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Effect of cycocel and micronutrients on quality parameters of Kagzi Lime (*Citrus aurantifolia* Swingle)

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Abstract

The study titled "Effect of Cycocel and Micronutrients on Fruit Setting of Kagzi Lime (*Citrus aurantifolia* Swingle)" was conducted at the Rainfed Research Sub-Station for Sub-Tropical Fruits (RRSS) Raya, SKUAST-Jammu, during 2023-2024. The experiment assessed the impact of various treatments on biochemical parameters of Kagzi lime. Among the treatments, Cycocel at 1000 ppm combined with $ZnSO_4$ at 0.3% (T_6) significantly improved several biochemical attributes of the fruit. This treatment resulted in increased total soluble solids (TSS) at 8.32 °Brix, elevated reducing sugars (0.87%), non-reducing sugars (0.79%), and total sugars (1.71%). It also enhanced vitamin C content to 34.34 mg/100 g and juice content to 56.54%. Additionally, the TSS: acid ratio improved to 1.58 were higher compared to the control. These results suggest that Cycocel at 1000 ppm in conjunction with $ZnSO_4$ at 0.3% optimally boosts the biochemical quality of Kagzi lime, making it a recommended practice for enhancing fruit quality in lime cultivation.

Keywords: *Citrus aurantifolia* Swingle, Cycocel, zinc, biochemical parameters

Introduction

Kagzi lime (*Citrus aurantifolia* Swingle), also known as acid lime, is a significant fruit crop belonging to the Rutaceae family with a chromosome number of 2n = 18. Known for its thin, papery rind and rich vitamin C content, Kagzi lime is cultivated extensively in India and other tropical regions (Mandloi *et al*., 2021) [12]. India is the leading global producer, contributing significantly to the 21.5 million metric tons of limes and lemons produced worldwide. In India, Kagzi lime is grown across various states, with a notable production of 14,150 metric tons from an area of 1,091 hectares. Kagzi lime flowering occurs in three distinct periods: Ambe (January-February), Mrig (June-July), and Hasta Bahar (September-October). The Hasta Bahar crop, which fruits in April-May, is particularly valued but faces challenges due to incomplete pollination and high monsoon rainfall (Lal *et al*., 2017) [10]. This necessitates interventions like plant growth regulators and micronutrients to enhance flowering and fruiting. Cycocel (chlormequat chloride) is a growth regulator that inhibits gibberellin biosynthesis, promoting flowering and fruit set (Rademacher and Brahm, 2010) [14]. Micronutrients such as zinc and boron play crucial roles in enhancing fruit development and quality. Zinc aids in flowering by synthesizing tryptophan, a precursor of auxin, while boron improves chlorophyll content and fruit quality (Dabhi *et al*., 2023) [7]. This research in Jammu's subtropical climate assessed the effect of cycocel and micronutrients on kagzi lime. The application of Cycocel significantly improved fruit setting, and the addition of micronutrients further enhanced fruit development and quality. This study aims to determine the optimal concentration of Cycocel and micronutrients for effective flowering and fruit setting, and to identify the best treatment combinations for maximizing Kagzi lime yield and quality in the Hasta Bahar season.

Materials and Methods

The investigation titled "Effect of Cycocel and Micronutrients on Fruit Setting of Kagzi Lime (*Citrus aurantifolia* Swingle)" was conducted at the Rainfed Research Sub-Station for

Sub-Tropical Fruits (RRSS) Raya, SKUAST-Jammu, Jammu & Kashmir, during the 2023-2024 period. This study focused on assessing how Cycocel, a plant growth regulator, and various micronutrients affect the biochemical properties of Kagzi lime, specifically evaluating their impact on total soluble solids (TSS), acidity, sugars, vitamin C content and juice content.

Experimental Site

The experiment was situated at RRSS Raya, positioned at an elevation of 332 meters above sea level with geographical coordinates of 32°39′ N latitude and 74°53′ E longitude. This site is characterized by a sub-tropical climate with pronounced seasonal variations. Summers are hot and dry, with temperatures reaching up to 46 °C, while winters are chilly, with temperatures dropping to as low as 3.4 °C. Average summer temperatures fluctuate between 24 °C and 36 °C, accompanied by humidity levels ranging from 54% to 81%. Winter temperatures vary between 6 °C and 22 °C. The annual precipitation in the region ranges between 1000 and 1200 mm, contributing to the area's overall climatic profile.

