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Effect of foliar application of micronutrients on growth, yield and fruit quality of acid lime (*Citrus aurantifolia* Swingle) var. PKM-1

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Abstract
Acid lime (*Citrus aurantifolia* Swingle) belongs to the family Rutaceae and widely grown in tropical and subtropical regions of India. Fruits are rich in vitamin C, minerals and salts. Micronutrients such as Zinc, Iron and boron play a vital role in acid lime for growth and development. Generally, acid lime is micronutrient loving plant hence application of micornutrients considerably increases flowering, fruit set and fruit quality and reduces fruit drop. With this background, the present experiment was conducted at find out optimum levels of foliar application of micronutrients on growth, yield and fruit quality of acid lime var. PKM-1 at Citrus Research Station (TNAU), Sankarankovil, Tirunelveli district, Tamil Nadu during 2019-2020. Foliar application was given twice in a season *viz.*, the first spray at at peak flowering stage and next spray during fruit set stage on selected five trees for each treatment at farmer's field. The trial was laid out in a randomized block design (RBD) with thirteen treatments and replicated thrice. The present study results revealed that T_{12} (1.0% Ferrous sulphate + 1.0% Zinc sulphate + 1.0% Copper sulphate + 1.0% Manganese sulphate + 0.3% borax) recorded the highest values of growth, yield and quality traits such as plant height (3.90 m), tree spread (4.70 m) (5.05 cm), number of fruits per plant (612.20), fruit weight (42.80 g), fruit girth (4.95 cm), fruit volume (40.10 cc) and yield per plant (15.08 kg/tree) and quality traits *viz.*, TSS (6.53 ^{o}Brix), juice content (35.50 ml), ascorbic acid content (33.30 mg/100g), acidity (8.90%) and B:C ratio (2.10) and followed by T_{11} (0.5% Ferrous sulphate + 0.5% Zinc sulphate + .5% Copper sulphate + 0.5% Manganese sulphate + 0.1% borax) whereas the lowest values was observed in control (T_{13}).

Keywords: Acid lime, micronutrients, growth, yield, quality characters, B:C ratio

Introduction
Citrus is considered as one of the most important fruits widely cultivated different parts of the world. It belongs to the family Rutaceae. Acid lime (*Citrus aurantifolia* Swingle) is an important commercial species of citrus considered to be indigenous to India, and is extensively cultivated in many parts of India across tropical and subtropical regions. India is the largest producer of acid lime in the world. In India, Maharashtra, Andhra Pradesh, Assam, Tamil Nadu, Gujarat, Rajasthan, and Bihar are the leading states in acid lime cultivation. In Tamil Nadu, it is widely cultivated in Tirunelveli, Tenkasi, Turicorin, Dindigul, Madurai, Theni, Perambalur, Tiruchirapalli, Coimbatore and Virudhunagar districts under rainfed and irrigated conditions in an area of about 9.88 thousand hectares which accounts for the production of 34.51 thousand MT. Fruits are being used for preparation of pickles, beverages and rich in citric acid, ascorbic acids, minerals and salts. Foliar feeding is one of the ways towards this goal, because there by nutrients are applied directly to the site of their metabolism. Generally, acid lime is a micronutrient loving plant and hence, application of micronutrient considerably enhances the flowering and fruit quality. Micronutrients such as zinc, iron and boron plays a vital role in acid lime and also they are equally significant like other macronutrients, in spite of their requirement in meagre quantities. Their acute deficiencies are sometimes incurable in nature (Kumar, 2002) [7]. Zinc is essential component of enzymes responsible for nitrogen metabolism, thereby resulting increase the uptake of nitrogen by the plant. It increase the flowering, fruit set, fruit size and control the fruit drop and ultimately increase the yield (Awasthi *et al.* 1975) [2]. Iron increases the manufacture of more carbohydrates in the leaves which increase the flowering, fruit set, fruit size, control the fruit drop and ultimately increases the yield (Rana and Sharma, 1979) [10]. Similarly, boron also plays a vital role in the growth behaviour and productivity of citrus fruits.

