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Effect of plant growth regulators on growth, yield and quality of acid lime (*Citrus aurantifolia* Swingle.) var. PKM 1

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Abstract
The investigation was carried out to study the effect of plant growth regulators on growth, yield and quality of acid lime (*Citrus aurantifolia* swingle.) var. PKM 1 at the Department of Fruit crops, Horticultural College and Research Institute, Periyakulam, Tamil Nadu. Treatment consisted of soil drenching of Paclobutrazol (PP_{333}) (0.5, 1.0 and 1.5 g a.i/m^2), foliar application of Cycocel (CCC) (500 and 1000 ppm) and Napthalene acetic acid (NAA) (100 and 200ppm). Result revealed that growth, yield and quality parameters such as tree spread, fruit set percentage, fruit retention percentage, number of fruits per tree, yield per tree, juice volume, acidity and ascorbic acid were found to be higher in the treatment combination of PP_{333} 1.5g a.i/m^2 + NAA 200ppm.

Keywords: Acid lime, paclobutrazol, cycocel, napthalene acetic acid and flowering

Introduction
Acid lime (*Citrus aurantifolia* Swingle) is most one of the important citrus crop in India. It belongs to the family Rutaceae, with chromosome number (2n = 18). In India, acid lime is grown in a variety of agro – climates. Citrus are evergreen, generally show a relatively long juvenility (2 to 5 years) for commercial production. The growth period in acid lime varies under ecological set up. Citrus has no peculiar requirement of winter chilling but termination of growth during winter helps in flower bud induction resulting in spring flowering (Devi *et al.*, 2011) [9]. Flowering in acid lime is recurring under tropical and sub- tropical condition unless synchronized into well-defined period of extreme stress. Since the market for the fruits remains very high during summer it is very essential to regulate the flowering so as to get fruiting in the month of April and May (Ranganna *et al*., 2017) [19]. The fruiting will get higher returns to the grower compared to the income receive during other season. The regulation of bahar and enhancement in productivity could be achieved by the use of plant growth regulators at suitable time and proper concentration. Hasta-bahar (September-October) management through the use of plant growth regulators play an important role to get maximum fruit yield during summer (Mukuda *et al.*, 2014) [15]. The plant growth regulators, they have been used to manipulate plant growth and development for the enhancement of quality and quantity of the produce in order to enable the fruit growers to meet the pressure of increasing demand for food of high quality (Bons *et al.*, 2015) [6]. The acid lime trees under Tamil Nadu conditions flower normally twice a year during January- February and June- July and yield fruits mainly during July- August and December-January. If this seasonality of production could be altered by artificial means, then it would be favouring to the acid lime growing farmers. The present study was undertaken to investigate the effect of combination of plant growth regulators *viz*, Paclobutrazol (PP_{333}), Cycocel (CCC) and Napthalene acetic acid (NAA) to increase the yield and quality of acid lime.

Materials and Methods
Treatment details
The experiment was conducted at the Department of Fruit crops, Horticulture College and Research Institute, Periyakulam with Factorial Randomized Block Design (FRBD) and each treatment was replicated thrice. The age of the tree was seven years and the variety selected for the experiment was PKM1.The tree were spaced in 7x7m. The treatment consisted of different method of chemical spraying such as soil drenching of PP_{333} 0.5 g a.i /m^2 (S_1), PP_{333} 1.0 g a.i /m^2 (S_2), PP_{333} 1.5 g a.i /m^2(S_3) and foliar spraying of NAA 100ppm (F_1), NAA 200ppm (F_2), CCC 500ppm (F_3), CCC 1000ppm(F_4). The observations were recorded on tree spread (m) in both North-South and East-West direction, number of fruits per tree, fruit weight, fruit yield

(kg/tree), the fruit set was calculated at pea size stage and expressed in percentage and the fruit retention was calculated at the time of harvest and expressed as percentage.

The juice content of fruit for each treatment was measured. The mean was calculated and expressed in per cent. The T.S.S was recorded by using a hand refractrometer and expressed as ^{0}Brix. Acidity was estimated in the pulp of the fruit following A.O.A.C. (1978) [1] method. The ascorbic acid content was volumetrically determined as per the method described by Sadasivam and Manickam (1996) [20] and expressed as mg/100 g. Data collected on yield and quality attributes were statistically analyzed as per the methods suggested by Panse (1967) [17].

