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Synergistic Effects of Gibberellic Acid and Brassinosteroids on Fruit Development, Yield and Quality in Kokum (*Garcinia indica)*

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ABSTRACT

Kokum (*Garcinia indica*) is an under utilized fruit crop native to the Sahyadri mountain range valued for its health benefits and applications in various industries. Despite its potential, Kokum cultivation faces challenges such as low yield and sub-optimal fruit quality. This investigation undertaken at Sahaja Farms, Kokada in the Uttara Kannada district during the 2022–2023 cultivation cycle explored the modulatory effects of gibberellic acid (GA_3) and brassinosteroids (BRs) on the qualitative and quantitative parameters of Kokum fruit. Employing a Randomized Block Design encompassing nine different treatments with triplicate replications, the study discerned that foliar administration of BR at 1 ppm synergized with GA_3 at 100 ppm (T_8) elicited remarkable augmentation in fruit biometrics in achieving a mass of 35.37 g, a length of 4.23 cm, a circumference of 12.60 cm, and an elevated productivity yield (42.60 kg/tree). Additionally, T_8 (BR @ 1 ppm + GA_3 @ 100 ppm) enhanced total soluble solids (15.65 ºbrix), titratable acidity (4.25 %), ascorbic acid content (9.96 mg/100 g), reducing sugar, non-reducing sugar and total sugar (5.98, 5.29 and 11.17 %) and anthocyanin content (2.37 g/100 g). The synergistic effects of BRs and GA_3 promoted cellular activities and biochemical efficiency, contributing to improved crop performance which highlighted the efficacy of BRs and GA_3 in enhancing Kokum cultivation outcomes.

Keywords: Kokum, Brassinosteroids, Gibberellic Acid, Yield, Quality.

INTRODUCTION

Kokum [*Garcinia indica* (Dupetit-Thouars) Choisy], a botanically intriguing yet under exploited fruit species, has recently garnered heightened scholarly and industrial interest owing to its myriad therapeutic virtues and multifaceted utility across gastronomic, pharmaceutical, and cosmetological domains. Taxonomically classified within the family Clusiaceae under the order Malpighiales, Kokum is indigenous to the biodiverse Sahyadri hill tracts of peninsular Western India (Mayura *et al,* 2014). Its natural provenance extends across the humid littoral and montane belts of southwestern India, including ecologically rich zones such as Wayanad in Kerala, Uttara Kannada, Udupi, and Dakshina Kannada in Karnataka, the basal terrains of the Nilgiris, as well as the Konkan seaboard of Maharashtra and Goa. Sporadic populations have also been documented in the sylvan landscapes of Assam, West Bengal, and the northeastern uplands (Chate *et al,* 2019).

Cytological investigations have revealed discrepancies in its somatic chromosome complement, with counts reported as either 2n = 54 (Krishnaswamy and Raman, 1949) or 2n = 48 (Thombre, 1964). Morphologically, Kokum manifests as a lofty, evergreen, and long-lived arboreal species characterized by a monopodial axis of growth. Kokum is a languidly maturing arboreal species, distinguished by its elegant, svelte architecture, typically attaining a stature of up to 10 m, though certain mature individuals may ascend to an imposing 15 m. The tree exudes a yellowish, resinous sap. Following a juvenile latency of 7 to 8 years, Kokum enters its reproductive phase, typically flowering between November and February. Fruit maturation culminates from April to May (Parle and Dhamija , 2013). The drupe consists of three anatomical segments: the outer rind (pericarp), the fleshy mesocarp (pulp), and the enclosed seed. The pericarp is imbued with anthocyanin pigments having principally cyanidin-3-glucoside and cyanidin-3-sambubioside, which bestow the fruit's characteristic crimson hue. The anthocyanin concentration within the rind is estimated at approximately 2.4% (Nayak *et al,* 2010).

Kokum is predominantly localized within the Uttara Kannada district of Karnataka, comprising approximately 10–12% of the overall Kokum

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population (Kureel *et al,* 2009). Trees bearing this yellow-fruited morphotype typically exhibit a more diminutive growth habit compared to their red-fruited counterparts. Kokum cultivation is beset with a multitude of constraints that adversely affect both yield and fruit quality. Prominent limitations include diminutive fruit dimensions, reduced mass, shortened length, diminished girth, suboptimal yield, and inferior biochemical characteristics namely, decreased total soluble solids (TSS), titratable acidity, sugar concentration, and ascorbic acid content. These physiological deficiencies are frequently attributed to endogenous hormonal imbalances, restricted mitotic activity, and insufficient cellular elongation. In this context, the synergistic foliar application of Gibberellic Acid (GA_3) and brassinosteroids has emerged as a promising agronomic intervention to ameliorate these impediments.

