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Impact of plant growth regulators on seed characteristics of rambutan (*Nephelium lappaceum* L.) variety N-18

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Abstract
A field experiment was conducted during 2023 and 2024 to study the effect of plant growth regulators (PGRs) on seed characters of rambutan (*Nephelium lappaceum* L) variety N-18. The study was carried out on six-year-old, healthy and uniformly maintained trees at the Plant Propagation and Nursery Management Unit, College of Agriculture, Vellanikkara, Thrissur, and Kerala. The experiment followed a Randomized Block Design (RBD) with seven treatments which include NAA @ 20 and 40 ppm, GA_3 @ 25 and 50 ppm, 2, 4, 5-T @ 25 and 50 ppm, and water spray as control, each replicated thrice. The seed parameters recorded seed length, width, weight, colour and shape. The results revealed significant variation among the treatments. GA_3 @ 50 ppm (T4) showed the most promising performance with the highest seed length (3.41 cm), width (1.52 cm), and weight (2.54 g) on a pooled basis. This was followed by NAA @ 40 ppm and 2, 4, 5-T @ 50 ppm, which also showed improvement over the control. In contrast, the control treatment recorded the lowest values for all seed parameters, with pooled values of 1.25 cm, 0.28 cm, and 1.31 g for seed length, width and weight respectively. The seed colour and shape remained consistent across all treatments and years, with all seeds displaying a creamish hue and an obovoid, elongated form. The results suggest that GA_3 at 50 ppm, plays a key role in enhancing seed development in rambutan, likely through its influence on cell elongation and nutrient translocation. Overall, the study highlights the potential of growth regulator application in improving seed quality traits, which could contribute to enhanced seedling vigor and better propagation outcomes in rambutan cultivation.

Keywords: Rambutan, *Nephelium lappaceum*, N18, seed characters, plant growth regulators

Introduction
Rambutan (*Nephelium lappaceum* L.), a tropical evergreen fruit from the Sapindaceae family, is closely related to litchi and longan. Native to Southeast Asia, it has gained prominence in India, particularly in Kerala, Karnataka, and Tamil Nadu, owing to its adaptability to humid tropical climates and its commercial potential due to the fruit's appealing flavor and nutritional value (Yong & Ng, 2020; NHB, 2021) [21, 13]. Although rambutan is commercially propagated through vegetative methods, seed traits remain integral for understanding fruit development, physiological maturity, and quality attributes particularly in breeding, physiological, and developmental studies.

Seed characteristics such as weight, length, width, shape, and colour are key indicators of fruit maturity and internal resource allocation. These traits are not only critical for seed viability and vigor but also influence consumer perception and postharvest handling. In rambutan and related crops like litchi and mango, seed morphology has been linked with fruit development patterns, aril thickness, and even taste (Singh *et al.*, 2011; Kumar *et al.*, 2017) [16, 6].

Seed traits are largely under genetic control, but significantly modulated by environmental conditions and endogenous hormonal levels during fruit growth (Bewley *et al.*, 2013) [2]. Among these regulatory agents, plant growth regulators (PGRs) especially Gibberellic Acid (GA_3), Naphthalene Acetic Acid (NAA), and 2, 4, 5-Trichlorophenoxyacetic acid (2, 4, 5-T) have been shown to alter seed filling, nutrient translocation, and cellular expansion (Taiz & Zeiger, 2010; Daviere & Achard, 2013) [18, 4].

In rambutan, GA_3 application has been observed to significantly enhance seed weight, likely due to increased endosperm development and resource mobilization (Marboh *et al.*, 2020) [11]. Similar effects have been documented in litchi, where Zhang *et al.* (2019) [22] reported increased seed length under GA_3 treatments, underscoring the role of gibberellins in seed elongation. Auxins like NAA contribute to seed enlargement indirectly by improving fruit retention and assimilate flow (Sharma *et al.*, 2015) [15]. Additionally, Verma *et al.* (2017) [19] reported increased seed girth and width in mango when treated with specific PGR combinations, highlighting their influence on seed dimension and morphology.

Seed colour and shape, though more genetically predetermined, can serve as indicators of physiological maturity and varietal identity. For instance, Singh *et al.* (2021) [17] noted creamish-white seed colour in fully mature litchi. Kumar *et al.* (2018) [7] reported that obovoid or oblong seed shapes were stable across different growth regulators treatments and remain an important taxonomic and varietal trait in litchi.

Despite the recognized importance of seed traits and the influence of PGRs in related fruit crops, limited information exists regarding their role in rambutan particularly in elite variety like N-18. Understanding how PGRs influence seed characteristics in rambutan is crucial for advancing knowledge on fruit physiology and improving fruit quality. Therefore, the present investigation was undertaken to assess the effect of GA_3, NAA, and 2, 4, 5-T on key seed characters namely weight, length, width, shape, and colour in rambutan variety N-18 under tropical humid conditions.

