Plant Archives Vol. 24, No. 1, 2024 pp. 331-336 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.1.047

INFLUENCE OF NAPHTHALENE ACETIC ACID, GIBBERELLIC ACID AND CALCIUM CHLORIDE ON FRUITING, PHYSICAL PARAMETERS AND YIELD OF KAGZI LIME (*CITRUS AURANTIFOLIA* SWINGLE)

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(Date of Receiving-16-11-2023; Date of Acceptance-17-01-2024)

ABSTRACT

To investigate the influence of Naphthalene acetic acid, gibberellic acid and Calcium chloride on fruiting, physical parameters and yield of Kagzi lime (*Citrus aurantifolia* Swingle) cv. Kagzi lime an experiment was carried out at the Garden Department of Fruit Science, C. S. Azad University of Agriculture and Technology, Kanpur (U.P.) during the cropping season 2022 and 2023. The experiment was laid out in Randomized Block Design with three replications and Ten treatments *viz.*, T_1-NAA (20 ppm), T_2-NAA (40 ppm), T_3-NAA (60 ppm), T_4-GA_3 (10 ppm), T_5-GA_3 (20 ppm), T_6-GA_3 (30 ppm), T_7-$CaCl_2$ (0.10%), T_8-$CaCl_2$ (0.15%), T_9-$CaCl_2$ (0.2%) and T_0-Control (water spray only)**.** Results of the study clearly shows that the highest fruit set was achieved with foliar application of GA_3 at 20 ppm resulting in a remarkable 74.35% fruit set, closely followed by GA_3 at 10 ppm (72.61%). These treatments significantly outperformed with each other's. Fruit drop was also notably reduced with the application of GA_3 20 ppm showing the lowest drop (45.61% in 2022 and 45.63% in 2023). In terms of fruit weight, plants treated with GA_3 20 ppm produced the heaviest fruits, with an average weight of 62.56 grams. Furthermore, both GA_3 and NAA treatments led to larger fruit sizes but the plants treated with GA_3 20 ppm again being the most effective. The number of fruits per tree substantially increased with GA_3 20 ppm, yielding 497.67 fruits. The highest yield per tree was also observed in the GA_3 20 ppm treatment with a remarkable yield of 48.42 kg fruits per plant. These findings demonstrate the efficacy of GA_3 and NAA in enhancing fruit characteristics, providing valuable insights for optimizing Kagzi Lime production in the plains of north India.

Key words : Naphthalene acetic acid, Gibberellic acid, Calcium chloride, *Citrus aurantifolia*.

Introduction

Acid lime, scientifically known as *Citrus aurantifolia* Swingle, belonging to the family Rutaceae, is believed to be originated in the southern slopes of the Himalayan region. From there, it spread to the Middle East and various other tropical and subtropical countries. In India, it ranks as the third most significant citrus crop, following mandarins and sweet oranges. This fruit thrives in both tropical and subtropical climates and is typically grown in the lowlands up to an elevation of 1200 meters above sea level. The fruit of acid lime is highly valued for its medicinal and nutritional properties. Commercial cultivation of acid lime is prominent in various Indian states, including Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Bihar and West Bengal. Plant bio-regulators play a pivotal role in horticultural practices and can greatly influence the yield and quality of fruit crops.

NAA is a synthetic auxin hormone that is known for its ability to stimulate fruit development and ripening, potentially improving fruit size and quality. GA_3 increases the fruit length, fruit diameter, fruit weight ultimately the yield was increased. NAA checking the fruit drops and increasing the fruit retention and also increasing the fruit weight and total soluble solids in many fruits. Calcium

chloride, on the other hand, is a source of calcium, an essential nutrient for plant growth and development, which can positively impact fruit quality and storage. Keeping this view, the present experiment was planned to get concrete information on the influence of naphthalene acetic acid, gibberellic acid and calcium chloride on fruiting, physical parameters and yield of Kagzi Lime (*Citrus aurantifolia* Swingle) in the plains of north India.

