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Effect of foliar application of plant growth regulators and micronutrients on growth and yield parameters 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 parameter viz., plant height, plant spread, days required for initiation of new vegetative flush, days required for flower initiation, days required for harvesting, number of flower/shoot, fruit set per cent, fruit drop per cent, number of fruits/tree, fruit weight, fruit volume, yield Kg/tree, Among all the treatments, T_{11} GA_3 (50 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%) recorded maximum increase in plant height (0.25 m), plant spread East-West spread (3.74 m), North-South spread (3.54 m) and minimum days required for initiation of new vegetative flush (17.00 days), flower initiation after vegetative flush (14.00 days) and harvesting (144.00 days). While among all treatments, (T_{11}), GA3 (50 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%) recorded maximum number of fruits/tree (148.00 fruits/tree), fruit weight (43.33 g), fruit volume (41.30 ml), yield (6.41 kg/tree), fruit set (51.20 %), number of flower/shoot (18.57) and minimum fruit drop (35.20 %).

Keywords: Foliar application, plant growth regulators, micronutrients, growth, yield parameters, 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) [8, 2]. Severe deficiency of Zn was noted long ago in the citrus orchards of Punjab and Pakisthan (Rehman *et al.*, 1999) [17]. However, foliar

application of Zn can improve the citrus fruit yield, quality and control the premature fruit drop (Rodriguez *et al*., 2005) [16]. 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) [4, 18].

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 growth and yield parameters 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 days of required for initiation of new vegetative flush was measured after giving bahar treatment of plants. The days of required for flower initiation was measured after giving bahar treatment of plants. Visual observations for position of flower intensity on shoot were observed during flowering and described as maximum on the middle of the shoot, maximum on middle to upper part of the shoot, scattered from basal to upper part of the shoot according to the nature of flower intensity on shoot observed. Randomly five flowering shoots per tree per replication were selected and number of flowers per shoot recorded and average was worked out per treatment. The plant height was measured with the help of measuring tape in meters before spraying and after the harvest of fruits. The volume occupied by plant canopy was measured in E-W and N-S direction and canopy height with the help of measuring scale and plant canopy volume was calculated by taking E-W and N-S plant spread in m3.

The fruit drop per cent was calculated by following equation:

$$\text{Fruit drop (\%)} = \frac{\text{Total number of fruit set} - \text{Total number of fruit at Harvest time}}{\text{Total number of fruits}} \times 100$$

The fruits were plucked up when they were matured and counted separately for each experimental tree. All the fruits were harvested at once and number of fruits per plant was recorded. Four randomly selected fruits from each treatment were taken and weight of individual fruit was recorded on electronic balance and average weight of all the four fruits was computed in gram. The picked fruits from each experimental tree were weighed immediately after harvesting and yield per tree was recorded in kg per tree and later as computed in tones per hectare. Randomly five shoot were selected for recording fruit set. From each shoot initially number of fruits per shoot counted and at harvesting number of fruits retained per shoot counted by using following formula.

$$\text{Fruit set (\%)} = \frac{\text{No. of initial fruits / shoot}}{\text{No. of flowers / shoot}} \times 100$$

Fruits of each tree in every treatment and replication were counted at each harvesting. After all harvesting it was summed up and average number of fruits per tree was computed. The weight of five observational fruit was recorded on the top pan balance. The values were summed up and average fruit weight was computed by dividing total weight of fruits by total number of fruits. At each picking, the weight of the harvested fruits from each tree under a treatment was recorded. The sum total of each picking was worked out for each tree. The average for a tree was computed and presented. Yield per tree (kg) was calculated by the following formula.

$$\text{Yield per/tree (Kg)} = \frac{\text{Total number of fruits / tree X Average fruit Weight (g)}}{1000}$$

The volume of five randomly selected fruit was measured separately by the water displacement method. The mean volume of the fruit for each treatment was calculated separately and presented.

