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Impact of foliar application of growth regulators and micronutrients on yield and quality of acid lime (*Citrus aurantifolia* Swingle)

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Abstract
The present study was carried out to study the effect of micronutrients and plant growth regulators on yield and quality of acid lime (*Citrus aurantifolia* Swingle) at Madhukampalayam village of Dharapuram block in Tamil Nadu during December 2019 to June 2020. The treatment consists of foliar application of growth regulators *viz.*, NAA, GA_3 and 2,4-D and micronutrients such as boric acid, $FeSO_4$ and $ZnSO_4$. The plant growth regulators and micronutrients are very much essential for growth and development of acid lime. The study denotes that yield, number of fruits per plant, fruit weight, fruit diameter, fruit circumference, fruit volume, juice content and ascorbic acid were found to be increased by application of NAA 30ppm+Boric acid (0.2%) and the number of seeds were found to be reduced by application of 2,4-D when compared to control.

Keywords: Acid lime, micronutrient, PGR, ascorbic acid

Introduction
Acid lime (*Citrus aurantifolia* Swingle) is one of the major fruit crop grown in India. It belongs to the family Rutaceae with the chromosome number 2n=18. India is the largest producer of acid lime in the world. The area and production of acid lime in India is about 305.0 thousand hectares and 3482.0 thousand MT, respectively (NHB, 2019). In Tamil Nadu, acid lime is cultivated in an area of about 9.88 thousand hectares which accounts for the production of 34.51 thousand MT. In Tamil Nadu the major districts under cultivation of acid lime are Dindigul, Perambalur, Theni, Tenkasi, Tirunelveli, Tiruchirappalli, Thoothukudi and Virudhunagar.

Acid lime serves as the rich source of vitamin C, vitamin B and also trace amount of vitamin A, folate, minerals and dietary fibers. It contains many phytochemicals like flavonoids, phenolic acids, carotenoids and amino acids. Acid lime has two major flowering seasons in Tamil Nadu. First season is during December to February (Ambe bahar) which comes for fruiting in July – August and the flowering of second season occurs in June - July (Mirg bahar) in which the fruits matures during December – January (Thirugnavel *et al*., 2007).

Among the several factors responsible for reduction in yield and quality of acid lime, deficiency of soil micronutrients is the major hinder that cause significant loss in economic yield. Generally, acid lime is a micronutrient loving crop and hence, application of micronutrient considerably enhances the flowering and fruit quality.

Plant growth regulator plays a major role in acid lime cultivation. Plant growth regulators are the compound which are used in very low concentration but have higher effects on plant physiology. Auxin compounds like Naphthalene Acetic Acid (NAA) and 2, 4-Dichlorophenoxyacetic acid plays a vital role in enhancing fruit set and reducing fruit drop. Foliar application is the most effective method of application of plant growth regulators and micronutrients when compared to soil drenching.

Materials and Method
The experiment was carried out during December 2019 - June 2020 in Madhukampalayam village of Dharapuram block in Tamil Nadu. The four year old acid lime trees of spacing 5m X 5m were selected. The experiment was carried out with 14 treatments which the combinations of micronutrients and growth regulators *viz*., T1 Control, T2 boric acid (0.2%), T3 ZnSO4 (0.5%), T4 FeSO4 (1%), T5 Boric acid (0.2%) + ZnSO4 (0.5%) + FeSO4 (1%), T6 NAA 30ppm + Boric acid (0.2%), T7 NAA 30ppm + ZnSO4 (0.5%), T8 NAA 30ppm + FeSO4

(1%), T9 GA3 10ppm + Boric acid (0.2%), T10 GA3 10ppm + ZnSO4 (0.5%), T11 GA3 10ppm + FeSO4 (1%), T12 2,4-D 20ppM + Boric acid (0.2%), T13 2,4-D 20ppm + ZnSO4 (0.5%), T14 2,4-D 20ppm + FeSO4 (1%). Randomized block design was followed with two replications. Each treatment was imposed on five uniform trees and the observations were recorded. The spray was given twice in a season. The first spray was given during initial flowering stage and next spray was given during peak flowering stage.

Micronutrients such as Boric acid (0.2%), ZnSO4 (0.5%), FeSO4 (1%) were prepared by dissolving in water and growth regulators were prepared by dissolving them initially in a small quantity of alcohol and then the volume was made up.

The yield parameters, physiological parameters and quality characters were recorded by following methodologies.

Results and Discussion

It was evident that significant effect and maximum number of fruits per tree (226.11) were recorded in treatment T6 [NAA 30ppm + Boric acid (0.2%)] whereas minimum number of fruits were recorded in control (141.64). This was due to the fact that application of NAA increased the auxin level which controlled the formation of abscission layer between pedicel of fruit and stem. Simultaneously, application of boron increases the fruit set. This result was similar to the findings of Deshlehra *et al*., (2019) [4] in acid lime.

