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Flowering and fruiting pattern of acid lime as affected by different growth regulators and chemicals

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Abstract
The present investigation was carried out at Experimental area, College of Agriculture, Gwalior (M.P.) during 2018-19 and 2019-20. The experiment aimed at finding out the effect of growth regulators and chemicals on flowering and fruiting patterns of acid lime. T_{10} ($GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%) was found to be significantly superior to rest of the treatments under study but was reported to be at par with T_9 ($GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%) for all the parameters like Days to first flowering (43.00, 41.67 and 42.33 during first, second and pooled year), Number of flowers per shoot (141, 146 and 144 during first, second and pooled year respectively), Initial fruit set (51.53, 51.60 and 51.57% during first, second and pooled year respectively), Fruit retention at harvest (27.63, 27.34 and 27.49% during first, second and pooled year respectively).

Keywords: acid lime, *Citrus aurantifolia*, flowering pattern, fruiting pattern, Vikram

Introduction
Acid lime (*Citrus aurantifolia*)(Kagzi lime, Sour lime, and Mexican lime) is also known as Neebu. It belongs to the family Rutaceae and has chromosome no. 2n=18. Citrus is the 3rdimportant fruit crop after Mango and Banana. It is a profusely branched thorny shrub, the leaves are small with narrowly winged petioles. The flowers are small, pure white and are borne in clusters. The fruits are more or less round or oval, smooth having thin rind (papery) attached tightly. The immature fruits are dark green in colour which changes to light yellow when ripe. The colour of the pulp is light greenish-yellow, taste is acidic, aromatic, cells fine and shiny. The numbers of segments are 9-11 and numbers of seeds per fruit are 9-10.

Fruits of acid lime possess great medicinal and nutritional value. It is a rich source of vitamin "C". Fruits being acidic in nature, they are largely used for garnishing and flavouring several vegetarian and non- vegetarian dishes. Besides its value-added products like pickle, juice, squash etc. Lime peel oil, peel powder are also in great demand in the soap and cosmetic industry.

The Nutritional value of raw limes is 88% water, 10% carbohydrates and less than 1% each of fat and protein. Only vitamin C content at 35mg/100g of fruit. The Daily Value (DV) per 100 g serving is significant for nutrition, with other nutrients present in low DV amounts. Lime juice contains slightly less citric acid than lemon juice (about 47 g/l), nearly twice the citric acid of grapefruit juice, and about five times the amount of citric acid found in orange juice.

Lime is found in most parts of the sub-tropics. In India, it is cultivated in Andhra Pradesh, Gujarat, Maharashtra, Karnataka, Bihar, Madhya Pradesh, Assam, and Chhattisgarh. In M.P., it is cultivated in Badawani, Khargon, Khandwa, Ujjain, Ratlam, Mandsaur, Neemach, Shajapur, Gwalior, Burhanpur, Hoshangabad, Morena, Guna, Jabalpur and Bhopal districts. The total area and production of Acid lime in India is about 252 MH and 2546 MT respectively (Anonymous 2017-18). The total area and production of acid lime in Madhya Pradesh are 0.064 MH and 0.13 MT respectively.

Acid lime trees flower thrice a year in the months of January-February, June-July and September-October known as Ambe, Mrig and Hasta bahar, respectively. The fruits of the Ambe, Mrig and Hasta bahar flowering become available in the months of June-July, November-December and April-May months, respectively. The flowering percentage of Ambe, Mrig and Hasta bahar occurs 47%, 36% and 17%, respectively. The fruits of Hasta 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 into profuse flowering, use of plant growth regulators and chemicals gives an effective alternative. Use of Gibberellic acid (GA_3) during the stress period is known to reduce the intensity of flowering in the following flowering season. Cycocel (CCC) has been found very effective for imposing stress for inducing flowering. Potassium nitrate (KNO_3) chemical for sprouting has been found effective in acid lime.

The water stress with hormones played an important role in regulation of flowering and there is a relationship between severity of stress and flowering response (South Wick and Davenport, 1987; Barbera and Garimi, 1988) [17, 2]. Considering the importance of Hasta baharfruits, it is necessary to undertake the study on stress period with some chemicals for assured flowering of Hasta bahar in acid lime. Therefore, these plant growth regulators and chemicals can be effectively used for obtaining profuse flowering and fruiting for Hasta bahar in acid lime.