Results and discussion

Data given in table 1 revealed that, maximum increase in plant height (0.25 m) was recorded in T_{11}, (GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%), These results are on similar lines as that of Baku, (1989) who reported that Zn and GA_3 treatment combinations resulted in the greatest terminal shoot length, number of leaves/terminal shoot and percent dry weight of the terminal shoot in kagzi lime. However, the total leaf area of the terminal shoot was greatest when 0.6 % Zn were applied. And Prasad *et al.* (2013) [15] reported that, the application of N increases shoot growth, plant height, spread canopy volume in kinnow. The growth of acid lime fruit were significantly influenced by the application of zinc and iron fertilizers (0.25, 0.50 and 0.75 %). Maximum growth observed with two sprays at one month interval of 0.5 % $ZnSO_4$ and 0.5 % $FeSO_4$. Jagtap *et al*. (2013) [9] in acid lime and Eiada *et al.* (2013) [5] in pomegranate.

Data given in table 1 revealed that, maximum east-west spread (3.74 m) was recorded in the treatment T_{11}. maximum north-south spread (3.54 m) was recorded in the treatment T_{11}.Among the various plant growth regulators and micronutrients treatments attempted, application of GA_3 (50ppm) + $ZnSO_4$ (1 %) + $FeSO_4$ (1 %) resulted in higher increase in plant spread as compared to other treatments.

These results are on similar lines as that of Jagtap *et al*. (2013) [9], who reported that treatment with $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 % produced significantly maximum plant canopy volume East-west canopy spread (3.44, 3.76 and 4.04 m). North-South canopy spread (3.40, 3.70 and 3.97 m at 4, 6 and 8 month after first spray) in acid lime, respectively.

Prasad *et al*. (2013) [15], in acid lime, El-Saida (2001) [6] in Washington Navel orange, and Khan *et al*. (2009) [11], reported that foliar spray of 39 g $FeSO_4$, 98 g ZnSO4 and 39 g $MnSO_4$ per 20 litre separately or in combinations had the greatest effect on tree growth. The present results were in accordance with the finding of Singh *et al*. (2008) [22] in aonla.

Minimum days required for initiation of new vegetative flush (17.00) and Minimum days required for flower initiation (14.00) was recorded in the treatment T_{11}. GA_3 (50ppm) + $ZnSO_4$ (1 %) + $FeSO_4$ (1 %) Which was statistically at par with T_{10}. Among the various plant growth regulators and micronutrients treatments attempted. These results are on similar lines as that of Babu *et al*. (1984) [3] in acid lime in acid lime and in mango. (Table 1).

Data given in table 2 revealed that, maximum number of flowers (18.57/shoot) and Minimum days required for harvesting (144.00) was recorded in the treatment T_{11} (GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%). Foliar application of growth regulators GA_3 and NAA application significantly reduced the flower drop and increased fruit retention therefore, number of number of flower per shoot was found highest in GA_3 treated acid lime trees. These results are in accordance with the findings of in acid lime.

Maximum weight of fruit (43.33 g) and The maximum volume of fruit (41.30 ml) was recorded in the treatment T_{11} (GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%). These findings are in accordance with the results obtained by Sinha *et al*. (1999) [23] in acid lime, Babu *et al*. (1984) [3] in lemon tree, The combined treatment (GA_3 + ZnSO4 + FeSO4 + MnSO4) recorded highest fruit weight due to cumulative effects of GA_3, zinc, iron and manganese in acid lime. Sharma *et al*. (2005) [20] Maximum number of fruit (148.00 fruit/tree), Maximum yield (6.41 Kg/tree), The maximum fruit set (51.20 %) and Minimum fruit drop (35.20 %) was recorded in the treatment T11. Foliar application of The growth regulators GA3 and NAA application significantly reduced the fruit drop and increased fruit retention therefore, number of fruits per tree was found highest in GA3 treated acid lime trees. These results are in accordance with the findings of Kachave and Bhosle (2007) [7] in kagzi lime, Singh and Rethy (1995) [21] in acid lime and Babu *et al*. (1984) [3] in lime. The cumulative effect of NAA along with zinc and iron increased the yield per tree than control. (Table 2).

Table 1: Effect of foliar application of plant growth regulators and micronutrients on height, plant spread, days required for new vegetative flush and days required for flower initiation of acid lime.

