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Effect of foliar application of plant growth regulators and micronutrients on quality of acid lime (*Citrus aurantifolia* L.) CV. Sai Sarbati

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Abstract
The field study was carried out at Sweet Orange Research station, Badnapur, Dist. Jalna during 2017-18. The experiment was laid out in Randomized Block Design (RBD) with 13 treatments and three replication. Observations were recorded on juice per cent, peel per cent, total soluble solids, acidity, ascorbic acid, total sugars, reducing sugars and non-reducing sugars. Among all the treatments, Treatment T_{11}, GA_3 (50 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%) recorded maximum TSS (8.57^0B), Ascorbic acid (30.35 mg/100 ml juice), juice per cent (50.60%), total sugars (1.825%), reducing sugars (0.90%),non-reducing sugar (0.92%) and maximum per cent acidity (7.07%) and minimum peel per cent (25.21%).

Keywords: Foliar application, plant growth regulators, micronutrients, acid lime (*Citrus aurantifolia* L.)

Introduction
Acid lime (*Citrus aurantifolia* Swingle) is one of the most commercially grown fruit crop which is widely grown in tropical and sub-tropical region of India. It belongs to family Rutaceae. The principal cultivar grown widely is Kagzi lime. In India, acid lime is mainly grown in the states of Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Madhya Pradesh, Bihar, Assam, Jharkhand and Chhattisgarh. The area under acid lime in India is 255.20 thousand hectares with production of 2523.50 thousand MT and productivity 9.9 MT, while in Maharashtra, it is cultivated on 45.00 thousand hectares with production of 246.00 thousand MT with 5.5 MT productivity (Annon., 2017) [1]. In Maharashtra, the main acid lime growing districts are Ahmednagar, Solapur, Akola, Jalgaon, Pune, Nagpur, Beed, Jalna and Aurangabad.

Acid lime trees in tropical and sub-tropical conditions tends to give out continuous flushes of growth, both vegetative as well as reproductive throughout the year unless manipulated externally into a concentrated bloom in a particular season. Acid lime trees flower thrice in a year in the months of January- February, June- July and September-October known as *Ambia*, *Mrig* and *Hasta bahar*, respectively. The fruits of the *Ambia*, *Mrig* and *Hasta bahar* flowering becomes available in the month of June-July, November-December and April-May months, respectively. The flowering percentage of *Ambia*, *Mrig* and *Hasta bahar* occurs 47%, 36% and 17%, respectively.

The fruits of *Hatsa bahar* flowering become available in the months of April-May when there is heavy demand and are sold at premium price. But *Hasta bahar* (Summer cropping) bear only 17% flowering and fruiting is achieved in the uncontrolled condition because of the monsoon rains preceding flower initiation. Therefore, in *Hasta bahar*, to force the acid lime plants in to profuse flowering, use of plant growth regulators and micronutrients gives an effective alternative. Use of Gibberellic acid (GA_3) during stress period is known to reduce the intensity of flowering in the following flowering season nepthalic acitic acid (NAA), and gibberellic acid (GA) (Michael *et al.*, 1999) [13]. Similarly, deficiency of micronutrients (Zn, Cu, Fe, and Mn) in the soil of citrus orchards also affects the fruit yield, quality, fruit drop (Ibrahim *et al.*, 2007; Ashraf *et al.*, 2012) [9, 3]. Severe deficiency of Zn was noted long ago in the citrus orchards of Punjab and Pakisthan (Rehman *et al.*, 1999) [16]. However, foliar application of Zn can improve the citrus fruit yield, quality and control the premature fruit drop (Rodriguez *et al.*, 2005) [15]. Different workers suggested that application of suitable combination of plant growth regulators and macro and micro-nutrients can control the excessive fruit drop and improve the yield and quality of citrus fruit (Doberman and Fairhurst, 2000; and Saleem *et al.*, 2005) [6, 17].

Micronutrients can tremendously boost horticultural crop yield and quality. In general Zn and Fe deficiency are regular in all citrus crops. However, these can be corrected through use of organic matter and spray of zinc sulphate and ferrous sulphate during the active growth period of the Acid lime tree. Application of micronutrients either through foliar spray is important in flowering and quality fruit production. Hence, considering the need, the present investigation study on response of soil and foliar application of PGR and micronutrients on quality of acid lime (*Citrus aurantifolia* L.) Cv. Sai sarbati. Has been conducted.