There is a possibility that if plant growth regulators are used, the plant maturity may be hastened considerably. Some plant growth regulators like gibberellic acid is recognized as a revolutionary growth regulator as it promotes the cell elongation hasten the growth of the plant, increases the yield, size and weight of fruits.CCC is a growth retardant which blocks the gibberellins biosynthesis. It influences the steroid metabolism and also affects other physiological processes. It is generally used for suppressing vegetative growth and to induce flowering and increasing fruit set. KNO3 is effective for sprouting buds.

Advantages of foliar application of nutrients are economical as compared to the soil application. The efficiency is more. The nutrients are made easily available if supplied at proper stage and at optimum concentration. The respective nutrient can be given when needed. Absorption through foliage is easier and effective and the phenomenon of antagonism is avoided. Micro-nutrients are applied to correct the deficiency through the foliage.

The present study was therefore undertaken to investigate the effect of combinations of plant growth regulators *viz*., GA_3 and Cycocel, chemicals *viz*., KNO_3 and Thiourea on flowering and fruiting patterns of acid lime.

Material and Methods

Location

The experiment was conducted at Agro technology Park, Krishi Vigyan Kendra, College of Agriculture**,** Gwalior (M.P.). Ten-year-old Acid lime trees of uniform vigour and size were selected for the present study. All the trees were maintained under a uniform cultural schedule during the course of investigation.

Design and Layout of the experiment

The experiment was conducted in Randomized Block Design (RBD) with 11 treatments replicated thrice. A total of 33 acid lime plants spaced at 3X3 m were selected for the study.

Experimental details

Name of crop: Acid lime
Variety: Vikram
Design: RBD
No. of Treatments: 11
Number of replications: 03
Total number of plants: 33
Spacing: 3×3 m

Treatments Combinations

T_0- Control (water spray)
T_1- $GA_3$30 ppm + Cycocel 1000 ppm
T_2- $GA_3$60 ppm + Cycocel 2000 ppm
T_3- $GA_3$30 ppm + Cycocel 1000 ppm + KNO_3 1%
T_4- $GA_3$30 ppm + Cycocel 1000 ppm + KNO_3 2%
T_5- $GA_3$30 ppm + Cycocel 1000 ppm + Thiourea 1%
T_6- $GA_3$30 ppm + Cycocel 1000 ppm + Thiourea 2%
T_7- $GA_3$60 ppm + Cycocel 2000 ppm + KNO_3 1%
T_8- $GA_3$60 ppm + Cycocel 2000 ppm + KNO_3 2%
T_9- $GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%
T_{10}- $GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%

Selection of plants for observations

One plant per treatment was taken in three replications.

Preparation and mixture of growth regulators and chemicals

GA_3 30 ppm solution: GA_3 30 mg was dissolved in a little absolute ethyl alcohol solution and then the volume was made up to 1 liter with distilled water to get 30 ppm of GA_3 solution.

GA_3 60 ppm solution: GA_3 60 mg was dissolved in a little absolute ethyl alcohol solution and then the volume was made up to 1 liter with distilled water to get 60 ppm of GA_3 solution.

Cycocel 1000 ppm solution: Cycocel 1000 mg was dissolved in a little absolute ethyl alcohol solution and then the volume was made up to 1 liter with distilled water to get 1000 ppm of Cycocel solution.

Cycocel 2000 ppm solution: Similarly, Cycocel 2000 mg was dissolved in a little absolute ethyl alcohol solution and then the volume was made up to 1 litre with distilled water to get 2000 ppm of Cycocel solution.

1% KNO_3 solution: The desired nitrate solution was prepared by dissolving 10 grams of potassium nitrate in 1litre of distilled water.

2% KNO_3 solution: The desired nitrate solution was prepared by dissolving 20 grams of potassium nitrate in 1litre of distilled water.

1% Thiourea solution: The desired solution was prepared by dissolving 10 grams of thiourea in 1litre of distilled water.

2% Thiourea solution: The desired solution was prepared by dissolving 20 grams of thiourea in 1litre of distilled water.

