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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(9): 2462-2465

www.thepharmajournal.com
Received: 21-06-2023
Accepted: 25-07-2023

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Effect of plant growth regulators and chemicals in flower regulation during hasta bahar in acid lime cv. Balaji

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Abstract
The present investigation entitled "Effect of plant growth regulators and chemicals on flower regulation during hasta bahar in acid lime cv. Balaji" was carried out in Horticultural Research Station, Anantharajupeta, Annamayya district during September, 2022 - May, 2023. The experiment was laid out in a randomized block design with three replications and nine treatments. Among the treatments maximum number of flowers per shoot (16.64) was reported in T_2 (Cycocel @ 1000 ppm in September + Thiourea @ 1% in October). Application of Cycocel @ 1000 ppm in September + Potassium Nitrate @ 1% in October + GA_3 @ 50 ppm in December resulted in maximum initial fruit set (64.69%), fruit retention at harvest per shoot (51.81%), number of fruits per tree (356.95) and fruit yield per tree (18.33 kg/tree) while minimum number of days for flower initiation (41.45) and days for fruit maturity from flower initiation (152.67). However application of Cycocel @ 1000 ppm in September + 2,4-D @ 10 ppm in December resulted in minimum fruit drop percentage (48.19%).

Keywords: Acid lime, cycocel. flower regulation, gibberellic acid, hasta bahar, potassium nitrate thiourea

Introduction
Acid lime (*Citrus aurantifolia* Swingle) holds significant agricultural value in India, originating from South-East Asia. Acid lime is alternatively referred to as Kagzi lime, Sour lime and Mexican lime. It is classified under the Rutaceae family and possesses a chromosome number 2n=18. The shrub is densely branched, characterized by its thorny nature, and its leaves are petite, featuring narrowly winged petioles. The fruit is typically rounded or oval in shape, with smooth texture. It is renowned for its high vitamin C content and potent antioxidant attributes. Due to their acidic nature, these fruits are widely employed to enhance the flavor of food.

Acid lime trees exhibit three distinct flowering periods throughout the year: the Ambe bahar in January-February, the Mrig bahar in June-July, and the Hasta bahar in September-October. Consequently, fruits become available during June-July, November-December, and April-May, corresponding to these respective flowering seasons. The Ambe bahar has a flowering of 47%, 36% in Mrig bahar, and the Hasta bahar lags behind with a modest 17% flowering rate. Despite its lower flowering percentage, Hasta bahar fruits are in high demand and sold in premium prices in the market.

As the demand for these fruits peaks during the summer season, it becomes essential to manage the flowering process to ensure maximum fruit production in April and May. The underlying principle for inducing flowering suggests that in acid lime, the timing of flushing and flowering can be controlled through inducing stress such as soil moisture and lower temperature, as well as by using growth regulators. Enforcing bahar treatment in Andhra Pradesh during the months of September-October is challenging due to the monsoon rains. Consequently, the utilization of plant growth regulators and chemicals becomes crucial for effectively regulating hasta bahar flowering and maximizing fruit yields during the summer season.

Material and Methods
The present investigation was carried out in Horticultural Research Station, Anantharajupeta, Annamayya district during September, 2022- May, 2023.

Nine year old acid lime trees of spacing 6m X 6m were selected. The study was designed using randomized block design, including three replications and nine different treatments *viz.*, T_1- Cycocel (1000 ppm) in September + Potassium Nitrate (1%) in October + GA_3 (50 ppm) in December, T_2- Cycocel (1000 ppm) in September + Thiourea (1%) in October, T_3- Cycocel (1000 ppm) in September + 2,4-D (10 ppm) in December, T_4- Cycocel @ (1000 ppm) in September + Potassium Nitrate (2%) in October + NAA (50 ppm) in December, T_5- Salicylic acid (100 ppm) in September + Thiourea (1%) in October, T_6- Potassium iodide (0.3%) in September + Cycocel (1000 ppm) in October, T_7- Water stress in September + Cycocel (1000 ppm) in October + Potassium nitrate (1%) in November, T_8- Water stress in September, T_9- Control. Three uniform trees were subjected to each treatment, and for data collection, ten shoots were consistently marked from all orientations on each tree. Subsequently, the collected data was statistically analysed using the analysis of variance technique. (Panse and Sukhathme 1985) [6].

Results and Discussion

Table1: Effect of plant growth regulators and chemicals on days to flower initiation, no. of flowers per shoot, initial fruit set (%) and days to fruit maturity from flower initiation in acid lime cv. Balaji during hasta bahar.

