Influence of Naphthalene Acetic Acid, Gibberellic acid and Calcium chloride on Quality Parameters of Kagzi lime (*Citrus aurantifolia*Swingle)

ABSTRACT

An experiment was carried out to investigate the influence of Naphthalene acetic acid, Gibberellic acid and Calcium chloride on quality parameters of Kagzi lime (*Citrus aurantifolia*Swingle) in the Garden, Dept. of Fruit Science, C. S. Azad University of Agriculture and Technology, Kanpur (U.P.) during two cropping seasons *i.e.*, 2021-2022, 2022-2023. 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_{10}-Control (water spray only). During both years of investigation, it was recorded that GA_3 at 20 ppm exhibited significantly higher amount of total soluble solids (9.30^{0}Brix) andtitratable acidity (8.70%) as compared to all other treatments. Similarly, NAA treatments also contributed to an increase in the TSS and titratable acidity content with the rise in their concentrations. In terms of TSS: acid ratio, there were no significant differences were recorded within the treatments, indicating its stability. Ascorbic acid content was significantly higher in GA_3 treated fruits and with the GA_3 at 20 ppm maximum amount of ascorbic acid was recorded (56.47 mg/100ml juice)while the control fruits had the lowest ascorbic acid content. The juice content in fruits were increased in NAA and GA_3 treatments, while in $CaCl_2$ treatments it remained relatively stable. Higher amount of juice content (56.49%) was also recorded in fruits treated with GA_3 at 20 ppm. In the context of sugar content, GA_3 at 20 ppm also exhibited the highest reducing (0.86%), non-reducing (0.70%) and total sugar (1.56%) content in the plains of north India.

Keywords: Kagzi lime, Citrus, NAA, GA_3, $CaCl_2$

INTRODUCTION

Kagzi lime, scientifically known as (*Citrus aurantifolia*Swingle) belongs to the Rutaceae family has an origin in India and spread to the Middle East and various tropical and subtropical regions. The Citrus genus is globally recognized for its commercial significance, particularly in the production of juice and pulp. Quality fruit production holds increasing significance in the fruit industry, both domestically and internationally. Plant growth regulators (PGRs) are biosynthesized naturally by plants that modify growth enhancement in the branching and rebranching of shoot and root growth, alter or trigger inter aliafruit maturation, reproduction, of cultivated plants and play a role significant in mitigating abiotic stresses.

Micronutrients are required for different physicochemical and biological plant development and are used in modest amounts in agricultural industries. Foliar application is often used to correct vitamin shortages throughout the growing season, allowing spraying with a modest amount and composition of the nutrient, according to the individual requirements at various stages of crop growth. The catalytic effect of micronutrients, especially at greater concentrations, may be responsible for the improvement in fruit quality. Foliar treatments boosted uptake in tissues and organs quickly, which in turn improved fruit crop quality in fruits.

The NAA has been shown to greatly increase cellulose fiber formation and synthetic auxin in plants. In the majority of fruit plants fruit drop is controlled by spraying of NAA in different fruit crops in different concentrations. Gibberellins are mostly used for regulating physiological processes, but they also be commercially used to improve the fruit quality of crops. The influence of GA_3 also has the ability to postpone fruit senescence, and in a more recent study, it is suggested that GA_3 may even encourage flowering. As the effect of calcium is concerned, it plays an important role in maintaining quality of fruits. It also protects from disorganization of membrane and prevents the increase of apparent free space in the tissue. Which is generally associated with senescence and maintains the protein synthesizing ability of cell.

Keeping in view, the importance of these plant bio-regulators and micronutrient the present experiment was planned to get concrete information on the influence of Naphthalene acetic acid, gibberellic acid and calcium chloride on quality parameters of Kagzi lime in the plains of north India.

MATERIALS AND METHODS

The kagzi lime trees were about 20 years old but properly maintained of located in the Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology Kanpur selected for the present investigations during 2022 and 2023. During the entire course of investigation, the whole of the orchard was kept clean cultivation. 30 uniform plants of Kagzi lime were selected for the experimentation work. Randomized Block Design was used with three replications and 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%) including on contents used for Spraying were done twice *i.e.,* before flowering (20January) and at pea stage (05 March) during both the years of investigation.

