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Effect of plant growth regulators and micronutrients on growth and yield of acid lime (*Citrus aurantifolia* swingle) in *hasta bahar*

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Abstract

Vidarbha region of Maharashtra, famous for quality citrus production and acid lime is one of the important member of citrus group. Regulation of flowering in *Hasta bahar* is important for obtaining off season acid lime fruits. Keeping in view all these considerations, an experiment was carried out to study the effect of plant growth regulators (GA_3, cycocel and paclobutrazol), KNO_3 and micronutrients like zinc and boron on growth and yield of acid lime in *Hasta bahar*. The study revealed that application of GA_3 50 ppm in June + Cycocel 1000 - 2000 ppm, Paclobutrazol 2.5 and 3.5 g a.i. / tree and 1000 - 2000 ppm in September + KNO_3 (0.2%), Zinc (0.3%) and Boron (0.1%) in October showed bet er performance in plant height, mean plant spread and canopy volume. Maximum yield was obtained with the application of GA3 50 ppm + Cycocel 2000 ppm + KNO3 0.2% + Zn 0.3% + Boron 0.1%.

Highlights

- GA_3 50 ppm in June + cycocel 1000 - 2000 ppm, paclobutrazol 2.5 and 3.5 g a.i. / tree and 1000 - 2000 ppm in September + KNO_3 (0.2%), zinc (0.3%) and boron (0.1%) in October found to be effective in relation to plant height, mean plant spread, canopy volume.
- GA3 50 ppm + Cycocel 2000 ppm + KNO3 0.2% + Zn 0.3% + Boron 0.1% was found effective for maximum yield in acid lime.

Keywords: Acid lime, plant growth regulators, micronutrients, growth and yield.

In India, citrus is one of the major fruit crops, and it cultivated in 1.042 Mha area with the production of 10.089 MT, among which lemon and lime contribute about 0.255 Mha in area, 2.523 MT on production basis (Anon 2013). In India mandarins, sweet oranges, lime and lemons grown commercially. Lime and lemon have high medicinal values, as these are source of antiscorbutic vitamin C (Jawandha *et al*. 2014). Acid lime (*Citrus aurantifolia* Swingle) comes under a citrus group and belongs to family Rutaceae. It originated in India and is commonly known as '*Nimbu'*. In Maharashtra state citrus is grown on about 0.277 Mha area with production of about 0.861MT fruits annually and productivity is 3.10 MT/ha. Total area under acid lime cultivation in Maharashtra is 0.045 Mha with production of 0.246 MT, having productivity of 5.5 MT/ha (Anon, 2013). Generally lime has peculiar tendency of bearing more number of fruits in one season and lean in subsequent season. Thus, acid lime exhibits some sort of alternate bearing

that leads to fluctuation in production which renders continuous supply of fruits to market is difficult. The regulation of bahar and improvement in productivity could be achieved by the use of growth regulators at appropriate time and proper concentration. Since the discovery of the plant growth regulators, they have been used to manipulate plant growth and development for the improvement of quality and quantity of the produce in order to enable the fruit growers to meet to pressure of increasing demand for food of high quality Bons *et al.* (2015). The suitable combinations of macronutrients, micronutrients and growth regulators could control the excessive fruit drop and improve the citrus fruit yield and its quality (Doberman and Fairhurst 2000) Besides growth regulators, the nutrient elements, especially micronutrients when applied as foliar spray exerted pronounced influence on plant growth and yield (Ibrahim *et al*. 2009). Acid lime flowers thrice in a year in Vidarbha region of Maharashtra. Greater flowering is obtained in *Ambia bahar* (60%) followed by *Mrig bahar* (30%) and *Hasta bahar* (10%). Hence market gets glut ed with *Ambia bahar* fruits which are harvested in the month of June-July resulting in low price of fruits. In case of *Hasta bahar* flowering is observed in month of October- November and fruits become ready for harvest in March-May producing predominantly off season fruits. Hence the experiment was carried out to maintain plant growth and yield during *Hasta bahar* for quality production with the use of growth retardants and micronutrients.

