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Effect of nano-urea, urea and NAA on quality attributes of acid lime (*Citrus aurantifolia*) cv. Kagzi

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Abstract

A comprehensive field study conducted during 2021-2022 at the Fruit Research Station, Imaliya, JNKVV, Jabalpur (Madhya Pradesh, India), evaluated the efficacy of foliar-applied nano-urea, conventional urea, and NAA (naphthalene acetic acid) on quality enhancement of Acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi, using a randomized block design with seven treatments replicated across 28 plants (spacing: 6×6 m). The treatments comprised: T₁ (control, water spray), T₂ (2.0% urea), T₃ (4.0% urea), T₄ (0.2% nano-urea), T₅ (0.4% nano-urea), T₆ (20 ppm NAA), and T₇ (30 ppm NAA), applied twice at 50% flowering and post-fruit set on clay-loam soil. Quality parameters, assessed at fruit maturity via standardized protocols (Ranganna, 1986), revealed that T₆ (20 ppm NAA) consistently outperformed other treatments, registering the highest total soluble solids (TSS: 9.11°Brix), juice content (53.86%), ascorbic acid (45.91 mg/100 g pulp), total sugars (1.26%), reducing sugars (0.69%) and non-reducing sugars (0.57%), alongside the lowest acidity (5.50%) and highest TSS:acid ratio (1.66). The runner-up, T₅ (0.4% nano-urea), showed significant but comparatively lower improvements (e.g., TSS: 8.88°Brix; juice: 52.48%). In contrast, the control (T₁) exhibited the poorest outcomes (TSS: 7.61°Brix; acidity: 6.81%; juice: 43.90%). The superiority of NAA is attributed to its role in enhancing carbohydrate mobilization from leaves to fruits, activating α -amylase to hydrolyze starch into sugars, and regulating enzymatic pathways that elevate osmotic pressure, thereby boosting juice accumulation and sugar synthesis while reducing organic acids. The study concludes that foliar NAA (20 ppm) is optimal for maximizing Kagzi lime quality, offering a sustainable strategy to enhance marketability, while nano-urea emerges as an efficient nitrogen alternative for integrated nutrient management.

Keywords: Acid lime, NAA, nano-urea, foliar spray, fruit quality, TSS, ascorbic acid, juice content

Introduction

Acid lime (*Citrus aurantifolia* Swingle) is the third most important citrus fruit crop in India just after mandarins and sweet oranges. Acid lime belongs to Rutaceae family with chromosome number 2n=18. It is mainly subtropical in nature but can also be cultivated in tropical regions. The fruits of acid lime are small, round or oval in shape and polyembryonic in nature. Flesh of acid lime is greenish yellow in color and fruits are juicy, highly acidic with distinctive aroma. Juice of acid lime is commonly used in human diet due to its nutritional and medicinal values as it has high sugar, fruit acids, citric acid, vitamin C and antioxidant properties (Thirugnanavel *et al.* 2007 and Prasad and Kumar, 2012) [20, 14]. It has been estimated that each 100 g of fruit juice contain 80 g water, 26 IU vitamin A (carotene), 20 mg vitamin B₁, 0.1 mg Riboflavin, 63 mg Vitamin C, 1.83 mg Iron, 0.16 mg copper etc which make it very essential for human health.

Plants of Acid lime are medium in height, bushy and vigorous in nature with spreading branch habit. The leaves of citrus are dense, small, pale green, broadly lanceolate and normally blooms thrice in a year i.e. Ambia or Ambe bahar (Jan-Feb), Mrig Bahar (June-July) and Hasta bahar (Sept-Oct). Acid lime is being considered as a heavy feeder fruit crop, hence the productivity and quality of lime juice is directly governed by nutrients supply to the plants. Undoubtedly, balanced fertilization is the key practice for increasing productivity maintaining quality of fruits but indiscriminate and imbalance use of chemical fertilizers results in environmental disruption, soil degradation and deterioration in productivity and quality of fruits which ultimately affects the human health. Hence, appropriate strategies should be identified for application of plant nutrients

to harness the potential benefits in terms of productivity and use efficiency with effective check on environmental health. This could be achieved through curtailing the amount of application, especially the highly mobile nutrients such nitrogen, and increasing the effectiveness. In this direction use of Nano fertilizers are being advocated at commercial scale in recent past as an alternative to overcome these problems. It have also been reported that foliar application of Nano urea in fruit plants as an alternative and more effective over conventional urea as it curtail the requirement of conventional urea to the extent of 50% and improve the use efficiency up to 90%.

The use of bio-regulators has been highlighted as one of the most essential strategies for improving the productivity and quality of fruits through betterment in flowering, fruit set, fruit size and shape; and also curtailment in fruit drops. In light of above facts present investigation was carried out to develop the protocol for application of nitrogen, through conventional urea and nano-N molecules, and bio-regulator for getting potential benefits in acid limes.

