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Study of transition from vegetative shoots to flower buds in acid lime (*Citrus aurantifolia* Swingle)

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Abstract
Acid lime (Khagzi lime) (*Citrus aurantifolia* Swingle), is the third most important commercial citrus fruit in India and flowers continuously under tropical and subtropical conditions. To apply the proper bahar treatment, a study of shoot maturity is necessary. In the present experiment, the maturity of the shoots was studied by applying 5% $ZnSO_4$ in February, followed by borax at 2g/L 25 days later, and then NAA at 100 ppm 15 days after the borax spray in March. A study across several months found that plant growth metrics, including terminal flushes, showed a significant increasing pattern. A non-significant increasing pattern was observed in axillary flushes and the number of leaves. Specifically, terminal flushes increased from 9.12 in April to 11.23 in August, and axillary flushes rose from 33.83 in April to 37.42 in August. Similarly, the number of leaves increased from 445.57 in February to 531.85 in June. In contrast, the number of flowers showed a significant increase over the same period. The number of flowers per plant increased from zero in April and June to 5.286 in August, indicating a progressive floral bud differentiation as the months went by. Hence, from the present study it can be concluded that acid lime requires at least 4-6-month-old shoots for flowering. Additionally, the plants must have a cool temperature and complete their juvenile period when grown under West Bengal conditions.

Keywords: Acid lime, shoot maturity, floral bud differentiation, terminal flushes, $ZnSO_4$

Introduction

Acid lime or Khagzi lime (*Citrus aurantifolia* Swingle) is the third important citrus crop in India next to mandarins and sweet oranges and commercialy grown in the states like largely cultivated in Andhra Pradesh, Telangana, Karnataka, Odisha, Madhya Pradesh and Maharashtra, Assam, Bihar, Chattisgarh, Manipur, Jharkhand, Tamil Nadu, Tripura and Mizoram. Sub-tropical condition is well suitable for growing sweet orange, mandarins and grape fruit, whereas lime and lemons are suitable for tropical climatic conditions. 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. Lime is one of the popular citrus species in West Bengal for its refreshing juice. Juvenility period is varied among the different citrus species from 2-5 years and it is again varied with agroclimatic condition. In case of acid lime commercial fruiting starts after 7 years in dry tropical condition of Telangana and even more time in sub humid tropical areas. Being an evergreen plant, acid lime does not require chilling hours but to get profuse spring flowering and fair yield at market demanding time, cessation of growth is necessary. It has peculiar cyclic flushing behaviour and continuous flowering throughout the year in tropical condition with the peak season in February to march (Ambe Bahar 47%) and lean flowering period from July to August (Mrig Bahar 36%) But the most demanding flowering period at the time of October to November (Hasta Bahar 17%) will be least (Mandloi *et al.*, 2021) [19]. However, hasta Bahar fruits are ready to harvest in the months of April-May when market demand is high and get best prise. But limes from most of the lime growing regions arrives in rainy season when price gets start decreasing. Hence it is more scope to induce the flowering in Hasta bahar by tackling major constraint of rain just preceding the flowering time and uncertainty of cultural methods to induce the flowering. Thus, the exogenous plant growth regulators, nutrients and chemical is expected to have a marked influence profuse vegetative flushing, postponement of flowering for better bud burst, increased flower production and yield in required time.

However, the study of physiological maturity of the shoot to produce the flowering is also equally important to fix the pruning frequency and intensity and the calender operations for particular bahar treatment.

Hence present study is conducted to study the maturity of shoots needed to produce flower buds by using the chemicals like $ZnSO_4$, NAA and Borax.

Material and Methods

The present experiment entitled was conducted at the Instructional Farm, Faculty of Agriculture, Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur, West Bengal, during the 2020-2021. The experiment field was located approximately at 22°56' N latitude and 86°48' E longitude having an average altitude of 9.75 meter above mean sea level. In the present study, 2-year-old air layered lime plants were used. Plot was mulched using jute GO textile and irrigated by drip irrigation method periodically. All the plants were commonly sprayed with 19 all sprayed in the month of December and plant protection chemicals were sprayed on necessary base. To study the maturity of shoots to produce flowers plants were treated with foliar application of $ZnSO_4$ at 5% in the month of February, Borax at 2 g/L 25 days after $ZnSo_4$ spray and NAA at 100 ppm in the month of March after 15 days of borax spray. And recorded number of auxiliary flushes, number of terminal flushes, number of leaves and number of flowers in April, June and August months was recorded. Table one shows the minimum, maximum and average temperature and relative humidity figure 1 shows average rain fall during the experiment period.