The juice was extracted for chemical analysis by pressing the flesh through a Lemon squeezer. A digital refractometer was used to estimate the total soluble solid content (^{0}Brix). The titratable acidity, ascorbic acid (mg/100 ml) and sugar (%) of fruit juice and TSS/Acid ratio was calculated were estimated as the methods suggested in **AOAC (1980).**

RESULTS AND DISCUSSION

TOTAL SOLUBLE SOLIDS (^{0}BRIX)

Among all treatments, fruits produced from the plants treated with GA_3 20 ppm had significantly higher total soluble solids (9.29^{0}Brix) over the rest of all the treatments followed by GA_3at 10 ppm and NAA at 60 ppm has been represented in Table 1. Among all the treatments, the fruits produced from plants kept as control produced fruits having significantly lower total soluble solids, *i.e.*, 7.29^{0}Brix. **Tripathi and Shukla (2008)** also observed improved total soluble solids contents in aonla cv. Banarasi fruit as results of GA_3 and NAA treatments. Similarly, **VivekaNand*et al.*, (2023)** in litchi and **Tiwari*et al.*, (2017)** in aaonla, **Dubey*et al.*, (2017)** in strawberry and **Anushi*et al.*, (2021)** in mango also noticed that spraying of GA_3resulted in higher total soluble solids in their experiments. **Gunjate*et al.*, (1983)**, in their experiment on 'Alphonso' mango, reported an increased total soluble solid as the result of NAA in comparison to the control. An increase in total soluble solids could be attributed due to higher solutes as a result of enhanced mobilization of carbohydrates in these treatments. This may be due that the activity of cytoplasmic sucrose phosphate synthase, a key enzyme in regulating the pool size of sucrose in the leaf, had been shown to be stimulated by foliar applications of plant growth regulators and promotes phloem loading.

TITRATABLE ACIDITY (%)

Gibberellic acid at 20 ppm treated fruits have the highest titratable acidity percent (8.70%) followed by GA_3 at 10 ppm (8.50 %). NAA treatments also showed an increase in titratable acidity content in fruits with increasing NAA concentration has been reprasented in Table 1. In the year 2022, plants treated with NAA 20ppm had titratable acidity content of 7.60%, which increased to 7.63% in 2023. A similar pattern was observed in plants treated with NAA 40ppm, with values of 7.78% in 2022 and 7.80% in 2023. Plants treated with NAA @ 60ppm also exhibited the same trend, with acidity content of 8.43% in 2022 and 8.45% in 2023 while the differences between $CaCl_2$ treatments were statistically significant, indicating that $CaCl_2$ concentrations had a notable impact on acidity content. Calcium chloride may also suppress respiration rate, and slows down the synthesis and the use of metabolites, resulting in the reduction of total soluble solids by slowing down the hydrolysis of carbohydrates to sugars **Das *et al.*, (2013).**These results were similar to those of **Nawaz *et al*., (2008) in** Kinnow Mandarin, **Kumar *et al.*, (2023)** in phalsaand **Tripathi*et al.*, (2018)** in aonla.

TSS: ACID RATIO

According to Table 1, fruits produced from the plants treated with NAA @ 20ppm had a TSS: acid ratio of 0.96 in 2022, which decreased slightly to 0.91 in 2023. NAA 40ppm treated fruits also had a consistent TSS: acid ratio of 0.96 in both years, as NAA 60ppm treated plants with a ratio of 0.97. When the data in pooled were compared, the differences between NAA treatments were statistically non-significant. This suggests that NAA concentrations did not have a significant impact on the TSS: acid ratio in Kagzi lime fruit. The GA_3 treatments also displayed TSS: acid ratios close to 1, which is similar to the control. In the pooled data, non-significant differences were observed between the GA_3 treatments on TSS: acid ratio in Kagzi lime fruit. The $CaCl_2$ treatments demonstrated TSS: acid ratios ranging from 0.97 to 1.09, reflecting a balance between soluble solids and acidity. This suggests that $CaCl_2$ concentrations have non-significant impact on the TSS: acid ratio in Kagzi lime fruit. **Duarte *et al*., (2006)** and **Saleem*et al.*, (2008)** also noticed reduced TSS: acid ratio with the foliar application of GA_3 in citrus cultivars. Reports of **Badal and Tripathi (2021)** in guava, **Dubey*et al.*, (2017)** in strawberry, **Kaur*et al*., (2008)** in plum also in-line with the reports of present findings.