Materials and Methods

The investigation titled “Effect of Nano-urea, Urea and NAA on growth, yield and quality of Acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi”, was carried out during 2021-2022 at the well-established Kagzi lime orchard of Fruit Research Station, Imaliya, Department of Horticulture JNKVV (MP). The study involved totalling 28 numbers of plants, spaced at regular intervals of 6 m x 6 m. The experiment included seven treatments, incorporating different concentrations of urea (2.0% and 4%), nanourea (0.2 and 0.4%) and NAA (20 ppm and 40 ppm). Two rounds of foliar spraying were administered for each treatment, first at 50% flowering, followed by the second spray after fruit set. The soil composition predominantly had a clay-loam texture with traces of heavy clay. Fruits were sampled separately from each tree at full maturity. Weights of five randomly selected mature ripe fruits from each plant were recorded.

Total soluble solids (TSS) were measured by a hand refractometer and the values were corrected at 20°C (Ranganna, 1986). Titrable acidity was determined by filtrating a know quantity of blended (homogenized) pulp, diluted with distilled water, against NaOH solution (IN), using phenolphthalein as indicator and results were expressed as percentage of citric acid. TSS acid ratio was calculated by dividing the TSS value by acidity, total, reducing and non-reducing sugar from the pulp of ripe fruits was analyzed as suggested by Ranganna (1986). The experimental data were subjected to factorial analysis of variance for randomized block design and the differences tested at $p < 0.05$.

Results and Discussion

Total Soluble Solids (⁰Brix)

The data represents the TSS of Acid lime which was significantly influenced by the foliar application of nano-urea, Urea and NAA. The results revealed that the maximum TSS (9.11⁰Brix) was

observed with the foliar application of NAA @ 20 ppm under T₆ followed by T₅ (8.88⁰Brix). However, the minimum TSS (7.61⁰Brix) was recorded under treatment T₁ (control).

Acidity percentage

The results revealed that the acidity was significantly reduced affected by treatments. The minimum acidity (5.50%) of Acid lime was recorded with foliar application of NAA @ 20 ppm under treatment T₆ and the maximum acidity (6.81%) was recorded under control (T₁).

TSS/Acid ratio

The results revealed that the maximum TSS/ acid ratio (1.66) was recorded in treatment T₆ (foliar spray of NAA @ 20 ppm) while the minimum TSS/acid ratio was recorded under control.

Ascorbic acid (mg/100 g)

It is clear from the data that the ascorbic acid was significantly affected by various treatments. The results revealed that the maximum ascorbic acid (45.91 mg/100 g) was recorded under the treatment T₆ (foliar spray of NAA @ 20 ppm) while the minimum ascorbic acid (36.96 mg/100 g) was recorded under control (T₁).

Juice percentage

It is clear from the data that the juice% was significantly influenced by the foliar spray of various treatments of different concentrations. The result revealed that the maximum juice content (53.86%) was recorded under the treatment T₆ (foliar spray of NAA @ 20 ppm). However, the minimum juice content (43.90%) was noted under control T₁.

Total sugar

The effect of various treatments on total sugar% was found to be highly significant. The results revealed that the maximum total sugar content (1.26%) was noted in treatment T₆ (foliar application of NAA @ 20ppm). However, the minimum total sugar (0.90%) was observed in T₁ (Control).

Reducing sugar

Reducing sugar content of Acid lime was significantly improved under the effect of different treatments. The results revealed that the maximum reducing sugar (0.69%) was noted under treatment T₆ (foliar spray of NAA @ 20 ppm) which was found to be at par with the treatment T₅ (0.68%) while the minimum reducing content (0.51%) was observed in control (T₁).

Non-Reducing sugar

It is clear from the data that the non- reducing sugar was found significantly maximum (0.57%) with the spray of NAA @ 20 ppm under treatment T₆ which was found to be significantly at par with treatment T₅ (0.55%). However, the minimum non-reducing sugar content (0.39%) was observed in T₁ (control).

