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Effect of Plant Growth Regulators and Micronutrients Spray on Growth, Fruit Yield and Quality of Acid Lime (*Citrus aurantifolia* Swingle) cv. Ganganagar Lime – 1

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A B S T R A C T

The investigation was carried out at the experimental orchard, Department of Fruit Science, Banda University of Agriculture and Technology, Banda during 2020-21. The experiment was planned in RBD having 10 treatments with 3 replications consisting of different combinations of plant growth regulators and micronutrient spray on acid lime cv. Ganganagar Lime – 1 to improve the yield of good quality fruits. Among the plant growth characteristics, the maximum increment in trunk girth (3.55 cm) were recorded with the treatment T_8 - GA_3 (75 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%) and maximum leaf area (24.56 cm^2) were observed with the treatment T_9 NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%). Whereas the maximum yield (10.01 kg/plant) and minimum fruit drop (22.85 %) were observed with the treatment T_{10} - GA_3 (75 ppm) + NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%). The fruit quality characteristics like maximum average fruit weight (28.39 g), fruit length (41.26 mm), fruit width (40.51 mm), TSS (7.2 °Brix), ascorbic acid (30.20 mg/100g) and juice percentage (52.73 %) were also recorded with the treatment T_{10} - GA_3 (75 ppm) + NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%). While, the maximum titratable acidity (6.81 %) were recorded with the treatment T_9 - NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%). The growth, yield and fruit quality of acid lime improved a lot as compared to untreated plants and the spray of GA_3 (75 ppm) + NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%) was recorded as the best treatment for the plants.

Introduction

Acid lime (*Citrus aurantifolia* Swingle) is the third most important fruit crop next to mandarin and sweet orange. It originated in India and spread all over the world, commonly known as "Lime" also called as "Nimbu" in local language. Limes are rich source of bioflavonoid, acid and volatile oils, good source of antioxidant and also contain small amounts of riboflavin, niacin, folate, phosphorus and magnesium, hence a very good source of nutrients. The total area, production and productivity of acid

lime in India was about 259.3 thousand hectare with 2789.0 thousand MT production and 10.8 MT/ha productivity respectively (NHB, 2017).

Acid lime flowers throughout the year in three distinct seasons known as 'Bahar' *viz.* Ambe, Mrig and Hasth bahar. Due to continuous flowering and heavy crop load on trees, the size of fruits remain usually very small and fruit quality characters also get affected, resulting into harvest of poor quality and unmarketable fruits. Citrus orchards in India are facing problems of fruit size, colour, quality and excessive premature fruit drop which is due to the incomplete pollination (Jagtap *et al.,* 2013). The acid lime cv. Ganganagar Lime – 1 is precocious and prolific bearer with attractive fruit colour (deep yellow), aroma, high juice content, less number of seeds (5-6 seeds/fruit), thin rind, resistance to canker and high productivity. Due to high productivity, the fruit size of Ganganagar Lime – 1 is lower than other commercial lime varieties in Bundelkhand region of Uttar Pradesh. Plant growth regulators and micronutrients play a vital role in many physiological phenomena of the plants and their foliar spray can be used to increase the yield of good quality fruits. The pre harvest sprays of plant growth regulators are also used to control fruit drop and to improve fruit retention percentage. NAA used on fruit plants checks the fruit drop, increase the fruit retention and also increased the fruit weight and TSS of the fruits. GA_3 increased the fruit size, fruit diameter and fruit weight which ultimately increased the yield (Shinde *et al.,* 2008). Application of GA_3 stimulates cell division and cell elongation and also influences the flowering in acid lime. Hence, in the present experiment, studies were carried out to estimate the best combination of the spray of the plant growth regulators and micronutrients for the future recommendation to get the better fruit quality of Ganganagar Lime -1 cultivar of acid lime for Bundelkhand region of Uttar Pradesh.

Materials and Methods

The present investigation was carried out during the period of 2020 – 2021 at the experimental orchard in the University campus, Department of Fruit Science, Banda University of Agriculture and Technology, Banda. The experiment was laid out in Randomized Block Design (RBD) with ten treatments having three replications. The first spray was done at the last week of August (before flowering), second spray at last week of September (pea stage) in Hasth Bahar crop with the following treatments- T_1 - Control (water spray)**,** T_2 - GA_3 (75 ppm) + NAA (100 ppm), T_3 - $ZnSO_4$ (1%) + $FeSO_4$ (1%), T_4 - GA_3 (75 ppm) + $ZnSO_4$ (1%), T_5 - GA_3 (75 ppm) + $FeSO_4$ (1%), T_6 - NAA (100 ppm) + $ZnSO_4$ (1%), T_7 - NAA (100 ppm) + $FeSO_4$ (1%), T_8 - GA_3 (75 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%), T_9 - NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%) and T_{10} - GA_3 (75 ppm) + NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%). The data on growth parameters like increment in trunk girth, annual increment in plant height and leaf area were recorded by using measuring tape and Automatic Leaf Area Meter (Licor Model-3100) respectively at the end of growing season in both the years. Fruits were harvested during mid of February and yield was expressed in kg per plant. The fruit drop percentage was calculated with the following equation:

$$Fruit\ drop\ (\%) = \frac{Total\ number\ of\ fruit\ set - total\ number\ of\ fruits\ at\ the\ time\ of\ harvest}{Total\ number\ of\ fruit\ set} \times 100$$