Table 1: Effect of Naphthalene Acetic Acid, Gibberellic acid and calcium chloride on total soluble solids, titratable acidity content and TSS: acid ratio of fruits

Treatments	TSS content (^{0}Brix)			Titratable acidity content (%)			TSS: acid Ratio		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
NAA 20ppm	7.29	6.95	7.12	7.60	7.63	7.62	0.96	0.91	0.93
NAA 40ppm	7.50	7.52	7.51	7.78	7.80	7.79	0.96	0.96	0.96
NAA 60ppm	8.16	8.18	8.17	8.43	8.45	8.44	0.97	0.97	0.97
GA_3 10ppm	8.76	8.78	8.77	8.49	8.51	8.50	1.03	1.03	1.03
GA_3 20ppm	9.29	9.31	9.30	8.68	8.71	8.70	1.07	1.07	1.07
GA_3 30ppm	7.16	7.17	7.17	6.85	6.85	6.85	1.05	1.05	1.05
$CaCl_2$ 0.10%	6.47	6.49	6.48	6.70	6.72	6.71	0.97	0.97	0.97
$CaCl_2$0.15%	6.38	6.40	6.39	6.46	6.49	6.48	0.99	0.99	0.99
$CaCl_2$ 0.20%	6.28	6.29	6.29	5.74	5.76	5.75	1.09	1.09	1.09
Control	6.13	6.15	6.14	5.36	5.38	5.37	1.14	1.14	1.14
CD at 5% level	0.162	0.353	0.183	0.128	0.137	0.014	0.066	0.078	0.026
SE(M) ±	0.054	0.118	0.056	0.043	0.046	0.004	0.022	0.026	0.026
SE(d) ±	0.076	0.167	0.080	0.060	0.065	0.006	0.031	0.037	0.011

ASCORBIC ACID (mg/100ml juice)

Higher vitamin C content imparts significant effects on the nutritive value to fruits. The data on ascorbic acid content indicates significant differences among the treatments. The lowest ascorbic acid content was observed in fruits produced from the plants kept under control (43.39mg/100ml juice) as compared to all other treatments have been represented in Table 2. The maximum ascorbic acid contents were recorded in the fruits which were produced from the plants treated withGA_3@ 20 ppm (56.47mg/100ml juice) followed by GA_3@ 10 ppm (55.63mg/100ml juice) and NAA 60ppm (54.54 mg/100ml juice). The pronounced decrease in ascorbic acid content was found in the non-treated fruits because of decrease in ascorbic acid contents which may be due to enzymatic loss of L-ascorbic acid which is converted in to 2-3-dioxy–L-gluconic acid **(Mapson, 1970).** Results of present findings are similar to those of **Dubey*et al.*, (2017)** in strawberry, **Tripathi*et al.*, (2018)** in aonla cv. NA-7, who also reported maximum ascorbic acid content in GA_3 treated fruits.

JUICE CONTENT (%)

During the present experimentation period juice content in fruits were signifinctly influenced by the treatment of plant bio-regulators (NAA and GA_3) and micronutrient ($CaCl_2$). Data presented in Table 2, clearly revealed significant insights during both years of experimentation. The control treatment (T_{10}) maintained a stable juice content percentage of around 33.37% over two years, showing no statistically significant fluctuations. In contrast, NAA treatments demonstrated an increasing trend in juice content with higher concentrations, reaching 48.43% in 2022 and 48.49% in 2023 for T_3 (NAA 60ppm). GA_3 treatments also exhibited the similar pattern, as the higher concentrations results in an increased juice content. Fruits produced from the plants treated with GA_3 20ppm increased juice percent by 56.47% over control. Conversely, $CaCl_2$ treatments showed relatively stable juice content percentages and have non-significant differences between the concentrations. In 2022, fruits produced from plants treated with $CaCl_2$ 0.10% had a juice percentage of 39.50%, while with $CaCl_2$ 0.15% and $CaCl_2$ 0.20% treated plants had 37.44% and 35.44% of juice, respectively. This work was in close conformity with the reports of **Nawaz *et al.*, (2008)** who reported that the GA_3 treatments proved superior to increase juice percentage in Kinnow mandarin. A similar finding is also reported by **Lal*et al.*, (2016)** in KinnowMandarin and **Tiwari*et al.*, (2017)** in aonla.

