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# Impact of growth regulators and micronutrients on growth, yield and quality of acid lime (*Citrus aurantifolia* Swingle) under HDP system

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**Abstract**
Experiment was carried out to study the effect of growth regulators, micronutrients and chemicals on growth, yield and quality of acid lime (*Citrus aurantifolia* Swingle) under HDP system". The experiment comprised of 13 treatments consisting of plant growth regulators ($GA_3$ and NAA), micronutrients ($FeSO_4$ and Boron) and chemicals ($KNO_3$ and Salicylic acid) on fruit yield and quality of acid lime. Significant results were obtained in treatment $GA_3$100 ppm + $KNO_3$ 2% + Salicylic acid 200 ppm + $FeSo_4$ 1% + Boron 1% ($T_{11}$) for days to flower bud initiation (38.5 days), days to 50% flowering (49.0 days), fruit setting percentage (87.1%), fruit diameter at 120 days (4.59 cm), average fruit volume at harvest (41.8 cc), total soluble solid (8.93 $^0$Brix), number of fruits per plant (974.2), and average yield per tree (38.3 kg). Treatments which included micronutrients showed good results in terms of quality and quantity attributes of fruits.

**Keywords:** Citrus, micronutrients, growth regulators, salicyclic acid

## Introduction
Acid lime (*C. aurantifolia* Swingle), a member of Rutaceae family, is native of India, cultivated in various regions of arid and semi arid areas of southwest region to humid tropical climate of North-East India. India ranks fifth among major lime and lemon producing countries in the world. Citrus fruits are not only delicious and refreshing but they provide vitamins, minerals and many other substances as well. Citrus fruits contain considerable amounts of Vitamin C and antioxidants also they are an excellent source for healing and cleansing the body.

The acid lime occupies 2.83 lakh hectares with the production and productivity of 32.21 lakh tonne and 12.3 ton/ha respectively (Anonymous, 2017) [1]. Acid lime grows best between temperature ranges of 13 $^0$C to 37 $^0$C. A temperature below 4ºC is harmful for the young plants. Hot wind during summer results in desiccation and heavy drop of flowers and developing fruits.

## Materials and Methods
The investigation was carried out during 2016-17 and 2017-18. at the experimental area, College of Agriculture, Gwalior (M.P) in Randomized Block Design with three replications. Gwalior is situated at 26° 13` N latitude and 78º 14' E longitudes at an altitude of 211.5 m above mean sea level in gird belt. It has a subtropical climate with hot and dry summer where maximum temperature exceeds 45$^0$ C in May June.

The treatment was imposed four months before flowering in October followed by January-February through foliar spray. $GA_3$ was given in first fortnight of October whereas spraying of NAA and salicylic acid was done in mid of January and $KNO_3$, $FeSO_4$ and boron were sprayed on mid of February in both years. Observations recorded during the investigation were subjected to analysis of variance using randomized block design and the significance of different source of variation was tested by error mean square by 'F' test. The mathematical model of randomized block design used were as follows: $Y_{ij} = \mu + v_i + b_j + e_{ij.}$

## Results
### Reproductive and physiological parameters
Significant results were obtained from pooled year data (Table-1)under treatment $GA_3$ 100 ppm + $KNO_3$ 2% + Salicylic acid 200 ppm + $FeSO_4$ 1% + Boron 1% ($T_{11}$) regarding growth

parameters like days to flower bud initiation (38.5 days), days to 50% flowering (49.0 days), days to fruit set percent (87.1%), fruit diameter at 120 days (4.59 cm) and average fruit volume at harvest (41.8 cc) which was at par with results obtained from treatment NAA 300 ppm + $KNO_3$ 2% + salicylic acid 200 ppm + FeSO4 1% + boron 1% ($T_{13}$). Treatment ($T_{11}$) showed maximum fruit setting percentage, fruit diameter and possesed maximum fruit retention percentage associated due to rapid action of growth regulators, micronutrients and salicylic acid to retain fruits till harvesting. Chemicals and growth regulators such as $GA_3$, $KNO_3$ and salicylic acid contribute towards being with best along with positive effect of boron for retaining fruits and increasing fruit diameter. This trend was also supported by, Debaje *et al.* (2011) [4], Shukla (2009) [3], Jagtap *et al.* (2013) [6], Bhati *et al.* (2016) [2] and Meena *et al.* (2017) [7].