Treatment details	Days to flower initiation	No. of flowers per shoot	Initial fruit set (%)	Days to fruit maturity from flower initiation
T_1: Cycocel (1000 ppm) in September + Potassium nitrate (1%) in October + GA_3 @ 50 ppm in December	41.45	12.54	64.69	152.67
T_2: Cycocel (1000 ppm) in September + Thiourea (1%) in October	46.14	16.64	45.98	158.96
T_3: Cycocel (1000 ppm) in September + 2,4-D (10 ppm) in December	43.45	7.27	54.57	154.78
T_4: Cycocel (1000 ppm) in September + Potassium nitrate (2%) in October + NAA @ 50 ppm in December	43.27	11.31	63.45	154.40
T_5: Salicylic acid (100 ppm) in September + Thiourea (1%) in October	46.41	15.85	43.67	160.76
T_6: Potassium iodide (0.3%) in September + Cycocel (1000 ppm) in October	52.97	6.88	48.09	164.74
T_7: Water stress in September + Cycocel (1000 ppm) in October + Potassium nitrate (1%) in November	51.62	9.77	59.63	164.57
T_8:Water stress in September	57.31	7.99	51.66	160.60
T_9:Control	59.23	5.37	40.57	167.62
S.Em±	0.43	0.32	0.74	0.57
C.D @ 5%	1.28	0.95	2.21	1.70

Table 2: Effect of plant growth regulators and chemicals on fruit drop (%), fruit retention at harvest (%), no. of fruits per tree and yield per tree (kg) in acid lime cv. Balaji during hasta bahar.

Treatment details	Fruit drop (%)	Fruit retention at harvest (%)	No. of fruits per tree	Yield per tree (kg)
T_1: Cycocel (1000 ppm) in September + Potassium nitrate (1%) in October + GA_3 @ 50 ppm in December	48.99	51.81	356.95	18.33
T_2: Cycocel (1000 ppm) in September + Thiourea (1%) in October	61.13	38.87	275.04	11.43
T_3: Cycocel (1000 ppm) in September + 2,4-D (10 ppm) in December	48.19	44.96	320.18	13.64
T_4: Cycocel (1000 ppm) in September + Potassium nitrate (2%) in October + NAA @ 50 ppm in December	51.83	50.98	338.09	15.41
T_5: Salicylic acid (100 ppm) in September + Thiourea (1%) in October	61.38	38.62	283.96	11.23
T_6: Potassium iodide (0.3%) in September + Cycocel (1000 ppm) in October	59.02	40.98	279.74	11.30
T_7: Water stress in September + Cycocel (1000 ppm) in October + Potassium nitrate (1%) in November	55.04	48.17	302.30	13.26
T_8:Water stress in September	64.62	35.38	284.53	11.51
T_9:Control	69.40	30.60	257.31	9.17
S.Em±	0.78	0.56	5.65	0.71
C.D @ 5%	2.34	1.67	16.93	2.13

Days to flower initiation

The mean data related to minimum days for flower initiation was reported in table 1 and the data indicated that minimum days for flower initiation (41.45) was reported in T_1 - Cycocel (1000 ppm) in September + Potassium Nitrate (1%) in October + GA_3 (50 ppm) in December which was followed by treatment T_4- Cycocel (1000 ppm) in September + Potassium Nitrate (2%) in October + NAA (50 ppm) in December (43.27). While control (T_9) recorded the maximum days for flower initiation (59.23). Cycocel application in plants could potentially lead to increased levels of chlorophyll and carotenoids, acceralating photophosphorylation, enhancing the photosynthetic rate and the distribution of photo-assimilates within the plant (Wang and Xiao, 2009) [10]. This quicker photo-assimilate partitioning might have led to earlier flowering when compared with other treatments.

Number of flowers per shoot

Data pertaining to number of flowers per shoot was reported in table 1. The highest number of flowers per shoot (16.64) was recorded in treatment T_2- Cycocel (1000 ppm) in September + Thiourea (1%) in October which was at par with T_5 Salicylic acid (100 ppm) in September + Thiourea (1%) in October (15.85). Lowest number of flowers per shoot (5.37) was recorded in T_9 (control). Cycocel inhibits gibberellic acid biosynthesis, thereby reducing vegetative growth, increasing reproductive growth and Thiourea might have improved the source to sink relationship and promoted export of sucrose to developing reproductive organs (Pandey *et al.*, 2013) [5]. The above results are in conformity with the findings of Awati *et* *al*. (2018) [1] in acid lime, Patel *et al*. (2016) [7] in mango.

