

Research Article

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Investigation of biological characteristics of fruit development and physiological disorders of Musang King durian (*Durio zibethinus* Murr.)

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Abstract: This study investigates the biological characteristics of fruit development and physiological disorders in the Musang King durian (*Durio zibethinus* Murr.). The experiment was conducted on 20 7-year-old trees cultivated in Nhon Nghia commune, Phong Dien district, Can Tho City, from October 2023 to July 2024. The results revealed a 7-day flowering period post-first bloom, with peak blooming observed between the second and fourth days. Flower opening commenced at 16:00–17:00 h, achieving a fruit set rate of 93%. Fruit development spanned 90 days after fruit set (DAFS) and was characterized by three distinct growth phases: slow growth (0–28 DAFS), rapid growth (28–70 DAFS), and ripening (70–90 DAFS). Immature fruit drop primarily occurred within the first 14 days (35.0%). The fruit's flesh began to form at 42 DAFS, reaching its maximum growth rate by 56 DAFS. At harvest, fruits averaged 2161.8 ± 74.7 g, with an edible portion constituting 24.8% of total weight. Physiological disorders, including hardened flesh and discoloration, were first observed at 70 DAFS (16.7%), increasing to 30.0, 6.7, and 13.3% at harvest for hardened flesh, aril tip burn, and flesh discoloration, respectively. These disorders significantly impacted commercial fruit quality.

Keywords: *Durio zibethinus* Murr., fruit development, Musang King, physiological disorders

1 Introduction

Durian (*Durio zibethinus* Murr.) is one of the most prized tropical fruits, often referred to as the “king of fruits” due to its distinctive aroma, rich flavor, and cultural significance in Southeast Asia [1–4]. Among the various durian varieties, Musang King, locally known as “Raja Kunyit” or “Mau Shan Wang,” is particularly esteemed for its deep yellow, creamy-textured flesh, and complex aroma profile, which have earned it a reputation as a premium variety on the international market [5]. First cultivated in Kelantan, Malaysia, Musang King has become synonymous with quality and commands some of the highest prices among durian varieties. In Vietnam, durian cultivation has traditionally been dominated by varieties such as Monthong and Ri 6. However, the introduction of Musang King in 2018 has marked a new chapter in Vietnamese durian production. By 2022, the variety achieved its first commercial harvest, particularly in the southern provinces, where the tropical climate and rich soils create favorable conditions for its cultivation [4]. Despite its growing popularity and economic potential, research on Musang King durian in Vietnam remains limited. Current knowledge gaps include its phenological stages, fruit development characteristics, and susceptibility to physiological disorders, which are critical for optimizing its cultivation and ensuring consistent fruit quality. Fruit development in durian is a complex process influenced by genetic, environmental, and agronomic factors. Understanding this process is vital for addressing challenges such as immature fruit drop, uneven ripening, and physiological disorders that can significantly impact yield and marketability [6–8]. Physiological disorders such as hardened flesh, discoloration, and aril tip burn are particularly concerning, as they not only affect the aesthetic and sensory qualities of the fruit but also reduce its commercial value [9–11]. These issues are often exacerbated by environmental stressors and suboptimal management practices during the fruit development

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phase. This study aims to investigate the biological characteristics of flowering and fruit development, as well as the prevalence and causes of physiological disorders in Musang King durian cultivated in the Mekong Delta region of Vietnam. By providing insights into the phenology and key challenges associated with this variety, the research seeks to establish a scientific basis for developing targeted agronomic practices to enhance productivity, fruit quality, and profitability for durian growers.

2 Materials and methods

2.1 Study site and experimental design

The study was conducted from October 2023 to July 2024 on 20 7-year-old Musang King durian trees (*Durio zibethinus* Murr.) grown in Nhon Nghia commune, Phong Dien district, Can Tho City. The experimental trees were managed under typical local agronomic practices, including fertilization, irrigation, and pest control. Data were collected on flowering characteristics, fruit set, fruit drop, fruit development, and physiological disorders. Weather data, including temperature and relative humidity, were obtained from the Meteorological and Hydrological Center of Can Tho City (Figure 1).

2.1.1 Sample selection

Samples were randomly selected from 6 to 7-year-old Musang King durian trees, ensuring uniformity in health, absence of pests and diseases, and consistent cultivation conditions.

2.1.2 Flowering characteristics

Flowering was monitored by marking 10 flowers per tree and recording flowering events every 4 h (at 02:00, 06:00,

10:00, 14:00, 18:00, and 22:00). Parameters recorded included flower bud opening, petal separation, full petal opening, stamen and pollen development, pistil maturation, nectar secretion, and pollination completion. A total of 200 flowers across 20 trees were observed to determine the duration of each flowering stage.