Materials and Methods

About 20 years old but properly maintained thirty uniform plants of Kagzi lime, located at Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, India were selected for the present investigations during 2022 and 2023. During the course of the investigation the whole of the orchard was kept under clean and uniform cultivation practices. The experiment was carried out using 10 treatments *viz.*, 3 levels each of NAA (20, 40 and 60ppm), GA_3 (10, 20 and 30ppm) and Calcium chloride (0.1,0.15 and 0.2%), which were replicated thrice in Randomized Block Design. The spraying of plant bio-regulators and micronutrient were done twice *i.e.*, before flowering (20 January) and at pea stage (05 March) during both the years.

During experimentation observations on fruit per panicle, fruit drop, and fruit retention were made. Fruit weight and yield per plant were recorded during each picking by weighing machine. Ten randomly chosen fruits were measured using a vernier caliper for their fruit length and width and expressed in centimeters (cm). Using a volumetric flask and the water displacement method, data on the volume of fruits were determined and expressed in cc.

Results and Discussion

Fruit set (%)

Application of growth regulator as well as micronutrients significantly increased the per cent fruit set as compared to control. Significantly maximum fruit set (74.35%) was noted in foliar application of GA_3 20 ppm followed GA_3 10 ppm *i.e.* 72.61% (Table 1). These treatments were followed by their respective lower levels. However, these two treatments were significantly superior over each other. In general, the various levels of NAA, GA_3 and $CaCl_2$ helped in increasing the per cent fruit set. Application of GA_3- accelerates the development of differentiated inflorescence which also leads to an increased number of fruits per panicle. The findings obtained by Prasad *et al.* (2011), Nkansah *et al.* (2012), Anushi *et al.* (2021)and Singh *et al.* (2023) in mango.

Fruit drop and retention (%)

The data obtained in respect of fruit drop and retention (%)as affected by the application of growth regulator and micronutrients is presented in Table1 revealed that significant differences among different treatments in respect of per cent fruit drop and retention due to application of GA_3, NAA and $CaCl_2$ were recorded during both the years of investigation. Plants treated with the foliar application of GA_3 20 ppm resulted in significantly reduced minimum fruit drop (45.61 and 45.63%) and retention (68.51, 68.54%) during 2022 and 2023, respectively, followed by lower levels of GA_3 10 ppm 48.42 and 48.44% fruit drop and 65.39 and 65.41% fruit retention) and NAA 60 ppm which produced (50.37 and 50.49% fruit drop and 63.44 and 63.47% fruit retention) during 2022 and 2023, respectively.

Gibberellic acid causes the production of a larger number of flowers with rapid elongation of the peduncle, leading to the full development of flower buds having all reproductive parts functional leading to increased fruit set and fruit retention thus also minimizing fruit drop. Singh *et al.* (2017) reported that in mango also reported that the use of GA_3 at 20ppm greatly reduced fruit drop and increased fruit retention. These results are in similar lines with the findings of Bhati *et al.* (2016) in acid lime, Tripathi *et al.* (2019) in aonla and Kaur (2017) in litchi, Anushi *et al.* (2021), Singh *et al,* (2023) in mango.

Weight and volume of the fruit

The impact of foliar application of growth regulators and micronutrient on the average weight and volume of Kagzi lime fruits is presented in Table 2 clearly demonstrates significant differences among the various treatments, indicating the effectiveness of GA_3, NAA, and $CaCl_2$ in influencing fruit weight and volume. Fruits produced from the plants treated with GA_3 20ppm resulted in the significantly highest average weight (62.52g and 62.60g, respectively) and volume (45.56 and 45.58cc, respectively) during both years of experimentation. However, fruits with poorest weight (40.43g and 40.47g, respectively) and volume (28.42 and 28.43cc, respectively) during both years of experimentation were produced from the plants kept under control. This increase in weight and volume in fruits produced from GA_3 treated plants may be due to the involvement of GA_3 to increase the cell division and translocation of food material which might be responsible to improve the weight of fruits. Singh *et al.* (2017) reported that in mango fruit weight and volume was greatly influenced by the use of GA_3 at 20ppm. Similar effects were also observed by Singh *et al.* (2015), Kumar and Tripathi (2009) in strawberry,

Table 1 : Effect of Naphthalene Acetic Acid, Gibberellic acid and Calcium chloride on Fruit set, drop and retention per cent.