Materials and Methods

An experiment was conducted during the year 2013-2014 at acid lime orchard, College of Horticulture, Dr. P.D.K.V., Akola. Akola is situated at 307-457 meter altitude from sea level at 20.42° latitude and 72.02°E longitude and has marginal tropical climate in Vidarbha region of Maharashtra. The field trial was statistically laid out in randomized block design (RBD), each uniformly selected tree was replicated thrice. The required dose of manures, fertilizers, irrigation and plant protection measures were given to each selected tree. The treatments applied consist of T_1 (control), T_2 (GA_3 50 ppm + Cycocel 1000 ppm + KNO_3 0.2% + Zn 0.3% + Boron 0.1%), T_3 (GA_3 50 ppm + Cycocel 2000 ppm + KNO_3 0.2% + Zn 0.3% + Boron 0.1%), T_4 (GA_3 50 ppm +Paclobutrazol 2.5 g a.i./tree (soil application) + KNO_3 0.2 % + Zn 0.3% Boron 0.1%), T_5 (GA_3 50 ppm + Paclobutrazol 3.5 g a.i./tree (soil application) + KNO_3 0.2% + Zn 0.3% + Boron 0.1%), T_6 (GA_3 50 ppm + Paclobutrazol 1000 ppm (foliar application) + KNO_3 0.2% + Zn 0.3% + Boron 0.1%) + and T_7 (GA_3 50 ppm + Paclobutrazol 2000 ppm (foliar application) + KNO_3 0.2% +Zn 0.3% + Boron 0.1%). Spraying of GA_3 was given in first fortnight of June whereas spraying of cycocel and paclobutrazol was done while releasing trees for water stress (*i.e.* 15th September) and KNO_3, Zn and Boron was sprayed 2 to 3 days prior to releasing trees from water stress. (*i.e.*15th October). The plant height was measured with the help of marked bamboo. Spread of tree was recorded by measuring maximum spread in North-South and East-West directions in meters with the help of marked bamboo and canopy volume of tree was calculated as per formula suggested by Blozan (2004). Number of fruits per plant and yield per tree were counted manually during harvesting.

Results and Discussion

Plant Height

Data recorded (Table 1) in respect to plant height was found significant difference af er spraying of GA_3 while, plant height af er three months of GA_3 spray, showed non significant increase in height over initial plant height. However in all the treatments of GA_3 spray showed more trend of increase in height as compared to control. Maximum (9.75 %) increase in height was recorded by the treatment T_5 whereas least (7.02 %) increase in plant height was recorded in T_1. Highest (0.40 m) plant height which comes to 13% increase over initial height in control which was significantly superior over all other remaining treatments. Least (0.31 m) increase in height was recorded in T_4 and T_6. Whereas, least (9.30 %) increase in height over initial height was observed in T_3. Srihari Babu (1989) found similar results with spray of 50 ppm GA_3 in kagzi lime. Study also supported

Table 1. Effect of plant growth regulators and micronutrients on plant height in *Hasta bahar* of acid lime.

Treatments		Plant height before spray of growth retardant (i.e. 3 month after spray of GA_3)			Plant height at the time last harvest		
	Initial plant height (m)	Plant height (m)	Increase in height (m)	Initial plant height (%)	Plant height (m)	Increase in plant height (m)	Increase in plant height over initial height (%)
T_1	3.08	3.29	0.22	7.02 (2.74)*	3.48	0.40	13.00 (3.67)
T_2	3.13	3.42	0.30	9.49 (3.16)	3.47	0.35	11.09 (3.40)
T_3	3.51	3.81	0.31	8.73 (3.04)	3.83	0.33	9.30 (3.13)
T_4	3.16	3.45	0.28	8.99 (3.08)	3.51	0.31	9.94 (3.23)
T_5	3.05	3.34	0.30	9.75 (3.20)	3.41	0.37	12.05 (3.54)
T_6	3.20	3.49	0.29	9.00 (3.08)	3.49	0.31	9.62 (3.18)
T_7	3.02	3.30	0.29	9.51 (3.16)	3.40	0.33	10.84 (3.37)
F-test	---	S*	NS	S*	NS	S*	S*
SE (m)±	---	0.09	0.01	0.16	0.09	0.01	0.14
CD at 5%	--	0.27	---	0.49	---	0.03	0.45

*****Figs in parenthesis indicate transformed values; S* singnigicant; NS nonsignificant

Table 2. Effect of plant growth regulators and micronutrients on mean plant spread of *Hasta bahar* in acid lime (m)