Observations Recorded

a. Days to first flowering (Days)
b. Number of flowers per shoot (no.)
c. Initial fruit set (%)
d. Fruit retention at harvest (%)

Result and Discussion

Days to first flowering and number of flowers per shoot

The minimum days to flowering (43.00, 41.67 and 42.33 during first, second and pooled year) were taken under the treatment T_{10} ($GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%) which was significantly superior to all the treatments

under study except T_9 ($GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%) that took 43.33, 42.33 and 42.83 days to first flowering during first, second and pooled year respectively. The maximum days to flowering during the first year (58.00, 58.33 and 58.17 during first, second and pooled year respectively) was recorded under T_0 (Control) Water spray.

The maximum number of flowers per shoot (141, 146 and 144 during first, second and pooled year respectively) were taken under the treatment T_{10} ($GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%) which was significantly superior to all the treatments under study except T_9 ($GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%) that reported 133, 135 and 134 flowers per shoot during first, second and pooled year respectively. The minimum number of flowers per shoot (122.33, 122.00 and 122.17 during first, second and pooled year respectively) was recorded under T_0 (Control) Water spray. The findings of the present investigation are in close agreement to the reports by Thukral *et al.* in 1993 [19], Yoshiko *et al.* in 1998 [20], Ingle *et al.* in 2001 [9], Mudzunga *et al.* in 2001 and Khatab *et al.* in 2006 [13, 10].

Initial fruit set (%) and fruit retention at harvest

The maximum initial fruit set% (51.53, 51.60 and 51.57% during first, second and pooled year respectively) was recorded under the treatment T_{10} ($GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%) which was significantly superior to all the treatments under study except T_9 ($GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%) that reported initial fruit set of 44.17, 43.84 and 44.01% during first, second and pooled year respectively. The minimum initial fruit set % (35.52, 35.10 and 35.31% during first, second and pooled year respectively) was recorded under T_0 (Control) Water spray.

The maximum fruit retention at harvest (27.63, 27.34 and 27.49% during first, second and pooled year respectively) was recorded under the treatment T_{10} ($GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%) which was significantly superior to all the treatments under study except T_9 ($GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%) that reported fruit retention at harvest of 24.43, 24.28 and 24.36% during first, second and pooled year respectively. The minimum fruit retention at harvest (17.72, 18.35 and 18.03% during first, second and pooled year respectively) was recorded under T_0 (Control) Water spray. The findings are in line with the observations by Lima and Davies (1985) [12], Thirugnanavel *et al.* (2007) [18], Kumar *et al.* (2009) [11], Dixit *et al.* (2013) [7], Elkhishen (2015) [8], Bhati *et al.* (2016) [6], Debbarma and Hazarika (2016) [5], Ranganna (2017) [15], Chaudhary *et al.* (2018) [4], Rai *et al.* (2018) [14], Singh *et al.* (2018) [16], Arunadevi *et al.* (2019) [1] and Deshlehra *et al.* (2019) [6].

Table 1: Effect of plant growth regulators and chemicals onDays to first flowering in acid lime c.v. Vikram

Tr.	Treatments	Days to first flowering (Days)		
		Year 1	Year 2	Pooled
T_0	Control (water spray)	58.00	58.33	58.17
T_1	$GA_3$30 ppm + Cycocel 1000 ppm	54.00	54.67	54.33
T_2	$GA_3$60 ppm + Cycocel 2000 ppm	53.67	53.00	53.33
T_3	$GA_3$30 ppm + Cycocel 1000 ppm + KNO_3 1%	52.00	52.33	52.17
T_4	$GA_3$30 ppm + Cycocel 1000 ppm + KNO_3 2%	51.67	50.00	50.83
T_5	$GA_3$30 ppm + Cycocel 1000 ppm + Thiourea 1%	51.33	51.00	51.17
T_6	$GA_3$30 ppm + Cycocel 1000 ppm + Thiourea 2%	48.67	50.67	49.67
T_7	$GA_3$60 ppm + Cycocel 2000 ppm + KNO_3 1%	47.00	46.67	46.83
T_8	$GA_3$60 ppm + Cycocel 2000 ppm + KNO_3 2%	46.33	46.00	46.17
T_9	$GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%	43.33	42.33	42.83
T_{10}	$GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%	43.00	41.67	42.33
SEm ±		0.968	1.283	0.804
CD 5%		2.846	3.774	2.297

Table 2: Effect of plant growth regulators and chemicals onNo of flowers per shoot in acid lime c.v. Vikram

