of growth regulators. The application of GA_3 improves the size, shape and weight of the fruits. It increases fruit set and fruit retention in the tree. The fruit yield was recorded maximum with the spray of GA_3@150ppm in guava (Jagveer *et al*. 2016) [16]. NAA application synchronizes flowering and improves fruit set by decreasing the fruit drop. NAA had a significant effect on the vegetative growth yield and fruit quality in guava (Manish and Devi 2018) [24].
Micronutrients are key elements in plant growth and development. These elements play very important role in various enzymatic activities and synthesis. Their acute deficiencies sometime pose serious problems (Kumar, 2002) [20]. Imbalances in micronutrient management may lead to reduced yield and poor fruit quality. There is an urgent need to re-look into the problems that can be solved by micronutrients in fruits to overcome the hidden hunger (Shahroon *et al*. 2018) [39]. Zinc is important for the formation and activity of chlorophyll and in the functioning of several enzymes and growth hormone, auxin. Boron affects pollination and the development of viable seeds which in turn affect the normal development of fruits. The maximum fruit set percent and least fruit drop were recorded with foliar application of zinc sulphate + copper

sulphate + borax 0.5% in guava (Ram *et al*. 2014) [31]. Magnesium is the metallic constituent of chlorophyll and regulates the uptake of other nutrients (Ram and Bose, 2000) [32]. Copper is essential for photosynthesis, for the functioning of several enzymes, in seed development and for the production of lignin which gives physical strength to shoots and stems. Copper activates several enzymes in plant, helps in chlorophyll synthesis (Ram and Bose, 2000) [32].

Even though many studies have been conducted on pre harvest spray of PGRs and mineral nutrients individually, no much work has been done in combination. Considering the above facts, the present investigation was formulated to assess the influence of plant growth regulators in combination with nutrients on yield and economics of guava.

Material and Methods

An experiment was conducted in fifteen years old, well grown, uniform statured trees of guava cv. Lucknow-49 spaced at 5x5m to study the effect of pre harvest sprays of plant growth regulators and micronutrients on fruit quality during July, 2018 to January, 2019 (Hasta bahar crop) at Fruit Research Station (FRS), Sangareddy, SKLTSHU, Telangana. The experiment was laid out in a randomized block design with factorial concept (FRBD) replicated thrice. The study was carried out with 16 different treatments involving different combinations of PGRs and micronutrients. Treatmental trees were selected by random numbers (Oliver, 1965) [26]. The fruits were harvested based on their maturity indices *viz*., change in colour of the fruit from dark green to yellowish green.

Aqueous solutions of the PGRs were prepared. Naphthalene acetic acid 200 ppm stock solution was prepared by weighing 2g of NAA into a beaker, Dissolve it completely by addition of small quantity of 1N NaOH, then made the volume up to 10 litres by addition of distilled water. Gibberellic acid and salicylic acid 100 ppm stock solutions were prepared by taking 1g each them separately into a beaker by dissolving completely with little quantity of alcohol and the volume was made up to ten litres by adding distilled water. The boron, zinc, magnesium and copper solutions at 0.4% concentrations were prepared by weighing 40gm of boric acid, zinc sulphate, magnesium sulphate and copper sulphate and dissolving them in little quantity of distilled water, then diluted to ten litre respectively. Plant growth regulators and micronutrients were sprayed a using hand sprayer.

Statistical analysis

The data recorded were tabulated and statistically analysed by adopting randomised block design with Factorial concept as suggested by Panse and Sukhatme (1978) [28]. The differences among the treatmental means were tested for significance by F value at 5% level. The critical difference values were calculated at 0.05 levels wherever the treatment mean differences were found to be significant.

Results and Discussion

The data furnished in tables clearly indicate that treated plants with PGRs and micronutrients foliar spray performed significantly better than control plants.

Length of fruit (cm)

The effect of growth regulators and micronutrients on fruit length in guava cv. Lucknow-49 was presented in the table 1

Significant differences were observed in interaction effect between plant growth regulators and micronutrients on fruit length in guava. Maximum fruit length (7.69) was recorded in GA_3@100ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% which was followed by NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% (7.59). Minimum fruit length (6.01) was recorded in no growth regulator and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4%.