2.1.3 Pollination and fruit set

Farmers manually pollinated flowers using pollen collected from Ri-6 durian flowers blooming at the same time. Pollen was applied with a nylon brush between 18:00 and 20:00. The fruit set rate was calculated as the proportion of pollinated flowers that developed into fruits. Observations continued until the ovary began to develop or dried up and dropped.

2.1.4 Fruit drop

Immature fruit drop was monitored by tagging 200 fruits across 20 trees and recording dropped fruits weekly from the fruit set until the cessation of fruit drop. The percentage of dropped fruits was calculated based on the total number of observed fruits.

2.1.5 Fruit development

Fruit development was assessed every 14 days by measuring fruit weight, length, and width, as well as the weights of the fruit rind, flesh, and seeds. Three fruits were sampled per tree during each measurement interval, resulting in 60 fruits per sampling period. At harvest (90 days after fruit set (DAFS)), fruit samples were analyzed for average weight, flesh yield (percentage of total weight), and quality parameters, including °Brix, total soluble solids

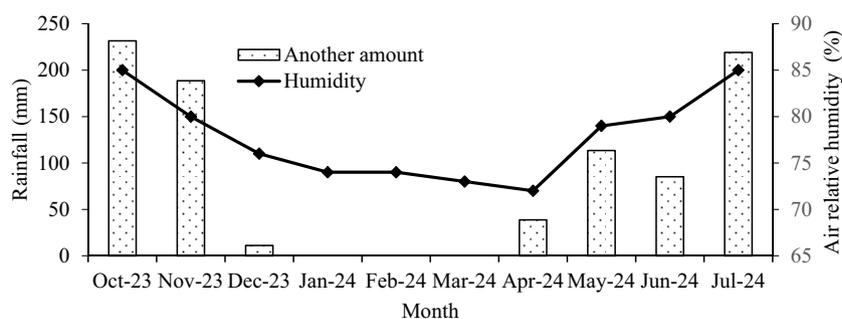


Figure 1: Air temperature and air relative humidity in Phong Dien district, Can Tho City, from November 2023 to July 2024.

(TSS), total sugar content, starch content, and water content.

2.1.6 Brix measurement (%)

A 0.5 g sample was ground with 1 mL distilled water and centrifuged using a HETTICH EBA 21 centrifuge at 3,500 rpm for 5 min. One drop of the supernatant was measured using an ATAGO refractometer (ATAGO Co., Ltd., Japan). The result was multiplied by three to obtain the final value.

2.1.7 TSS, °Brix

The measurement of TSS was carried out using a Brix refractometer according to DuBois et al. [12]. Approximately 2 g of the fruit sample was finely ground and diluted to 25 mL with distilled water in a volumetric flask. A 0.5 mL aliquot of the diluted sample solution was mixed with 0.5 mL of 5% polyethylene glycol solution and centrifuged for 2–3 min at 3,500 rpm to obtain a clear supernatant. The °Brix value was then measured using the refractometer.

To calculate TSS, the °Brix value of the blank sample was subtracted from the measured °Brix of the sample, and the result was adjusted for dilution as per the formula: TSS (°Brix) = °Brix (read) – °Brix (blank) × (1 + V/W), where TSS is the total soluble solids, V is the volume of water used for dilution (mL), and W is the weight of the fruit sample (g).

2.1.8 Total sugar content

Total sugar was extracted and measured using the phenol-sulfuric acid method [12]. Specifically, 0.3 g of the sample was mixed with 10 mL of 90% methanol and heated in a water bath at 70–99°C to extract sugars. The extraction process was repeated twice with 80% methanol. The combined extracts were filtered and diluted to 50 mL. A 1 mL aliquot was further diluted to 50 mL with distilled water for a colorimetric reaction with 5% phenol and concentrated sulfuric acid in a ratio of 1:1:5. Absorbance was measured at 490 nm using a Shimadzu UV-1201 V spectrophotometer. Total sugar content was calculated based on a glucose standard curve using the formula:

$$\text{Sugar content} = \frac{(a - b) \times V_1 \times \text{hspl} \times 100\%}{W \times 1,000 \times v},$$

where a is the measured sugar content (mg), b is the control sugar content (mg), V_1 is the volume of sugar extract (mL), v is the volume of diluted solution for measurement

(mL), hspl is the dilution factor, W is the sample weight (g), 1,000 is the conversion factor from g to mg.

