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IMPACT OF INTEGRATED HORTICULTURAL PRACTICES ON ACID LIME PRODUCTION IN HASTA BAHAR

U.G. Thakare[1], G.J. Tupkar[2*] and Dimpal K. Gawande[3]

[1]Scientist & Head, Krishi Vigyan Kendra, Akola, Maharashtra, India.
[2]Subject Matter Specialist (Horticulture), Krishi Vigyan Kendra, Akola, Maharashtra, India
[3]Young Professional -1, Krishi Vigyan Kendra, Akola, Maharashtra, India
[*]Corresponding author E-mail: gajanantupkar064@gmail.com

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ABSTRACT

A decade-long field study (2014–15 to 2023–24) was conducted across multiple acid lime orchards in Maharashtra to evaluate the effectiveness of two distinct agronomic treatments: T1 (Farmer's Practice), involving a single spray of Lihocin in August, and T2 (Hasta Bahar Management), a scientifically structured package including the spraying of Gibberellic acid (50 ppm) in June, application of Cycocel (1000 ppm) in September, Potassium Nitrate (1%) in October, and a split application of NPK (600:300:300 g/plant) from October to November.The study assessed parameters such as fruit count, average fruit weight, total yield per hectare, input costs, gross income, net returns, and benefit-cost ratio. Results consistently demonstrated that Hasta Bahar Management (T2) significantly outperformed Farmer's Practice (T1) across all key metrics. Hasta Bahar Management T2 led to a notable increase in fruit yield (up to 40%), enhanced fruit quality, and a substantial improvement in economic returns.The findings strongly support the adoption of Hasta Bahar Management as a sustainable and economically viable practice for maximizing the productivity and profitability of acid lime cultivation, particularly under the agro-climatic conditions of Maharashtra.

***Key words*: Acid lime; cost-benefit ratio; Nutrients; Plant growth regulator; Yield**

Introduction

Acid lime (*Citrus aurantifolia Swingle*) belongs to the family Rutaceae. It has a chromosome number of 2n=18. It is an important commercial species of citrus considered to be indigenous to India and is extensively cultivated in many states under tropical and subtropical climatic conditions. India is the largest producer of acid lime in the world (Chadha, 2002). In India, acid lime is the third most important citrus crop after mandarins and sweet oranges. Currently, India leads global acid lime production with an area of 3.09 lakh hectares yielding 37.71 lakh metric tonnes (Anonymous, 2023-24). Acid lime is grown in Maharashtra in mostly areas of less rainfall viz., the Jalgaon, Ahmednagar, Solapur, Parbhani, Jalna, Pune, and Akola districts. In Maharashtra acid lime is grown on 43,000 ha with a production of 2.58 lakh tonnes, and productivity is 6.00 tonnes/ha.

Acid lime flowers thrice a year, in the months of January-February, June-July and September-October, under Vidharbha conditions, and these seasons are generally known as Ambia, Mrig, and Hasta bahar, respectively. Maximum flowering occurs in Ambia bahar (60%), followed by Mrig bahar (30%) and Hasta bahar (10%). Hence, the market is inundated with Ambia bahar fruits, which are harvested in June-July, leading to the lowest price of the fruit during a year in this period. Hasta bahar flowering occurs in October-November, and the fruits are ready for harvest in March-May, which is predominately the off-season for acid lime fruits (Thirugananavel *et al.*, 2007). In the Vidharbha region, it is highly difficult to regulate bahar treatment during September-October due to the absence of sufficient rains. Here, manipulation of Hasta Bahar flowering with the use of plant growth regulators can serve as an alternative to achieve maximum yields during summer. Keeping the above in view, the present study was aimed at investigating the effect of different combinations of plant growth regulators and micronutrients on reproductive attributes in acid lime in the Hasta Bahar season in comparison to regular practices followed by farmers. Horticultural practices play a pivotal role in enhancing crop production and farmer income.

Materials and Methods

The data was collected from the year 2014-15 to 2023-24 at an acid lime orchard in Akola district. Akola has a marginal tropical climate in the Vidarbha region of Maharashtra. The required dose of manures, fertilizers, irrigation and plant protection measures was given to each selected tree orchard. The treatments applied consist of farmer practice (T1) including one spray of Lihocin in August and Hasta Bahar management (T2) consisting spraying of gibberellic acid 50 ppm in June, application of Cycocel 1000 ppm in September, spraying of potassium nitrate 1% in October, doses of NPK 300:300:300 g/plant in the second week of October and the remaining 300 g of N after one month.