Experimental Details

The study utilized a Randomized Block Design (RBD) to investigate the effects of various treatments on Kagzi lime, involving 10 distinct treatment combinations applied to a total of 30 plants, with each treatment replicated thrice. The experimental treatments included: T_1, a control with water spray; T_2, a combination of 0.2% $ZnSO_4$ and 0.2% Borax; T_3, 0.3% $ZnSO_4$ and 0.3% Borax; T_4, 0.4% $ZnSO_4$ and 0.4% Borax; T_5, 500 ppm Cycocel combined with 0.2% $ZnSO_4$; T_6, 1000 ppm Cycocel with 0.3% $ZnSO_4$; T_7, 1500 ppm Cycocel with 0.4% $ZnSO_4$; T_8, 500 ppm Cycocel with 0.2% Borax; T_9, 500 ppm Cycocel with 0.3% Borax; and T_{10}, 1000 ppm Cycocel with 0.4% Borax. This design allowed for a comprehensive evaluation of how different combinations of Cycocel and micronutrients impact the biochemical properties of the Kagzi lime.The treatments were applied as foliar sprays during the Hasta Bahar period, specifically on September 1 and September 15, with each treatment applied twice to ensure thorough coverage.

Preparation of Solutions

For the preparation of solutions, Cycocel was dissolved in ethyl alcohol and then diluted with distilled water to achieve concentrations of 500 ppm, 1000 ppm, and 1500 ppm. For $ZnSO_4$, a 2% stock solution was initially prepared, from which the required concentrations (0.3% and 0.4%) were made by further dilution. Boron solutions were prepared by dissolving borax in distilled water to obtain concentrations of 0.2%, 0.3%, and 0.4%.

Observations Recorded

To evaluate the impact of the treatments on Kagzi lime, several biochemical parameters were meticulously recorded. Total Soluble Solids (TSS) were measured with a digital refractometer, applying temperature corrections as specified by A.O.A.C. (1990) [19]. Titratable acidity was determined by titration with 0.1 N sodium hydroxide using phenolphthalein as an indicator, following A.O.A.C. (1995) [5] procedures. Reducing sugars were quantified by titrating extracted and neutralized samples with Fehling solutions, while non-reducing sugars were calculated by subtracting reducing sugars from total sugars, adjusted by a factor of 0.95. Total sugars were estimated from the same filtrate used for reducing sugars, after adding citric acid before titration. Vitamin C content was measured using the 2,6-dichlorophenol indophenol dye method, with results expressed in mg per 100 g of juice. The TSS: acid ratio was calculated by dividing TSS by titratable acidity, providing insight into the fruit's sweetness relative to its acidity. Finally, juice content was assessed by extracting juice from the fruit and calculating the percentage yield by weight.

Results and Discussions

The study on the effect of Cycocel and micronutrients on Kagzi lime's biochemical properties revealed significant findings across various parameters. As per Table 1., total Soluble Solids (TSS) were notably higher in treatment T_6 (Cycocel 1000 ppm + $ZnSO_4$ 0.3%), reaching 8.32°Brix, compared to the control, which had a minimum of 6.20°Brix. This increase in TSS is attributed to Cycocel's role in enhancing the mobilization of carbohydrates from source to sink, thus increasing sugar concentration in the fruit. This observation aligns with Ilyas *et al*. (2015) [8] in acid lime and others. The role of zinc in hydrolyzing complex polysaccharides into simpler sugars and facilitating the synthesis of metabolites contributes further to the observed increase in TSS. Titratable acidity showed a reduction in T_6, with a minimum of 5.16%, while the control had a maximum of 6.09%. This decrease in acidity is likely due to increased TSS and the conversion of organic acids into sugars, which might involve reversal of the glycolytic pathway or utilization in respiration. This finding is consistent with similar responses documented by Siddiqui and Gupta (1995) [15] in ber and other researchers across various fruit types. Regarding sugar content, T_6 also resulted in the highest levels of reducing sugars (0.87%), non-reducing sugars, and total sugars (1.71%) (Table 2). The lowest values for these sugars were recorded in the untreated control, indicating that Cycocel and zinc accelerate fruit ripening and enzymatic activities, leading to higher sugar content. This effect of Cycocel in enhancing sugar content through accelerated fruit ripening and increased hydrolytic enzyme activities is supported by studies on fig (Thonte, 1983) [18], litchi (Brahmachari and Rubby, 2001) [6], and grape. Zinc's role in enzymatic reactions and auxin synthesis further explains the increase in sugar content, as detailed by Ilyas *et al*. (2015) [8] and others. As per Table 2, vitamin C content was highest in T_6, at 34.34 mg/100 g juice, compared to the control, which had the lowest at 27.53 mg/100 g. The elevated vitamin C levels are attributed to the enhanced translocation of photosynthates to the fruit pulp, a trend observed in other studies as well (Singh and Rajput, 1976) [16]. The increase in vitamin C reflects the overall higher quality of the fruit under Cycocel and $ZnSO_4$ treatments. The TSS: acid ratio, which is a critical indicator of fruit quality, was highest in T_6 at 1.58, demonstrating a favorable balance of sweetness to acidity. This ratio was significantly lower in the control (1.01), highlighting the effectiveness of the treatments in improving fruit sweetness relative to its acidity. This improvement is consistent with observations by Khan *et al.* (2017) [11] in lime. Juice content was also maximized in T_6 with 56.54% per fruit, compared to 47.44% in the control. This increase is likely due to the enhanced mobilization and accumulation of nutrients and minerals towards the developing fruits, which improves the juice content. This finding aligns with previous studies on sweet orange (Tariq *et al*., 2007) [17], mandarin (Meena *et al*., 2016) [13], and other fruits, confirming the role of micronutrient treatments in increasing juice content.