It increases the phenolic compound production in the plant system that is responsible for the polar transport of auxin. This increases the auxin activity resulting in increasing the vegetative growth of citrus plants (Gurjar *et al.* 2015) [6]. Another micronutrient copper also plays a significant role in citrus trees and it is involved in stimulation activities for lignifications of the cell wall of plants, and photosynthesis, and acts as an electron carrier in the plant system. Copper helps in production of sugar compounds and leads to more accumulation of total soluble solids in the fruit juice (Singh *et al.* 2018) [16]. Acid lime var. PKM-1 being a heavy and regular bearer which bears fruits throughout the year and has to supplied with adequate nutrients to ensure the yield and quality. Most of the time, growers are not following proper nutrient application. With this background, the present experiment was undertaken to investigate the effect of foliar application of different combinations of micronutrients on growth, fruit yield and quality of acid lime var. PKM-1.

Materials and Methods

The present experiment on the effect of foliar application of micronutrients on growth, yield and quality of acid lime var. PKM-1 was conducted at farmers' field, Vannikonendal of Tirunelveli district, Tamil Nadu. The aim of the present study is to find out the suitable micronutrient combination for increasing flowering, yield and quality of acid lime fruits. The experiment was conducted during 2019 - 2020. Seven years old trees of acid lime var. PKM-1 were selected at farmers' field and used for the experiment. Five trees were used for each replication. Trees were planted at a spacing of 6 x 6 m. Foliar application of micronutrients sprayed during September - October and March – April every year (two seasons). Each treatment was imposed in five uniform trees. The first spray was given during peak flowering stage (October) and next spray was given during fruit set stage (15 days after first spray). Micronutrients such as ferrous sulphate, copper sulphate, zinc sulphate, manganese sulphate and borax were prepared by dissolving in water and then the required volume was made up. The experiment was laid out in a Randomized Block Design (RBD) with thirteen treatments and replicated thrice.

The treatment details are as follows.

T_1	-	0.5% Ferrous sulphate
T_2	-	1.0% Ferrous sulphate
T_3	-	0.5% Zinc sulphate
T_4	-	1.0% Zinc sulphate
T_5	-	0.5% Copper sulphate
T_6	-	1.0% Copper sulphate
T_7	-	0.5% Manganese sulphate
T_8	-	1.0% Manganese sulphate
T_9	-	0.1% borax
T_{10}	-	0.3% borax
T_{11}	-	0.5% Ferrous sulphate + 0.5% Zinc sulphate + .5% Copper sulphate + 0.5% Manganese sulphate + 0.1% borax
T_{12}	-	1.0% Ferrous sulphate + 1.0% Zinc sulphate + 1.0% Copper sulphate + 1.0% Manganese sulphate + 0.3% borax
T_{13}	-	Absolute control

The quality characters such as juice content of ten fruits from each treatment weighted and mean was calculated and expressed in per cent. TSS recorded by using Hand Refractometer and expressed as ºBrix. Ascorbic acid content was calculated by using AOAC, (1975) [1] method as expressed as mg per 100 g of fruit weight. Acidity was determined by the method described by Ranganna, (1986) [13] and expressed in percentage. The observations such as plant height, tree spread, number of fruits per plant, fruit girth, fruit volume, fruit weight, yield per plant, B:C ratio, ascorbic acid content, acidity, TSS and fruit juice content were recorded and analysed statistically as per the methods suggested by Panse and Sukhatme, (1967) [9].