2.1.9 Starch content

Starch content was determined using the method described by Coomibs et al. [13]. Samples were dried at 60–70°C for 30 min after sugar extraction. Subsequently, 5 mL of distilled water was added, and the mixture was heated in a water bath for 15 min. After cooling, 2 mL of 9.2 N perchloric acid was added and stirred for 15 min. The solution was diluted to 10 mL and centrifuged at 4,000 rpm for 3 min to collect supernatant (1). The residue was treated again with 2 mL of 4.6 N perchloric acid, stirred for 15 min, diluted to 10 mL, and centrifuged to obtain supernatant (2). The combined supernatants were used to quantify glucose. A 5 mL aliquot of starch extract was diluted to 50 mL with distilled water. A 5 mL portion of this solution was mixed with 10 mL of anthrone reagent and heated in a water bath for 7.5 min. After rapid cooling in an ice bath, absorbance was measured at 630 nm. Starch content was calculated using the formula:

$$\text{Amylose content} = \frac{(a - b) \times V_1 \times \text{hspl} \times 100\%}{W \times 1,000 \times v},$$

where a is the measured starch content (mg), b is the control starch content (mg), V_1 is the volume of starch extract (mL), v is the volume of diluted solution for measurement (mL), hspl is the dilution factor (5 mL extract/100 mL distilled water), W is the sample weight (g), and 1,000 is the conversion factor from g to mg.

2.1.10 Physiological disorders

Physiological disorders such as hardened flesh, discoloration, and aril tip burn were recorded at 70 and 90 DAFS. Affected fruits were categorized, and the percentage of segments showing symptoms was calculated. Disorders were linked to potential causes such as environmental stress or nutritional imbalances.

2.1.11 Agronomic management

The fertilization schedule was designed to support optimal fruit development and minimize physiological disorders in Musang King durian. Fertilizer was applied four times during the fruit development stage. At 30 DAFS, each tree received 1 kg of NPK fertilizer with a 15:15:15 formula to provide a balanced supply of essential nutrients for early

fruit growth. Subsequently, at 45 DAFS, 1 kg of NPK fertilizer with a 30:10:10 formula was applied to enhance nitrogen availability during the phase of rapid fruit development. At 60 DAFS, 0.5 kg of NPK fertilizer with a 20:10:10 formula was provided to maintain steady growth as the fruit flesh began forming. Finally, at 75 DAFS, 0.5 kg of NPK fertilizer with an 11:12:18 formula was applied to support fruit ripening and quality improvement, particularly for enhancing phosphorus and potassium levels.

Irrigation was carried out every other day in the morning throughout the fruit development period to ensure sufficient moisture availability and prevent water stress. The volume of water supplied was adjusted based on the developmental stage of the fruit. From fruit set to 14 DAFS, 100 L of water were provided per tree during each irrigation cycle to support initial fruit formation. From 15 to 70 DAFS, the water volume was increased to 200 L per tree to accommodate the rapid growth phase when water demand is highest. In the final stage, from 71 to 90 DAFS, the water volume was reduced back to 100 L per tree to prevent overhydration and reduce the risk of physiological disorders, such as hardened flesh and aril tip burn.

This comprehensive fertilization and irrigation management strategy was tailored to meet the dynamic nutrient and water requirements of Musang King durian during its fruit development cycle. By aligning nutrient supply and moisture availability with critical growth stages, the approach aimed to optimize fruit yield and quality while mitigating the occurrence of physiological disorders.

2.1.12 Flower induction

Flowering was induced in the favorable season from October 2023 to July 2024, following the third shoot topping.

Paclobotrazol at a concentration of 1,250 ppm was applied uniformly to each tree. The solution was sprayed to wet both the inner and outer surfaces of the canopy leaves, using 10 L of solution per tree. Applications were conducted early in the morning under cool conditions, avoiding direct sunlight.

To enhance flower bud induction, MKP (0-52-34) was applied twice at a concentration of 0.5%, seven and 14 days before flowering. Due to favorable weather, particularly a prolonged dry period from January 25, 2024, to February 15, 2024, flowering conditions were ideal. Flower buds began to emerge on February 10, 2024, with a uniform flowering pattern and no dormancy, achieving a flowering rate of 90%.

2.2 Data analysis

Data were processed using Excel to calculate mean values and standard deviations. Observations were compared to relevant literature to contextualize findings and identify deviations or trends.

3 Results and discussion

3.1 Flowering dynamics

The investigation of the flowering process of Musang King durian revealed that flowers begin to bloom 49 days after bud (DAB) emergence, with each cluster averaging 28.3 ± 6.7 flowers per cluster. Durian flowers typically grow on large branches, with clusters ranging from 1 to 80 flowers