Application of potassium nitrate may be incorporated to progress the photosynthetic competence of leaves and a possible rise in translocation of assimilates into the fruits, resulting in greater fruit size and also plays a key role in the interplay of metabolic events involved in fruit ripening and senescence (Kaur *et al*., 2012). Foliar application of potassium nitrate (KNO_3) increased leaf K more rapidly compared to soil-applied fertilizers because plant uptake was much faster, but the positive effect lasts for a shorter time period (Zekri and Obreza, 2013).

Use of Plant Growth Regulators Their Effect on Behavior and Fruit Quality

The regulation of bahar and enhancement in productivity could be achieved by the use of plant growth regulators at suitable times and in proper concentrations. Hasta bahar (September-October) management through the use of plant growth regulators plays a significant role in getting maximum fruit yield during summer (Mukunda *et al*., 2014). Use of gibberellic acid (GA3) during the stress period is known to reduce the intensity of flowering in the following flowering season. Cycocel (CCC) has been found very effective for imposing stress for inducing flowering. Potassium nitrate (KNO_3) chemical used for sprouting has been found effective in acid lime. The application of GA3 increased flowers per shoot and initial fruit set apart from the delay in flowering in acid lime. The number of days to first flowering is an important criterion that governs either the delay or earliness of a crop. It is influenced by diverse factors like genetic, environmental, physiological, nutritional, hormonal and cultural ones. Application of GA3 100 ppm in June + cycocel 1000 ppm in September + KNO_3 two percent in October showed better performance in delaying flowering, number of flower shoots, initial fruit set, fruit retention, number of fruits and yield in acid lime. This might be due to more vegetative growth by GA3, which reduced the generative shoot and increased the vegetative shoot development. Cycocel, known as a growth retardant, which was sprayed in September, might have acted as an antigibberellin compound and arrested the vegetative bud development, nucleic acid synthesis and protein metabolism by specific antimetabolites, which induce flower formation (Thirugnanavel *et al*., 2018).

The implementation of varied treatment techniques can significantly influence yield outcomes and economic viability. This study assesses the effectiveness of two treatments, T1 and T2, based on data collected from multiple farmers across different villages.

Farmers practice (T1): One spray of Lihocin in August

Hasta Bahar Management (T2):Spraying of gibberellic acid 50 ppm in June, application of Cycocel 1000 ppm in September, spraying of potassium nitrate 1% in October. Doses of NPK 300:300:300 gms/plant in the second week of October and the remaining 300 gms of N after one month

Data were collected from farmers of different villages in Akola District, and the key performance indicators evaluated were

- Number of fruits per plant
- Weight of fruits per plant (kg)
- Yield in quintals per hectare (Q/ha)
- Expenditure per hectare
- Gross income
- Net income
- Cost:Benefit (C:B) ratio

Number of fruits per tree

Fruits of each tree in every treatment and replication were counted at each harvesting. After all the harvesting, it was summed up, and the number of fruits per tree was computed.

Fruit weight (g)

Fruit weight was calculated by dividing the total weight of fruits per tree by the total number of fruits per tree.

$$\text{Fruit weight (g)} = \frac{\text{Total weight of fruits / tree}}{\text{Total number of fruits / tress}}$$

Table 1: Effect of Hasta bahar management on Fruit Count per Plant.

ANOVA for number of fruit per plant						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	42984404	120	358203.3667	9.795537212	1.75225E-30	1.351886459
Columns	20987542.52	1	20987542.52	573.9316624	1.49212E-47	3.920124409
Error	4388161.983	120	36568.01653			
Total	68360108.5	241				

Fruit yield (q/ha)

At each picking, the weight of the harvested fruits from each tree under a treatment was recorded. Total yield per hectare was calculated by multiplying the hectare factor by the yield per tree. Fruit yield (q/ha) was calculated by the following formula:

$$\text{Fruit yield (q/ha)} = \frac{\text{Fruit yield (kg / tree)} \times \text{No. Of tress per hectare}}{100}$$

Increase in yield over control

The yield of respective treatments was subtracted from the control treatment and expressed as a percentage increase in yield over control.

Statistical Analysis

Source of variation	Sum of square(ss)	Degrees of freedom(df)	Mean square (MS)	F-value
Between the treatments	SSB=(Group mean-grand mean)^2	k-1	MSB= $\frac{SSB}{k-1}$	F= $\frac{MSB}{MSW}$
Within Group (Error)	SSW=$\sum$(x-group mean)^2	N-k	MSW= $\frac{SSW}{N-k}$	
Total	SST=$\sum$(x-grand mean)2	N-1		

Results and Discussion

The percent increase in yield over farmer practices was calculated and found to be statistically significant. Analysis of variance (ANOVA) confirmed that the differences observed among treatments were not due to chance ($p < 0.05$), indicating a real and meaningful effect of Hasta Bahar management. If calculated F valueis larger than the critical F-value (from F-distribution table at chosen significance level), we reject the null hypothesis that "all group means are equal."