Results and Discussion

The present study results exhibited the significant impact on foliar application of micronutrients on growth, yield and its attributing parameters are depicted in Table 1. The results revealed that T_{12} (1.0% Ferrous sulphate + 1.0% Zinc sulphate + 1.0% Copper sulphate + 1.0% Manganese sulphate + 0.3% Borax) recorded the highest values of growth traits such as plant height (3.90 m), plant spread (4.70 m) (5.05 cm) and number of fruits per plant (612.20) followed by T_{11} (3.71 m; 4.45 m; 4.98 m; 601.45) whereas the lowest values registered in control (T_{13}) (3.15 m; 3.66 m; 4.01 m; 465.30). This might be due to foliar application of micronutrients along with nutrients which increased the plant height, tree spread and number of fruits per tree. There is also a correlation between fruit drop and internal hormonal level in the plant system. As the level of internal auxin concentration in the plant system is higher, then the fruit retention capacity will be more leading to increase in number of fruits per plant. Application of micronutrient combinations increased the number of fruits, plant height and plant spread in the acid lime var. Vikarm under Uttar Pradesh condition (Mishra *et al.* 2021) [8]. Application of boron increase the fruit set and thereby increases the number of fruits reported by Sheikh *et al.* (2021) [15] in Assam lemon.

In fruiting traits, T_{12} observed the highest values of fruit girth (4.95 cm), fruit weight (42.8 g) and fruit volume (42.8 cc) followed by T_{11} (4.68 cm; 41.50 g; 39.5 cc). Control (T_{13}) registered the lowest values for the fruiting traits *viz.*, fruit girth, fruit weight and volume of the fruit (3.30 cm; 33.60 g, 31.10 cc). Zinc facilitates in the synthesis of tryptophan, the precursor of auxin synthesis and consequently the auxin level increases in the fruit. This lead to the higher enlargement of cell because of cell vacuolization resulting in increased size of vesicles, dimension of locules and eventually the fruit weight and size increased. Therefore, the significant influence of Zn in increasing the fruit weight was revealed by Sheikh *et al.* (2021) [15] in Assam lemon, and Ghosh and Besra, (2000) [5] in sweet orange. Iron and zinc also play a vital role in the enlargement of cell, division of cell and formation of starch. Thus, the additive effect of these micronutrients resulted in increased fruit weight. This is in conformity with the findings of Babu *et al.* (1982) [3]; Rajamanickam *et al.* (2022) [11] in acid lime. The rise in fruit weight might be the higher translocation of photosynthates to fruits. Similar findings were revealed by Waskela *et al.* (2013) [18] in guava and Rajamanickam *et al.* (2015) [12] in cashew.

Regarding yield traits, the same trend was noticed. In the present study, treatment T_{12} recorded the highest yield per plant (15.62 kg/tree) which was followed by T_{11} (14.65 kg/ha) whereas control (T_{13}) registered the lowest yield of 11.81 kg/tree was obtained. This might be due to the synergistic effect of different micronutrients as they directly take part in

many physiological processes and activity of many enzymes for greater gathering of food materials. Zinc helps in prevention of abscission layer formation and increase the synthesis of tryptophan which is the precursor of auxin synthesis and this facilitates the ovary to remain intact with the shoot, ensuring in minimizing the flower and fruit drop and maximize the retention of fruits in the plants. Earlier reports indicated that the application of zn and boron increases fruit yield and quality (Rodriguez *et al.* 2005) [14]. This is in conformity with the findings of Deshmukh *et al.* (2015) [4] in acid lime and Gurjar *et al.* (2015) [6] in Kinnow mandarin. B:C ratio recorded the highest in T_{12} of 2.10 which was followed by T_{11} (2.09) whereas control (T_{13}) registered the lowest benefit cost ratio of 1.81 was obtained. This might be due to highest net profit, number of fruits per tree and yield per tree which enhanced the benefit cost ratio compared with control.The quality parameters of fruits were significantly improved by the foliar application of micronutrients (Table 2). The treatment T_{12} exhibited higher values of the quality traits *viz.*, TSS (6.53 ºBrix), juice content (35.50 ml), ascorbic acid content (33.30 mg/100g) and acidity (8.90%) followed by T_{11} (6.33 ºBrix, 33.30 ml; 30.00 mg/100 g; 8.60%) while control (T_{13}) observed the lowest values for all the quality traits (5.25 ºBrix, 24.90 ml; 22.28 mg/100 g; 7.35%). The increased juice content due to application of micronutrients might be due to the role of zinc in plant metabolism. Increased in TSS with the application of micronutrients especially zinc might be due to increased photosynthetic activity and chlorophyll content of leaves which resulted in production of more TSS in fruit juice (Tagad *et al.* 2018) [17]. Zinc is required in enzymatic reactions namely hexokinase, carbohydrate and protein synthesis. In addition to this, boron helps in the transportation of sugar in the form of boron-sugar complex and it also intensifies hydrolysis of carbohydrates into simple sugar. Copper helps in elevating the photosynthetic efficiency that results in higher rate of photosynthesis. The results of the current investigation are in line with the results obtained by Babu and Yadav (2005) [3] in Khasi mandarin and Singh *et al.* (2018) [16] in Sweet orange cv. Mosambi. Hence, it was concluded that T_{12} treatment recorded the highest values of growth, yield and quality traits in acid lime.