The fruit quality parameters like average fruit weight, fruit size, juice percentage, total soluble solids, titratable acidity and ascorbic acid content were analysed in the laboratory. The average fruit weight of ten fruits was calculated. The fruit size was measured with the help of digital vernier calliper in millimetres. Hand refractometer was used to measure T.S.S. Juice percentage was measured with the following equation.

$$Juice\ (\%) = \frac{Total\ weight\ of\ juice\ (g) - Beaker\ weight\ (g)}{Total\ weight\ of\ fruit\ (g)} \times 100$$

The data recorded on different parameters were subjected to analysis of variance (ANOVA).

Results and Discussion

It is evident from the present investigation that the growth regulators and micronutrients application increased the plant growth in acid lime (Table 1). The maximum increment in trunk girth (3.55 cm) was observed with the treatment T_8 [GA_3 (75 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%)] and the maximum leaf area (24.56 cm^2) was observed with the treatment T_9 [NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%)]. While the effect of foliar spray on annual increment in plant height and increment in canopy volume was non significant. The application of plant growth regulators had a positive influence on the vegetative growth of the plant. Gibberellic acid increased the stem growth by increasing cell elongation in sub apical meristem. The rapid growth was a result of both, more number of cells formed and increased elongation of the individual cells. These results are in conformity with the findings of Debaje *et al.,* (2010) in acid lime. The increase in plant growth might be due to the zinc which is the activator of enzymes, involved in protein synthesis and had direct effect on the level of IAA in plants and iron increased the photosynthetic activity resulting into greater supply of food and ultimately more efficient cellular activity.

It is evident from the present investigation that the plant growth regulators and micronutrients influenced the fruit drop and fruit yield in acid lime (Table 2). The minimum percentage of fruit drop (22.85 %) and maximum yield (10.01 kg/plant) were recorded with the treatment T_{10} [GA_3 (75 ppm) + NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%)]. Whereas the maximum average weight of fruit (28.39 g), fruit length (41.26 mm) and fruit width (40.51 mm) were also observed with the treatment T_{10} [GA_3 (75 ppm) + NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%)]. The NAA treatment decreases fruit drop by the suppressing the formation of abscission layer (Frolove, 1967). The beneficial role on sweet orange for reducing fruit drop may be explained from the fact that it maintains the ongoing physiological and biological process of inhibition of abscission (Tomaszewska and Tomaszewska, 1970). The increase in fruit weight might be due to the transient increase in cell number and cell division or combination of both in cells of ovary caused by gibberellins (Rai *et al.*, 2018). The fruit length, fruit width, fruit weight and fruit volume significantly varied due to foliar spray of micronutrients and plant growth regulators (Chaudhary *et al.*, 2018). The increase in size of fruit might be due to the fact that gibberellic acid plays a dominant role in cell enlargement during the fruit development. The possible reason for the enhancement of fruit size (length and diameter) with GA_3, NAA and zinc might be due to their involvement in hormonal metabolism, increased cell division, elongation and expansion of cells. Gibberellins are known for their ability to increase cell enlargement and enhancing fruit growth in certain species such as citrus (Gurung *et al.*, 2016). The data presented in Table 3 showed that the fruit quality was significantly affected by treatment with growth regulators and micronutrients. The results indicated that the maximum total soluble solids (7.2 ^oBrix), ascorbic acid (30.20 mg/100 g) and juice percentage (52.73 %) were observed with the treatment T_{10} [GA_3 (75 ppm) + NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%)]. While the maximum titratable acidity (6.81 %) were recorded with the treatment T_9 [NAA (100 ppm) + $ZnSO_4$ (1%) + $FeSO_4$ (1%)]. The improvement in TSS of fruits could easily be explained by the fact that iron is helpful in photosynthesis which ultimately lead to the accumulation of carbohydrates and helped to increase the TSS (Jitendra *et al.*, 2017). Increase in acidity could be attributed to an increased osmotic pressure by cell expansion due to auxin, which lead to accumulation of organic acids (Ganga *et al.*, 2019). The increase in ascorbic acid content might be due to the catalytic influence of GA_3 on the biosynthesis of ascorbic acid from sugars. The maximum vitamin C content was observed in aonla cv. Narendra Aonla – 6 with foliar spray of zinc sulphate + copper sulphate (Patel *et al.*, 2018). The increase in juice percentage with spray might be due to their influence on enhancing cell wall expansion, which increases the vesicle capacity for juice accumulation (Agusti *et al.*, 2002).