Materials and Methods

Experimental site

The study was conducted during 2023 and 2024 on six-year-old rambutan trees (*Nephelium lappaceum* L.) of the N18 variety, maintained at the Plant Propagation and Nursery Management Unit, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur, Kerala. The selected trees were uniform in vigor, health, and canopy structure. The site experiences a humid tropical climate with an average annual rainfall of 2800-3000 mm, predominantly from the southwest monsoon.

Experimental Design and Treatments

The experiment was laid out in a Randomized Block Design (RBD) with seven treatments and three replications. Each treatment was applied to two randomly selected trees per replication. Uniform cultural and management practices were followed throughout the experimental period.

Table 1: Treatment details of plant growth regulators and their concentration applied in rambutan (*Nephelium lappaceum* L.) variety N-18

Treatments	Plant growth regulator	Concentration (ppm)
T_1	Napthalene Acetic Acid (NAA)	20
T_2	Napthalene Acetic Acid (NAA)	40
T_3	Gibberellic Acid (GA_3)	25
T_4	Gibberellic Acid (GA_3)	50
T_5	2,4,5-Trichlorophenoxy acetic acid (2,4,5-T)	25
T_6	2,4,5-Trichlorophenoxy acetic acid (2,4,5-T)	50
T_7	Control	Water spray

Method of application

The application of plant growth regulators was performed in two stages to assess their influence on seed characteristics. The first foliar spray was administered at the onset of flower initiation, ensuring complete coverage of the tree canopy to maximize absorption. The second spray was conducted one month after fruit set**,** coinciding with the early stages of seed development. Each treatment was applied uniformly across the designated trees according to the specified concentrations. Trees in the control group (T_7) were sprayed with water following the same schedule and application volume to ensure uniformity in treatment conditions.

Observations recorded

Seed morphological traits such as seed weight (g), seed shape, seed length (cm), seed width (cm), and seed color were evaluated from a randomly selected sample of ten fully developed fruits per tree. Digital calipers were used for linear measurements, while seed weight was measured using an electronic precision balance. Seed shape was described based on morphological observations, and color was assessed visually. The recorded data were statistically analyzed using Analysis of Variance (ANOVA) appropriate for the RBD to determine the significance of treatment effects. Critical Difference (CD) at 5% and Coefficient of Variation (CV%) were computed to assess variability and statistical reliability.

Table 2: Effect of different plant growth regulators on seed length (cm) and seed width (cm) of rambutan

Treatments	Seed length (cm)			Seed width (cm)		
	2023	2024	Pooled	2023	2024	Pooled
T_1	2.66	2.93	2.79^c	0.83	1.03	0.93^c
T_2	2.83	3.18	3.01^b	1.13	1.43	1.28^b
T_3	2.41	2.82	2.61^d	0.46	0.66	0.56^d
T_4	3.25	3.57	3.41^a	1.37	1.67	1.52^a
T_5	2.37	2.67	2.52^d	0.56	0.76	0.66^d
T_6	2.67	3.02	2.84^c	1.13	1.43	1.28^b
T_7	1.15	1.36	1.25^e	0.3	0.26	0.28^e
CV (%)	22.3	19.7	1.7	25.1	18.9	9.0
CD @ 5%	0.98	0.98	0.11	0.37	0.35	0.21

Table 3: Effect of different plant growth regulators on seed weight (g) of rambutan

Treatments	Seed weight (g)		
	2023	2024	Pooled
T_1	1.78	2.14	1.96^b
T_2	1.55	2.49	2.02^a
T_3	1.92	1.85	1.89^b
T_4	2.41	2.68	2.54^a
T_5	1.6	2.21	1.92^b
T_6	1.45	2.17	1.81^b
T_7	1.06	1.5	1.31^c
CV (%)	24.4	13.0	12.1
CD @ 5%	0.73	0.50	0.57

Table 4: Effect of different plant growth regulators on seed colour and seed shape of rambutan

Treatments	Seed colour			Seed shape		
	2023	2024	Pooled	2023	2024	Pooled
T_1	Creamy white	Creamy white	Creamy white	Obovoid elongated	Obovoid elongated	Obovoid elongated
T_2	Creamy white	Creamy white	Creamy white	Obovoid elongated	Obovoid elongated	Obovoid elongated
T_3	Creamy white	Creamy white	Creamy white	Obovoid elongated	Obovoid elongated	Obovoid elongated
T_4	Creamy white	Creamy white	Creamy white	Obovoid elongated	Obovoid elongated	Obovoid elongated
T_5	Creamy white	Creamy white	Creamy white	Obovoid elongated	Obovoid elongated	Obovoid elongated
T_6	Creamy white	Creamy white	Creamy white	Obovoid elongated	Obovoid elongated	Obovoid elongated
T_7	Creamy white	Creamy white	Creamy white	Obovoid elongated	Obovoid elongated	Obovoid elongated

Results and Discussion

The influence of different plant growth regulators (PGRs) on seed characteristics in rambutan was assessed based on parameters such as seed weight, seed shape, seed length, seed width, and seed color. The results from both 2023 and 2024 showed significant variation across treatments, reflecting the specific effects of each PGR on seed development.

