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Regulation of flowering in acid lime (*Citrus aurantifolia* Swingle)

M. Prabhu*, S. Parthiban, A. Ramesh Kumar, B. Usha Rani and A. Vijayasamundeeswari

Horticultural College and Research Institute,
Tamil Nadu Agricultural University, Periyakulam – 625 604, Tamil Nadu, India.
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ABSTRACT

India is the largest producer of acid lime in the world and they are used as fresh fruit or for the preparation of pickles and beverages. They are rich in vitamin C, minerals and salts. The seasonality of production leads to market glut which results in poor returns to the farmers. Hence, an experiment was conducted to manipulate and regulate flowering by using various plant growth regulators *viz*., GA_{-3} and cycocel, chemicals *viz*., KNO_3 and salicylic acid at 11 different treatment combinations. The experiment was conducted in randomized block design (RBD) and each treatment was replicated thrice. The age of the trees was seven years and the variety used was PKM1. The experiment conducted in four consecutive years. The experimental results showed that there were significant differences among the treatments. Acid lime trees sprayed with GA_3 50 ppm in June + cycocel 1000 ppm in September + KNO_3 2% in October recorded the highest number of fruits tree^{-1} (1003), weight of fruits (48.60 g) and average fruit yield (28.96 kg tree^{-1}). The same treatment registered the highest values for juice content (32.13 %), TSS (7.29^o Brix) and ascorbic acid content (32.56 mg / 100ml).

Key words: Growth regulators, Lime, Quality, Yield.

INTRODUCTION

India ranks fifth among major lime and lemon producing countries in the world. India is the largest producer of acid lime in the world. In India, citrus group fruits cultivated in an area of 1.08 million hectare and the production is 11.15 million tons (NHB, 2014). It is largely cultivated in Andhra Pradesh, Maharashtra, Tamil Nadu, Gujarat, Rajasthan and Bihar. Limes are available throughout the year in our country. They are used as fresh fruit or for the preparation of pickles and beverages. They are rich in vitamin C, minerals and salts. The seasonality of production leads to market glut which results in poor returns to the farmers. In recent years, chemical regulation of flowering and fruiting has been successfully proven in several fruit crops. In citrus, use of plant growth regulators for promoting or inhibiting flowering has been suggested by Moss (1969) and Iwahori and Oohata (1981). Hence, an experiment was conducted to manipulate and regulate flowering by using various plant growth regulators *viz*., GA_{-3} and cycocel, chemicals *viz*., KNO_3 and salicylic acid in PKM 1 acid lime under Periyakulam conditions of Tamil Nadu.

MATERIALS AND METHODS

Treatment details

The treatments consisted of chemicals, plant growth regulators and the details are furnished below:

T_1 : Control (Water spray)
T_2 : Spraying of GA_3 50 ppm in June + Cycocel 1000 ppm in September
T_3 : Spraying of GA_3 100 ppm in June + Cycocel 1000 ppm in September
T_4 : T_2 + Spraying of 1% KNO_3 in October
T_5 : T_2 + Spraying of 2% KNO_3 in October
T_6 : T_2 + Spraying of Salicylic acid 100 ppm in October
T_7 : T_2 + Spraying of Salicylic acid 200 ppm in October
T_8 : T_3 + Spraying of 1% KNO_3 in October
T_9 : T_3 + Spraying of 2% KNO_3 in October
T_{10} : T_3 + Spraying of Salicylic acid 100 ppm in October
T_{11} : T_3 + Spraying of Salicylic acid 200 ppm in October

The experiment was conducted in randomized block design (RBD) and each treatment was replicated thrice. The age of the trees was seven years and the variety used was PKM 1. The experiment conducted in four consecutive years. Four trees were used for each replication. The trees were spaced at 5x5m. The growth regulator (GA_{-3}) and chemical (salicylic acid) were first dissolved in small quantities of ethyl alcohol and required volume was made up by adding water. The observations were recorded on tree spread (m) in both East – West and North – South directions, number of fruits per tree, fruit weight (g), fruit

*Corresponding author's address and e-mail: muthusamyprabhu@gmail.com; Department of Floriculture and Landscaping, Tamil Nadu Agricultural University, Coimbatore.

yield (kg tree^{-1}). The initial fruit set was calculated at pea size stage in randomly selected twenty shoots in all the treatment trees and expressed in numbers. The fruit set was calculated at pea size stage as follows and expressed in percentage.

$$\text{Fruit set percentage} = \frac{\text{Number of fruits}}{\text{Total number of fruits formed at initial stage}} \text{X } 100$$

