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ENHANCING QUALITY OF ACID LIME (*Citrus aurantifolia*) cv. BALAJI THROUGH INTEGRATED SPRAY STRATEGIES

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ABSTRACT

An experiment was conducted during December 2025 to April 2026 at the Centre of Excellence (Fruits), Mulugu, Siddipet district, Telangana to evaluate integrated spray combining botanicals, insecticides, fungicides and bioregulators on quality attributes of Acid lime cv. Balaji. Ten treatments were tested in a randomized block design with three replications. Among different treatments T_6 (Soap nut extract @ 7.5% as 1st spray, Lambda-cyhalothrin @ 1ml/L + Streptomycin sulphate @ 3g/L + Copper oxychloride 3g/L as 2nd spray, GA_3 @ 100 ppm + KNO_3 @ 2%) as 3rd spray at 15 days interval recorded the highest Total soluble solids (8.90 °Brix), reducing sugars (0.68%), Total sugars (1.52%), non-reducing sugars (0.84%), TSS/Acid ratio and minimum titratable acidity 3.39% under integrated sprays compared to control. The findings demonstrate that integrated spray treatments improve fruit quality, supporting their adoption in sustainable citrus production.

Key words : Acid lime, Integrated spray schedule, Soap nut extract, GA_3, KNO_3, Reducing sugars, Total sugars and Non-reducing sugars.

Introduction

Citrus fruit crop is important among horticultural crops, which is cultivated extensively in tropical and subtropical regions, belonging to the family Rutaceae. Citrus species includes mandarins, sweet orange and acid lime. Acid lime ranking as the third most important and significant species in citrus group. Acid lime is valued not only for its refreshing flavour but also for its nutritional richness, being a source of vitamins C, A, B minerals like calcium, iron and antioxidants. Its adaptability and economic importance make it a key fruit crop in India and other citrus-growing countries.

Globally, citrus is cultivated in more than 52 countries in which China is leading producer followed by the USA. India ranks fourth place in citrus production with an area of about 1.13 million hectares and production of 12.45 million metric tonnes, yielding an average productivity of 11 metric tonnes per hectare. Within India states such as Madhya Pradesh, Maharashtra, Andhra Pradesh and Telangana are major contributors in citrus production. In Telangana citrus occupies 175.90 thousand hectares with a production of over 2 million metric tonnes and acid lime is widely grown in districts like Nalgonda, Suryapet, Gadwal, Mahbubnagar and Rangareddy districts.

Despite its importance, citrus cultivation faces serious challenges due to pests and diseases. More than 250 insect - pests attack citrus crops causing yield losses of up to 30 per cent. In Telangana citrus leaf miner, citrus butterfly and citrus canker are destructive organisms which reduces canopy vigour, photosynthetic activity, fruit quality and yield.

Integrated management techniques have become more popular as a means of overcoming these limitations. Researchers have shown that nutrient sprays like KNO_3 and plant growth regulators like GA_3 can greatly improve acid lime flowering, fruit set, yield and quality features (Rai and Patil, 2020). Higher-quality fruits with higher levels of ascorbic acid, titratable acidity and total sugar

are always sold for higher prices, which helps growers get paid more. However citrus canker, citrus butterfly and leaf miner pose the most challenges to the production and quality of acid lime. Nevertheless, there are few thorough research conducted in Telangana that combine bioregulators, fungicides, insecticides and botanicals in the formation of acid lime. In order to ensure sustainable citrus production, such measures are crucial for reducing the occurrence of pests and diseases, maintaining a healthy canopy and improving both yield and fruit quality.

Materials and Methods

The experiment was conducted at Centre of Excellence (Fruits), Mulugu, Siddipet district, Telangana. The soil of the experimental location was calcareous and PH is 7.60, EC 0.48 ds/m. The experiment was laid out in randomized block design with ten treatments and three replications. The following observations were recorded.

Total Soluble Solids

The total soluble solids (TSS) of acid lime fruits were measured using an ATAGO Digital Hand Held Refractometer with readings expressed as °Brix.