Material and methods

The experiment was conducted during 2017-18, on uniform five years old plants of cv. Sai Sarbati planted at the spacing of 5X5 m at Sweet Orange Research Station, Badnapur of Vasantrao Naik Marathawada Krishi Vidyapeeth, Parbhani. Station is situated at 409 m above mean sea level at 19.50^0 latitude and 47.53^0C longitudes with an altitude of 520 meters. The average rainfall of the station is about 650 mm received mostly during June to September. The minimum and maximum temperature during the last five years were 15.25 and 43.85^0 and the mean relative humidity ranges from 30 to 90 per cent and rainfall in recent year (2016-17) is 662 mm. The experiment was laid out in a Randomized Block Design (RBD) with three replication and thirteen treatments these are of Comprising spraying of Gibberellic acid (GA_3) at 50 ppm along with micronutrients combination of $ZnSO_4$ + $FeSO_4$ at 0.5% and 1% both, NAA at 100 ppm along with micronutrients combination of $ZnSO_4$ + $FeSO_4$ at 0.5 and 1% both and control. The plant growth regulators and micronutrients were sprayed at two times. First spraying of plant growth regulators and micronutrients was carried at petal fall stage in the second week of March and second spraying 45 days after first spray separately in the last week of April, 2017. The juice from fruit was extracted by lemon squeezer. The percentage of juice content was calculated in relation to weight of fruit for each treatment. The total soluble solids was recorded with the help of Erma Hand refractometer (0-32 0Brix). A drop of juice was placed on the prism facing the light source and value was recorded. Care was also taken to clean the prism with distilled water and dry it before taking next reading. The titrable acidity of the juice was determined according to the method given in for this, 10 ml of juice was titrated against 0.1 N NaOH solution using phenolphthalein as an indicator. The acidity was expressed as per cent citric acid.

Acidity (%) = 0.064 x Burette reading

Ascorbic acid content was estimated by the procedure described by Ranganna (1979) [14] by using 2, 6 dichlorophenol dye as an oxidizing agent for titration. The ascorbic acid content of the juice was estimated on fresh weight basis and expressed as mg/100 ml juice of fruit. The ascorbic acid content less than 100 mg /100 ml pulp was termed as fair, those between 100 to 200 mg as good and those above 200 mg as high. The reducing sugar from juice was estimated as per the method described by Ranganna (1979) [14] and expressed in percentage. Fifty ml composite juice sample of the same kind of juice was taken and precipitated by using 2 ml neutral lead acetate (45%). After 10 minutes, 1.8 ml of potassium oxalate (22%) was added to delead the sample solution and then the final volume was made upto 250 ml. After filtration, the filtrate was used for estimating reducing sugar by titrating it against Fehling solution (Fehling A and B in 1 : 1 proportion) at boiling temperature with an end point as brick red by using methyl blue as an indicator.

$$\text{Reducing sugar (\%)} = \frac{50}{\text{Burette reading}} \times 100$$

It was calculated by subtracting the value of the reducing sugar from total sugar of the juice from each sample separately. Total sugar was estimated by the same method as that of reducing sugar. For this, 50 ml clean filtrate was taken in 50 ml volumetric flask and 5 ml of 35 per cent hydrochloric acid (HCL) was added to it. This was hydrolysed for half an hour in hot water bath. After hydrolyzing, the excess acid was neutralized by sodium carbonate (40%) and the volume was made to 250 ml. It was then titrated against 5 ml each of Fehling A and Fehling B solutions using methyl blue as an indicator.

$$\text{Total sugar (\%)} = \frac{250 \text{ ml}}{\text{Burette reading}} \times 100$$

The peel percentage of each fruit was measured by a taking of weight of peel and presented in percentage.

Results and discussion

Data embodied in table 1. Revealed that, the significantly maximum juice (50.60%) was recorded in the treatment T_{11} (GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%). Which was statistically at par with T_9, T_{10}, T_{12} and T_{13}. Whereas, minimum juice per cent (38.50%) was observed in treatment T_1 (control). Similar results were reported in acid lime by Gill *et al*. (1983) [8] in sweet orange,

The increase in juice per cent of the fruit due to application of micronutrients might be due to role of zinc in plant metabolism. Zinc regulates the semi permeability of cell wall by which more water was mobilized into the fruits, thereby increasing the percentage of juice. Similarly, the iron also accelerated the fruit development, due to which, more metabolites might have diverted from the leaves to the fruits thereby increasing the juice content of fruit.

The significantly minimum peel (25.21%) was recorded in the treatment T_{11} (GA_3 @ 50ppm + $ZnSO_4$ @1.0% + $FeSO_4$@1.0%). It was statistically at par with T_{10} and T_{13}. Whereas, maximum peel (45.21%) was observed in treatment T_1 (control). Similar type of results has also been reported by Brar *et al*. (1990) [4] in Kinnow mandarin, Kaur *et al*. (1993) [12] in sweet orange, in kagzi lime, Debaje *et al*. (2011) [5] in acid lime, Anees *et al*. (2011) [2] in mango.