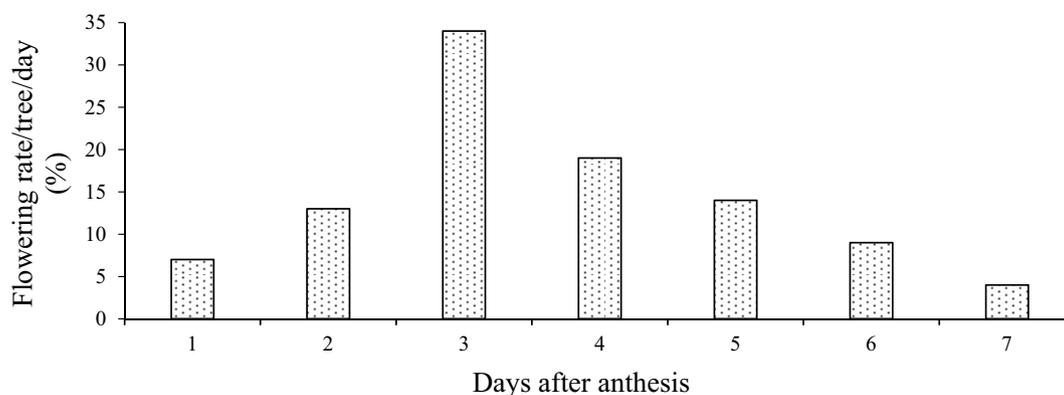


Figure 2: The flowering process of Musang King durian in Phong Dien District, Can Tho City.

[14]. A study by Hau et al. [15] on Ri 6 durian in Tien Giang found an average of 35.9 ± 24.0 flowers per cluster, while 33.6 ± 12.0 flowers per cluster for Bi Ro, a sterile-seed durian variety in Hau Giang. These results highlight the genetic variability in floral density among different durian cultivars.

The flowering process of Musang King durian spans 7 days, beginning with a gradual increase in blooming flowers over the first 3 days and peaking at 34% of flowers on the branch on the third day. This is followed by a gradual decline, with flowering ceasing entirely by the seventh day (Figure 2). Flowers typically begin blooming in the late afternoon, around 3 PM, when they excrete a sweet, sticky nectar that attracts pollinators. Pollen release begins around 5 PM, initiating the pollination process. By 2 AM the following morning, black spots appear on the stigma, signaling the end of receptivity, and the flower begins to drop. Each flower blooms and is pollinated only once during its life cycle. According to Nakasone and Paull [8], the flowering period for durian trees lasts 2–3 weeks, though concentrated flowering treatments can shorten this duration [4].

The flowering process of a single Musang King durian flower encompasses distinct stages over 4 days, beginning with calyx splitting and ending with the cessation of pollination. The calyx starts to split at approximately $8:32 \pm 0.26$ on the first day, fully dividing into 2–3 segments by $11:32 \pm 0.21$ on the second day. The stigma emerges at $12:12 \pm 0.19$ on the third day, and the petals begin to open at $15:15 \pm 0.15$, accompanied by stigma secretion of a sticky substance that facilitates pollen adherence. Full bloom occurs at $16:48 \pm 0.02$,

followed by complete anther dehiscence at $17:28 \pm 0.08$, marking the start of pollination. By 3 AM on the fourth day, black spots appear on the stigma, and the petals and stamens begin to abscise (Figure 3). These findings align with observations of other durian varieties, such as Ri 6, Monthong, and Bi Ro hat lep, which exhibit similar flowering durations. Hau [16] noted that durian flowers typically bloom for 3–4 days, while Lim and Luders [17] reported consistent bloom times between 3:30 and 6:00 PM. According to Ramingwong [18], petals and stamens usually abscise before midnight, whereas unpollinated stigmas persist for 3–5 days before dropping. The asynchronous maturation of stigmas and anthers in durians, including Musang King, promotes cross-pollination, as the stigma ripens before anther dehiscence [4].

The flowering dynamics of Musang King durian underscore the species' reliance on cross-pollination for a successful fruit set. The sequential stages of floral development – from calyx splitting to stigma receptivity and anther dehiscence – highlight a highly synchronized process that aligns with the activity of nocturnal pollinators, such as bats and moths. However, in regions where natural pollinator populations have declined, manual pollination remains essential to ensure fertilization during the narrow window of floral receptivity. The secretion of nectar during petal opening further enhances the flower's attractiveness to pollinators, reinforcing its dependence on external agents for reproductive success.