Table 1: Effect of foliar application of micronutrients on growth and yield characters of acid lime var. PKM-1

Treatment details	Plant height (m)	Tree spread (m)		Number of fruits per tree	Fruit girth (cm)	Fruit weight (g)	Fruit volume (cc)	Fruit yield (kg tree^{-1})	B:C ratio
		E- W	N-S						
T_1	3.58	4.18	4.52	490.3	3.95	39.80	37.55	12.80	1.96
T_2	3.65	4.12	4.20	494.6	4.10	40.62	38.15	13.42	2.01
T_3	3.57	4.40	4.85	510.1	3.98	40.30	38.20	13.66	2.05
T_4	3.62	4.45	5.38	526.7	4.23	41.30	38.25	13.80	2.06
T_5	3.59	4.48	5.27	529.2	3.84	37.50	34.80	13.20	1.96
T_6	3.48	4.14	4.58	535.8	4.21	36.50	34.65	14.25	2.04
T_7	3.42	4.47	4.50	560.1	3.75	39.60	37.40	14.10	2.01
T_8	3.53	3.83	4.65	584.6	4.55	41.52	38.15	14.40	1.98
T_9	3.62	4.07	4.25	550.2	4.10	35.20	32.75	13.55	2.03
T_{10}	3.68	4.25	4.72	565.4	4.39	35.45	32.80	13.88	2.05
T_{11}	3.71	4.45	4.98	601.4	4.68	41.50	39.50	14.65	2.09
T_{12}	3.90	4.70	5.05	612.2	4.95	42.80	40.10	15.08	2.10
T_{13}	3.15	3.66	4.01	465.3	3.30	33.60	31.10	11.81	1.87
S.Ed	0.113	0.005	0.006	18.97	0.129	1.523	1.259	0.274	
CD (P= 0.05%)	0.258	0.009	0.010	39.28	0.271	3.068	2.656	0.562	

Table 2: Effect of micronutrients of quality characters of acid lime var. PKM-1

Treatment details	TSS (ºBrix)	Juice content (ml)	Ascorbic acid content (mg/100 g)	Acidity (%)
T_1	6.15	30.90	26.97	7.45
T_2	6.18	31.10	28.42	7.54
T_3	5.80	28.50	26.15	7.64
T_4	5.65	30.25	26.43	7.69
T_5	5.60	27.40	26.32	7.62
T_6	5.85	28.50	26.51	7.68
T_7	6.35	29.80	28.19	8.05
T_8	6.30	33.00	29.05	8.10
T_9	5.95	31.10	26.80	8.30
T_{10}	6.20	32.30	27.01	8.35
T_{11}	6.33	33.30	30.00	8.60
T_{12}	6.53	35.50	33.30	8.90
T_{13}	5.25	24.90	22.28	7.35
S.Ed	0.271	1.255	0.982	0.239
CD (P= 0.05%)	0.520	2.450	1.996	0.541

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