MATERIALS AND METHODS

Research studies were carried out on the Kokum crop (local cultivar) at Sahaja Farms, Kokada, Uttara Kannada district, during 2022–2023. The experiment employed a Randomized Block Design (RBD) to assess the influence of diverse foliar spray regimens, administered during the post-anthesis phase, on fruit morphometrics and quality attributes. The RBD included nine treatments, each replicated three times. Data analysis followed the methodology proposed by Panse and Sukhatme (1978), with a critical difference calculated at a 5% significance level. Statistical computations were performed using the IRRISTAT software package.

RESULTS AND DISCUSSION

The data (Table 1) illustrated the significant effects of foliar spray treatments on the fruit weight (g), fruit length (cm) and circumference (cm) and yield (kg/tree). The current study demonstrated that spraying BRs and GA_3 significantly enhanced the fruit weight of Kokum, with the T_8 treatment (BR @ 1 ppm + GA_3 @ 100 ppm) yielding the highest fruit weight of 35.37 g. Conversely, the lowest fruit weight of 23.59 g was observed in the T_9 treatment (control). The augmentation in fruit mass is plausibly ascribed to enhanced cellular elongation and the efficient translocation of assimilates toward the developing fruits, facilitated by the synergistic interplay between BRs and GA_3, as reported by Fujioka (1997). These findings align with previous studies by Engin *et al* (2016) on sweet cherries and Rajan *et al* (2017) on banana cv. Grand Naine.

The study revealed that spraying BRs and GA_3 significantly improved fruit length and circumference in Kokum, with T_8 treatment (BR @ 1 ppm + GA_3 @ 100 ppm) producing the highest values of 4.23 cm and 12.60 cm, respectively. In contrast, the lowest fruit length and circumference (2.75 cm and 10.71 cm) were recorded in the T_9 treatment (control). This improvement can be attributed to the synergistic effect of BRs and GA_3, promoting growth through enhanced RNA and DNA content and increased protein synthesis. These outcomes resonate with the empirical observations of Thorat *et al* (2018) in custard apple, Mostafa and Koth (2018) in sugar apple, IŞÇI (2019) in grapes and Khatoon *et al* (2021) in strawberries.

Similarly, the study observed a significant increase in fruit yield in Kokum under the T_8 treatment (BR @ 1 ppm + GA_3 @ 100 ppm), which recorded a maximum yield of 42.60 kg/tree. The T_9 treatment (control) showed the lowest yield at 31.82 kg/tree. This enhancement in yield can be linked to the beneficial effects of BRs and GA_3, which boost carboxylation efficiency, protein synthesis and the coordination of key biochemical and physiological processes in the Kokum plant. The present findings were in concordance with the observations documented by Pujari *et al* (2021) in custard apple and Rajan *et al* (2017) in banana cv. Grand Naine.

The data (Table 2) illustrated the significant effects of foliar spray treatments on the TSS (ºBrix), titratable acidity (%), ascorbic acid content (mg/100 g), reducing sugars (%), non-reducing sugars (%), total sugars (%) and anthocyanin content. The study revealed that spraying BRs and GA_3 significantly improved the total soluble solids (TSS) in Kokum, with the highest TSS (15.65 ºBrix) recorded in the T_8 treatment (BR @ 1 ppm + GA_3 @ 100 ppm). In contrast, the T_9 treatment (control) showed the lowest TSS (13.67 ºBrix). This enhancement may be ascribed to the accelerated biochemical transformation of organic substrates such as starch and pectin into soluble solutes and simple sugars via enzymatic hydrolysis. These inferences were consonant with the empirical findings of Ghorbani *et al* (2017) in Thompson Seedless grapes, Mahorkar *et al* (2020) in custard apple and Sen *et al* (2023) in mango cv. Amrapali. Analogously, a marked diminution in titratable acidity was observed in Kokum fruits subjected to BR and GA_3

Table 1: Influence of Brassinosteroids and GA_3 on fruit Development and yield parameters of Kokum.

Treatment	Fruit weight (g)	Fruit length (cm)	Fruit circumference (cm)	Yield (kg/tree)
T_1 - BR @ 0.5 ppm	25.71	2.93	10.95	33.15
T_2 - BR @ 1 ppm	27.09	3.12	11.18	34.48
T_3 - GA_3 @ 50 ppm	28.47	3.30	11.40	35.81
T_4 - GA_3 @ 100 ppm	29.85	3.49	11.64	37.14
T_5 - BR @ 0.5 ppm + GA_3 @ 50 ppm	33.99	4.04	12.20	38.47
T_6 - BR @ 0.5 ppm + GA_3 @ 100 ppm	31.23	3.67	11.87	39.93
T_7 - BR @ 1 ppm + GA_3 @ 50 ppm	32.61	3.86	12.14	40.72
T_8 - BR @ 1 ppm + GA_3 @ 100 ppm	35.37	4.23	12.60	42.60
T_9 – Control	23.59	2.75	10.71	31.82
S. Ed	0.58	0.06	0.12	0.39
C.D (p=0.05)	1.17	0.13	0.25	0.80