**Quality Parameters**

Positive impact of growth regulators and micronutrients on fruit juice was observed for both years and pooled data analysis. Fruit juice directly affects fruit weight and fruit volume. Maximum juice percentage was recorded in treatment $GA_3$ 100 ppm + $KNO_3$ 2% + salicylic acid 200 ppm + $FeSO_4$ 1% + boron 1% ($T_{11}$) followed by NAA 300 ppm + $KNO_3$ 2% + salicylic acid 200 ppm + $FeSO_4$ 1% + boron 1% ($T_{13}$) and NAA 200 ppm +$KNO_3$ 1% + salicylic acid 100 ppm + $FeSo_4$ 0.5% + boron 0.5% ($T_{12}$). Average fruit volume were recorded in treatment $GA_3$ 100 ppm + $KNO_3$ 2% + salicylic acid 200 ppm + $FeSO_4$ 1% + boron 1% ($T_{11}$) which was significantly at par with treatment NAA 300 ppm + $KNO_3$ 2% + salicylic acid 200 ppm + $FeSO_4$ 1% + boron 1% ($T_{13}$). Micronutrients such as boron and $FeSO_4$ helps to boost nutrient levels in fruit which initiate increase in volume of fruit whereas growth regulators retains fruit stability. These results were in accordance with findings made by Shukla, H.S. (2009) [3], Jagtap *et al.* (2013) [6], Bhati *et al.* (2016) [2], Meena, *et al.* (2017) [7] Rokaya *et al.* (2016)[10], Vijaya *et al.* (2017) [14] and Tagad S.S. *et al.* (2018).

**Yield Parameters**

Results obtained from pooled data analysis showed (Table-2) significant difference in treatment $GA_3$ 100 ppm + $KNO_3$ 2% + salicylic acid 200 ppm + $FeSO_4$ 1% + boron 1% ($T_{11}$) for maximum number of fruits per plant (974.2) and average yield per tree (38.3 kg) which was significantly at par with NAA 300 ppm + $KNO_3$ 2% + salicylic acid 200 ppm + $FeSo_4$ 1% + boron 1% ($T_{13}$) and NAA 200 ppm +$KNO_3$ 1% + salicylic acid 100 ppm + $FeSO_4$ 0.5% + boron 0.5% ($T_{12}$). The minimum number of fruits per plant was recorded in control ($T_1$). Yield attributing traits such as number of fruits per tree, average fruit weight contributes towards average yield. Balanced nutrient supply from best treatments showed that micronutrients dose and $GA_3$ and NAA released from growth regulators not only form good quality fruits but also enhance fruit yield traits. Similar findings were presented by Singh *et al.* (2011) [11], Jagtap *et al.* (2013) [6], Deshmukh *et al.* (2015), Mukunda *et al.* (2014) [8], Bhati *et al.* (2016) [2] and Neware, *et al.* (2017) [9] and Tagad *et al.* (2018) [13].