Table 1: Effect of cycocel and micronutrients on total soluble solids, titratable acidity, reducing and non-reducing sugars attributes of kagzi lime

Treatments	Total soluble solids (ºBrix)	Titratable Acidity (%)	Reducing sugars (%)	Non-reducing sugars (%)
T_1 Control	6.20	6.09	0.69	0.61
T_2 $ZnSO_4$ (0.2%) + Borax (0.2%)	6.33	5.90	0.73	0.66
T_3 $ZnSO_4$ (0.3%) + Borax (0.3%)	6.61	5.77	0.74	0.68
T_4 $ZnSO_4$ (0.4%) + Borax (0.4%)	7.03	5.64	0.77	0.71
T_5 Cycocel (500 ppm) + $ZnSO_4$ (0.2%)	7.12	5.57	0.76	0.71
T_6 Cycocel (1000 ppm) + $ZnSO_4$ (0.3%)	8.32	5.16	0.87	0.79
T_7 Cycocel (1500 ppm) + $ZnSO_4$ (0.4%)	7.23	5.49	0.81	0.73
T_8 Cycocel (500 ppm) + Borax (0.2%)	7.32	5.39	0.83	0.74
T_9 Cycocel (500 ppm) + Borax (0.3%)	8.28	5.23	0.85	0.76
T_{10} Cycocel (1000 ppm) + Borax (0.4%)	8.08	5.35	0.85	0.75
Mean	7.25	5.56	0.79	0.71
S.E m±	0.75	0.01	0.02	0.02
CD at 5%	2.22	0.03	0.07	0.07

Table 2: Effect of cycocel and micronutrients on total sugars, juice content, vitamin C, TSS: acid ratio content of kagzi lime

Treatments	Total Sugars (%)	Juice content (%)	Vitamin C mg/100 g of juice	TSS: acid ratio
T_1 Control	1.27	47.44	27.53	1.01
T_2 $ZnSO_4$ (0.2%) + Borax (0.2%)	1.37	48.15	28.06	1.05
T_3 $ZnSO_4$ (0.3%) + Borax (0.3%)	1.39	48.76	28.44	1.13
T_4 $ZnSO_4$ (0.4%) + Borax (0.4%)	1.44	49.35	28.92	1.25
T_5 Cycocel (500 ppm) + $ZnSO_4$ (0.2%)	1.54	49.75	29.16	1.28
T_6 Cycocel (1000 ppm) + $ZnSO_4$ (0.3%)	1.71	56.54	34.34	1.58
T_7 Cycocel (1500 ppm) + $ZnSO_4$ (0.4%)	1.56	49.91	29.27	1.30
T_8 Cycocel (500 ppm) + Borax (0.2%)	1.58	50.11	29.59	1.34
T_9 Cycocel (500 ppm) + Borax (0.3%)	1.67	52.58	32.51	1.56
T_{10} Cycocel (1000 ppm) + Borax (0.4%)	1.61	54.53	30.72	1.51
Mean	1.51	50.71	29.85	1.31
S.E m±	0.06	1.54	1.11	0.01
CD at 5%	0.19	4.57	3.30	0.04

Conclusions

The study demonstrated that the application of Cycocel and micronutrients significantly improved the biochemical properties of Kagzi lime. Treatment T_6 (Cycocel 1000 ppm + $ZnSO_4$ 0.3%) resulted in higher Total Soluble Solids, reduced acidity, and increased sugar content, including vitamin C and juice content, compared to the control. These enhancements are attributed to Cycocel's promotion of carbohydrate mobilization and zinc's role in sugar metabolism and enzymatic activities. Overall, the treatments effectively increased fruit sweetness, reduced acidity, and improved juice quality, confirming their beneficial impact on fruit development and quality.

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