Treatments	Initial mean plant spread (m)	Mean plant spread before spray of growth retardant (i.e. 3 month after spray of GA_3)			Mean plant spread at the time last harvest		
		Mean plant spread (m)	Difference	Increase in mean plant spread (%)	mean plant spread (m)	Increase in mean plant spread (m)	Increase in mean plant spread over initial spread (%)
T_1	4.45	4.61	0.19	3.57 (2.01)*	4.85	0.40	8.99 (3.08)
T_2	3.94	4.21	0.27	6.91 (2.70)	4.26	0.32	8.12 (2.94)
T_3	4.34	4.62	0.28	6.43 (2.62)	4.64	0.31	6.91 (2.72)
T_4	4.24	4.51	0.27	6.37 (2.61)	4.54	0.30	7.07 (2.75)
T_5	4.36	4.64	0.28	6.41 (2.62)	4.66	0.30	6.88 (2.72)
T_6	3.75	4.05	0.30	8.03 (2.92)	4.08	0.33	8.80 (3.05)
T_7	4.60	4.89	0.29	6.29 (2.60)	4.94	0.34	7.39 (2.81)
F-test	---	S*	NS	S*	NS	S*	S*
SE (m)±	---	0.13	0.02	0.12	0.13	0.01	0.003
CD at 5%		0.40	---	0.39	---	0.03	0.0009

Figs in parenthesis indicate transformed values; S singnigicant; NS nonsignificant

Table 3. Effect of plant growth regulators and micronutrients on canopy volume in *Hasta bahar* of acid lime (m^3)

Treatment		Canopy volume before spray of growth retardant (i.e. 3 month after spray of GA_3)			Canopy volume at the time last harvest		
	Initial canopy volume (m3)	Canopy volume (m3)	Difference	Increase in canopy volume (%)	Canopy volume (m3)	Increase in canopy volume (m3)	Increase in canopy volume over initial volume (%)
T_1	29.96	34.41	4.45	14.85 (3.85)*	40.22	10.25	34.22 (5.85)
T_2	23.88	29.85	5.97	25.01 (5.00)	31.01	7.13	29.86 (5.46)
T_3	32.53	40.08	7.55	23.19 (4.82)	40.64	8.10	24.91 (4.99)
T_4	27.98	34.50	6.52	13.31 (4.83)	35.26	7.29	26.05 (5.10)
T_5	29.88	36.89	7.01	23.45 (4.84)	37.42	7.54	25.23 (5.02)
T_6	20.86	26.64	5.78	27.74 (5.27)	27.82	6.97	33.40 (5.78)
T_7	31.69	39.31	7.61	24.02 (4.90)	40.96	9.26	29.22 (5.19)
F-test	---	NS	NS	NS	NS	Sig	Sig
SE (m)±	---	3.07	0.93	0.28	3.12	0.74	1.86
CD at 5%	--	---	---	---	---	2.28	5.72

Figs in parenthesis indicate transformed values; S significant; NS nonsignificant

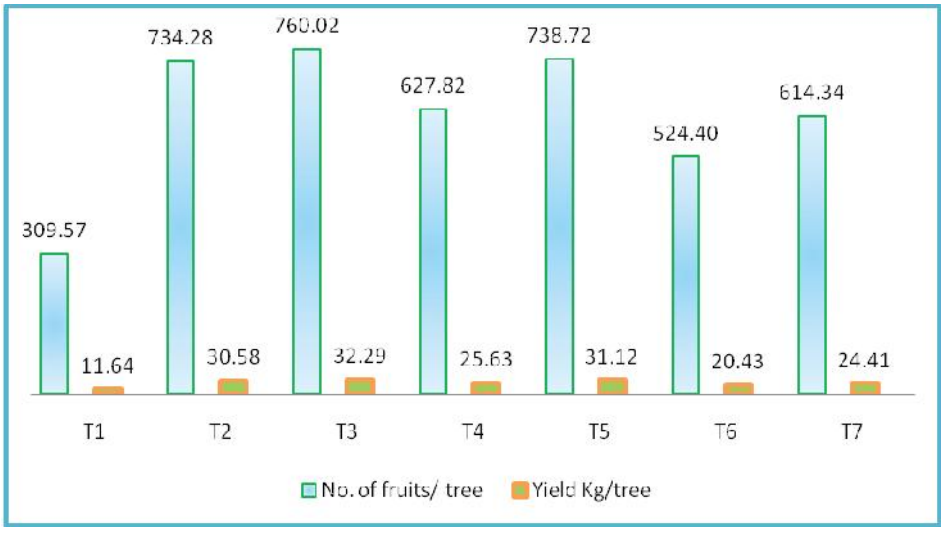

Fig. 1. Effect of plant growth regulators and micronutrients on number of fruits per plant of Hasta bahar in acid lime.

SE (m) ± 16.49(No. of fruits per tree); 0.66(Yield kg/tree)

CD at 5% 50.82 (No. of fruits per tree); 2.04 (Yield kg/tree)

by Nir *et al.* (1972) in acid lime with cycocel 1000 ppm and Delgado *et al.* (1986) in sour orange.