Reducing sugars (%)

Reducing sugars were quantified using the Lane and Eynon method (AOAC, 1965) wherein clarified juice samples were titrated against Fehling's solution (A and B in 1:1) with methylene blue indicator and calculated by following formula.

$$\text{Reducing sugars (\%)} = \frac{\text{Factor (0.05)} \times \text{Volume made up} \times 100}{\text{Titre value} \times \text{Weight of the sample}}$$

Total Sugars (%)

Total sugars were estimated by the Lane and Eynon method (AOAC, 1965) wherein clarified juice samples were hydrolyzed with HCL, neutralized with sodium hydroxide and titrated against Fehling's solution under boiling conditions.

$$\text{Total sugars} = \frac{\text{Factor value} \times \text{Dilution} \times 100}{\text{Titre value} \times \text{weight of sample} \times \text{aliquot (ml)}}$$

Non Reducing Sugars (%)

Non reducing sugar content of acid lime fruits was calculated by subtracting the percentage of reducing sugars from the total sugar content.

Non reducing sugars (%) = Total sugars – Reducing sugars.

Titratable acidity

Titratable acidity was estimated following the procedure described by Ranganna (1986). 10 ml of fruit juice were diluted to 100 ml in a volumetric flask filtered through Whatman No. 1 paper and a 10 ml aliquot was titrated against 0.1 N NaOH using phenolphthalein indicator. The appearance of a pink colour marked the endpoint and results were expressed as percentage citric acid.

$$\text{Titratable acidity} = \frac{\text{Titre value (mL)} \times \text{N (NaOH)} \times \text{Vol made up} \times \text{Eq. wt. Acid} \times 100}{\text{Weight of sample} \times \text{Volume of aliquot taken (ml.)}}$$

TSS/Acid ratio

TSS/Acid ratio was computed by Total Soluble Solids divided by Acidity %

$$\text{TSS/Acid ratio} = \frac{\text{Total soluble solids } (^0\text{Brix})}{\text{Acidity (\%)}} \times 100$$

Results and Discussion

Total soluble solids (°Brix)

The maximum total soluble solids content (8.90° Brix) was observed in T_6 (soap nut extract at 7.5% as the 1st spray, lambda cyhalothrin (1ml/L) + streptomycin sulphate (3g/L) + Copper oxychloride (3 g/L) as 2nd spray, GA_3 at 100 ppm + KNO_3 at 2% as 3rdspray at 15 day intervals). This was followed by T_3 (8.26 °Brix) and T9 (8.06 °Brix) while the untreated control (T_{10}) 6.23 °Brix.

The increase in TSS may be attributed to the pivotal role of potassium in facilitating the translocation of photo assimilates from source tissues to fruits, thereby improving sweetness and overall fruit quality (Kumar *et al.*, 2015; Mounika *et al.*, 2021 and Vijay *et al.*, 2017).

Reducing sugars

The highest reducing sugar content (0.68%) was recorded in T_6 (soap nut extract at 7.5% as 1st spray, followed by lambda cyhalothrin (1ml/L) + streptomycin sulphate (3 g/L) + COC (3 g/L) as 2ndspray, GA_3 at 100 ppm + KNO_3 at 2% as 3rd spray at 15 day intervals). This was followed by T_3 (0.62%), while the untreated control (T_{10}) recorded 0.35%.

Jagtap *et al.* (2013) reported that foliar sprays of GA_3 enhanced reducing sugar content and KNO_3 improved sugar accumulation. The combined application of GA_3 and KNO_3 improved reducing sugar content in acid lime through enhanced translocation of assimilates from source to sink (Karakal *et al.*, 2023).

Total sugars

Maximum total sugar content (1.52%) was recorded in T_6 (Soap nut extract at 7.5% as 1st spray, lambda-cyhalothrin @ 1ml/L+ streptomycin sulphate @ 3g/L + COC @ 3g/L as 2nd spray, GA_3 at 100 ppm and KNO_3 at

2% as 3rd spray) at 15 days interval. This was followed by T_3 (1.30%) and T_9 (1.28%). In contrast, untreated control (T_{10}) recorded minimum total sugars content (0.93%). KNO_3 supplies nitrogen and potassium in which both elements are crucial for chlorophyll synthesis and photosynthetic efficiency, ultimately increasing carbohydrate production and sugar accumulation. (Guevara *et al*., 2012).