Comparing flowering characteristics across durian varieties reveals subtle differences that can inform orchard

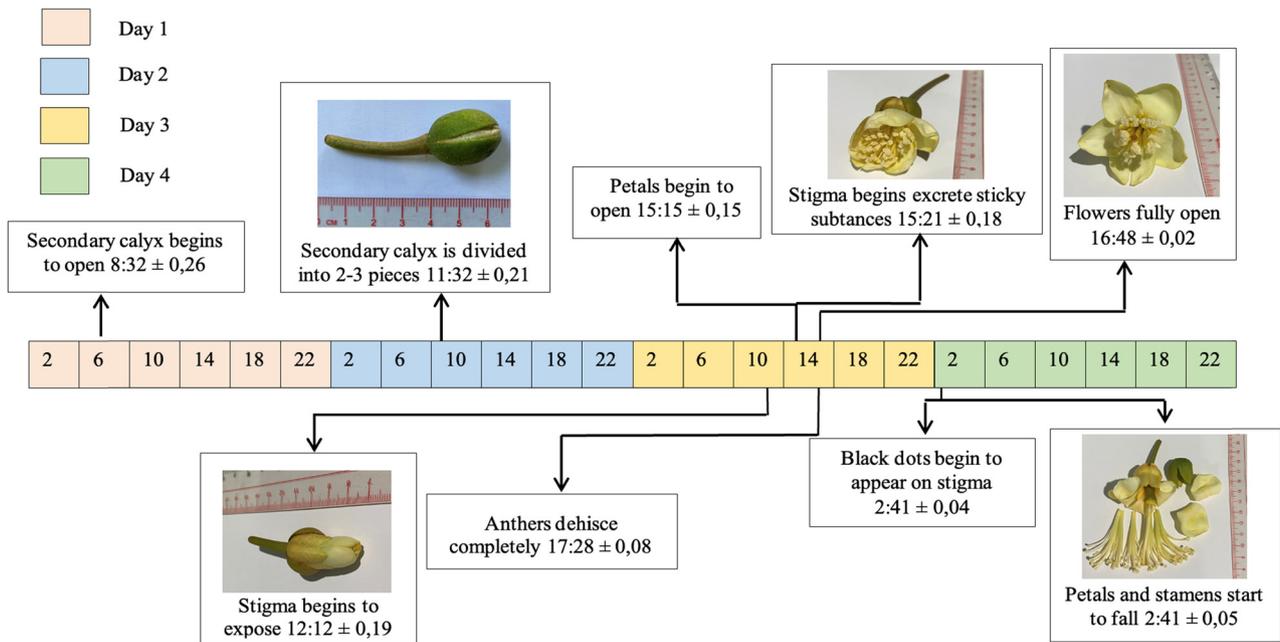


Figure 3: Flowering process of Musang King durian in Phong Dien District, Can Tho City. Source: Created by the author.

management strategies. Musang King's shorter and more concentrated flowering period may provide an agronomic advantage by simplifying pollination scheduling and resource allocation. Planting multiple durian varieties with complementary flowering traits, such as Ri 6 or Monthong, can further enhance cross-pollination efficiency, increasing fruit set and reducing fruit drop [4,19,20]. This approach also diversifies the genetic pool, potentially improving orchard resilience to environmental stressors.

Environmental factors, including temperature, humidity, and photoperiod, play critical roles in regulating flowering behaviors. For instance, elevated temperatures can accelerate floral development, while high humidity extends nectar secretion periods, potentially altering pollinator activity. Understanding these interactions is crucial for optimizing flowering synchronization and pollination success under varying climatic conditions. Concentrated flowering treatments, as suggested by Hau *et al.* [4], offer an effective strategy to reduce variability and improve yield consistency.

These findings emphasize the importance of precise timing in agronomic practices, such as nutrient management and irrigation, to support the flowering process. Future research should explore the genetic and molecular mechanisms governing flowering dynamics in durians, providing insights that can be leveraged to develop high-yielding, climate-resilient cultivars.

3.2 Fruit set and immature fruit drop

3.2.1 Fruit set

The fruit set rate of Musang King durian was recorded at 93%, which is notably high compared to other durian cultivars. This success is attributed to the combination of

supplementary manual pollination and favorable environmental conditions. The compatibility between Musang King flowers and Ri-6 pollen further enhanced fertilization efficiency. Manual pollination ensured a controlled transfer of pollen, overcoming challenges posed by the declining population of natural pollinators. These findings align with previous research indicating that manual pollination improves fruit set by ensuring fertilization during the narrow window of floral receptivity [15,16].

Several factors influenced the high fruit set observed in this study. Precise timing during the peak flowering period, characterized by maximum stigma receptivity and pollen viability, was critical. Environmental conditions, such as temperature and relative humidity, also played a role, as excessive heat or prolonged wetness can negatively impact pollination success. For instance, optimal humidity levels during the late afternoon facilitated pollen adherence and fertilization. These results highlight the importance of integrating agronomic practices with environmental monitoring to achieve high fruit set rates.

Comparatively, Ri-6 durian in Tien Giang achieved an average fruit set rate of 86% under similar conditions [15]. The slightly higher performance of Musang King may be due to its floral morphology, which better supports manual pollination. Future studies should investigate whether genetic factors or specific pollination techniques further contribute to this advantage (Figure 4).