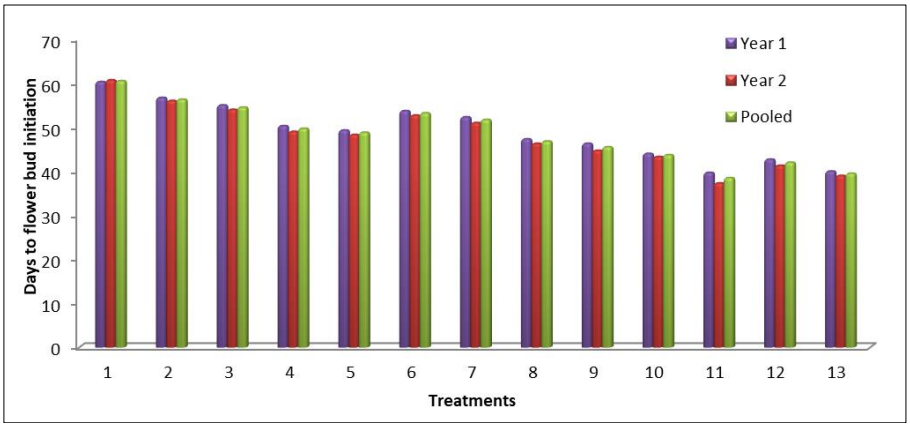


**Fig 1:** Days to flower bud initiation

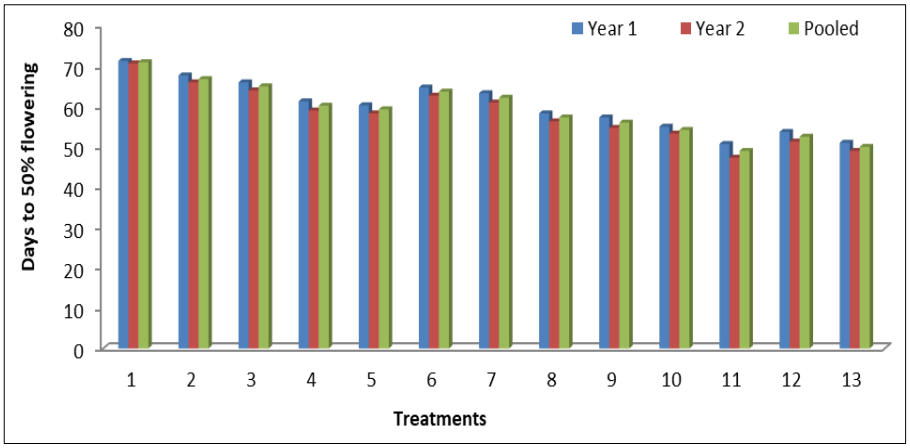


**Fig 2:** Days to 50% flowering

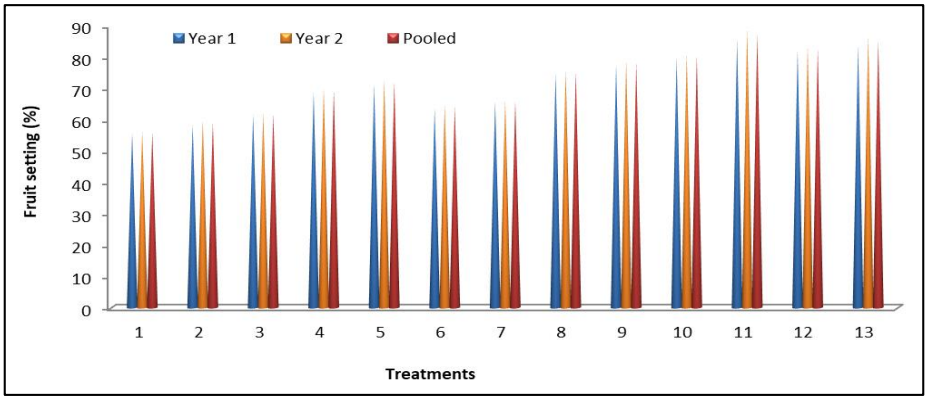


**Fig 3:** Fruit setting %

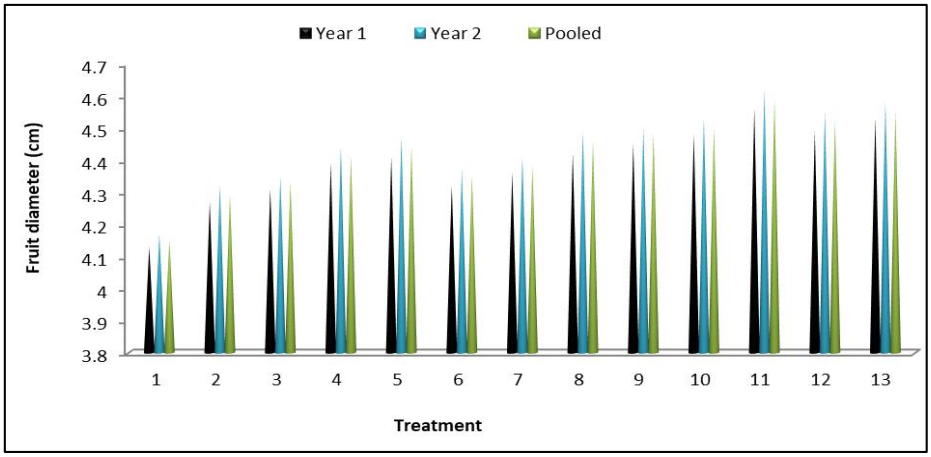


**Fig 4:** Fruit diameter

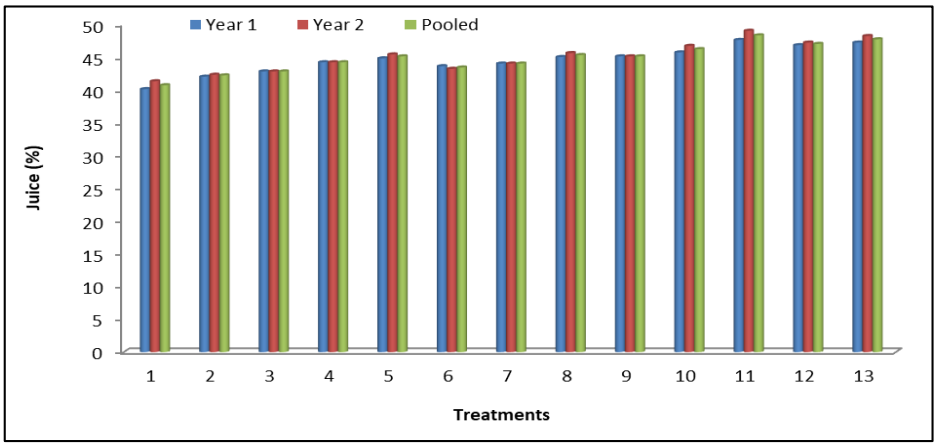


**Fig 5:** Juice %

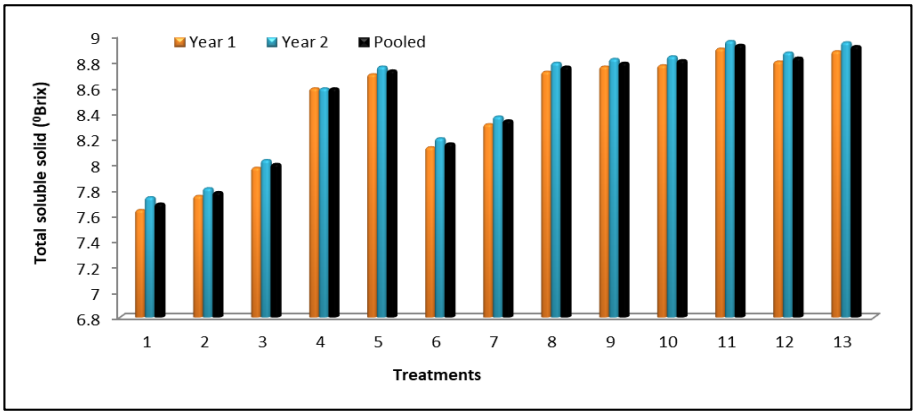


**Fig 6:** Total soluble solids

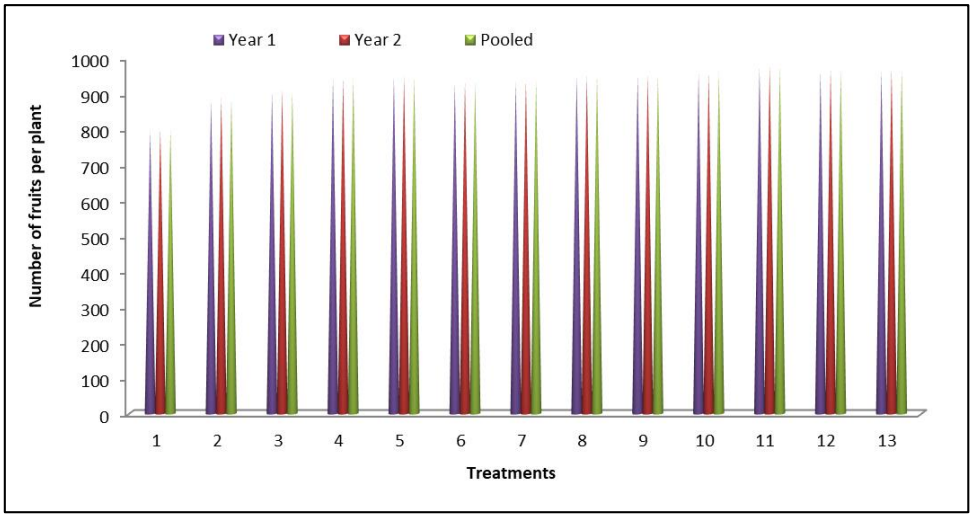


**Fig 7:** Number of fruits/plant

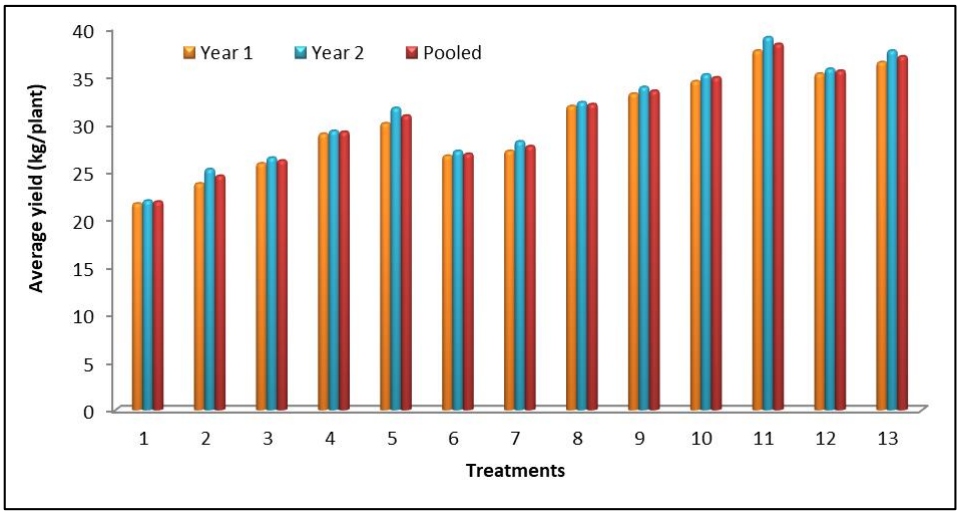


**Fig 8:** Average yield kg/plant

**Table 1:** Effect of growth regulators, micronutrients and chemicals on reproductive and physiological parameters.

| Treatment Symbol | Treatments | Days to flower bud initiation | Days to 50% flowering | Fruit setting (%) | Fruit diameter(cm) 60 Days |
|---|---|---|---|---|---|