Seed length (cm)

The pooled analysis of seed length (cm) demonstrated clear and statistically significant differences among the treatments. The treatment T_4 produced the longest seeds, measuring (3.41 cm) distinctly outperforming all other treatments. This was followed by T_2 with a seed length of 3.01 cm, T_6 (2.84 cm) and T_1 (2.79 cm). Treatments T_3 and T_5 exhibited moderate seed lengths of 2.61 cm and 2.52 cm, respectively, both lower than those recorded in T_2, T_6 and T_1. Shortest seeds were recorded in T_7 (1.25 cm), which was markedly lower than all other treatments, indicating a significant reduction in seed size under this treatment. Zhang *et al.* (2019) [22] found that plant growth regulators had a substantial influence on seed length in *Litchi chinensis*. Gibberellic acid (GA_3) significantly increased seed elongation, resulting in longer seeds compared to untreated control plants. The present findings highlight the importance of GA_3 in stimulating seed development and increasing seed length in rambutan.

Seed width (cm)

The pooled analysis of seed width (cm) demonstrated notable differences among the treatments. The treatment T_4 exhibited the greatest seed width (1.52 cm), significantly outperforming all other treatments. This was followed by T_2 and T_6 each measuring 1.28 cm. T_1 recorded a moderate seed width of 0.93 cm, while T_5 and T_3 had relatively lower values of 0.66 cm and 0.56 cm, respectively. The lowest seed width was observed in T_7 (0.28 cm) which was markedly lower than the values recorded in the other treatments. Kumar *et al.* (2020) [9] conducted a study on mango (*Mangifera indica*) and reported that the application of plant growth regulators, especially GA_3, significantly influenced seed morphology, including width. They found that the higher concentrations of GA_3 resulted in an increased seed girth and width, suggesting its positive role in enhancing seed size traits. These findings support the present observation in rambutan where treatments involving GA_3 resulted in greater seed width.

Seed weight (g)

The pooled data showed significant differences in seed weight among the treatments. The highest seed weight was recorded in T_4 (2.54 g) which was on par with T_2 (2.02 g). This was followed by T_1 (1.96 g) which were on par with each other T_5 (1.92 g). T_3 (1.89 g) and T_6 (1.81 g) which were on par with each other. The lowest seed weight was observed in T_7 (1.31 g), which was significantly lower than all other treatments. Treatments with greater concentrations of GA_3 significantly increased seed weight, as reported by Marboh *et al.* (2020) [11], who investigated the effect of growth regulators on rambutan seed properties. This is in line with the current study's pattern where GA_3 treatments specifically T_4 produced the heaviest seeds.

Seed colour

Across all the treatments, the seeds consistently exhibited a creamish white colour. No discernible variation was observed in response to different growth regulator applications, indicating that seed colour remained unaffected by treatment type or concentration. This uniformity suggests that the creamish white hue of the seeds is a stable trait likely governed by genetic factors, rather than influenced by external hormonal interventions. Ali *et al.* (2021) [1] investigated the influence of plant growth regulators on seed development in litchi (*Litchi chinensis*) and observed that while seed size was significantly affected by treatments, the seed colour remained relatively constant, typically appearing creamish white across all treatments. This consistency in colour was attributed to the genetic characteristics of the cultivar rather than treatment-induced variation. These findings support the current study in rambutan, where seed colour remained unchanged (creamish white) regardless of growth regulator application.

Seed shape

All the treatments resulted in seeds with a consistent obovoid elongated shape. There were no significant differences in seed shape across the various growth regulator treatments, indicating that the application of plant growth regulators did not affect the morphological characteristics of the seeds in terms of their shape. This suggests that the shape of the seeds remained stable regardless of the growth regulator used. Kumar *et al.* (2018) [7] reported that in their study on seed morphology of *Litchi chinensis*, seed shape remained consistent across treatments involving plant growth regulators, exhibiting an oblong to obovoid form regardless of the type or concentration of PGR applied. This suggests that seed shape is primarily governed by genetic factors rather than external chemical treatments. This observation aligns with the findings in the current study on rambutan, where all treatments, including those involving GA_3, NAA, and 2, 4, 5-T, resulted in obovoid elongated seed shapes showing no variation due to the treatments.

Conclusion

The findings of this study clearly demonstrate that exogenous application of plant growth regulators, especially GA_3 @ 50 ppm significantly enhances seed morphological traits such as length, width, and weight in rambutan (cv. N-18). However, traits like seed color and shape appear to be genetically fixed and remain stable across treatments. These results suggest that GA_3 @ 50 ppm can be effectively utilized to improve seed quality in rambutan, potentially leading to more vigorous seedlings and uniform propagation material. This has practical implications for nurseries and commercial rambutan growers seeking to enhance quality of planting materials.

Future studies could explore the physiological and molecular mechanisms behind seed enhancement due to GA_3, assess the long-term impact of PGR-induced seed improvements on seedling performance and evaluate the cost-effectiveness of such treatments under different agro-climatic conditions.

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