Table 1: Month-wise meteorological data at the experimental site during 2020-2021

Month	December (2020)	January (2021)	February (2021)	March (2021)	April (2021)	May (2021)	June (2021)	July (2021)
Min. temperature (°C)	8.64	11.3	12.8	20.1	24.0	23.5	25.24	25.84
Max. temperature (°C)	26.06	25.5	29.4	35.2	36.5	33.8	32.69	32.79
Avg. temperature (°C)	17.35	18.4	21.1	27.65	30.25	28.65	28.96	29.315
Avg. RH (%)	62.5	78.3	67	65.75	69.2	75.5	83.84	85.38
No. of rainy days								
	0	0	0	0	2	12	15	20

Source: Department of Agro-Meteorology and Physics, BCKV, Mohanpur, Nadia, West Bengal.

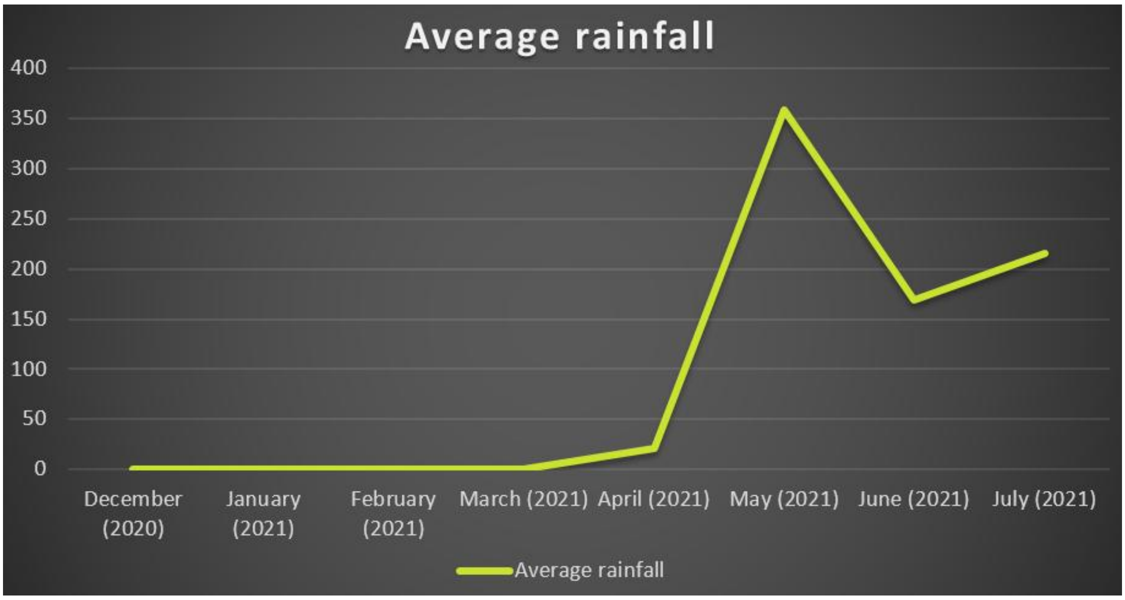

Fig 1: Monthly record of total rainfall (mm)

Results and Discussion

Weather data

In the Gangetic Plains of West Bengal, the brief and mild winter lasts from November to early February, with average temperatures dropping below 20 °C. Temperatures begin to rise in the second week of February, peaking in April-May. From April to early June, the region receives unpredictable North-West showers of 150-250 mm. The south-west monsoon typically arrives by the second week of June, though its onset can be delayed until late June. This monsoon accounts for 70-80% of the region's long-term average annual rainfall of 1396 mm. Overall, rainfall is limited from November to March.

Table 1 shows the details of the weather characteristics over the experimentation period (December 2020 to July 2021). The highest maximum temperature was recorded in April 2021 (36.5 °C), and the lowest temperature was recorded in January 2021 (11.3 °C) (Table 1). The total rainfall received during the experiment was 379.8 mm (Fig 1). The mean monthly relative humidity reached its highest point in July 2021 (85.38%) and its lowest point in March 2021 (65.75%) (Table 1).