| $T_1$ | Control (water spray) | 60.5 | 71.0 | 55.9 | 2.90 |
| $T_2$ | $GA_3$ 50 ppm + $KNO_3$ 1% | 56.3 | 66.8 | 59.0 | 3.05 |
| $T_3$ | $GA_3$ 100 ppm + $KNO_3$ 2% | 54.5 | 65.0 | 61.8 | 3.08 |
| $T_4$ | $GA_3$ 50 ppm + Salicylic acid 100ppm | 49.7 | 60.2 | 69.2 | 3.17 |
| $T_5$ | $GA_3$ 100 ppm + Salicylic acid 200ppm | 48.8 | 59.3 | 71.9 | 3.19 |
| $T_6$ | NAA 200ppm + $KNO_3$ 1% | 53.2 | 63.7 | 64.1 | 3.10 |
| $T_7$ | NAA 300ppm + $KNO_3$ 2% | 51.7 | 62.2 | 65.8 | 3.14 |
| $T_8$ | NAA 200ppm + Salicylic acid 100ppm | 46.8 | 57.3 | 75.2 | 3.21 |
| $T_9$ | NAA 300ppm + Salicylic acid 200ppm | 45.5 | 56.0 | 78.1 | 3.23 |
| $T_{10}$ | $GA_3$ 50 ppm + $KNO_3$ 1% + Salicylic acid 100ppm + $FeSO_4$ 0.5% + Boron 0.5% | 43.7 | 54.2 | 80.3 | 3.26 |
| $T_{11}$ | $GA_3$ 100 ppm + $KNO_3$ 2% + Salicylic acid 200ppm + $FeSO_4$ 1% + Boron 1% | 38.5 | 49.0 | 87.1 | 3.34 |