Table 2: Influence of Brassinosteroids and GA_3 on fruit quality parameters of Kokum

Treatment	TSS (°B)	Titratable Acidity (%)	Ascorbic acid (mg/100g)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	Anthocyanin content (g/100 g)
T_1 - BR @ 0.5 ppm	13.92	3.89	8.60	4.70	3.87	8.98	1.95
T_2 - BR @ 1 ppm	14.16	3.82	8.79	4.88	4.07	9.76	2.07
T_3 - GA_3 @ 50 ppm	14.39	3.75	8.98	5.06	4.26	9.24	2.01
T_4 - GA_3 @ 100 ppm	14.64	3.96	9.16	5.23	4.67	9.50	2.13
T_5 - BR @ 0.5 ppm + GA_3 @ 50 ppm	15.20	4.03	9.64	5.71	4.47	9.87	2.19
T_6 - BR @ 0.5 ppm + GA_3 @ 100 ppm	14.88	4.11	9.36	5.42	5.02	10.29	2.25
T_7 - BR @ 1 ppm + GA_3 @ 50 ppm	15.17	4.13	9.58	5.63	4.88	10.51	2.31
T_8 - BR @ 1 ppm + GA_3 @ 100 ppm	15.65	4.25	9.96	5.98	5.29	11.17	2.37
T_9 – Control	13.67	3.67	8.41	4.52	3.66	8.19	1.89
S. Ed.	0.15	0.03	0.09	0.05	0.04	0.10	0.02
C.D (p=0.05)	0.32	0.08	0.20	0.11	0.09	0.21	0.05

applications. The titratable acidity (4.92) was recorded under the T_8 treatment, whereas the minimum acidity (3.67) emerged in the untreated control (T_9). This decline may plausibly be attributed to metabolic reconfigurations wherein organic acids are enzymatically converted into sugars and allied metabolites. These observations were in harmonious alignment with the findings reported by Thakur *et al* (2015) and Paikra *et al* (2018) in *Fragaria × ananassa*.

Moreover, the highest ascorbic acid content (9.96 mg/100 g) was discerned in the T_8 treatment, whereas the minimal level (8.41 mg/100 g) was observed in the control (T_9). This enhancement in ascorbic acid content may be ascribed to sustained glucose biosynthesis during the fruit maturation phase, catalyzed by the physiological action of brassinosteroids and gibberellic acid. Comparable trends have been documented by Rajan *et al* (2017) in banana, Ali *et al* (2022) in strawberry, and Siddiqui *et al* (2018) in tomato. Furthermore, the highest ascorbic acid content (9.96 mg/100 g) was recorded in the T_8 treatment, while the lowest content (8.41 mg/100 g) was noted in the T_9 treatment. The improvement in ascorbic acid levels may be due to the continuous glucose synthesis during fruit development induced by BRs and GA_3. Similar observations were reported by

Rajan *et al* (2017) in banana, Ali *et al* (2022) in strawberry and Siddiqui *et al* (2018) in tomato.

The T_8 treatment also resulted in the highest levels of reducing sugars (5.98%), non-reducing sugars (5.29%) and total sugars (11.17%) in Kokum, compared to the control (T_9), which had reducing sugars at 4.52%, non-reducing sugars at 3.66% and total sugars at 8.19%. This enhancement can be attributed to the synergistic effect of BRs and GA_3, which promote efficient mobilization of photosynthates from source to sink. These results align with Mostafa and Koth (2018) in sugar apple and Zhang *et al* (2022) in *Musa acuminate* cv. Huangdi. T_8 treatment also resulted in the anthocyanin content (2.37 g/100 g), while the lowest content (1.89 g/100 g) was noted in the T_9 treatment. Exogenous application of gibberellic acid (GA_3) and brassinosteroids has been shown to augment anthocyanin accumulation in Kokum by upregulating pivotal enzymatic activities within the phenylpropanoid biosynthetic cascade most notably phenylalanine ammonia-lyase (PAL) and chalcone synthase (CHS). While GA_3 facilitates fruit morphogenesis and cellular expansion, brassinosteroids fortify stress resilience and amplify metabolic throughput, thereby synergistically enhancing anthocyanin biosynthesis and intensifying fruit chromaticity.

CONCLUSION

This study demonstrated the significant potential of gibberellic acid (GA_3) and brassinosteroids (BRs) in enhancing the growth, yield and quality of Kokum. The application of BR @ 1 ppm + GA_3 @ 100 ppm (T_8) proved to be highly effective, resulting in improved fruit weight, size, yield and overall fruit quality, including higher total soluble solids, titratable acidity, ascorbic acid content, sugar levels and anthocyanin content. These findings underscored the synergistic effects of BRs and GA_3, which promote cellular growth and biochemical efficiency in Kokum plants. The results offerred valuable insights for improving Kokum cultivation, addressing challenges related to yield and fruit quality and enhancing its commercial and nutritional potential.

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