Results and discussion

Growth and yield parameters

Tree spread in North-South and East-West direction (m)

Application of Paclobutrazol @ 1.0 g a.i /m^2 + NAA 200ppm (T_6) recorded the highest tree spread in N-S (2.93m) and 2.78m in E-W respectively. The tree spread was least in Paclobutrazol @ 0.5 g a.i /m^2 + NAA 100ppm (T_1),which registered N-S (2.46 m)and (2.13m) in E-W. This increase in the tree canopy spread may be due to effective conversion of stored food materials for the initiation of more side branches in the trees. This fact was corroborated with the work of Jayavalli (2006) in mango. The results of the present study were also in accordance with the findings of Baskaran (2009) [5] in acid lime. (Table-1)

Fruit set (%)

Higher fruit set (71.18%) was recorded on the application of Paclobutrazol @ 1.5 g a.i /m^2 + NAA 200ppm (T_{10}).The percentage of fruit set was lowest (60.86%) in control. The increase in fruit set with soil applied paclobutrazol might be due to its effect on shifting of assimilates, mineral element and soluble proteins in leaves, stem and root (Wang *et al*. 1985) [21]. These was in close conformity with the results obtained by Tripathi and Dhakal (2005) in acid lime and Ghadage nitish jagannath (2013) [11] in acid lime. NAA application resulted in higher fruit set due to the better nutritional status of shoots provide better opportunities to set more number of fruits. The results of the present study were in accordance with the findings of Azher Nawaz *et al*. (2011) [2] in Kinnow mandarin. (Table-1)

Fruit retention (%)

The highest fruit retention (57.09%) was recorded in Paclobutrazol @ 1.5 g a.i /m^2 + NAA 200ppm T_{10}, and the fruit retention was lowest in control with (26.18%). The role of NAA in inhibiting formation of abscission layer was well known. Auxin content in fruits during 2-3 weeks after pollination was low and the ability of fruits to mobilize food material was poor due to low auxin level which results in fruit drop. As the fruit develops, the amount of auxin rises rapidly which was helpful in mobilization of food material (Chacko *et al.*, 1972) [7]. At this stage the competition among developing fruits starts and the fruits which compete less successfully were forced to drop. The result of the present study was in accordance with the findings of Pandey (1999) [18] in Ber and Gulab sanodiya (2015) [12] in acid lime. (Table-1)

Number of fruits/ tree

Number of fruits per tree is highest (885) with the application of Paclobutrazol @ 1.5 g a.i /m^2 + NAA 200ppm (T_{10}) However, lowest number of fruits (455) per tree was recorded with the control. The external application of NAA had a significant increase the fruit retention which might be due to balancing the internal status of auxin responsible for inhibiting the formation of abscission layer which leads to produce more numbers of fruits at various stages. Paclobutrazol might be due to its effect on shifting of assimilates, mineral element and soluble proteins in leaves, stem and root (Wang *et al*. 1985) [21] and Similar results have been reported by Ghosh *et al*. (2009) [10] in pomegranate, and Jagtap *et al*. (2013) in Kagzi lime. (Table-1)

Fruit yield (kg tree^{-1})

The increase in yield with soil application of Paclobutrazol @ 1.5 g a.i /m^2 + NAA 200ppm (T_{10}) has recorded significantly highest fruit yield per tree (52.05kg).The lowest fruit yield was recorded in control treatment (23.94 kg). The yield increase in paclobutrazol treated trees was due to higher fruit set from enhanced flowering and higher hermaphrodite flowers and the alteration of source sink relationship in the plant which directly reallocates the carbohydrate reserves by suppressing the vegetative growth. Application of paclobutrazol before the bud break during vegetative growth will not only suppress the enhanced growth but also promote the yield.Similar results were also found by Chuaycharoen *et al*. (2007) in lime and Ghadage nitish jagannath (2013) [13] in acid lime. (Table-1)

Quality parameters

Juice volume (ml)

The maximum juice volume was recorded in (T_{10}) application of Paclobutrazol @ 1.5 g a.i /m^2 + NAA 200ppm which measured (35.62ml) per fruit.Whereas, minimum juice volume was recorded in control (27.04 ml). The increase in volume of juice might be due to paclobutrazol changes metabolic activities, which increased the stored food material in the tissue. Similar result was also obtained by Ghadage nitish jagannath (2013) [11] in acid lime and Arvind singh bhati (2015) [3] in acid lime. (Table-2)

Acidity (%)

The higher acidity was recorded in paclobutrazol @ 1.5 g a.i /m^2 + NAA 200ppm (T_{10}) which recorded (8.82) per cent, the lowest acidity (7.09) was recorded in control. Nawaz *et al*. (2008) [16] also stated that highest acidity of 1.04 % was observed with 15 ppm NAA spray followed by 20 ppm NAA spray in kinnow mandarin. (Table-2)