Plant Spread

Data pertaining (Table 2) to initial plant spread and plant spread recorded just after spraying GA_3 *i.e.*first fortnight of June, but before spraying of growth retardants indicated significant variation among the various treatments. However, difference between spread recorded three months after spraying of GA_3 and initial spread indicated non significant differences in the increase of mean spread within treatment. Treatment T_6 recorded significantly maximum spread (8.03%) as compared to remaining treatments, whereas control (T_1) recorded minimum (3.57 %) increase in spread. The final spread recorded at the time of last harvest indicated non significant variation in plant spread. The maximum (4.94 m) and minimum (4.08 m) mean plant spread was recorded in T_7 and T_6 respectively. However, the difference or increase in spread recorded within a treatment indicated significant gain over the initial values. Treatment T_1 had significantly maximum increase in spread (8.99%) whereas treatment (T_5) recorded least increase in spread (6.88%).

Mukhopadhyay (1976) stated that the application of cycocel at 500 ppm was effective in suppression of growth and promotion of flowering in fruit plant and also increased the yield of young 'Langra' and 'Baramasi' mango trees. Shikhamany and Reddy (1989) reported that application of 1000 ppm cycocel, sprayed at 5 leaf stage was favorable in reducing the shoot vigour as indicated by the reduced petiole length and leaf area but the application of 3000 ppm cycocel at 15 leaf stage was found to be effective in increasing yield per vine and increased bunch weight in grape cv. 'Thompson seedless'.

Canopy Volume

Data estimated on canopy volume, elaborated in Table 3, indicated non-significant differences among the treatment for canopy volume recorded at initial and three months after GA_3 spray (*i.e.* 15th September). The maximum (40.08 m^3) canopy volume with 7.55 m^3 increase over initial volume was recorded in T_3 whereas the least (34.41 m^3) canopy volume with 4.45 m^3 increase over initial volume was recorded in T_1. Increase in canopy volume after three months of GA_3 spray indicated maximum (27.7%) increase in the treatment T_6. The final volume recorded (at the time of harvest 30th April) indicated non-significant variation among the treatment for the canopy volume. However, the increase in volume over initial volume recorded *i.e.* difference of final volume and initial volume indicated significantly maximum increase in canopy volume (10.25 m^3) in the treatment T_1, which was 34.22% increase. The treatment T_6 recorded least increase in canopy volume (6.97 m^3). However, treatment T_3 recorded least (24.91 %) increase in canopy volume. In all the treatments (except control) increase in the growth parameters like plant height, mean spread and canopy volume after three months of spray of GA_3 was more. It has been largely due to the effect of GA_3 which promotes cell elongation, increase in both cell size and number and also increase cell multiplication (Knoche *et al*. 2000). The minimum increase in growth parameters values and% increase in growth parameters was noted in control up to second fortnight of September but increase in growth parameters which is calculated by difference of final and initial values of growth parameters and converted to percentage indicated maximum increase in control over all the treatments. This was mainly due to the effect of growth retardants like Cycocel and Paclobutrazol which act as anti-gibberellins inhibiting growth thus checking the growth rate after spray of growth retardant leading to less increase in growth, both in meters and in per cent values compared to the control.

Yield (No. Fruits/tree and Fruits kg/tree)

The estimated value in Figure 1 clearly indicated that yield in terms of number of fruits per tree and yield kg per tree was significantly influenced by the application of plant growth regulators and micronutrients. Treatment T_3 showed more number of fruits (760.02) per plant, whereas less number of fruits (309.57) was found with treatment T_1. The highest (32.29 kg/plant) yield was observed with T_3

while, lowest yield (11.64 kg/plant) was recorded in T_1 (control). Earlier reports indicated that the application of Zn increases the fruit yield and quality (Rodriguez *et al.* 2005). Thirugnanavel *et al.* (2007) also found that the highest number of fruits per plant and yield per plant was obtained with application of Cycocel 1000 ppm in September + KNO_3 (2%) in October in acid lime and similar results were reported by Nikhare (2002) in acid lime.

Conclusion

Based on above findings, appropriate combination and concentration of growth regulators as well as micronutrients i.e. GA_3 50 ppm in June + cycocel 1000 - 2000 ppm, paclobutrazol 2.5 and 3.5 g a.i. / tree and 1000 - 2000 ppm in September + KNO_3 (0.2%), zinc (0.3%) and boron (0.1%) in October found to be effective in relation to plant height, mean plant spread, canopy volume whereas, GA3 50 ppm + Cycocel 2000 ppm + KNO3 0.2% + Zn 0.3% + Boron 0.1% was found effective for higher number of fruits and yield in acid lime. So, it is envisage amicable solution for the regulation of *Hasta bahar* with proper growth and yield which promises more return for acid lime growers.

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