3.2.2 Immature fruit drop

Immature fruit drop was most pronounced during the first 14 DAFS, with a cumulative drop rate of 35% (Figure 5). This early-stage drop was primarily attributed to incomplete pollination, limited resource allocation, and environmental stress. By 42 DAFS, the fruit drop rate stabilized



Figure 4: Musang King durian from pollination to fruit set stage: (a) durian fruit after pollination, (b) durian fruit after fertilization, developing ovary, and (c) unfertilized durian fruit. Source: Created by the author.

at a total of 48.5%, consistent with the natural thinning processes observed in other tropical fruit species [21,22]. Additionally, vegetative growth during fruit development, such as the emergence of new shoots, may have contributed to resource competition, further exacerbating fruit drop [16]. The timing of fruit drop reflects competition among developing fruits for resources such as carbohydrates and water. During the rapid growth phase, insufficient availability of these resources often triggers the abscission of weaker fruits. This process is regulated by hormonal signals, particularly a reduction in auxin levels and an increase in ethylene production in stressed or underdeveloped fruits [23,24]. Addressing these imbalances through targeted agronomic interventions, such as balanced fertilization and consistent irrigation, significantly reduced drop rates in this study.

Agronomic practices implemented during the study period played a key role in minimizing excessive fruit drop. Regular irrigation tailored to the developmental needs of the fruit ensured adequate water supply, preventing stress-induced abscission. The application of NPK 30:10:10 fertilizer at 45 DAFS provided essential nutrients during the period of rapid fruit development, supporting retention. These findings corroborate previous research emphasizing the importance of nutrient and water management in mitigating fruit drop [25,26].

The high fruit set rate observed in Musang King durian underscores the effectiveness of manual pollination, particularly when conducted during the peak flowering period. This practice is vital for cultivars that exhibit asynchronous flowering or rely heavily on cross-pollination for reproductive success [27,28]. The results suggest that pairing Musang King with complementary varieties, such as Ri-6, can further enhance fruit set by ensuring consistent pollen availability. The significant reduction in fruit drop achieved through resource optimization highlights

the importance of early intervention. Addressing key factors such as pollination success, hormonal regulation, and resource competition can substantially improve fruit retention. Future studies should explore the molecular mechanisms underlying fruit abscission to develop more targeted solutions.

Finally, the integration of environmental monitoring with agronomic management offers a promising strategy for improving both fruit set and retention. Precision agriculture tools, such as automated irrigation systems and real-time nutrient monitoring, could further optimize resource allocation, ensuring sustainable durian production in the face of climatic variability.

3.3 Fruit development

3.3.1 Fruit size

The growth of Musang King durian fruit followed a typical sigmoid curve, with distinct phases of development (Figure 6). Fruit size increased gradually during the first 28 DAFS, corresponding to the slow growth phase. Between 28 and 70 DAFS, the fruit entered a rapid growth phase, during which significant increases in both length and width were observed (Figure 6b). By 70 DAFS, fruit size reached near-maximum dimensions, with further increases tapering off as the fruit transitioned into the ripening phase.

Initially, the growth in length outpaced width, particularly between 14 and 42 DAFS (Figure 6a). However, from 56 DAFS onward, the growth in width exceeded that of length, contributing to the characteristic round to elliptical shape of Musang King durian. At harvest (90 DAFS), the average fruit size was 22.8 ± 0.8 cm in length and 21.1 ± 1.1 cm in width. These findings align with earlier studies on

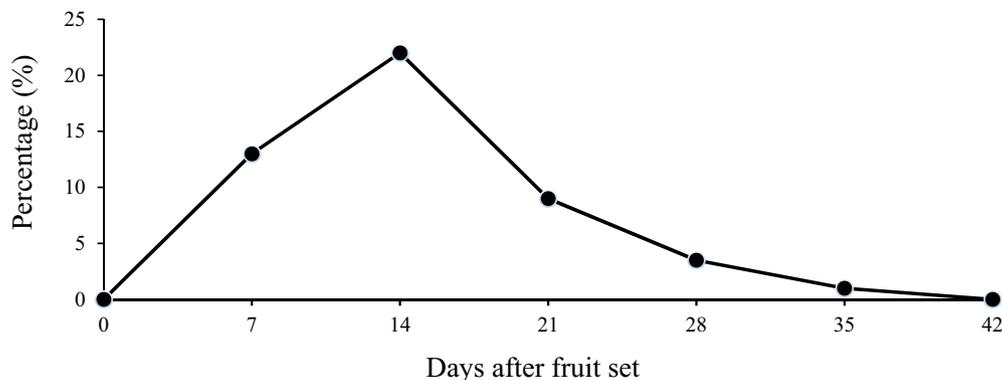


Figure 5: Percentage of immature fruit drop from fruit set to harvest of Musang King durian in Phong Dien District, Can Tho City.