| $T_{12}$ | NAA 200ppm +$KNO_3$ 1% + Salicylic acid 100ppm + $FeSO_4$ 0.5% + Boron 0.5% | 42.0 | 52.5 | 82.6 | 3.27 |
| $T_{13}$ | NAA 300ppm +$KNO_3$ 2% + Salicylic acid 200ppm + $FeSO_4$ 1% + Boron 1% | 39.5 | 50.0 | 85.0 | 3.31 |
| | S.Em ± | 1.164 | 1.285 | 1.061 | 0.028 |
| | CD 5% | 3.275 | 3.615 | 2.986 | 0.078 |

| Treatment | Treatments | Average fruit volume (cc) at harvest | TSS (%) | Juice (%) | Number of fruits per plant | Average yield (kg/plant) |
|---|---|---|---|---|---|---|
| $T_1$ | Control (water spray) | 23.9 | 7.69 | 40.7 | 797.5 | 21.8 |
| $T_2$ | $GA_3$ 50 ppm + $KNO_3$ 1% | 26.1 | 7.78 | 42.2 | 882.7 | 24.5 |
| $T_3$ | $GA_3$ 100 ppm + $KNO_3$ 2% | 27.6 | 8.00 | 42.8 | 905.5 | 26.1 |
| $T_4$ | $GA_3$ 50 ppm + Salicylic acid 100ppm | 30.8 | 8.59 | 44.2 | 940.8 | 29.1 |
| $T_5$ | $GA_3$ 100 ppm + Salicylic acid 200ppm | 33.5 | 8.73 | 45.1 | 946.2 | 30.8 |
| $T_6$ | NAA 200ppm + $KNO_3$ 1% | 28.2 | 8.16 | 43.4 | 929.8 | 26.8 |