Effect of Hasta Bahar Management on Fruit Count per Plant

As depicted in Table 1, the analysis revealed that Hasta Bahar management significantly increased the average number of fruits per plant compared to both treatments. The mean fruit count per plant under Hasta Bahar management was 1525.71, whereas the control plot (untreated) recorded only 936.73 fruits per plant. This translates to a 62.89% increase in fruit number over the control. The increased fruit count in Hasta Bahar management can be attributed to the integrated use of growth regulators, specifically gibberellic acid (GA3) applied in June, which is known to promote cell division and elongation, enhancing vegetative growth and increasing photosynthetic efficiency. Additionally, cycocel (CCC) application in September likely helped regulate apical dominance and promoted reproductive transition by restricting excessive vegetative growth. The subsequent application of potassium nitrate (KNO_3) in October likely enhanced bud differentiation, leading to improved floral induction and fruit set.

These physiological responses indicate that a sequential treatment protocol combining GA3 , CCC, and KNO_3 can effectively stimulate higher fruit production, which aligns with earlier findings by [Deshmukh, H.K. *et al.*, 2015], who reported similar outcomes in acid lime.

Effect on Fruit Weight (kg per Plant)

As seen in Table 2, the Hasta Bahar management had a notable effect on average fruit weight per plant. The highest fruit weight was recorded under Hasta Bahar management at 68.6 kg per plant, whereas the control group exhibited a significantly lower fruit weight of 49.64 kg per plant. This increase can be attributed to improved source-sink dynamics. The treatments possibly enhanced the plant's carbohydrate assimilation and translocation to the developing fruits, resulting in larger and heavier fruit development. Gibberellins are known to enhance sink strength by enlarging fruit cells, while potassium aids in sugar translocation and starch synthesis, which are critical during the fruit enlargement phase.

These findings reinforce the synergistic effect of growth regulators and nutrients in promoting not only fruit

Table 2: Effect on Fruit Weight (kg per Plant).

ANOVA for weight of fruit per plant						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	183884.4649	120	1532.370541	43.01243397	3.09357E-65	1.351886459
Columns	21935.60331	1	21935.60331	615.7151052	4.44337E-49	3.920124409
Error	4275.146694	120	35.62622245			
Total	210095.2149	241				

Table 3: Yield (Quintals per Hectare).

ANOVA for yield						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Rows	280138.4302	120	2334.486918	17.75063264	8.37571E-44	1.351886459
Columns	120932.7258	1	120932.7258	919.5306999	4.24866E-58	3.920124409
Error	15781.88428	120	131.5157023			
Total	416853.0403	241				

count but also quality and biomass accumulation.

Yield (Quintals per Hectare)

As depicted in Table 3, yield performance data indicated a statistically significant difference among treatments. The control plot recorded a yield of 111.38 Q/ha, while Hasta Bahar management achieved a maximum yield of 156.09 Q/ha, representing a 40.13% increase in yield over the control. Such a substantial improvement in yield highlights the efficacy of the combined application of plant growth regulators and foliar nutrients. The improvement may be the result of enhanced reproductive efficiency (more flowers and fruits) and better fruit retention under Hasta Bahar management. These factors cumulatively result in more marketable produce per hectare.

Yield improvements due to PGRs and nutrient application have been widely documented in literature (e.g., Sharma *et al.*, 2018; Patel and Desai, 2020), further validating the outcome of this research.

The interaction between treatment types and measured parameters such as fruit number, fruit weight, and total yield was statistically significant. This indicates that the applied treatments had a consistent and favorable impact across different yield components. Moreover, the results suggest that the treatment timing (month-wise application) played a crucial role in synchronizing vegetative and reproductive phases, which may have amplified the overall yield benefits.

Table 4: Percent Increase.

Parameter	FP	HBM	PI
Average Yield (Q/ha)	111.38	156.09	40.13%
Average Fruit Weight (kg/plant)	49.64	68.60	38.25%
Average No. of Fruits/plant	936.73	1525.71	62.89%
B:C Ratio	1.78	2.45	37.64%
FP: Farmer Practices (T1); **PI:** Percent Increase; **HBM:** Hasta bahar management(T2)			

Percent Increase in Yield

As shown in Table 4 despite a marginal increase in cultivation cost due to additional inputs in Hasta Bahar management, the economic returns were substantially higher. The benefit-cost ratio (2.45) under Hasta Bahar management was more favorable than in farmer practices (1.78), mainly due to the significantly higher yield and better quality of fruits.