No of leaves and no of Axillary and Terminal flushes per plant

The number of leaves produced each month varied non significantly. Number of leaves were produced in February

445.57, in April 482.57 and in June 531.85 (Table 2, Fig. 4), which showed an increasing pattern of amount of leaves/plant with the months. Terminal flushes were in April 9.12, in June 10.06 and in August 11.23 (Table 2, Fig. 2), which showed an increasing pattern of terminal flushes/plant with the months. Terminal flushes produced each month significantly in the month of august compare to previous month. Axillary flushes produced each alternative month non-significantly. Auxiliary flushes were in April 33.83, in June 35.47 and in August 37.42, which showed an increasing pattern of axillary flushes with the months (Table 2, Fig. 3). A similar effect of Zn on plant spread was found by Bhanukar *et al*. (2018) [3] and Khan *et al*., (2010) [8] by B and $ZnSO_4$ in kinnow citrus. Ram and Bose (2000) [14] reported a significant effect of foliar application of $ZnSO_4$ (0.5%) on plant canopy spread as compared to control. Yadav *et al*. (2020) [18] also reported the effect of Zn on plant spread increment of Kagzi lime as compared to water. The study of Seed treatment with GA3 and $ZnSO_4$ were led to reduce seed germination percentage however it increased in the vegetative growth parameters (Al-Musawi Mohammed AHM, and Sadeq MA Al-Moussawi, 2020) [1]. A study by Vajodi *et al*. (2016) [16] found that the foliar application of ZnSO4 at a concentration of 2000 mg L-1 enhanced plant height, vegetative shoot growth, and the content of chlorophyll a, b, total chlorophyll, and carotenoids in pelargonium. Foliar application of $ZnSO_4$ promoted plant height at 2000 mg L^{-1} along with the vegetative shoots and Chlorophyll a, b, total chlorophyll and carotenoid contents in pelargonium (Vajodi *et al*., 2016) [16]. Similarly, other studies have shown that zinc foliar application drastically increases the vegetative biomass of plants. Ayad *et al*. (2010) [2] reported this effect in geranium at a concentration of 200 mg L-1, Cakmak (2008) [4] in wheat, and Salehi Sardoei *et al*. (2014) [15] in petunia. This is because the foliar application of micronutrients typically influences the availability and absorption of soil-based micronutrients, thereby promoting overall plant growth, development, and yield components.

Number of flowers/plants

The number of flowers produced in alternative months varied significantly. Zero flowers were produced in April, 0.571 in June, and 5.286 in August, which showed an increasing pattern of floral bud differentiation over the months (Table 2, Fig 5). The vegetative flush produced in January and February produced flowering in the month June onwards. Hence acid lime requires minimum 6-month-old shoots to produce flower. However, the plants failed to produce a significant number of flowers. In the case of citrus, once the juvenile phase is completed, citrus species are regular bearers. However, flowering depends on many exogenous and endogenous factors. Among exogenous factors, a cool temperature just preceding flowering can effectively induce flowering in citrus under tropical and subtropical conditions (Monselise, 1947; Inoue, 1990; Lenz, 1967; Moss, 1976; Nishikawa *et al*., 2007; Wilkie *et al*., 2008) [10, 7, 9, 12, 13, 17]. In Satsuma mandarin, floral induction occurs in trees exposed to 15 °C for more than 1.5 months (Inoue, 1990; Nishikawa *et al*., 2007) [7, 13]. In the present experiment, lime plants may not have gotten a sufficient cool period during February to March below 15 °C.

Citrus species have a relatively two to five-year juvenility period before reaching maturity and being able to produce flowers (Goldschmidt & Huberman, 1974; Monselise, 1996; Goldschmidt, 2013) [6, 11, 5]. In the present experiment, the insufficient maturity of the shoots is also one of the reasons for the failure to get a significant number of flowers in the trees, as the plants used in the experiment were just about two years old.

Table 2: Effect of foliar spray of $ZnSO_4$, NAA and Borax on number of terminal flushes, axillary flushes, number of leaves and number of flowers per plant.