In the present investigation, GA_3@100ppm and NAA@ 200 ppm were found almost equally effective in influencing the fruit length in guava cv. L-49. Increase in fruit length with GA_3 100 ppm could be attributed to promotion of cell division activity through biosynthesis of auxins indirectly (Lal *et al*. 2013) [22]. The increase in fruit size was due to accelerated rate of cell division and cell enlargement and more intercellular space with the application of higher concentration of growth substances. It may be also due to the fact that B & Zn have direct role in hastening the process of cell division and cell elongation due to which size and weight of fruits would have improved (Meena *et al*. 2014) [25].

The results are in conformity with those reported by Kher *et al*. (2005) [19], Pandey *et al*. (2012) [27], Katiyar *et al*. (2009) [18], Gaur *et al*. (2014) [11], Yadav *et al*. (2011) [42], Waskela *et al*. (2013) [41] and Rajkumar *et al*. (2010) [29] in guava, Rao (1997) [33] in banana.

Fruit diameter (cm)

The effect of growth regulators and micronutrients on fruit diameter in guava cv. Lucknow-49 was presented in the table 1

Maximum fruit diameter (7.53) was recorded in GA_3@100ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% which is followed by NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% (7.44). Minimum fruit diameter (6.07) was recorded in no growth regulator and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4%.

Improvement in fruit diameter by application of growth regulators were probably due to faster rate of fruit growth owing to rapid cell division and cell enlargement (Chaitanya *et al*. 2013) [6]. Boron was reported to regulate the semi permeability of cell wall thus mobilizing more water into the fruits, thereby increasing the size of fruit (Gaur *et al*. 2014) [11].

The results are in conformity with those reported by Pandey *et al*. (2012) [27], Gaur *et al*. (2014) [11], Yadav *et al*. (2011) [42], Waskela *et al*. (2013) [41] and Rajkumar *et al*. (2010) [29] in guava.

Fruit weight (gms)

The effect of growth regulators and micronutrients on fruit weight in guava cv. Lucknow-49 was presented in the table 1

Maximum fruit weight (187.07) was recorded in NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% which was on par with GA_3@100ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% (186.70) and also with NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% (185.17). Minimum fruit weight (135.73) was recorded in no growth regulator and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4%.

GA_3 enhanced deposition of solids which increased cell size by increasing the accumulation of water in intercellular space (Dhaker *et al*. 2013) [9]. Sayed *et al*. (2004) [39] found that fruit weight, fruit length and fruit diameter of Valencia orange were increased due to GA_3 sprays. Kundu and Mitra (1999)

[21] reported that the spray of Cu + B + Zn was most effective in increasing the fruit weight & yield of guava. 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 (Rajkumar *et al*. 2010) [29].

The other possible reason might be due to hormonal mediated direct transport, accumulation and ensure balanced partitioning of photosynthetic assimilates to the developing fruit than by enabling the shoot to meet the nutritional requirement of fruits throughout their development (Anawal *et al*. 2015) [3]. Increase in length and diameter of fruit significantly increased the weight of the fruit.

The results are in conformity with those reported by Jawed *et al.* (2017), Pandey *et al*. (2012) [27], Gaur *et al*. (2014) [11], Yadav *et al*. (2011) [42], Waskela *et al.* (2013) [41] and Rajkumar *et al*. (2010) [29] in guava, Haque *et al*. (2000) [14] in mandarin.

Yield per tree (kg)

The effect of growth regulators and micronutrients on yield per plant in guava cv. Lucknow-49 was presented in the table 1.

The data revealed that there was significant differences observed in interaction effect between plant growth regulators and micronutrients on yield per tree in guava. Maximum yield per tree (116.92) was recorded in NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% which was statistically on par with NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% (115.73) followed by GA_3@100ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% (102.69). Minimum yield per tree (67.87) was recorded in no growth regulator and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% +$MgSO_4$ @0.4%.