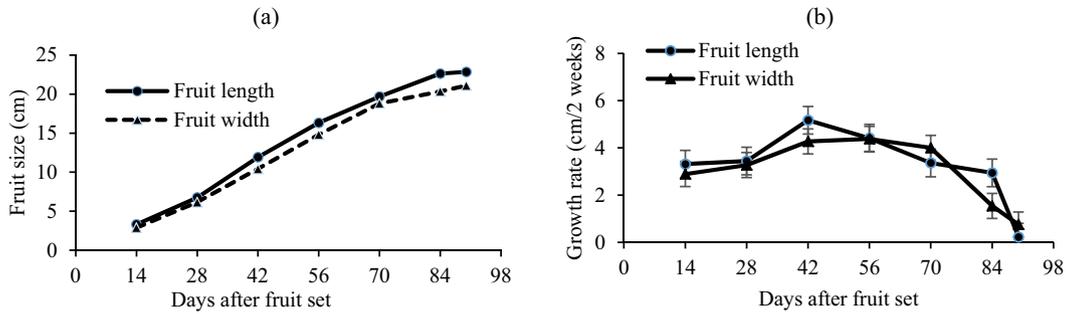


Figure 6: Growth (a) and growth rate (b) of Musang King durian fruit size in Phong Dien District, Can Tho City.

other durian varieties, such as Monthong and Ri-6, which exhibit similar growth patterns and size metrics [15].

3.3.2 Fruit weight

The weight development of Musang King durian follows a typical sigmoid growth curve with three distinct phases. From 0 to 28 DAFS, growth was slow, primarily involving organ formation. Between 28 and 70 DAFS, the fruit underwent rapid growth, characterized by the development of the rind, flesh, and seeds. Growth slowed again during the ripening phase, from 70 DAFS until harvest (Figure 7). The most significant weight gain occurred between 42 and 56 DAFS, driven by rapid flesh development, which peaked at a growth rate of 219.8 g per 2 weeks. Seed development also

peaked during this period at 85.2 g per 2 weeks, while the rind continued growing until 70 DAFS, with a maximum rate of 571.7 g per 2 weeks. According to Hau et al. [15] on Ri-6 durian and Hau et al. [4] on Bi Ro hat lep durian, similar significant growth rates were observed between 42 and 56 DAFS.

Sapii and Nanthachai [29] described durian fruit development as occurring in three distinct periods: slow growth during the first 4 weeks, rapid growth from weeks 5 to 11, followed by slow growth until week 14, and minimal changes in size thereafter until harvest. The findings from this study align with these observations. At harvest (90 DAFS), Musang King durian fruit had an average weight of $2,161.8 \pm 74.7$ g, with the husk contributing 70.1%, the flesh 24.8%, and the seeds 5.2% of the total weight. These proportions align with observations from

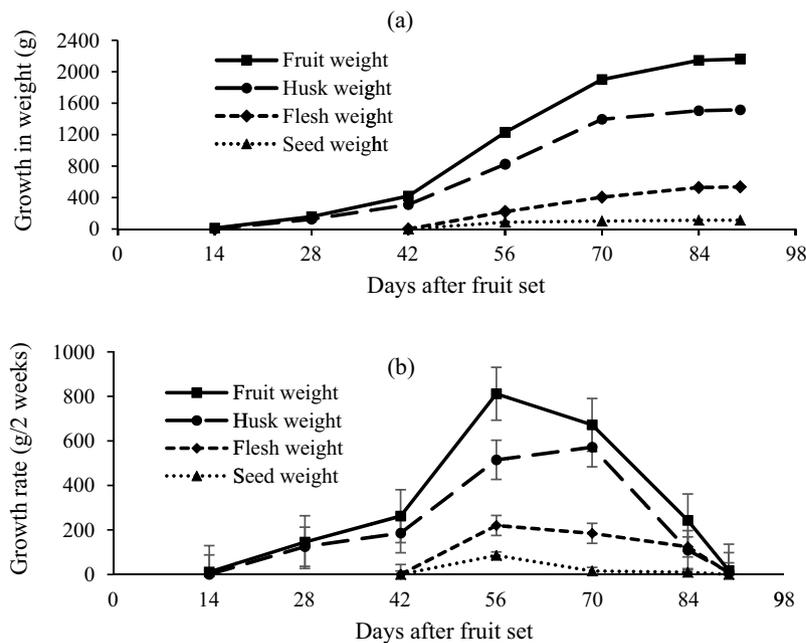


Figure 7: Growth in weight (a) and growth rate (b) of Musang King durian fruit components from fruit set to harvest in Phong Dien District, Can Tho City.

other durian cultivars, such as Ri-6, which typically weighs between 2.5 and 3.0 kg [4,15].