Sl. No.	Months	Number of terminal flushes/plants	Number of axillary flushes/plants	Number of leaves/plants	Number of flowers/plants
1	April	9.177	33.829	445.571	0.000
2	June	10.057	35.471	482.571	0.571
3	August	11.229	37.416	531.857	5.286
SE. m (±)		0.335	1.144	42.764	0.464
CD (5%)		1.003	N/A	N/A	1.39

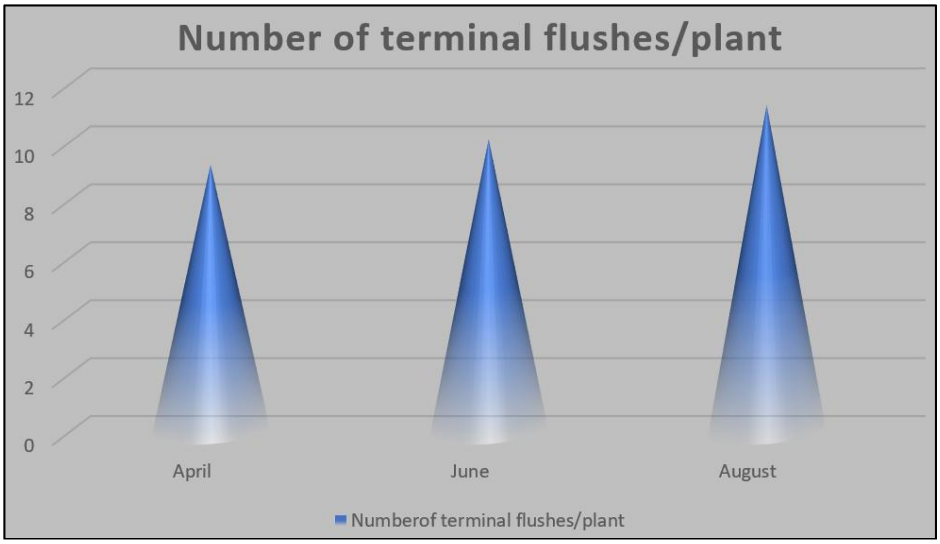

Fig 2: Effect of foliar spray of $ZnSO_4$, NAA and Borax on number of terminal flushes/plants

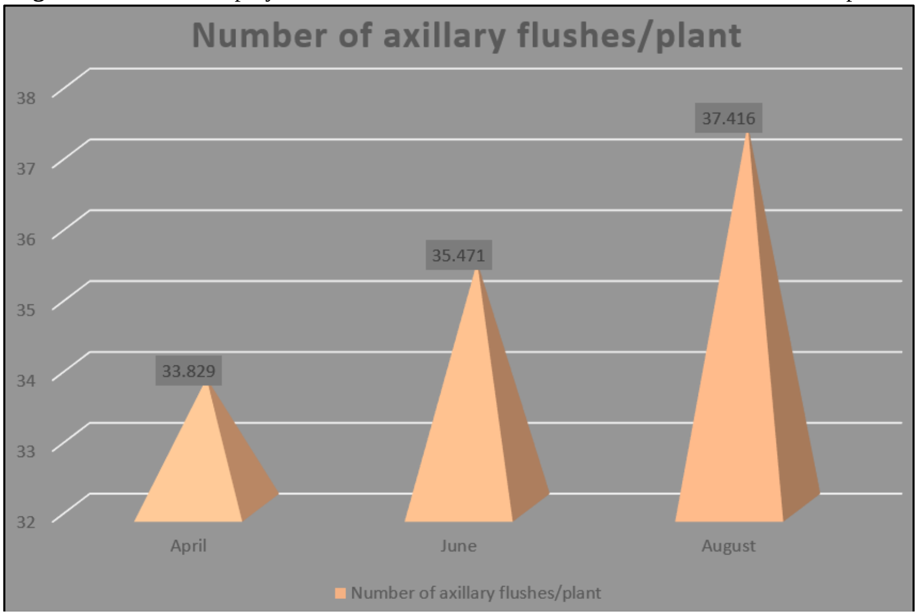

Fig 3: Effect of foliar spray of $ZnSO_4$, NAA and Borax on number of axillary flushes/plants