NAA increases fruit set by reducing fruit drop and thereby higher fruit yield (Hameed *et al*. 2001) in Barhee date palm. Effect of GA in cell enlargement, cell division and increasing the number and size of fruits which resulted in higher fruit yield (Adams *et al*., 1975; Kamijima, 1981) [1]. Spray of micronutrients (B & Zn) hastens the process of cell division and cell elongation and also to their stimulatory effect on plant metabolism and production of auxins (Meena *et al*. 2014) [25]. Mg and Zn might have induced the synthesis of chlorophyll and thus lead to increase in chlorophyll content which in turn resulted in higher vegetative growth and yield parameters (Bagali *et al*. 1993) [4].

The increase in yield by growth regulators and micronutrients was associated with higher rate of cell division, enlargement, photosynthesis and increase in enzymatic activities as well as involvement of biosynthesis of auxin, increase in the number of fruits, low percentage of fruit drop, more fruit retention and increased fruit size and weight and ultimately increased the yield (Mahaveer *et al*. 2017) [23].

The present results were in agreement with those of Ghosh (1986) [12], Sharma *et al.* (1991) [40], Lal *et al*. (2013) [22] in guava, Chaudhari *et al*. (2016) [7] in custard apple, Saima *et al.* (2010) [35] in phalsa, Hifny *et al.* (2017) [15] in sweet orange, Chavan *et al.* (2009) [8] in sapota, Bhujbal *et al.* (2017) [5] in phalsa.

Fruit yield per hectare (t ha^{-1})

The effect of growth regulators and micronutrients on fruit yield per hectare in guava cv. Lucknow-49 was presented in table 2

Significant differences were observed in interaction effect between plant growth regulators and micronutrients on fruit yield per hectare in guava. Maximum fruit yield per hectare (46.77) was recorded in NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% followed by NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% (46.29) followed by GA_3@100ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% (41.07). Minimum fruit yield per hectare (27.15) was recorded in no growth regulator and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4%.

The increase in yield per hectare is obviously due to the increase in volume and weight of fruit with the combined application PGRs and micronutrients. There was a positive and significant correlation between the length of fruit and diameter of fruit with weight of the fruit and increased number of fruits, low percentage of fruit drop, more fruit retention which increased yield per tree and ultimately fruit yield per hectare (Ghosh *et al*. 2009) [13].

The present results were in agreement with those of Ghosh (1986) [12], Sharma *et al.* (1991) [40], Lal *et al*. (2013) [22] in guava, Chaudhari *et al*. (2016) [7] in custard apple, Saima *et al.* (2010) [35] in phalsa, Hifny *et al.* (2017) [15] in sweet orange.

Benefit-cost ratio

In order to evaluate the practical utility of foliar sprays of different growth regulators the cost of different items related to spraying, gross and net returns were worked out based on yield obtained are presented in table 2.

Data revealed that the highest net returns (7.44 lakhs) was observed in plants sprayed with T_{12} followed by T_{10} (7.37 lakhs). Similarly, the highest benefit: cost ratio (5.07) was recorded with T_{11} followed by T_{10} (4.93). The lowest benefit: cost ratio (2.92) was recorded in (T_{16}).

A comparative analysis of the economic benefits from foliar application of PGR's and micronutrients revealed that T_{12} superiority among all the treatments both in terms of net profit of guava crop as well as benefit cost ratio.

This might be due to production of more number of fruits shoot$^{-1,}$ fruit weight, fruit size and fruit yield and the lower cost of expenditure on guava crop cultivation. The present results are in conformity with the findings of Pandey *et al.* (1980) [27] and Sayan *et al*. (2018) [37] in guava.

Conclusion

Keeping in view the results summarized above, **T_{12}-** NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% has recorded significantly maximum fruit weight, fruit yield per tree, yield per hectare and maximum net returns. Highest fruit length and diameter was recorded in GA_3@100ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4%. It is concluded that the NAA@200ppm and $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4% is best treatment to improve the yield and economics of guava cv. Lucknow-49.