Tr.	Treatments	No of flowers per shoot		
		Year 1	Year 2	Pooled
T_0	Control (water spray)	122.33	122.00	122.17
T_1	$GA_3$30 ppm + Cycocel 1000 ppm	124.00	123.67	123.83
T_2	$GA_3$60 ppm + Cycocel 2000 ppm	125.00	124.67	124.83
T_3	$GA_3$30 ppm + Cycocel 1000 ppm + KNO_3 1%	127.33	127.00	127.17
T_4	$GA_3$30 ppm + Cycocel 1000 ppm + KNO_3 2%	129.00	130.67	129.83
T_5	$GA_3$30 ppm + Cycocel 1000 ppm + Thiourea 1%	125.33	124.67	125.00
T_6	$GA_3$30 ppm + Cycocel 1000 ppm + Thiourea 2%	128.33	128.33	128.33
T_7	$GA_3$60 ppm + Cycocel 2000 ppm + KNO_3 1%	130.00	129.67	129.83
T_8	$GA_3$60 ppm + Cycocel 2000 ppm + KNO_3 2%	131.00	132.33	131.67
T_9	$GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%	133.00	135.00	134.00
T_{10}	$GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%	142.00	146.00	144.00
SEm ±		0.765	0.922	0.599
CD 5%		2.252	2.713	1.713

Table 3: Effect of plant growth regulators and chemicals onInitial fruit set (%) in acid lime c.v. Vikram

Tr.	Treatments	Initial fruit set (%)		
		Year 1	Year 2	Pooled
T_0	Control (water spray)	35.52	35.52	35.52
T_1	$GA_3$30 ppm + Cycocel 1000 ppm	36.11	36.11	36.11
T_2	$GA_3$60 ppm + Cycocel 2000 ppm	37.26	37.26	37.26
T_3	$GA_3$30 ppm + Cycocel 1000 ppm + KNO_3 1%	37.37	37.37	37.37
T_4	$GA_3$30 ppm + Cycocel 1000 ppm + KNO_3 2%	39.66	39.66	39.66
T_5	$GA_3$30 ppm + Cycocel 1000 ppm + Thiourea 1%	40.60	40.60	40.60
T_6	$GA_3$30 ppm + Cycocel 1000 ppm + Thiourea 2%	43.05	43.05	43.05
T_7	$GA_3$60 ppm + Cycocel 2000 ppm + KNO_3 1%	43.35	43.35	43.35
T_8	$GA_3$60 ppm + Cycocel 2000 ppm + KNO_3 2%	43.42	43.42	43.42
T_9	$GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%	44.17	44.17	44.17
T_{10}	$GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%	51.53	51.53	51.53
SEm ±		0.451	0.451	0.319
CD 5%		1.326	1.326	0.911

Table 4: Effect of plant growth regulators and chemicals onFruit retention at harvest in acid lime c.v. Vikram

Tr.	Treatments	Fruit retention at harvest (%)		
		Year 1	Year 2	Pooled
T_0	Control (water spray)	17.72	18.35	18.03
T_1	$GA_3$30 ppm + Cycocel 1000 ppm	20.90	20.63	20.77
T_2	$GA_3$60 ppm + Cycocel 2000 ppm	22.25	21.75	22.00
T_3	$GA_3$30 ppm + Cycocel 1000 ppm + KNO_3 1%	22.32	23.04	22.68
T_4	$GA_3$30 ppm + Cycocel 1000 ppm + KNO_3 2%	22.55	23.06	22.80
T_5	$GA_3$30 ppm + Cycocel 1000 ppm + Thiourea 1%	21.02	22.89	21.96
T_6	$GA_3$30 ppm + Cycocel 1000 ppm + Thiourea 2%	22.25	22.32	22.29
T_7	$GA_3$60 ppm + Cycocel 2000 ppm + KNO_3 1%	22.47	22.41	22.44
T_8	$GA_3$60 ppm + Cycocel 2000 ppm + KNO_3 2%	24.09	22.90	23.50
T_9	$GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%	24.43	24.28	24.36
T_{10}	$GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%	27.63	27.34	27.49
SEm ±		0.545	0.454	0.354
CD 5%		1.602	1.335	1.013

