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Flowering pattern and fruiting behaviour in acid lime (*Citrus aurantifolia* Swingle)

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Abstract
Acid lime (*Citrus aurantifolia*) belongs to the family Rutaceae and has chromosome no. 2 n = 18. In India, Andhra Pradesh top in lime production 33% followed by Gujarat 19% and Maharashtra (12%) Owing to its refreshing, nutritional, medicinal properties and industrial importance acid lime is gaining popularities across the country. Though it is generally grown under both tropical and subtropical climatic condition, however, acid lime is not grown like lemon or other citrus fruits in the North Eastern Region as a whole. In India, limes are still grown in home garden and hence the cultivation and improvement of lime did not receive much attention till date. There is an urgent need for regulation of cropping and fruit maturity in limes. In spite of great demand for this fruit, the commercial cultivation of acid lime have not been taken up so far in many feasible areas. The major constraints faced by growers of acid lime are the peak and lean production of the trees in a year. In this review the flowering pattern and fruiting behavior of acid lime were discussed.

Keywords: Acid lime, *Citrus aurantifolia*, flowering pattern, fruiting behavior, crop regulation

Introduction
Acid lime (*Citrus aurantifolia* Swingle) belongs to the family Rutaceae and it is the third important citrus crop in India next to mandarins and sweet oranges. Sweet orange, mandarins and grape fruit are sub-tropical, whereas lime and lemon are tropical in their climatic requirements. In India, acid lime is grown in a variety of agro - climates comprising from the northern plains and central highlands having hot semi-arid eco region with black and red soils. Acid limes are grown commercially in Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Bihar and West Bengal. Citrus species in general show a relatively long juvenility (2 to 5 years) for commercial production.

Citrus is the third important fruit crop after Mango and Banana. It is a profusely branched thorny shrub, 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. 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. 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. This gestation period in acid lime varies under ecological set up. In dry tropical region of Telangana region of Andhra Pradesh commercial fruiting starts after 7 years. In sub humid tropical places, it may take more time for commercial flowering. Acid lime being evergreen, it has no specific requirement of winter chilling but cessation of growth during winter helps in flower bud induction resulting in spring flowering. The major constraints faced by the growers of acid lime are the peak and lean production in consecutive years. Flowering in acid lime is recurrent under tropical and sub-tropical conditions unless synchronized into well-defined period of external stress.

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 (GA3) during the stress period is known to reduce the intensity of flowering in the following flowering season. Prasad *et al.,* (1980) [14] reported on the response on growth, fruiting and yield to the nitrogen and gibberellic acid treatment with foliar application of 1000 g N/tree with GA at 150 ppm resulted in the greatest number and size of leaves, fruit set, retention and yields in acid lime trees. Babu and Rajput (1982) [2] noted that February and June flowering was earliest with 2, 4-D at 10 or 20 ppm and latest with GA3 at 25 or 50 ppm.

Cycocel (CCC) has been found very effective for imposing stress for inducing flowering. Potassium nitrate (KNO3) 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, 4]. 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. Cassin *et al*., (1969) [5] reported that unrestricted growth gives rise to more vegetative growth than the reproductive growth, as temperature or moisture stress is essential for flowering. Regulated crops are desired to avoid the glut in the market and ensure the regular supply of fruits. Nir *et al*., (1972) [13] reported that increased intensity of flowering due to stress showed that flower differentiation occurred during moisture stress and that generative buds formed did not undergo flower development till water was supplied. Goell *et al.,* (1981) [7] reported that moisture stress followed by alleviation was effective in initiating and promoting vegetative flushing.

The flowering was delayed under longer period of stress which may be due to conditions like high and low temperature and low humidity condition. Singh and Chadha (1988) [16] advocated that imposition of stress caused uniformity in flushing and intensity depended on amount of stress as measured by relative water content in plant before alleviation. The acid limes bloom throughout the year but the main blooming period is February - March, with lean period from July to August. It is not uncommon to find, particularly in lime, flowers, fru1tlets, developing fruits and mature fruits all at a given time (Raj put and Babu, 1985) [15]. Flowering was related to the season rather than to the physiological age of the shoots. C. aurantifolia bear flowers mainly on lateral shoots, whereas C. latifolia flowered mainly on terminal shoots. (Hittalmani *et al.,* 1977) [9-10]. Athani *et al*. (1998) [1] noticed that the flowering was twice in Kamataka - once during December - January and again during July - August.

Webner (1943) [20] observed that the time of flowering is reported to vary with temperature. Ghawede *et al*., (2002) [6] revealed that, there were only two main flowering seasons, the first and the major one occurring in December - February (Ambe bahar) constituting more than 50% of total number of flowers produced in the year and second one in June - July (Mrig Bahar) constituting about 25% of total number of flowers. Motial (1964) [12] reported that kagzi lime flowered only once a year under Saharanpur conditions. Hittalmani (1977) [9-10] reported that the maximum flowering occurred only during December January and May July periods. Also the flowering potential appeared to be more related to the season than the age of the shoot.

Majority of the shoots which bore flowers were normal in vigour as measured in terms of length of shoot and flowers were mostly on lateral shoots and in the apical region of shoots. Increase in the number of flowers and fruits with every increase in the concentration of the chemical was also evident. Tripathi and Dhakal (2005) [19] reported that paclobutrazol applied on 17th July was the most effective in inducing early flowering at fourth week of December which was 70 days ahead of normal flowering days. The subsequent application on September, October and December also advanced flowering time by 59, 41 and 32 days respectively.

Babu and Rajput (1984) [3] at Varanasi showed that Zinc alone or in combination with either of the growth regulators had a marked influence on the chlorophyll content of the leaves. GA3 alone reduced the chlorophyll contents while 2, 4-D had no effect. They reported that fruit set was highest when GA3 at 50 ppm was sprayed alone or with ZnS04 at 0.6% in early January for the spring flush and in early May for the summer flush. Mahalle *et al.,* (2010) [11] reported in Hasta bahar flowering (i e., September and October) of Acid lime, two sprays of cycocel lOOOppm at an interval of one month before initiation of flowering that is in August and September resulted in maximum yield in terms of number of fruits per tree and weight of fruits and this treatment also improved the fruit quality. Thirugnanavel *et al.,* (2007) [18] revealed that application of GA3 50 ppm in June + cycocel 1000 ppm in September + KN03 2% in October showed better performance in delaying flowering by nearly two months, number of flowers per shoot, initial fruit set, fruit retention, number of fruits per tree and yield.

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