Non reducing sugars

Statistical analysis revealed that the highest non reducing sugar content (0.84%) was recorded in T_6 (soap nut extract at 7.5% as the 1st spray, lambda cyhalothrin (1ml/L) + streptomycin sulphate (3g/L) + COC (3 g/L) as 2nd spray, GA_3 at 100 ppm together with KNO_3 @ 2% as 3rd spray at 15 day intervals). While, untreated control (T_{10}) recorded 0.58% non-reducing sugars. potassium involved in translocation of sugars and organic acids from source to sink, thereby increasing sugar levels in fruits (Chaudhary *et al*., 2016 and Debbarma *et al*., 2016).

Titratable acidity

In this experiment, titratable acidity showed clear differences among treatments. The lowest acidity (3.39%) was recorded in T_6, followed by T_3 (4.29%), while the highest value (6.25%) was found in the untreated control (T_{10}). The reduction in acidity is linked to higher TSS faster conversion of organic acids into sugars. The decline in organic acids also results from their conversion into sugars. Debaj *et al*. (2011), Jagtap *et al*. (2013) and Ranganna *et al*. (2016). Overall, the integrated spray schedule influenced on acidity.

TSS/Acid ratio

Results showed that the highest TSS/Acid ratio (2.62%) was obtained in T_6, followed by T_3 (1.88%) and T_9 (1.83%), while the lowest ratio (1.06%) was recorded in the control (T_{10}).GA_3 enhanced assimilate mobilization,

Table 1 : Treatments details.

	1st spray	2nd spray (2 times)	3rd spray
T_1	Soap nut (2.5%)	Spinosad (0.3ml/L) + Hexaconazole (1ml/L) + COC (0.5g/L)	GA_3 (100 ppm)
T_2	Soap nut (5%)	Spinosad (0.3ml/L) + Hexaconazole (1ml/L) + COC (0.5g/L)	KNO_3 (2%)
T_3	Soap nut (7.5%)	Spinosad (0.3ml/L) +Hexaconazole (1ml/L) +COC (0.5g/L)	GA_3 (100 ppm) + KNO_3 (2%)
T_4	Soap nut (2.5%)	Lambda cyhalothrin (1ml/L) + COC (3gm/L) + Agrimycin (3g/L)	GA_3 (100 ppm)
T_5	Soap nut (5%)	Lambda cyhalothrin (1ml/L) + COC (3gm/L) + Agrimycin (3g/L)	KNO_3 (2%)
T_6	Soap nut (7.5%)	Lamdacyholthrin (1ml/L) + COC (3gm/L) + Agrimycin (3g/L)	GA_3 (100 ppm) + KNO_3 (2%)
T_7	Soap nut (2.5%)	Emamectin benzoate (0.3g/L) + Mancozeb (3g/L) + COC (1g/L)	GA_3 (100 ppm)
T_8	Soap nut (5%)	Emamectin benzoate (0.3g/L) + Mancozeb (3g/L) + COC (1g/L)	KNO_3 (2%)
T_9	Soap nut (7.5%)	Emamectin benzoate (0.3g/L) + Mancozeb (3g/L) + COC (1g/L)	GA_3 (100 ppm) + KNO_3 (2%)
T_{10}	Control	Control	Control

Table 1 : Effect of integrated spray schedule on Reducing, Total and Non reducing sugars of Acid lime (*Citrus aurantifolia* cv. Balaji).

Treatments	Reducing sugars (%)	Total sugars (%)	Non-reducing sugars (%)
T_1	0.45	1.02	0.57
T_2	0.54	1.14	0.60
T_3	0.62	1.30	0.68
T_4	0.40	1.00	0.60
T_5	0.50	1.16	0.66
T_6	0.68	1.52	0.84
T_7	0.42	1.13	0.72
T_8	0.50	1.19	0.69
T_9	0.55	1.28	0.74
T_{10}	0.35	0.93	0.58
S.E (m)	**0.01**	**0.03**	**0.03**
C.D (5%)	**0.03**	**0.08**	**0.09**
C.V.	**3.96**	**4.07**	**8.03**

Table 2 : Effect of integrated spray schedule on TSS, Acidity, TSS/Acidity ratio of Acid lime (*Citrus aurantifolia* cv. Balaji).