Treatments	Fruit set (%)			Fruit Drop (%)			Fruit retention (%)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
NAA 20ppm	66.52	66.55	66.54	53.42	53.44	53.43	56.31	56.33	56.32
NAA 40ppm	68.80	68.82	68.81	51.53	51.55	51.54	58.50	58.52	58.51
NAA 60ppm	70.45	70.48	70.46	50.37	50.39	50.38	63.44	63.47	63.46
GA_3 10ppm	72.59	72.62	72.61	48.42	48.44	48.43	65.39	65.41	65.40
GA_3 20ppm	74.34	74.36	74.35	45.61	45.63	45.62	68.51	68.54	68.53
GA_3 30ppm	65.61	65.63	65.62	64.41	64.43	64.42	54.76	54.78	54.77
$CaCl_2$ 0.10%	64.59	64.61	64.60	60.59	60.62	60.61	52.60	52.62	52.61
$CaCl_2$ 0.15%	62.84	62.87	62.86	58.63	58.64	58.64	50.63	50.65	50.64
$CaCl_2$ 0.20%	62.72	62.74	62.73	55.64	55.69	55.67	48.59	48.62	48.61
Control	60.44	60.46	60.45	67.58	67.33	67.46	46.42	46.44	46.43
CD at 5% level	**0.164**	**0.180**	**0.169**	**0.321**	**0.199**	**0.124**	**0.140**	**0.167**	**0.157**
SE(M) ±	**0.055**	**0.060**	**0.057**	**0.107**	**0.066**	**0.038**	**0.047**	**0.056**	**0.053**
SE(d) ±	**0.077**	**0.085**	**0.083**	**0.152**	**0.094**	**0.054**	**0.066**	**0.079**	**0.072**

Table 2 : Effect of Naphthalene Acetic Acid, Gibberellic acid and Calcium chloride on fruit weight, volume and diameter.

Treatments	Weight of the fruit (g)			Volume of the fruit (cc)			Fruit Diameter horizontal (mm)			Fruit Diameter vertical (mm)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
NAA 20ppm	48.28	48.34	48.31	38.45	38.47	38.46	63.41	63.43	63.42	58.37	58.38	58.38
NAA 40ppm	50.45	50.51	50.48	40.39	40.41	40.40	64.37	64.38	64.38	59.45	59.48	59.47
NAA 60ppm	56.51	56.59	56.55	42.49	42.51	42.50	66.58	66.59	66.59	61.43	61.45	61.44
GA_3 10ppm	58.57	58.63	58.60	44.45	44.46	44.46	68.54	68.56	68.55	63.67	63.69	63.68
GA_3 20ppm	62.52	62.60	62.56	45.56	45.58	45.57	70.61	70.62	70.62	65.55	65.57	65.56
GA_3 30ppm	54.51	54.56	54.54	36.49	36.50	36.50	62.46	62.48	62.47	57.42	57.44	57.43
$CaCl_2$ 0.10%	46.61	46.65	46.63	34.51	34.50	34.51	60.46	60.64	60.55	55.60	55.68	55.64
$CaCl_2$ 0.15%	44.55	44.60	44.58	32.47	32.49	32.48	59.47	59.48	59.48	54.49	54.51	54.50
$CaCl_2$ 0.20%	41.55	41.60	41.58	30.49	30.51	30.50	58.39	58.40	58.40	53.53	53.55	53.54
Control	40.43	40.47	40.45	28.42	28.43	28.43	57.31	57.33	57.32	52.30	52.33	52.32
CD at 5% level	**0.124**	**0.124**	**0.110**	**0.122**	**0.110**	**0.111**	**0.098**	**0.226**	**0.045**	**0.199**	**0.198**	**0.017**
SE (M) ±	**0.041**	**0.041**	**0.037**	**0.041**	**0.037**	**0.037**	**0.033**	**0.075**	**0.014**	**0.066**	**0.066**	**0.005**
SE(d) ±	**0.058**	**0.058**	**0.054**	**0.058**	**0.052**	**0.050**	**0.046**	**0.107**	**0.020**	**0.094**	**0.093**	**0.007**

