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Flushing - flowering behavior and regulation in acid lime – A critical review and research interventions

H. L. DEVI, S. K. SARKAR, L. DHANABATI AND D. MAJHI

Department of Fruits & Orchard Management, Faculty of Horticulture
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741252, Nadia, West Bengal
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ABSTRACT

A field research on efficacy of different bioregulators on flushing, flowering and fruiting of acid lime was conducted at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal. Acid lime being tropical fruit crop, its flushing and fruiting is dependent on the variation of climatic factors. In order to have a thorough understanding on the issue a critical review of the research findings was made and the results of the experiment were validated in the light of the review. The discrete concept for induction of flowering indicated that flushing and flowering in acid lime is regulated through stress (soil moisture and low temperature), through application of growth regulators. Imposition of stress measured in terms of soil moisture and low temperature resulted uniformity in flushing, as uncontrolled flushing is undesired. Flowering is related to the season rather than physiological maturity of the shoot. Out of the different bioregulators viz., bromouracil, 2, 4 - D and paclobutrazol in variable doses in different agro – climatic condition are effective for induction and regulation of the crop.

Key words: Acid lime, bioregulators, crop regulation, flushing, flowering

Acid lime (*Citrus aurantifolia* Swingle) 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. 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. To tackle the flowering and fruiting problem in acid lime, attempt has been taken to understand the explanations drawn by various workers globally and field experiment was conducted by present authors at BCKV, Mohanpur. The present manuscript contains the results of foresaid experiment along with a critical review of global research findings.

MATERIALS AND METHODS

In this backdrop an experiment was conducted on 6 years old acid lime plants cv. Local planted at 6m×4m distance for 2 consecutive years in 2007-08 to 2008-09 at Horticultural Research Station, BCKV, Mondouri, Nadia, West Bengal. The research station is situated at 22.43 ^{0}N latitude and 88.34 ^{0} E longitude with an altitude of 975m above MSL. The soil condition is sandy loam of nearly neutral pH (6 – 6.5) having sufficient depth, moderately fertile and proper drainage. The climate of the research station is sub – tropical humid with the maximum temperature varying from 24.83^{0}C to 38.03^{0}C and that of minimum from 11.03^{0}C to 25.77^{0}C during the period of investigation. Major rainfall was received during June to September, 2008 and relative humidity varied from 42.71 % to 98.73 %. The experiment was laid out with nine treatments; each replicated thrice having two trees per treatment in a randomized block design.

The treatments consisted of two concentrations of each of the four growth regulators and water sprayed control plants. The treatments were Paclobutrazol @ 2.5 ml m^{-1} and 5 ml m^{-1} canopy, Bromouracil @ 50 ppm and 100 ppm , GA_3 @ 25 ppm and 50 ppm, 2, 4-D @ 20 ppm & 40 ppm, and control having water spray. The observations on growth, flowering and fruiting characteristics (number of flowers shoot^{-1}, fruit set shoot^{-1}, fruit retention, number of fruits tree^{-1} and yield tree^{-1}) were recorded.

RESULTS AND DISCUSSION

Flushing behaviour

Shoot growth in acid lime occurs in well defined waves (growth flushes) though default flushes are also seen. Acid lime plant puts forth three to four flushes in phases: uncontrolled flushing results in perpetuation of diseases and pests. In the present experiment, it put forth 0.88, 2.56 and 0.79 numbers of flushes per shoot during Nov – Dec, Dec – Jan and Jan – Feb respectively, as evident from mean data of 2007-08 (Table1).

Email: sks_bckv@rediffmail.com

Regulation of flushing

Cassin *et al.* (1969) 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) 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) 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) advocated that imposition of stress caused uniformity in flushing and intensity depended on amount of stress as measured by relative water content (RWC) in plant before alleviation. Stress level of 92.26 ± 0.89 or 90.97 ± 1.12 RWC causes high intensity of flowering.

In the present experiment, growth regulators had modified the annual pattern of new flush over control. During Nov-Dec maximum new flush was observed in 2,4-D @ 40 ppm (1.35) as compared to control (0.9). The maximum new growth during Dec – Jan was observed in paclobutrazol 5 ml m^{-1}canopy (0.63) as compared to 0.15 in control. During Feb-March maximum new growth was observed in 2, 4 – D @ 20 ppm (2.367) followed by paclobutrazol @5 ml m^{-1}canopy (1.98).