Sr. No.	Treatment details	Plant height before spraying (m)	Plant height after spraying (m)	Increase in plant height (m)	East–West spread (m).	North-south spread (m).	Days required for new vegetative flush	Days required for flower initiation
T_1	Control	3.30	3.35	0.05	2.37	2.84	27.33	24.00
T_2	GA_3 @ 50ppm	3.55	3.63	0.08	2.84	3.06	27.56	22.33
T_3	NAA @ 100ppm	3.55	3.61	0.06	3.00	3.12	27.90	22.00
T_4	$ZnSO_4$ @ 0.5%	3.50	3.55	0.05	3.02	3.07	28.33	20.00
T_5	$FeSO_4$ @ 0.5%	3.55	3.63	0.08	3.07	3.06	27.33	23.50
T_6	$ZnSO_4$ @ 1.0%	3.30	3.45	0.15	3.08	3.11	29.33	21.33
T_7	$FeSO_4$ @ 1.0%	3.35	3.50	0.15	3.03	3.16	28.33	23.05
T_8	$ZnSO_4$ @ 0.5% + $FeSO_4$ @ 0.5%	3.25	3.35	0.10	3.01	3.15	26.05	22.09
T_9	$ZnSO_4$ @ 1.0% + $FeSO_4$ @ 1.0%	3.55	3.60	0.05	3.17	3.29	25.03	20.33
T_{10}	GA_3 @ 50 ppm +$ZnSO_4$ @0.5% +$FeSO_4$ @ 0.5%	3.50	3.70	0.20	3.60	3.41	20.00	15.67
T_{11}	GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%	3.60	3.85	0.25	3.74	3.54	17.00	14.00
T_{12}	NAA @ 100ppm + $ZnSO_4$ @0.5% + $FeSO_4$ @ 0.5%	3.40	3.48	0.08	3.40	3.43	27.50	18.57
T_{13}	NAA @ 100ppm +$ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%	3.60	3.64	0.04	3.51	3.50	24.33	16.33
	S.E.m ±	0.17	0.17		0.16	0.18	1.22	1.30
	C.D at 5%	NS	NS		0.47	0.53	3.56	3.80

Table 2: Effect of foliar application various plant growth regulators and micronutrients on number of flowers per shoot, days required for harvesting, weight of fruit (g) and volume of fruit (ml), number of fruit / tree and yield / tree (kg) in acid lime.

S. No.	Treatment details	Number of flower per shoot	Days required for harvesting	Weight of fruit (g)	Volume of fruit (ml)	Number of fruit/tree	Yield /tree (Kg)
T_1	Control	8.33	162.33	34.50	30.90	94.33	3.25
T_2	GA_3 @ 50ppm	9.45	160.00	35.07	32.03	126.67	4.44
T_3	NAA @ 100ppm	9.90	159.00	35.99	32.50	110.00	3.95
T_4	$ZnSO_4$ @ 0.5%	10.06	158.33	35.98	32.33	113.0	4.06
T_5	$FeSO_4$ @ 0.5%	13.90	161.00	36.65	34.98	117.00	4.28
T_6	$ZnSO_4$ @ 1.0%	14.10	157.67	36.80	34.50	120.33	4.41
T_7	$FeSO_4$ @ 1.0%	15	156.67	36.06	35.05	122.67	4.41
T_8	$ZnSO_4$ @ 0.5% + $FeSO_4$ @ 0.5%	15.90	154.85	37.10	36.10	134.67	5
T_9	$ZnSO_4$ @ 1.0% + $FeSO_4$ @ 1.0%	16.30	153.09	38.08	37.15	137.00	5.28
T_{10}	GA_3 @ 50 ppm +$ZnSO_4$ @0.5% +$FeSO_4$ @ 0.5%	17.45	147.67	40.20	38.05	145.00	5.82
T_{11}	GA_3 @ 50ppm + $ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%	18.57	144.00	43.33	41.30	148.00	6.41

T_{12}	NAA @ 100ppm + $ZnSO_4$ @0.5% + $FeSO_4$ @ 0.5%	16.90	151.68	39.06	35.04	139.33	5.45
T_{13}	NAA @ 100ppm +$ZnSO_4$ @1.0% +$FeSO_4$ @ 1.0%	17.65	150.00	40.16	37.90	142.33	5.71
	S.E.m ±	2.25	2.75	1.85	1.29	6.50	0.39
	C.D at 5%	6.65	8.03	5.41	3.76	18.97	1.25

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