Table 2: Effect of Naphthalene Acetic Acid, Gibberellic acid and calcium chloride on Ascorbic acid and juice content of citrus fruits

Treatments	Ascorbic acid (mg/100g juice)			Juice content(%)		
	2022	2023	Pooled	2022	2023	Pooled
NAA 20ppm	51.48	51.50	51.49	43.46	43.50	43.48
NAA 40ppm	52.44	52.46	52.45	45.45	45.48	45.47
NAA 60ppm	54.51	54.54	54.53	48.43	48.49	48.46
GA_3 10ppm	55.62	55.63	55.63	53.43	53.46	53.45
GA_3 20ppm	56.46	56.48	56.47	56.47	56.51	56.49
GA_3 30ppm	49.45	49.47	49.46	41.48	41.51	41.50
$CaCl_2$ 0.10%	47.51	47.54	47.53	39.50	39.52	39.51
$CaCl_2$0.15%	46.49	46.51	46.50	37.44	37.47	37.46
$CaCl_2$ 0.20%	43.38	44.54	43.96	35.44	35.47	35.46
Control	43.38	43.40	43.39	33.37	33.40	33.39
CD at 5% level	0.146	0.147	0.585	0.128	0.137	0.057
SE(M) ±	0.049	0.049	0.180	0.043	0.046	0.018
SE(d) ±	0.069	0.070	0.255	0.060	0.065	0.025

SUGARS (%)

According to Table 3, the highest reducing sugar (0.81%), non-reducing sugar (0.70%) and total sugars (1.51%) contents were recorded in fruits produced from the plants treated with GA_3 20 ppm (Table 3). On the other hand, the lowest value for reducing sugar (0.63%), non-reducing sugar (0.54%) and total sugars (1.17%) contents were observed in fruits produced from the plants kept as control. The increase in the content of total sugars in fruits is due to the degradation of polysaccharides into simple sugars by metabolic activities, conversion of organic acids into sugars, and loss of moisture **(Kumar *et al*., 2011).**This substantial range between the highest and lowest values underscores the substantial impact of GA_3 treatment on increasing reducing sugar, non-reducing and total sugar content, while $CaCl_2$ treatment had a limiting effect in this regard. Reports of **Badal and Tripathi (2021)** in guava, **Kumar and Tripathi (2009)** in strawberry, **Saraswat*et al*., (2006)** in litchi, **Kumar *et al*., (2023)** in phalsa and **Lal*et al*., (2016)** in KinnowMandarinare also similar to the findings.

Table 3: Effect of Naphthalene Acetic Acid, Gibberellic acid and calcium chloride on sugars content during

Treatments	Reducing sugar (%)			Non-reducing sugar (%)			Total sugars (%)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
NAA 20ppm	0.66	0.66	0.66	0.57	0.57	0.57	1.23	1.23	1.23
NAA 40ppm	0.67	0.67	0.67	0.59	0.59	0.59	1.26	1.26	1.26
NAA 60ppm	0.84	0.78	0.81	0.72	0.67	0.70	1.57	1.45	1.51
GA_3 10ppm	0.80	0.82	0.81	0.67	0.69	0.68	1.46	1.51	1.49
GA_3 20ppm	0.84	0.88	0.86	0.68	0.71	0.70	1.53	1.59	1.56
GA_3 30ppm	0.72	0.76	0.74	0.58	0.61	0.59	1.30	1.37	1.34
$CaCl_2$ 0.10%	0.61	0.65	0.63	0.52	0.55	0.53	1.13	1.20	1.16
$CaCl_2$0.15%	0.66	0.62	0.64	0.58	0.54	0.56	1.24	1.16	1.20
$CaCl_2$ 0.20%	0.64	0.64	0.64	0.56	0.56	0.56	1.20	1.20	1.20
Control	0.64	0.61	0.63	0.56	0.53	0.54	1.20	1.14	1.17

CD at 5% level	0.075	0.74	0.057	0.063	0.062	0.057	0.142	0.140	0.109
SE(M) ±	0.025	0.025	0.018	0.021	0.021	0.018	0.047	0.047	0.033
SE(d) ±	0.035	0.35	0.025	0.030	0.029	0.025	0.067	0.066	0.047

CONCLUSION

In this comprehensive study on Kagzi lime (*Citrus aurantiifolia* **Swingle**) on the effects of growth regulators and a micronutrient on various fruit quality attributes were meticulously explored. The results shed light on key factors that significantly influence fruit quality and nutritional content. The application of growth regulators and micronutrient has significant influence on the quality and nutritional content of Kagzi lime fruit. GA_3 at 20 ppm exhibited consistent improvements in total soluble solids, titratable acidity, juice and total sugar and ascorbic acid content. Understanding these effects is vital for citrus growers and processors to tailor treatments for specific fruit attributes to meet market demands and optimize Kagzi lime utilization in various applications, such as juice production and processing. These findings provide a valuable resource for the citrus industry and contribute to the overall knowledge of fruit quality enhancement.

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