Ascorbic acid content (mg/100g)

The highest ascorbic acid content (39.97) was noticed in application of paclobutrazol @ 1.5 g a.i /m^2 + NAA 200ppm (T_{10}) Whereas, lowest ascorbic acid content was recorded in (T_0) control treatment (28.31).The increase in ascorbic acid content with the application of NAA might be due to perpetual synthesis of glucose-6-phosphate throughout the period of growth and development of fruits which was thought to be the precursor of Vitamin C. These findings were similar as in Ber (Pandey, 1999) [18]. And also the increase in the ascorbic acid content could be attributed to the role of plant growth regulators in breaking down organic acids in to sugars at the time of fruit ripening. The present result is in conformity with the results achieved by Ghadage nitish jagannath (2013) [11] in acid lime. (Table-2)

Conclusion

The study revealed that application of PP_{333} 1.5g a.i/m^2 + NAA 200ppm showed better performance in growth, yield and quality parameters such as tree spread, fruit set percentage, fruit retention percentage, number of fruits per tree, yield per tree, juice volume, acidity and ascorbic acid in acid lime. When compared to the control. The increase in number of fruits and yield as a whole form the research will satisfy the glut and demand for the fruits in peak summer at periyakulam condition.

Table 1: Effect of plant growth regulators on growth and yield attributes of acid lime var. PKM1

Treatment	Tree spread (m)				Fruit set (%)		Fruit retention (%)		No. of fruits/ tree		Fruit yield (kg tree^{-1})	
	N – S		E – W									
S_1F_1	2.17		2.19		60.89		33.02		685.99		38.11	
S_1F_2	2.49		2.37		68.55		44.20		714.00		39.66	
S_1F_3	2.39		2.28		67.58		42.50		644.00		33.89	
S_1F_4	2.12		2.60		68.25		42.93		612.00		32.21	
S_2F_1	2.81		2.76		68.87		47.02		756.99		42.05	
S_2F_2	2.97		2.99		68.27		48.47		792.00		44.00	
S_2F_3	2.27		2.21		67.40		41.61		591.00		31.10	
S_2F_4	2.69		2.47		67.00		39.66		570.00		30.00	
S_3F_1	2.90		2.54		68.36		49.08		831.00		48.88	
S_3F_2	2.93		2.78		71.18		57.09		885.00		52.05	
S_3F_3	2.58		2.69		68.72		39.95		594.00		28.89	
S_3F_4	2.28		2.49		67.76		38.46		567.00		27.42	
Mean	2.55		2.53		67.73		43.66		679.33		37.35	
Control	2.46		2.13		60.86		26.18		455.00		23.94	
	SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD	SEd	CD
S	0.026	0.054	0.024	0.051	0.677	1.405	0.478	0.992	5.791	12.011	0.420	0.872
F	0.030	0.063	0.028	0.059	0.782	1.623	0.552	1.146	6.687	13.869	0.485	1.007
S X F	0.052	0.109	0.049	0.102	1.355	2.811	0.957	1.985	11.583	24.022	0.841	1.744

Table 2: Effect of plant growth regulators on quality attributes of acid lime var. PKM1

Treatment	Juice volume (ml)		Acidity (%)		Ascorbic acid content(mg/100g)		TSS	
S_1F_1	32.33		8.58		35.24		8.64	
S_1F_2	32.80		8.72		38.54		8.62	
S_1F_3	31.42		8.14		33.62		8.50	
S_1F_4	31.18		8.37		35.03		8.73	
S_2F_1	33.00		8.69		38.13		8.35	
S_2F_2	33.31		8.55		36.26		8.42	
S_2F_3	30.53		8.23		33.43		8.33	
S_2F_4	30.17		7.81		31.57		8.27	
S_3F_1	33.66		8.64		39.69		8.44	
S_3F_2	35.62		8.82		39.97		8.60	
S_3F_3	29.27		7.36		30.29		8.26	
S_3F_4	29.01		7.53		30.04		8.03	
Mean	31.85		8.28		35.15		8.43	
Control	27.04		7.09		28.31		7.80	
	SEd	CD	SEd	CD	SEd	CD	SEd	CD
S	0.465	NS	0.073	0.151	0.386	NS	0.090	0.186
F	0.537	1.114	0.084	0.174	0.446	0.926	0.103	NS
S X F	0.930	1.929	0.146	0.302	0.773	1.604	0.180	NS

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