The Hasta Bahar management led to a 40.13% yield increase, as compared to farmer practices, reinforcing the potential of PGRs and nutrient strategies in achieving higher productivity.

Table 5: Percent Share of Farmers based on change in Yield Attributes.

Change %	NFPP		WFPP		Yield (q/ha)	
	NF	%	NF	%	NF	%
Upto 16%	0	0	1	0.82	1	0.82
17-32%	6	4.95	34	28.09	32	26.44
33-48%	7	5.78	57	47.1	54	44.62
49-64%	62	51.23	21	17.35	20	16.52
Above 64%	46	38.01	8	6.61	14	11.57
	121	100	121	100	121	100
NF: Number of Farmer; **NFPP:** Number of Fruit Per Plant; **WFPP:** Weight of Fruit per plant						

Percent Share of Farmers based on change in Yield Attributes

As shown in Table 5 this chapter presents a detailed analysis and interpretation of the data collected from 121 farmers from the years 2014-15 to 2023-24 regarding the relationship between the percentage of change (adoption of Hasta Bahar Management) and its impact on productivity metrics such as the number of fruits per plant, weight of fruit per plant, and overall yield (quintals per hectare). For the number of fruits per plant, maximum farmers (51.23%) recorded an increase in the range of 49–64%, while 38.01% of farmers achieved more than

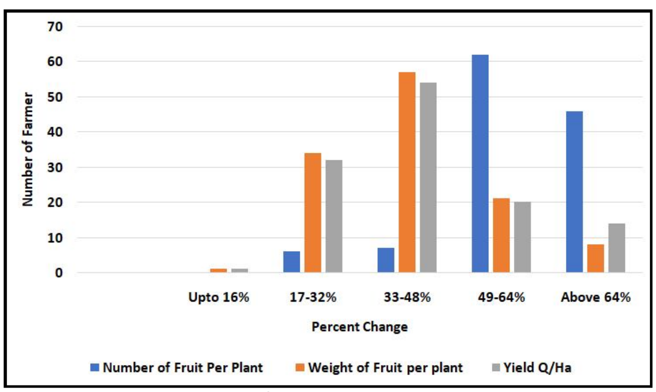

Fig. 1: Percent Share of Farmers based on change in Yield Attributes.

64% increase. This shows that the majority of farmers experienced a significant improvement in fruit count per plant. In the case of weight of fruits per plant, nearly half of the farmers (47.10%) reported an increase of 33–48. With respect to yield (q/ha), the highest proportion of farmers (44.62%) found in the 33–48% increase range, followed by 26.44% in the 17–32% range. Around 11.57% of farmers achieved more than 64% increase in yield. Thus, yield improvements were moderate to high, with most farmers clustering between 33–48% increase.

This analysis confirms that moderate levels of change can significantly improve agricultural productivity. However, adoption must be strategic and knowledge-backed. The data underline a critical message: more is not always better in agricultural transformation. Tailored guidance, sustained support, and farmer feedback loops are essential to ensuring that technological change translates into higher yield and income.This supports the conclusion that investment in advanced agronomic practices involving growth regulation is economically viable for fruit growers.

Conclusion

The comparative analysis of Farmer's Practice (T1) and Hasta Bahar Management (T2) over a 10-year period has provided valuable insights into the physiological and economic benefits of scientifically managed input strategies in acid lime cultivation. The strategic use of plant growth regulators (GA3 and CCC) and targeted nutrient applications (KNO_3 and NPK) in Hasta Bahar Management significantly enhanced fruit development by promoting a better balance between vegetative and reproductive phases.

The results showed consistent improvements in key horticultural parameters such as fruit count, average fruit weight, and total yield per hectare under the Hasta Bahar Management system. These improvements are attributed to the role of GA3 in promoting flowering, CCC in regulating plant growth, and KNO_3 in enhancing fruit set and quality.

Economically, Hasta Bahar Management proved to be far more profitable than Farmer's Practice, with up to 40–55% higher net income and an improved benefit-cost ratio(2.45). This highlights the practical viability of adopting modern, input-based strategies in commercial lime orchards.

Overall, the findings reinforce the conclusion that Hasta Bahar Management is not only agronomically superior but also economically justified, making it a highly recommended practice for acid lime farmers aiming to boost productivity, fruit quality, and farm income in Maharashtra and similar agro-climatic regions.

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