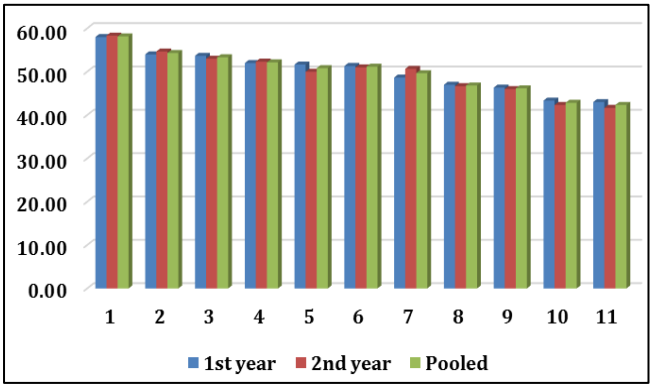

Fig 1: Effect of plant growth regulators and chemicals onDays to first flowering in acid lime c.v. Vikram

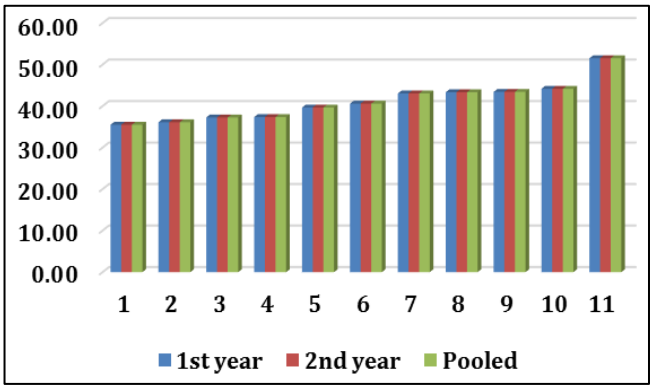

Fig 3: Effect of plant growth regulators and chemicals onInitial fruit set (%) in acid lime c.v. Vikram

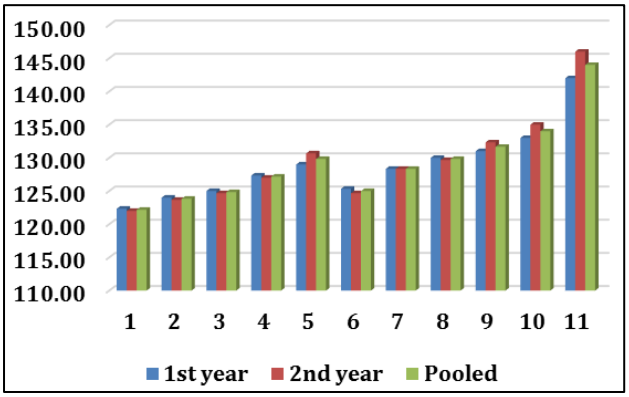

Fig 2: Effect of plant growth regulators and chemicals onNo of flowers per shoot in acid lime c.v. Vikram

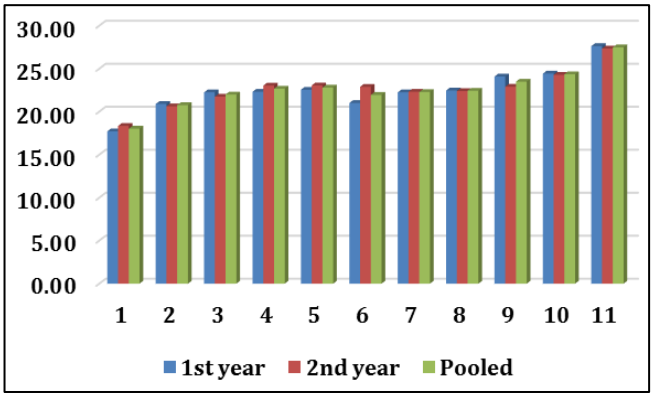

Fig 4: Effect of plant growth regulators and chemicals onFruit retention at harvest in acid lime c.v. Vikram

Conclusion

From the present study it may be concluded that

Parameters like Days to first flowering, Number of flowers per shoot, Initial fruit set, Fruit retention at harvest were significantly affected by the treatments. Treatment number T_{10} ($GA_3$60 ppm + Cycocel 2000 ppm +Thiourea 2%) was found to be significantly superior to rest of the treatments under study but was reported to be at par with T_9 ($GA_3$60 ppm + Cycocel 2000 ppm + Thiourea 1%).

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