Table 1: Effect of pre harvest spray of PGRs and micro nutrients on fruit size, weight and yield of guava cv. Lucknow-49

Treatment combinations	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit per tree (kg)
T_1-SA@ 100 ppm+ $ZnSO_4$ @ 0.4% + Boric acid @ 0.4%	6.66	6.92	159.52	87.74
T_2-SA @ 100 ppm+ $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4%	6.50	7.24	147.80	81.29
T_3-SA@ 100 ppm+ $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% +$MgSO_4$ @0.4%	6.70	7.0	155.47	85.51
T_4-Salicylic acid @ 100 ppm+ $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4%	6.96	7.12	161.13	88.62
T_5-GA_3 @ 100 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4%	7.29	7.08	150.80	82.94
T_6-GA_3 @ 100 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4%	7.32	7.37	169.28	93.11
T_7-GA_3 @ 100 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% +$MgSO_4$ @0.4%	7.12	7.20	182.13	100.18
T_8-GA_3 @ 100 ppm +$ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% +$MgSO_4$ @0.4%	7.69	7.53	186.70	102.69
T_9-NAA @ 200 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4%	7.25	7.19	154.47	96.54
T_{10}-NAA @ 200 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4%	7.42	7.24	185.17	115.73
T_{11}-NAA @ 200 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $MgSO_4$ @0.4%	7.31	7.35	163.26	102.04
T_{12}-NAA @ 200 ppm+ $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4%	7.59	7.44	187.07	116.92
T_{13}-$ZnSO_4$ @ 0.4% + Boric acid @ 0.4%	6.21	6.15	137.79	68.90
T_{14}-$ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4%	6.01	6.07	139.09	69.55
T_{15}-$ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $MgSO_4$ @0.4%	6.13	6.23	140.36	70.18
T_{16}-$ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4%	6.32	6.32	135.73	67.87
SE (m) ±	0.02	0.02	5.38	3.16
CD at 5%	0.06	0.07	15.54	9.15

Table 2: Effect of pre harvest spray of PGRs & micronutrients on B:C ratio of guava cv. L-49

Treatment combinations	Total cost of cultivation (Rs/ha)	Yield per hectare (t/ha)	Gross income (Rs/ha)	Net returns (Rs/ha)	Benefit-cost ratio
T_1-SA@ 100 ppm+ $ZnSO_4$ @ 0.4% + Boric acid @ 0.4%	153361	35.09	701888	548527	4.58
T_2-SA @ 100 ppm+ $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4%	183445	32.52	650320	466875	3.55
T_3-SA@ 100 ppm+ $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% +$MgSO_4$ @0.4%	156561	34.20	684053	527493	4.37
T_4-Salicylic acid @ 100 ppm+ $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4%	186545	35.45	708987	522442	3.80
T_5-GA_3 @ 100 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4%	201072	33.18	663520	462448	3.30
T_6-GA_3 @ 100 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4%	231056	37.24	744832	513776	3.22
T_7-GA_3 @ 100 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% +$MgSO_4$ @0.4%	204272	40.07	801387	597115	3.92
T_8-GA_3 @ 100 ppm +$ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% +$MgSO_4$ @0.4%	234256	41.07	821480	587224	3.51
T_9-NAA @ 200 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4%	157896	38.62	772333	614437	4.89
T_{10}-NAA @ 200 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4%	187880	46.29	925833	737953	4.93
T_{11}-NAA @ 200 ppm + $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $MgSO_4$ @0.4%	161096	40.82	816300	655204	5.07
T_{12}-NAA @ 200 ppm+ $ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4%	191080	46.77	935333	744253	4.89
T_{13}-$ZnSO_4$ @ 0.4% + Boric acid @ 0.4%	152552	27.56	551160	398608	3.61
T_{14}-$ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4%	182536	27.82	556373	373837	3.05
T_{15}-$ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $MgSO_4$ @0.4%	155752	28.07	561440	405688	3.60
T_{16}-$ZnSO_4$ @ 0.4% + Boric acid @ 0.4% + $CuSO_4$ @0.4% + $MgSO_4$ @0.4%	185736	27.15	542933	357197	2.92

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