Dubey *et al.* (2017), Tripathi and Shukla (2007), Tripathi and Shukla (2010), Verma *et al.* (2021) in strawberry in their experiments.

Fruit diameter (mm)

The impact of various treatments, including growth regulators (NAA and GA_3) and micronutrient ($CaCl_2$) on the horizontal and vertical fruit diameter of Kagzi lime presented in Table 2 showed significant differences among the treatments and provide valuable insights into the influence of these treatments on fruit diameter. Fruits produced from the plants, which were treated with GA_3 20 ppm consistently produced the fruits having largest horizontal (70.61 and 70.62mm, respectively) and vertical (65.55 and 65.57mm, respectively) diameter during both years of experimentation, closely followed by the fruits which were produced from the plants treated with GA_3 10 ppm having 68.54 and 68.56mm, respectively horizontal and 63.67 and 63.69mm, respectively vertical fruit diameter. However, fruits produced from the plants kept under control without any treatment, consistently displayed the smallest horizontal (57.31and 57.33 mm, respectively) and vertical (52.30 and 52.33mm, respectively) fruit diameter during both years of experimentation. This increase in fruit diameter with GA_3 application might be due to the accumulation of more food materials in fruit trees which ultimately transferred to the fruits during their growth and development stage and also increase in size.

The similar results reported by Vishwakarma *et al.*

Table 3 : Effect of Naphthalene Acetic Acid, Gibberellic acid and Calcium chloride on fruit size and number of fruits per plant.

Treatments	Fruit length (cm)			Fruit width (cm)			Number of fruits per plant		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
NAA 20ppm	5.35	5.36	5.36	5.24	5.26	5.25	357.67	373.00	365.34
NAA 40ppm	5.77	5.78	5.78	5.66	5.68	5.67	377.00	391.00	384.00
NAA 60ppm	5.93	5.94	5.94	5.82	5.84	5.83	426.67	436.00	431.34
GA_3 10ppm	6.13	6.15	6.14	6.04	6.05	6.05	451.67	458.33	455.00
GA_3 20ppm	6.23	6.24	6.24	6.12	6.14	6.13	477.33	497.67	487.50
GA_3 30ppm	5.39	5.13	5.26	5.04	5.03	5.04	321.00	329.33	325.17
$CaCl_2$ 0.10%	4.87	4.89	4.88	4.78	4.79	4.79	285.33	296.33	290.83
$CaCl_2$ 0.15%	4.72	4.73	4.73	4.60	4.63	4.62	269.67	280.33	275.00
$CaCl_2$ 0.20%	4.47	4.49	4.48	4.37	4.39	4.38	254.00	271.00	262.50
Control	4.25	4.27	4.26	4.15	4.17	4.16	230.00	244.67	237.34
CD at 5% level	**0.342**	**0.027**	**0.141**	**0.031**	**0.028**	**0.017**	**7.504**	**11.660**	**6.917**
SE (M) ±	**0.114**	**0.009**	**0.043**	**0.010**	**0.009**	**0.005**	**2.506**	**3.894**	**2.132**
SE (d) ±	**0.162**	**0.013**	**0.061**	**0.015**	**0.013**	**0.007**	**3.544**	**5.507**	**3.015**

(2022) in mango, explained that the maximum fruit diameter (6.16 cm) at harvest stage was found significant in treatment of GA_3 25 mg/l. similar view was also shared by Singh *et al*. (2013) in guava. Viveka Nand *et al*. (2023a) in litchi, Kumar and Tripathi (2009), Dubey *et al*. (2017), Tripathi and Shukla (2007), Tripathi and Shukla (2010), Verma *et al*. (2021) in strawberry, Singh *et al*. (2023) in mango.