The fruit retention was calculated at the time of harvest as follows and expressed as percentage.

$$\text{Fruit retention percentage} = \frac{\text{Number of fruits retained}}{\text{Total number of flowers}} \text{X } 100$$

The juice content of ten fruits from each treatment was weighed and the mean was calculated and expressed as per cent. The T.S.S was recorded by using a hand refractrometer and expressed as ^{0} Brix. The per cent acidity and ascorbic acid content (mg 100 ml^{-1}) were estimated using AOAC (1975) method. The reducing and non-reducing sugar contents were estimated as per the method suggested by Somogyi (1952) and expressed as percentage. Data collected on growth, yield and quality attributes were statistically analyzed as per the methods suggested by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Growth and yield parameters: The statistical analysis of data of the experiment on "Regulation of flowering in acid lime" revealed that significant differences found among the treatments for tree spread in both the directions. Application of spraying of GA_3 50 ppm in June + Cycocel 1000 ppm in September + spraying of 2% KNO_3 in October (T_5) recorded the highest tree spread of 4.71 and 4.95 m in E-W and N-S, respectively(Table-1). This was followed by the treatment T_6. The initial fruit set in terms of percentage was the highest in T_5 which registered 69.86 per cent which was followed by the trees treated with GA_3 50 ppm in June + Cycocel 1000 ppm in September + spraying of Salicylic acid 100 ppm in October (T_6) which recorded 66.10 per cent. The fruit retention percentage at the time of harvest was significantly influenced by the treatments and a similar trend was noticed as that of initial fruit set.

The data on fruit weight indicated that application of plant growth regulators and chemicals significantly increased the fruit weight over control. Among the various treatments, significantly higher value of fruit weight was obtained in T_5 which registered 48.60 g fruit^{-1}, followed by T_6 with application of GA_3 50 ppm + cycocel 1000 ppm + Spraying of Salicylic acid 100 ppm in October which recorded the fruit weight of 45.90 g fruit^{-1}. The similar results were obtained for number of fruits per tree too as that of fruit weight. The fruit yield was increased significantly over control due to the application of plant growth regulators and chemicals at different levels and combinations. The highest yield was obtained in T_5 which registered 28.96 kg tree^{-1}, followed by T_6, which recorded 22.36 kg tree^{-1}. However, both the treatments were significantly different from each other. The lowest yield (12.76 kg tree^{-1}) was recorded in control. In the present study, the increase in yield in T_5 might be due to more number of fruit set and highest fruit retention. The highest number of fruits per tree and highest fruit weight also recorded in this treatment leads to attain the highest yield. These findings are in agreement with Shrestha (1988). Investigations carried out in Navel orange (Jose Eduardo and Friedrick, 1984) with GA_3 have also supported the findings of present study in acid lime. Investigations carried out in Ellendale tangor (Rabe and Van Rensberg, 1996) by KNO_3 also supported the findings of the present study.

Quality parameters: The total soluble solids of the fruit were increased by the different treatments significantly over control. The highest TSS value was recorded in fruits obtained from the trees sprayed with GA_3 50 ppm + cycocel 1000 ppm in September + KNO_3 two per cent (T_5) which registered 7.29^0 Brix, followed by T_6 which recorded 6.85 ^{0}

Table-1. Effect of plant growth regulators and chemicals on growth, yield and yield attributes of acid lime var. PKM 1

Treatments	Tree spread (m)		Initial fruit set (%)	Fruit retention (%)	No. of fruits tree^{-1}	Weight of fruit (g)	Fruit yield (kg tree^{-1})
	East - West	North - South					
T_1	4.53	4.30	61.78	29.01	425	44.20	12.76
T_2	4.25	3.97	62.31	33.07	511	43.60	15.08
T_3	3.92	4.22	62.54	33.60	573	43.50	17.53
T_4	3.75	3.76	60.06	41.49	632	43.70	18.70
T_5	4.71	4.95	69.86	47.41	1003	48.60	28.96
T_6	4.67	4.74	66.10	45.19	791	45.90	22.36
T_7	4.50	4.70	61.13	36.35	681	41.90	19.40
T_8	4.38	4.65	61.99	42.09	703	43.80	20.40
T_9	4.49	4.44	60.01	35.87	605	43.60	17.54
T_{10}	4.59	4.83	61.11	42.52	750	44.70	21.07
T_{11}	4.23	4.57	60.44	40.78	652	43.20	19.54
SEd	0.21	0.26	0.82	0.80	6.96	0.71	0.36
CD (0.05)	0.42	0.52	1.64	1.61	15.04	1.53	0.78