Treatments	TSS (°Brix)	Acidity	TSS/Acid
T_1	6.53	5.50	1.18
T_2	7.36	4.44	1.66
T_3	8.26	4.29	1.88
T_4	6.60	5.36	1.16
T_5	6.66	4.69	1.42
T_6	8.90	3.39	2.62
T_7	7.10	4.96	1.43
T_8	7.30	4.97	1.47
T_9	8.06	4.55	1.83
T_{10}	6.23	6.25	1.06
S.E (m)	**0.22**	**0.11**	**0.06**
C.D (5%)	**0.66**	**0.33**	**0.18**
C.V.	**5.26**	**3.92**	**6.73**

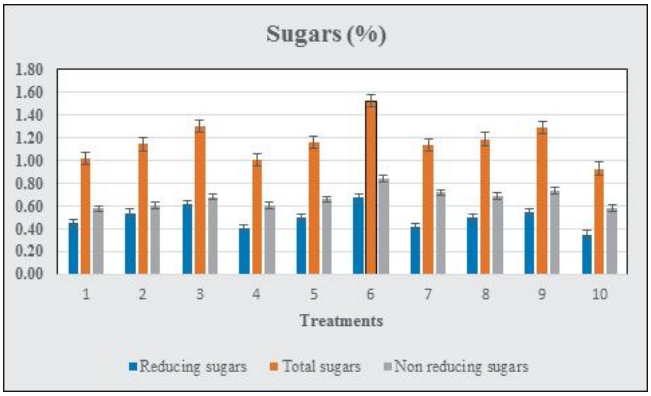


Fig. 1 : Effect of integrated spray schedule on Reducing, Total and Non- reducing sugars (%) of Acid lime (*Citrus aurantifolia* cv. Balaji).

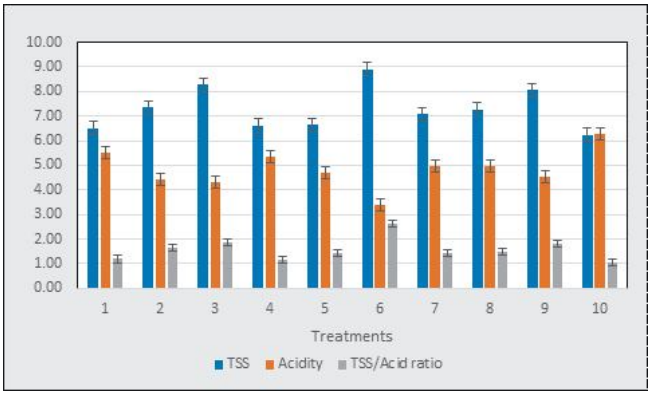


Fig. 2 : Effect of integrated spray schedule on TSS, Acidity and TSS/Acid ratio of Acid lime (*Citrus aurantifolia* cv. Balaji).

while KNO_3 improved nutrient uptake and carbohydrate accumulation (Guevara *et al.*, 2012). Hence, integrated spray schedule not only minimised the pest incidence but improved fruit quality.

Conclusion

The experiment on acid lime (*Citrus aurantifolia* cv. Balaji) evaluated integrated spray schedules combining botanicals, insecticides, fungicides, bactericides and bioregulators. Among different treatments, T_6 consistently recorded superior results in total soluble solids, reducing sugars, total sugars and non – reducing sugars. In contrast, the untreated control (T_{10}) showed the lowest values across all quality parameters. T_6 performed best regarding quality parameters and also this treatment effectively minimised the citrus pests and diseases. The improvement in fruit quality is due to combined application of botanicals, pesticides, fungicides and bio regulators. Pesticides and fungicides minimised the pest and disease incidence in which tree vigour and health improved, as a result overall fruit quality improved. Improvement in fruit quality is due to combined effect of all components in integrated spray schedule, but not due to single component in integrated spray schedule. As a result, T_6 out performed among different integrated spray schedule and can be used as sustainable integrated spray schedule in acid lime cultivation.

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