Flowering behaviour

The lemon, lime and citron are considered as continuous bloomers, particularly under tropical climate producing some flowers throughout the year, though the spring bloom is the heaviest. 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, fruitlets, developing fruits and mature fruits all at a given time (Rajput and Babu, 1985). Webner (1943) observed that the time of flowering is reported to vary with temperature. Flowering was about a month earlier in higher temperature zone (Florida) than in cooler temperature zone (California). Motial (1964) reported that kagzi lime flowered only once a year under Saharanpur conditions. Hittalmani (1977) 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. The magnitude of fruit setting and retention was however, higher in June flowering than in January. It was further revealed that, flowering was related to the season rather than to the physiological age of the shoots. *C. aurantifolia* bore flowers mainly on lateral shoots, whereas *C. latifolia* flowered mainly on terminal shoots. (Hittalmani *et al.*, 1977).

Rohidas and Chakrawar (1989) studied the *ambe bahar* flowering under Parbhani, Maharashtra, India condition and reported that flowering started as early as in November and continued till February with a duration of 50 to 55 days and peak between 15 to 31st January. Athani *et al.* (1998) noticed that the flowering was twice in Karnataka – once during December – January and again during July – August. Ghawede *et al.*(2002) revealed that in Akola, India, there were only two main flowering seasons, the first and the major one occurring in December – February (*Ambia bahar syn. ambe bahar*) constituting more than 50% of total number of flowes produced in the year and second one in June – July (*Mrig Bahar*) constituting about 25% of total number of flowers. 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 (> 80%) and in the apical region of shoots.

Flushing and flowering regulation through plant growth regulators

Desai *et al.* (1982) from Rahuri, Maharashtra, India revealed that cycocel sprayed at 1000 ppm once on 16th August and once on 16th September to be followed by spray of 2,4,5-T at 10 ppm on 30th September resulted in 58.2 percent flowers as against 16.3 percent in control. Increase in the number of flowers and fruits with every increase in the concentration of the chemical was also evident. Prasad *et al.* (1980) 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. The yields ranged from 152 – 156 fruits $tree^{-1}$ in the untreated control to 332 – 342 fruits $tree^{-1}$ with the best treatment.

Babu and Rajput (1982) noted that February and June flowering was earliest with 2, 4-D at 10 or 20 ppm and latest with GA_3 at 25 or 50 ppm. Trees treated with Zn (0.3 – 0.6%) occupied an intermediate position. Duration of flowering was shortest (22 – 24 days) with GA_3 at 50 ppm and longest in the controls (30 – 35 days) whereas Davenport (1983) reported that GA_3 applied to Tahiti lime (*Citrus latifolia* Tan.) markedly inhibited flowering, producing morphologically typical vegetative growth. Babu and Rajput (1984) 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. GA_3 alone reduced the chlorophyll contents while 2, 4 D had no effect. They reported that fruit set was highest (50 – 72%) when GA_3 at 50 ppm was sprayed alone or with $ZnSO_4$ at 0.6% in early January for the spring flush and in early May for the summer flush. Tripathi and Dhakal (2005) 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. The earliest (July) application of paclobutrazol was superior among the treatments under Chitwan, Nepal condition to induce and advance early flowering for off season market. Thirugnanavel *et al.* (2007) revealed that application of GA_3 50 ppm in June + cycocel 1000 ppm in September + KNO_3 2% in October showed better performance in delaying flowering by nearly two months, number of flowers per shoot (7.01), initial fruit set (4.59), fruit retention (3.21 fruit shoot^{-1}) number of fruits tree^{-1} (224 fruits) and yield tree^{-1} (11.15 kg).

Mahalle *et al.* (2010) reported in Hasta bahar flowering (i e., September and October) of Acid lime, two sprays of cycocel 1000ppm 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 tree^{-1} and weight of fruits tree^{-1} and this treatment also improved the fruit quality in respect to juice %, TSS, acidity, ascorbic acid content, peel and pomace %.

In the present experiment, flowering has been regulated through growth regulators with Paclobutrazol (5 ml/m canopy) treatment recording the highest number of flowers shoot^{-1} (13.68) *vis- a –vis* minimum number of flowers shoot^{-1} in control trees (3.16) which also resulted the highest number of fruits tree^{-1}(195.67) and yield (6.185 kg tree^{-1}) as compared to control trees recording 17.17 number of fruits tree^{-1} and 0.486 kg tree^{-1}. However, the cost benefit ratio is maximum in 2, 4 – D @ 40 ppm treatment (Table 2).