Initial fruit set (%)

Summarized data regarding initial fruit set was represented in table 1. The maximum initial fruit set (64.69%) was achieved by application of Cycocel (1000 ppm) in September + potassium nitrate (1%) in October + GA_3 (50 ppm) in December (T_1) which was statistically on par with treatment T_4- Cycocel (1000 ppm) in September + potassium nitrate (2%) in October + NAA (50 ppm) in December (63.45%) whereas minimum initial fruit set (40.57%) was recorded in T_9 (control). Applying Cycocel might have contributed to the efficient movement of carbohydrates from the source to the sink. When potassium nitrate is applied in October, it could potentially boost the potassium content within the leaves. This increase in potassium is essential for various vital plant functions, such as sugar and starch formation, protein synthesis and the transportation of photosynthetic products from the areas of photosynthesis to storage organs, ultimately resulting in improved fruit development. Similar results regarding initial fruit set have been reported by Awati *et al.* (2018) [1] in acid lime, Patel *et al.* (2016) [7] in mango.

Days for fruit maturity from flower initiation

Data pertaining to days for fruit maturity from flower initiation was summarized in table 1. The minimum days for fruit maturity from flower initiation (152.67) was reported in T_1- Cycocel (1000 ppm) in September + potassium nitrate (1%) in October + GA_3 (50 ppm) in December which was followed by treatment T_4- Cycocel (1000 ppm) in September + potassium nitrate (2%) in October + NAA (50 ppm) in December (154.40). While control (T_9) recorded the maximum number of days for fruit maturity from flower initiation (167.62). Bhati *et al.* (2016) [3] have also reported the similar results in acid lime.

Fruit drop (%)

The significant effect of plant growth regulators and chemicals on fruit drop (%) is summarized in Table 2. Among the treatments, minimum fruit drop (48.19 %) was recorded by foliar application of Cycocel (1000 ppm) in September + 2,4-D (10 ppm) in December (T_3) which was statistically at par with T_1- Cycocel (1000 ppm) in September + potassium nitrate (1%) in October + GA_3 (50 ppm) in December (48.99 %). And the maximum fruit drop (69.40 %) was reported in T_9 (control). External application of 2,4-D might have decreased the fruit drop by inhibiting the synthesis of hydrolytic enzyme cellulase, which is responsible for breaking down the cell wall at the abscission zone and thus maintaining the abscission zone cells. Similar results have also been reported by Bharti *et al*. (2020) [2]; Bhati *et al*. (2016) [3] in acid lime.

Fruit retention at harvest per shoot

The data pertaining to fruit retention at harvest per shoot is represented in table 2. The highest fruit retention at harvest per shoot (51.81%) was reported in T_1- Cycocel (1000 ppm) in September + potassium nitrate (1%) in October + GA_3 (50 ppm) in December which was statistically on par with T_4- Cycocel (1000 ppm) in September + potassium nitrate (2%) in October + NAA (50 ppm) in December (50.98%), while the lowest fruit retention at harvest per shoot (30.60%) was reported in control (T_9). The maximum fruit retention might be due to the indirect effect of gibberellins in the synthesis and synergistic effect on auxins which is associated with ovary growth leading to fruit development and thereby improving the fruit retention (Talon *et al*., 1997) [9]. The above results are in conformity with the findings of Rana *et al.* (2018) [8] in sweet orange, Patel *et al*. (2016) [7] in mango.

Number of fruits per tree

The significant effect of plant growth regulators and chemicals on number of fruits per tree is summarized in table 2. The highest number of fruits per tree (356.95) was recorded by spraying Cycocel (1000 ppm) in September + potassium nitrate (1%) in October + GA_3 (50 ppm) in December (T_1) followed by Cycocel (1000 ppm) in September + potassium nitrate (2%) in October + NAA (50 ppm) in December (T_4- 338.09). The lowest number of fruits per tree (257.31) was recorded in T_9 (control).

Fruit yield per tree

The mean data regarding fruit yield per tree is represented in table 2. The highest fruit yield (18.33 kg/ tree) was obtained in treatment T_1- Cycocel (1000 ppm) in September + potassium nitrate (1%) in October + GA_3 (50 ppm) in December followed by Cycocel (1000 ppm) in September + potassium nitrate (2%) in October + NAA (50 ppm) in December (T_4) (15.41 kg/ tree) while the lowest yield (9.17 kg/ tree) was recorded in T_9 (control). The increase in number of fruits and yield per tree might be attributed to combined effect of Cycocel, potassium nitrate and GA_3. The above results regarding number of fruits and yield per tree are found in line with the findings of Awati *et al.* (2018) [1]; Ranganna *et al.* (2017) [11] in acid lime.

Conclusion

The above results have indicated that application of Cycocel (1000 ppm) in September + Potassium Nitrate (1%) in October + GA3 (50 ppm) in December had improved the yield parameters like initial fruit set, fruit retention at harvest per shoot, number of fruits per tree and fruit yield per tree while minimum number of days for flower initiation and fruit maturity from flower initiation.

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