Fruit length and width (cm)

In this study, the impact of foliar application of GA_3, NAA, and $CaCl_2$ on fruit size, specifically fruit length and width, was investigated and presented in Table 3 which clearly indicate significant variations in fruit dimensions under different treatments.

Among the all treatments, fruits which were produced from the plants treated with GA_3 20 ppm consistently produced the fruits exhibited the most significant improvement having significantly maximum size of fruits in terms of length (6.23 and 6.24cm, respectively) and width (6.12 and 6.14cm, respectively) during both years of experimentation, closely followed by the fruits which were produced from the plants treated with GA_3 10 ppm having fruits length (6.13 and 6.15cm, respectively) and width (6.04 and 6.05cm, respectively). However, the plants kept under control without any treatment produced fruits consistently in the smallest size in terms of length (4.25 and 4.27cm, respectively) and width (4.15 and 4.17cm, respectively) during both years of experimentation.

This increase in size of fruits with the application of gibberellic acid might be due to the significantly increase in cell division and cell elongation. Similar result found by Vishwakarma *et al*. (2022) reported that the fruit length at harvest stage was found significantly maximum with GA_3 25 mg/l treatment in mango. Singh *et al*. (2017) reported that in mango fruit size was greatly influenced by the use of GA_3 at 20ppm. The results are in accordance with the findings reported by Viveka Nand *et al*. (2023a) in litchi, Kumar and Tripathi (2009), Dubey *et al*. (2017), Tripathi and Shukla (2007), Tripathi and Shukla (2010), Verma *et al*. (2021) in strawberry.

Number of fruits per tree

In the present study, it has been found that the maximum number of fruits per tree were produced with the treatment of plants with 20 ppm concentration of gibberellic acid which produced 477.33 and 497.67 fruits per plant, respectively during both years of experimentation, against 230.00 and 244.67 fruits per plant, respectively from the plants kept under control, during both years of experimentation *i.e.*, during the years 2022 and 2023 (Table 3). Similar result found by Viveka Nand *et al*. (2023a) reported that the higher number of fruits per node in litchi might be due to gibberellic acid and auxin help in chlorophyll formation that regulate the build-up of proper C:N ratio, which controls the flowering and fruiting in litchi plants. Thakur *et al*. (2017) also reported that the highest number of fruits (29.02) and yield (540.01 g) per plant was recorded in plant sprayed with 15 ppm GA_3 in strawberry, Tripathi and Shukla (2008) in strawberry, Anushi *et al*. (2021) in mango, Singh *et al*. (2023) in mango.

Yield per tree (kg)

Plants treated with the foliar application using different concentration of Naphthaleneacetic acid, gibberellic acid,