The onset of flowering in acid lime may be attributed to the prolonged rest period which is often associated with cool, sub tropical winter or water stress conditions in the tropics. The cessation of root growth as a result of low temperature, water stress, weak rootstocks and confined roots were necessary for floral induction. This was later explained that based on the flower inhibitory effects of exogenously applied GA_3, the citrus buds are continually induced to flower but inhibited from doing so by the presence of endogenous, root – produced gibberellins. Conditions conducive to inhibition of root growth would, thus reduce the levels of gibberellins distributed to buds resulting in expression of the depressed flowering buds. This proposal was proved by many workers as above. The flowering intensity increases due to stress and flower differentiation occurs during moisture stress and the generative buds formed do not undergo flower development till water is supplied. Pre-conditioning of plant by moisture stress is a pre requisite in acid lime flower formation. Carbohydrate accumulates during stress and GA availability is reduced due to restricted root growth. On watering GA level rises which is needed for generative branches resulting in flowering. Paclobutrazol inhibits the biosynthesis of GA and internode elongation which reduces the availability of GA, thus resulting in the production of more vegetative shoots as reflected in the present experiment.

Table 1: Effect of growth regulators on flushing behavior

Treatments	Number of new shoots before imposition (2007 - 08)			Number of new shoots after imposition(2008 - 09)		
	Nov – Dec	**Dec – Jan**	**Feb – Mar**	**Nov – Dec**	**Dec – Jan**	**Feb – Mar**
Paclobutrazol 2.5 ml m^{-1} canopy	0.68	3.85	0.29	0.82	0.48	1.71
Paclobutrazol 5ml m^{-1} canopy	1.23	4.23	1.21	0.78	0.63	1.98
Bromouracil 50ppm	0.57	2.67	0.56	1.10	0.45	1.62
Bromouracil 100ppm	1.06	1.39	1.07	1.12	0.08	0.95
GA_3 25ppm	0.79	2.39	0.75	0.78	0.18	1.60
GA_3 50ppm	0.29	2.73	0.57	0.95	0.53	1.38
2, 4 – D 20ppm	1.58	3.18	0.75	0.77	0.13	2.37
2, 4 – D 40ppm	1.17	1.27	0.75	1.35	0.12	1.95
Control	0.54	1.33	1.17	0.90	0.15	0.8
SEm(±)	**0.39**	**0.73**	**0.32**	**0.12**	**0.31**	**0.72**
LSD(0.05)	**NS**	**NS**	**NS**	**0.35**	**0.10**	**0.24**

*Note: * Mean of number of new shoots on all trees before imposition of treatments were Nov – Dec : 0.88, Dec – Jan : 2.56 & Feb – Mar : 0.79.*

It can be concluded that there are possibilities of regulating flushing and flowering in acid lime through water stress, low temperature stress and application of growth regulators. Imposition of stress measured in terms of soil moisture and low temperature resulted uniformity in flushing, as uncontrolled flushing is undesirable. Flowering occurs mainly on previous season growth, axillary, rarely terminal, but never on current growth. Flowering is related to the season rather than physiological maturity of the shoot. Bromouracil, 2, 4 - D and paclobutrazol in variable doses are effective in inducing flowering. In the present study, it has been observed that these flower inducing growth regulators will be more effective if application is followed by cessation of juvenility in new growth, depicting the necessity of maximum uniform flushing.

Table 2: Flowering and fruiting behavior before & after the growth regulators treatment

Treatments	Before imposition (2007 - 08)		After imposition (2008 – 09)			
	Number of fruits tree^{-1}	Yield (kg tree^{-1})	Number of flowers shoot^{-1}	Number of fruits tree^{-1}	Yield (kg tree^{-1})	C:B
Paclobutrazol 2.5 ml m^{-1} canopy	11.17	0.32	8.48	78.33	2.59	0.58
Paclobutrazol 5ml m^{-1} canopy	31.33	0.86	13.68	195.67	6.19	1.07
Bromouracil 50ppm	48.17	1.38	6.63	112.17	3.95	4.75
Bromouracil 100ppm	38.00	1.10	10.67	83.33	2.74	1.65
GA_3 25ppm	45.67	1.30	9.533	62.67	1.98	0.87
GA_3 50ppm	99.17	2.79	6.02	54.33	1.78	0.37
2, 4 – D 20ppm	49.83	1.37	6.47	47.33	1.55	68.96
2, 4 – D 40ppm	52.50	1.41	10.7	80.33	2.72	72.27
Control	21.11	0.60	3.16	17.17	0.49	1.00
SEm(±)	**25.30**	**2.12**	**1.78**	**19.94**	**0.63**	**5.78**
LSD(0.05)	**NS**	**NS**	**5.32**	**59.77**	**1.88**	**17.35**

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