Table 1: Effect of Nano-urea, Urea and NAA on quality attributes of Acid lime (*Citrus aurantifolia*) cv. Kagzi

Treatments	TSS	Acidity (%)	TSS/Acid ratio	Ascorbic acid (mg/100 g)	Juice content (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)
T ₁ -Control	7.61	6.81	1.12	36.96	43.9	0.9	0.51	0.39
T ₂ -Foliar spray of Urea @ 2%	7.83	6.26	1.25	39.37	45.34	0.96	0.53	0.43
T ₃ -Foliar spray of Urea @ 4%	8.44	5.79	1.45	45.77	50.98	1.17	0.66	0.52
T ₄ -Foliar spray of Nano-urea @ 0.2%	8.12	5.98	1.36	42.39	46.81	1.01	0.57	0.45
T ₅ -Foliar spray of Nano-urea @ 0.4%	8.88	6.08	1.46	44.42	52.48	1.22	0.68	0.55
T ₆ -Foliar spray of NAA @ 20 ppm	9.11	5.5	1.66	45.91	53.86	1.26	0.69	0.57
T ₇ -Foliar spray of NAA @ 30 ppm	8.37	6.58	1.27	44.31	48.01	1.11	0.62	0.49
S.Em±	0.06	0.077	0.022	0.5	0.45	0.014	0.008	0.008
CD 5%	0.177	0.23	0.066	1.48	1.33	0.04	0.023	0.023

Discussion

Effect of Nano-urea, Urea and NAA on quality attributes of Acid lime

It was found that the TSS of Acid lime was increased significantly with the application of foliar spray of 20 ppm NAA under treatment T₆ (9.11°Brix) followed by foliar spray of 0.4% Nano-urea (8.88°Brix). However, the minimum TSS (7.61°Brix) was recorded under treatment T₁ (control). The increase in TSS might be due to the increased mobilization of carbohydrates from the source to the sink (fruits) by auxin. The fact that NAA boost the activity of the enzyme α -amylase, which led to improved total soluble solid content and the conversion of starch into sugar might be the possibility. In addition, NAA also regulate enzymatic activity and the enzymes that break down carbohydrates into simple sugar. Similar, findings were reported by Pandey (1999)^[12] in ber. Similar effects of NAA were also reported by Makhija *et al.* (1990)^[10] and Bal *et al.* (1998)^[1] in ber. Singh and Sandhu (1987)^[17] had also found increase in TSS content of grapes due to application of NAA.

Maximum ascorbic acid (45.91 mg/100 g) was noted under the treatment T₆ (foliar spray of NAA @ 20 ppm) which was found to be at par with T₃ (foliar spray of Urea @ 4%) while the minimum ascorbic acid (36.96 mg/100 g) was recorded under T₁ (control). The increment in ascorbic acid content with the foliar spray of NAA 20 ppm may be due to perpetual synthesis of glucose-6-phosphate throughout the growth and development period of Acid lime which is the precursor of vitamin C. Similar findings were done by Pandey (1999)^[12] in ber.

Maximum total sugar content (1.26%), reducing sugar (0.69%) and non-reducing sugar (0.57%) was noted with the foliar application of NAA @ 20 ppm under treatment T₆ while the minimum total sugar (0.90%), reducing sugar (0.51%) and non-reducing sugar (0.39%) was recorded in T₁ (Control).

The results observed in the preceding chapter revealed that the acidity was significantly reduced affected by treatments. The minimum acidity (5.50%) of Acid lime was recorded with foliar application of NAA @ 20 ppm and the maximum acidity (6.81%) was recorded under control (T₁) followed by T₂ i.e. foliar application of 2% urea (6.26%). This might be caused by the fact that NAA aids in the process of photosynthesis, which causes higher accumulations of polysaccharides and oligosaccharides. In addition to this, it regulates the enzymatic activities, which increases sugars and TSS as a result of which fruit acidity is decreased. (Ilyas *et al.*, 2015). The findings of Debaje *et al.* (2011)^[3], Jain *et al.* (2014)^[6] in Nagpur Mandarin, and Kumar *et al.* (2015)^[8] in guava are also in agreement with these results. Therefore, the decrease in the titrable acidity was mainly due to the increase in TSS.

Maximum (53.86%) juice content was recorded under the treatment T₆ (foliar spray of NAA @ 20 ppm). However, the minimum (43.90%) juice content was noted under control T₁. It was observed that the juice content of Acid lime was greatly influenced by the treatment. The increase in juice content might be due to auxin, which is involved in the synthesis of α -amylase which is responsible for converting starch to sugars and consequently result in increase in osmotic pressure of the cell which led to accumulation of water. The same outcome was discovered by Sandhu (2013)^[15].

The results revealed that the maximum TSS/ acid ratio (1.66) was recorded in treatment T₆ (foliar spray of NAA @ 20 ppm) while the minimum (1.12) TSS/acid ratio was recorded under control (T₁). This may be due to rapid translocation of sugars from leaves to developing fruits and synthesis of cell wall material.

Thus, it can be concluded that among the various treatments, T₆

(foliar spray of 20ppm NAA) showed the maximum betterment in the quality attributes of Acid lime.

Conclusion

On the basis of result obtained in present experiment, it can be concluded that treatments, the foliar application of T₆ (foliar spray of 20 ppm NAA) was effective in enhancing quality parameters.

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