| $T_7$ | NAA 300ppm + $KNO_3$ 2% | 29.9 | 8.34 | 44.0 | 933.8 | 27.6 |
| $T_8$ | NAA 200ppm + Salicylic acid 100ppm | 35.0 | 8.76 | 45.3 | 948.8 | 32.0 |
| $T_9$ | NAA 300ppm + Salicylic acid 200ppm | 36.2 | 8.79 | 45.1 | 950.8 | 33.4 |
| $T_{10}$ | $GA_3$ 50 ppm + $KNO_3$ 1% + Salicylic acid 100ppm + $FeSO_4$ 0.5% + Boron 0.5% | 38.2 | 8.81 | 46.2 | 956.3 | 34.8 |
| $T_{11}$ | $GA_3$ 100 ppm + $KNO_3$ 2% + Salicylic acid 200ppm + $FeSO_4$ 1% + Boron 1% | 41.8 | 8.93 | 48.3 | 974.2 | 38.3 |
| $T_{12}$ | NAA 200ppm +$KNO_3$ 1% + Salicylic acid 100ppm + $FeSO_4$ 0.5% + Boron 0.5% | 38.8 | 8.83 | 47.0 | 963.8 | 35.5 |
| $T_{13}$ | NAA 300ppm +$KNO_3$ 2% + Salicylic acid 200ppm + $FeSO_4$ 1% + Boron 1% | 40.5 | 8.92 | 47.7 | 966.2 | 37.0 |
| | S.Em ± | 2.639 | 0.102 | 1.280 | 3.401 | 2.030 |
| | CD 5% | NS | 0.288 | NS | 9.572 | 5.796 |

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