Treatments T7 [NAA 30ppm+ZnSO4 (0.5%)] showed significant effect and highest fruit weight (59.65g) which was on par with the treatments T14 [2,4-D 20ppm+FeSO4 (1%)] (59.06g) and T6 [NAA 30ppm+ Boric acid (0.2%)] (58.04g) whereas, lowest fruit weight was observed in control (37.77g). The weight of fruit was increased by the application of zinc along with NAA since, it influences the tryptophan. Simultaneously, zinc plays a major role in source and sink relationship which results in the translocation of accumulated carbohydrates to the sink. This finding was similar to the findings of Neware *et al*., (2017) in sweet orange.

It was noticed that fruit circumference showed significant variation in all the treatments. The highest circumference was recorded in treatment T7 [NAA 30ppm+ ZnSO4 (0.5%)] (16.39cm) followed by T6 [NAA 30ppm+ Boric acid (0.2%)] (15.56cm) and the lowest value was recorded in control (13.64cm) in which water spray was given. Treatment T7 [NAA 30ppm+ ZnSO4 (0.5%)] recorded the highest fruit diameter (46.49) which was on par with treatments T14 [2,4-D 20ppm+FeSO4 (1%)] (46.31) and T8 [NAA 30ppm+FeSO4 (1%)] (45.56). The increased fruit circumference and fruit diameter was due to the fact that growth regulator, NAA along with micronutrients, zinc sulphate and ferrous sulphate regulated the nutrient flow. This result coincides with the findings of Shukla, H.S. (2009) in aonla, Jagtap *et al*., (2013) [5] and Deshlehra *et al*., (2019) [4].

Treatment T7 [NAA 30ppm+ ZnSO4 (0.5%)] results in significant variation and the peak value was observed for fruit volume whereas, lower value was obtained in control. This result was found almost similar to the results of Bhati *et al*., (2016) [2], the reason for the increased fruit volume might be due to the fact that the supplementation of plant growth regulator and micronutrients enhanced the availability of nutrients required for fruit development throughout the season. Number of seeds were found to be reduced and the minimum number of seeds were observed in the treatment T12 [2,4-D 20ppm+ Boric acid (0.2%)] and higher number of seeds were noticed in control. The result was contradictory to the findings of Debbarrna and Hazarika (2016) [3] in which GA3 was found to have less number of seeds due to the parthenocarpic effect. The yield was greatly influenced and maximum yield per tree was recorded in treatment T7 [NAA 30ppm+ ZnSO4 (0.5%)] (12.17 Kg). Simultaneously, lower yield per plant was obtained in control (6.40 kg). This decapitated that NAA and zinc sulphate plays a major role in increasing the number of fruits and fruit development which ultimately reflects in the yield of the crop. ZnSO4 helps in greater conversion of source into sink. This finding coincides with results of Kachave D.B. and Bhosale A.M., (2007) [6], Arunadevi *et al*., (2019) [1].

Juice content of fruit was greatly influenced by the treatment T7 [NAA 30ppm+ ZnSO4 (0.5%)] which recorded the peak value of 32.10 ml and the lowest value was recorded in control with 13.89 ml. The reason for maximum juice content was due to auxin, involved in the synthesis of α-amylase which converts the starch to sugars and consequently, increased osmotic pressure of the cell which resulted in accumulation of water. The same result was found by Sandhu (2013).

There was no significant difference in total soluble solids of acid lime among the treatments. The ascorbic acid content of the juice was found to be significantly influenced by imposing treatments. Among treatments, T7 [NAA 30ppm+ZnSO4 (0.5%)] recorded the peak value of ascorbic content (38.93 mgg-1) whereas control recorded the lowest value (26.57 mgg-1). The results obtained in the study were supported by the results of Neware *et al*., (2015), Sharma *et al*., (2003), Kachave and Bhosale (2009) [6] in Kagzi lime and Nawaz *et al*., (2008) in kinnow mandarin.