Table 1 revealed the maximum TSS (^{0}Brix) (8.57) in the treatment T11 (GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%). It was statistically at par with T_{10}. Whereas, minimum TSS (^{0}Brix) (6.50) was observed in treatment T_1 (control). Similar findings were recorded by, in kagzi lime, and Yadlod *et al*. (2009) [19] in banana.

Increase in TSS of juice with the application of micronutrients specially zinc might be due to increased photosynthetic activity and chlorophyll content of leaves which might have resulted in production of more TSS in fruit juice. Also plant growth regulator i.e. NAA application numerically increased the TSS content of juice in sweet orange. Thus cumulative effect of plant growth regulators and micronutrients increased the TSS in fruit of acid lime.

It is clear from the data given in table that maximum acidity (7.89%) was recorded in the treatment T_{11} (GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%). It was statistically at par with T_{10} and T_{13}. Whereas, minimum acidity (6.00%) was observed in treatment T_1 (control). Similar trend has also been reported by various workers. Debaje *et al*. (2011) [5] in acid lime, Anees *et al*. (2011) [2] in mango.

A critical observation of the data revealed that the significantly maximum total sugar (1.82%) recorded in the treatment T_{11} (GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%). Which was statistically at par with T_9, T_{13} and T_{10}. Whereas, minimum total sugar (0.98%) was observed in treatment T_1 (control) Similar results are in close conformity with finding of in kagzi lime.

The results, on critical observation, indicated that the significantly maximum reducing sugar (0.90%) was recorded in the treatment T_{11} (GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%). It was statistically at par with T_{10}. Whereas, minimum reducing sugar (0.61%) was observed in treatment T_1 (control). Similar results were also reported in acid lime by Debaje *et al*. (2011) [5] in acid lime.

On the basis of results obtained in the present study, it could be concluded the significantly maximum non reducing sugar (0.92%) was recorded in the treatment T_{11} (GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%).followed by treatment T_{10}, T_{13}, T_{12} and T_9, T_8. Whereas, minimum non reducing sugar (0.37%) was observed in treatment T_1 (control). The results are in line with findings of Debaje *et al*. (2011) [5] in acid lime.

The data given in table 1 revealed that, the significantly maximum ascorbic acid (30.35 mg/100ml juice) was recorded in the treatment T_{11} (GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%). It was statistically at par with T_{13} and T_{10}. Whereas, minimum ascorbic acid (24.69 mg/100 ml juice) was observed in treatment T_1 (control). These results are in accordance with the earlier findings of Jagtap *et al*. (2013) [10] in acid lime.

Table 1: Effect of foliar application of various plant growth regulators and micronutrients on various quality parameters in acid lime.

S. No.	Treatment details	Juice (%)	Peel (%)	TSS (^{0}Brix)	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100 ml juice)
T_1	Control	38.50	45.21	6.50	6.00	0.98	0.61	0.37	24.69
T_2	GA_3 @ 50ppm	41.35	42.20	6.58	6.26	1.15	0.75	0.40	25.06
T_3	NAA @ 100ppm	42.15	39.45	6.67	5.38	1.04	0.67	0.37	25.88
T_4	$ZnSO_4$ @ 0.5%	45.03	40.30	6.55	5.08	1.1	0.67	0.43	25.11
T_5	$FeSO_4$ @ 0.5%	39.90	38.74	6.86	5.00	1.19	0.69	0.50	25.21
T_6	$ZnSO_4$ @ 1.0%	43.96	38.17	6.86	5.93	1.36	0.72	0.64	25.07
T_7	$FeSO_4$ @ 1.0%	46.19	37.47	7.03	5.69	1.41	0.73	0.68	26.93
T_8	$ZnSO_4$ @ 0.5% + $FeSO_4$ @ 0.5%	45.88	32.04	7.05	6.66	1.58	0.77	0.81	27.97
T_9	$ZnSO_4$ @ 1.0% + $FeSO_4$ @ 1.0%	47.93	31.43	7.12	6.97	1.66	0.80	0.86	28.64
T_{10}	GA_3 @ 50 ppm +$ZnSO_4$ @0.5% +$FeSO_4$ @ 0.5%	49.03	27.11	8.20	7.87	1.71	0.85	0.86	29.33
T_{11}	GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%	50.60	25.21	8.57	7.89	1.82	0.90	0.92	30.35
T_{12}	NAA @ 100ppm + $ZnSO_4$ @0.5% + $FeSO_4$ @ 0.5%	48.87	30.59	7.26	7.07	1.62	0.80	0.82	28.90
T_{13}	NAA @ 100ppm +$ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%	48.90	28.63	7.75	7.26	1.66	0.82	0.84	28.97
	S.E.m ±	1.06	1.30	0.25	0.20	0.06	0.02	0.016	0.22
	C.D at 5%	3.10	3.81	0.74	0.60	0.18	0.07	0.047	0.66

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