Table.1 Effect of foliar spray of plant growth regulators and micronutrients on growth characteristics of acid lime cv. Ganganagar Lime - 1

Treatments code	Treatment Details	Increment in trunk girth (cm)	Annual increment in plant height (m)	Increment in canopy volume (m^3)	Leaf area (cm^2)
T_1	**(Control)**	1.19	0.24	0.29	19.45
T_2	**(GA_3 75 ppm + NAA 100 ppm)**	2.34	0.21	0.30	21.97
T_3	**($ZnSO_4$ 1% + $FeSO_4$ 1%)**	1.39	0.23	0.30	20.21
T_4	**(GA_3 75 ppm + $ZnSO_4$ 1%)**	2.91	0.21	0.29	22.94
T_5	**(GA_3 75 ppm + $FeSO_4$ 1%)**	2.61	0.22	0.29	22.36
T_6	**(NAA 100 ppm + $ZnSO_4$ 1%)**	2.19	0.20	0.29	21.71
T_7	**(NAA 100 ppm +$FeSO_4$ 1%)**	1.71	0.21	0.30	21.12
T_8	**(GA_3 75 ppm + $ZnSO_4$ 1% + $FeSO_4$ 1%)**	3.55	0.23	0.29	23.34
T_9	**(NAA 100 ppm + $ZnSO_4$ 1% + $FeSO_4$ 1%)**	2.10	0.22	0.29	24.56
T_{10}	**(GA_3 75 ppm + NAA 100 ppm + $ZnSO_4$ 1% + $FeSO_4$ 1%)**	3.25	0.23	0.30	23.82
C.D. at 5 %		**0.32**	**NS**	**NS**	**1.10**
S. Em.±		0.10	0.008	0.001	0.36

Table.2 Effect of foliar spray of plant growth regulators and micronutrients on fruit drop, yield and fruit quality characteristics of acid lime cv. Ganganagar Lime - 1

Treatment codes	Treatment details	Fruit drop (%)	Fruit yield (kg/plant)	Average fruit weight (g)	Fruit length (mm)	Fruit width (mm)
T_1	**(Control)**	36.53	5.30	21.85	29.30	27.44
T_2	**(GA_3 75 ppm + NAA 100 ppm)**	24.54	9.19	27.63	39.80	37.26
T_3	**($ZnSO_4$ 1% + $FeSO_4$ 1%)**	33.79	6.00	23.97	30.45	28.81
T_4	**(GA_3 75 ppm + $ZnSO_4$ 1%)**	30.39	7.04	26.86	35.30	32.61
T_5	**(GA_3 75 ppm + $FeSO_4$ 1%)**	31.63	6.50	24.99	32.31	29.06
T_6	**(NAA 100 ppm + $ZnSO_4$ 1%)**	25.64	8.78	27.06	37.68	35.16
T_7	**(NAA 100 ppm +$FeSO_4$ 1%)**	26.46	8.03	25.75	34.11	30.30
T_8	**(GA_3 75 ppm + $ZnSO_4$ 1% + $FeSO_4$ 1%)**	28.60	7.70	27.88	40.91	38.99
T_9	**(NAA 100 ppm + $ZnSO_4$ 1% + $FeSO_4$ 1%)**	23.94	9.54	28.07	41.13	39.78
T_{10}	**(GA_3 75 ppm + NAA 100 ppm + $ZnSO_4$ 1% + $FeSO_4$ 1%)**	22.85	10.01	28.39	41.26	40.51
C.D. at 5 %		**2.70**	**0.75**	**1.05**	**1.56**	**1.31**
S. Em.±		0.90	0.25	0.35	0.52	0.44

Table.3 Effect of foliar spray of plant growth regulators and micronutrients on fruit quality characteristics of acid lime cv. Ganganagar Lime - 1

Treatment codes	Treatment details	TSS (°Brix)	Titratable acidity (%)	Ascorbic acid (mg/100 g)	Juice percentage (%)
T_1	**(Control)**	5.83	5.11	24.83	42.15
T_2	**(GA_3 75 ppm + NAA 100 ppm)**	6.85	6.20	29.08	50.12
T_3	**($ZnSO_4$ 1% + $FeSO_4$ 1%)**	6.02	5.47	25.30	43.26
T_4	**(GA_3 75 ppm + $ZnSO_4$ 1%)**	6.60	5.84	27.86	47.81
T_5	**(GA_3 75 ppm + $FeSO_4$ 1%)**	6.23	5.53	26.00	45.39
T_6	**(NAA 100 ppm + $ZnSO_4$ 1%)**	6.71	6.08	28.77	49.47
T_7	**(NAA 100 ppm +$FeSO_4$ 1%)**	6.45	5.66	26.72	46.19
T_8	**(GA_3 75 ppm + $ZnSO_4$ 1% + $FeSO_4$ 1%)**	7.00	6.26	29.93	50.93
T_9	**(NAA 100 ppm + $ZnSO_4$ 1% + $FeSO_4$ 1%)**	7.10	6.81	30.00	51.66
T_{10}	**(GA_3 75 ppm + NAA 100 ppm + $ZnSO_4$ 1% + $FeSO_4$ 1%)**	7.20	6.46	30.20	52.73
C.D. at 5 %		**0.30**	**0.43**	**1.38**	**1.54**
S. Em.±		0.10	0.14	0.46	0.51

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