Table 1: Effect of micronutrients and growth regulators on fruit, yield and seed characters of acid lime

Treatments	No of fruits per tree	Fruit weight (g)	Fruit circumference (cm)	Fruit diameter (mm)	Fruit volume (ml)	Number of seeds	Fruit yield per plant (Kg)
T_1	141.64	37.77	13.64	39.81	33.21	5.18	6.40
T_2	166.66	43.50	14.50	44.74	41.81	6.54	7.49
T_3	176.68	49.54	15.13	43.33	36.21	6.63	7.57
T_4	186.91	48.44	15.37	46.06	42.15	6.40	10.13
T_5	195.97	49.67	14.06	43.06	43.87	8.96	10.71
T_6	226.11	58.04	15.56	44.18	48.40	5.10	11.16
T_7	206.31	58.65	16.39	46.49	55.97	5.54	12.17
T_8	200.37	56.06	15.42	45.56	52.00	5.49	11.14
T_9	205.34	51.08	15.53	45.21	44.22	6.74	11.07
T_{10}	188.85	42.84	14.29	44.80	48.70	5.62	9.00
T_{11}	212.58	56.56	14.86	42.98	45.78	8.22	9.95
T_{12}	203.49	46.81	15.24	47.24	50.95	3.61	10.60
T_{13}	213.28	55.78	14.54	43.98	42.51	4.96	11.13
T_{14}	203.91	59.06	15.47	46.31	50.38	5.99	10.87
SE(d)	3.84	1.59	0.37	1.30	1.25	0.16	0.26
C.D.	8.38	3.48	0.82	2.85	2.73	0.36	0.57

{T_1 Control, T_2 boric acid (0.2%), T_3 $ZnSO_4$ (0.5%), T_4 $FeSO_4$ (1%), T_5 Boric acid (0.2%)+$ZnSO_4$ (0.5%)+$FeSO_4$ (1%), T_6 NAA 30ppm+Boric acid (0.2%), T_7 NAA 30ppm+$ZnSO_4$ (0.5%), T_8 NAA 30ppm+$FeSO_4$ (1%), T_9 GA_3 10ppm+ Boric acid (0.2%), T_{10} GA_3 10ppm+$ZnSO_4$ (0.5%), T_{11} GA_3 10ppm+$FeSO_4$ (1%), T_{12} 2,4-D 20ppM+ Boric acid (0.2%), T_{13} 2,4-D 20ppm+$ZnSO_4$ (0.5%), T_{14} 2,4-D 20ppm+$FeSO_4$ (1%).}

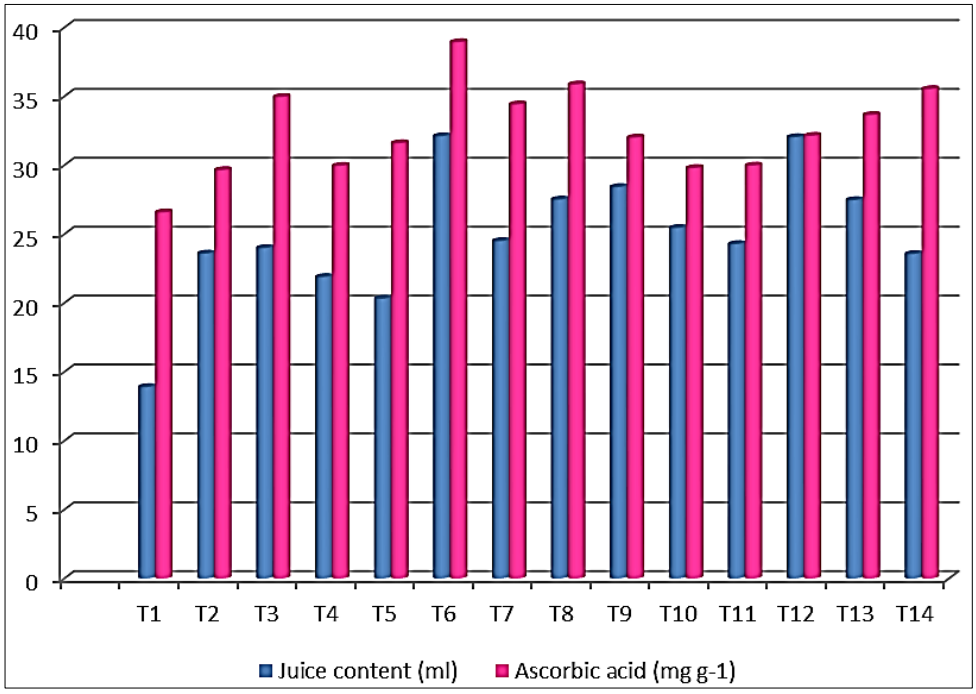

Fig 1: Effect of micronutrients and growth regulators on quality of acid lime

Conclusion

The results revealed that the effective use of plant growth regulators and micronutrients enhances the yield and quality of acid lime. Among the treatments, NAA 30ppm+ZnSO4 (0.5%) resulted in increased number of fruits per plant (226.11 fruits), juice content (32.10 ml) and ascorbic acid content (38.93 mgg-1) compared to control. The yield of the crop was doubled in the application of NAA 30ppm+ZnSO4 (0.5%) when compared to control.

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