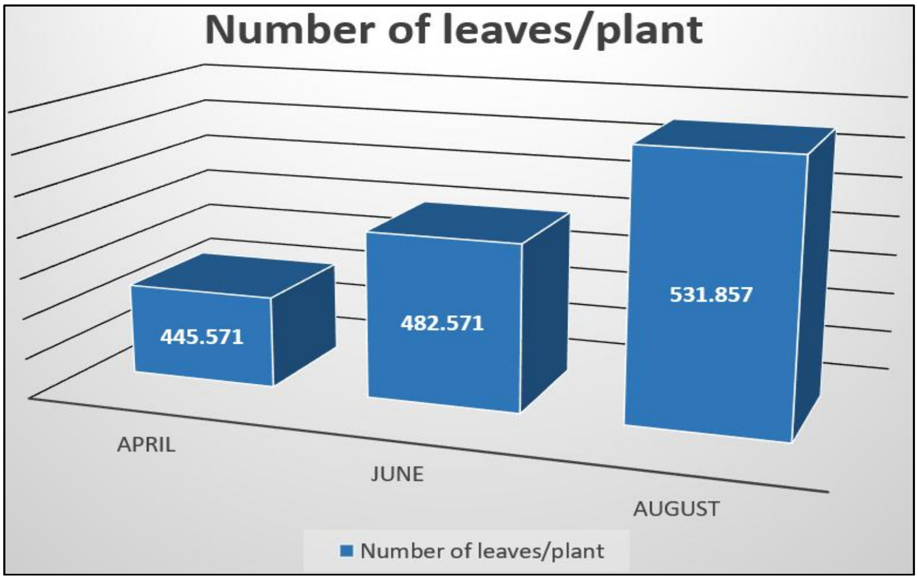

Fig 4: Effect of foliar spray of $ZnSO_4$, NAA and Borax on number of leaves/plants

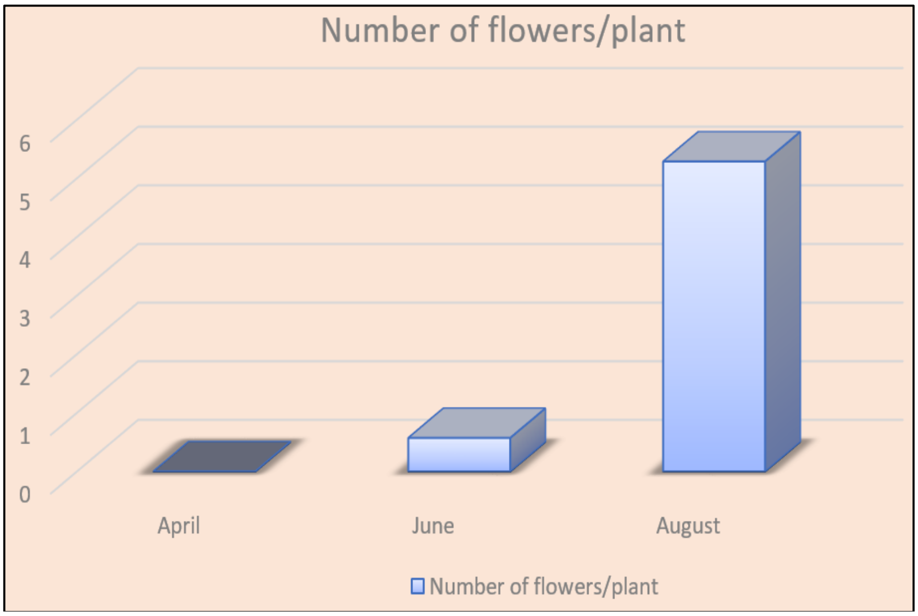

Fig 5: Effect of foliar spray of $ZnSO_4$, NAA and Borax on number of flowers/plants

Conclusion

The study found that the plants which were treated with foliar applications of Zinc Sulphate ($ZnSO_4$), Borax, and NAA showed increasing vegetative growth, including the number of leaves, terminal flushes, and axillary flushes, over the time from April to August. The number of flowers increased from zero in April to 5.286 in August, showing an increasing pattern of floral bud differentiation. However, the number of flowers produced was very low, with a failure to produce a significant number of flowers. Insufficient cool period and the young age of the plants were the main reasons for the failure to achieve significant flowering despite the chemical treatments.

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