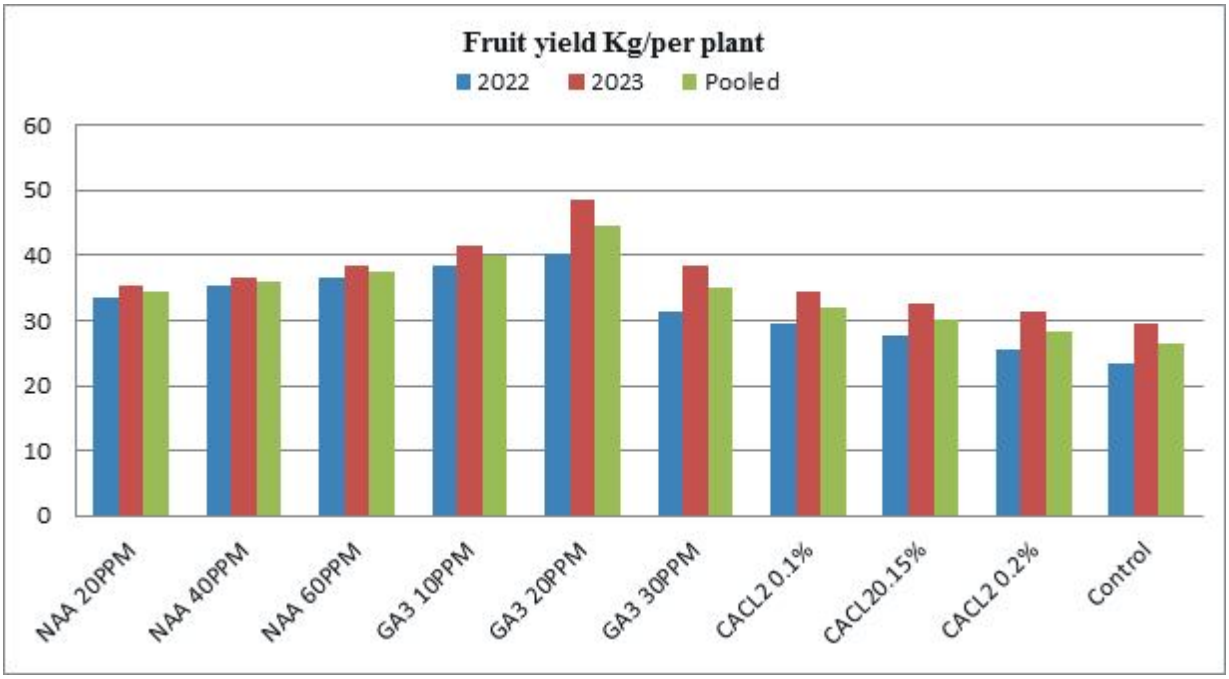

Fig. 1 : Effect of Naphthalene acetic acid, Gibberellic acid and Calcium chloride on fruit yield kg/per plant.

calcium chloride resulted significant increase on the yield per tree in Kagzi lime (Fig. 1). The highest yield per tree was harvested from the plants treated with GA_3 20ppm (40.41 and 48.42kg, respectively) during both years of experimentation *i.e.*, in the year 2022 and 2023, closely followed the plants treated with GA_3 10 ppm (38.53 and 41.55kg, respectively). In contrast, the plants kept as control (without any application) had the lowest yield per tree (23.36 and 29.38kg, respectively) during both years of experimentation. This significant increase in fruit yield in GA_3 treated plants might be due to their direct role in photosynthesis in the plants which results an increase in fruit size, weight, volume and ultimately yield of fruits.

The present findings are got the support with the findings of Tripathi *et al.* (2018) in aonla cv. NA-7 and Viveka Nand *et al.* (2023b) in litchi, Kumar and Tripathi (2009), Dubey *et al.* (2017), Verma *et al.* (2021) in strawberry, Anushi *et al.* (2021), Singh *et al.* (2017), Singh *et al.* (2023) in mango.

Conclusion

In summary, the research findings regarding the impact of growth regulators such as GA_3 and NAA and micronutrient ($CaCl_2$) applications on Kagzi lime fruit characteristics provide that the application of GA_3 at 20 ppm stood out as a highly effective treatment for improving various Kagzi lime fruit characteristics, including fruit set, reduced fruit drop, increased fruit weight, volume, diameter, length, and yield. NAA also had positive effects, while $CaCl_2$ exhibited different trends in fruit characteristics. These findings provide valuable insights for citrus growers aiming to optimize Kagzi lime production and fruit quality. It's essential to choose the most suitable treatment based on specific goals and requirements for fruit characteristics.

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