Table 2: Effect of plant growth regulators and chemicals on quality attributes of acid lime var. PKM 1

Treatments	Juice content (%)	TSS (°Brix)	Acidity (%)	Ascorbic acid content (mg.100ml^{-1})	Reducing sugars (%)	Non-reducing sugars (%)
T_1	23.22	6.01	7.09	27.81	1.26	0.51
T_2	25.83	6.43	7.55	29.16	1.18	0.38
T_3	27.39	6.41	8.37	28.77	1.17	0.29
T_4	28.77	6.66	8.84	29.23	1.19	0.27
T_5	32.13	7.29	9.20	32.56	1.14	0.13
T_6	29.85	6.85	8.55	31.65	1.15	0.15
T_7	27.13	6.36	8.73	29.31	1.19	0.26
T_8	26.96	6.53	8.69	28.89	1.20	0.23
T_9	27.19	6.72	8.77	29.56	1.19	0.29
T_{10}	24.15	6.38	8.34	29.41	1.18	0.27
T_{11}	25.65	6.65	8.58	30.38	1.16	0.28
SEd	0.10	0.07	0.15	0.09	0.001	0.07
CD (0.05)	0.214	0.14	0.30	0.19	0.01	0.15

Brix(Table-2). The lowest TSS (6.01 ^{0} Brix) was obtained in fruits from control trees. The acidity per cent was increased by spraying of the plant growth regulators and chemicals in acid lime. The more acidic fruits (9.20 per cent) were obtained from the tress which were sprayed with GA_3 50 ppm + cycocel 1000 ppm in September + KNO_3 two per cent (T_5) while the less acid i.e fruits were harvested from control trees. Significant difference in ascorbic acid content of acid lime fruits due to various flowering regulation treatments was obtained. Ascorbic acid content was the highest in T_5 which registered 32.56 mg 100 ml^{-1}, followed by T_6 (31.65 mg 100 ml^{-1}). Application of plant growth regulators and chemicals decreased both reducing and non-reducing sugar content of the fruits. The maximum contents of both reducing and non reducing sugar were found in control trees and the minimum contents were noticed in T_5.

The highest total soluble solids, acidity and ascorbic acid content are the very important attributes that decide the quality of acid lime. The acidity of acid lime is mainly due to the presence of citric acid, which is one of the most widely distributed plant acids. The ascorbic acid content is important attribute because the acid lime fruits are known for its vitamin 'C' content. In the present investigation, the highest TSS, acidity and ascorbic acid content of fruits were obtained (T_5) when compared to control. Increase in TSS might be due to the fact that GA_3 stimulated the functioning of number of enzymes in the physiological process, which probably caused an increase in TSS. These findings are in conformity with Nath and Barauh (2000). The cycocel increased the TSS due to increase in mobilization of carbohydrates from source to sink. These findings are in agreement with Singh and Phogat (1983) in litchi. Application of potassium nitrate mobilizes the carbohydrates from source to sink. These findings are in conformity with findings of Anbu *et al.* (2001). Increase in acidity of fruits was reported by Sharma *et al.* (2003) in mandarin with GA_3. Das and Narayana (1974) reported that CCC increased the titrable acidity in lemon. The reason for increase in ascorbic acid content in fruits by GA_3 treatment was attributed to perpetual synthesis of glucose-6-phosphate through the development of fruits, which is considered as precursor of vitamin C (Nath and Baruah, 2000). The different treatments decreased the sugar content of the fruits. The sugars are indirectly proportional to acidity (Shrestha, 1988). Perceptible differences were observed in juice content of fruits due to various levels and combinations of different growth regulators in acid lime. In fact, the juice content was increased due to growth regulators and chemical spraying. The highest juice content was recorded in T_5 which measured 32.13 per cent, followed by T_6, which measured 29.85 per cent. The least juice content was recorded in control (T_1), which measured the juice content of 23.22 per cent. The highest juice content was recorded in T_5 and might be due to enhancement of cell division and cell elongation. The plant growth regulators served as mobilizers, which preferentially direct the flow of various organic metabolites from other part of plants to fruit (Sharma *et al.*, 2003). Gibberellin treatment increased the juice content of citrus (Monselise, 1977), acid lime (Sathyamurthy *et al.*, 1978) and Egyptian lime (Stino *et al.*, 1980). The highest juice content was obtained with cycocel 500 ppm to 1250 ppm in sweet lime (Arora and Yamdagni, 1985).

CONCLUSION

The Acid lime trees sprayed with GA_3 50 ppm in June + cycocel 1000 ppm in September + KNO_3 2% in October was found to be best for yield and quality parameters.

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