3.3.3 Fruit size and weight dynamics

The results highlight the interrelation between fruit size and weight dynamics in Musang King durian. The observed sigmoid growth pattern for both metrics reflects common physiological processes in tropical fruits, driven by cell division during the early phase, followed by rapid cell expansion and accumulation of reserves in later phases. The initial dominance of length growth followed by width expansion contributes to the characteristic shape of Musang King durian, which may influence consumer preferences [30]. Comparatively, the size and weight dynamics of Musang King durian align closely with those reported for Monthong and Ri-6 durians, with minor variations attributable to genetic differences and environmental factors [4,30]. For instance, Musang King's smaller size but comparable weight highlights its higher density, which may affect texture and marketability. The rapid growth observed between 42 and 56 DAFS corresponds to the period of highest nutrient demand, emphasizing the need for targeted nutrient application and irrigation during this critical phase.

The uniformity in growth phases across trees suggests that Musang King durian is well-suited for synchronized agronomic practices. Stage-specific interventions, such as NPK 30:10:10 during rapid growth and consistent irrigation, can optimize both size and weight while reducing the risk of physiological disorders. Additionally, the observed rind-to-flesh ratio, while consistent with other varieties, underscores the importance of further research into increasing edible yield without compromising fruit protection [15,17].

The results of the survey on flowering treatment, fruit set, and fruit development are summarized in Table 1. The findings demonstrate that Musang King durian trees exhibit consistent reproductive processes, with minimal variation in timing among trees. The total duration from flower bud emergence to harvest was 149 days, including

90 days from fruit set to harvest. This uniformity in phenological stages suggests that the flowering and fruiting patterns of Musang King durian can be effectively predicted and managed under similar environmental and agronomic conditions.

3.4 Quality characteristics of aril

The evaluation of Musang King durian at 90 DAFS revealed a high average Brix value of $33.1\% \pm 1.9$, indicating its exceptional sweetness (Table 2). For comparison, Hau et al. [15] reported a lower Brix value of $22.5\% \pm 3.0$ for Ri-6 durian cultivated in Tien Giang. This significant difference highlights Musang King's superior sweetness, a defining characteristic that sets it apart from other durian varieties. The starch content of Musang King averaged $12.1 \pm 0.8\%$, while total sugar content ranged from 10.2 to 14.5%, with an average of $12.5 \pm 1.4\%$. These figures reflect the conversion of starch to sugars during ripening, driven by enzymatic activity, particularly amylases [31,32]. The conversion process is crucial for flavor development, as sugars contribute to the fruit's sweetness, while starch provides a reserve for the ripening phase.

The reduced water content of Musang King durian ($50.2 \pm 3.8\%$) compared to Monthong durian, which was reported by Hau et al. [15] to have 68.06% water content, further enhances its appeal. The lower water content results in a firmer, drier texture, making the fruit richer and more concentrated in flavor. This feature is important for consumers who favor creamy and dense flesh, which also makes Musang King durian more suitable for export markets due to its enhanced storage and transportability. Additionally, the lower water content may reduce post-harvest spoilage, contributing to a longer shelf life, a critical factor in maintaining the fruit's premium quality during distribution [33,34].

These findings underscore the complex interplay between genetic factors and environmental conditions in

Table 1: Flowering process of Musang King durian in Phong Dien District, Can Tho City

Time period	Lowest	Highest	Average (Avg) (day)	SD
Floral induction – bud emergencing	24.0	19.0	21.0	0.9
Bud emergencing – harvesting	151.0	148.0	149.0	0.6
Bud emergencing – anthesis	50.0	48.0	49.0	0.3
The Anthesis – fruit set	8.0	7.0	7.0	0.1
Pollination – fertilization	3.0	3.0	3.0	0.0
Fruit set – harvest	92	89	90.0	0.5

shaping fruit quality. The high sugar content, coupled with the low water content, is a key factor distinguishing Musang King from other durian varieties [3]. While Ri-6 durian, known for its sweetness, exhibits a higher water content and lower sugar concentration, resulting in a less intense flavor, Musang King's combination of rich sweetness and low water content suggests its genetic predisposition to perform well under certain growing conditions [15]. Factors such as optimal soil conditions, irrigation management, and fertilization practices likely contributed to the observed quality characteristics in this study.

The high Brix value, balanced sugar-to-starch ratio, and low water content are significantly influenced by precise harvest timing and effective agronomic management, which are essential for achieving optimal fruit quality [4,35]. Harvesting too early may lead to insufficient sugar accumulation, while harvesting too late can result in over-ripening and undesirable texture changes. For growers aiming to meet the expectations of premium consumers, it is crucial to refine post-harvest management techniques and ensure proper fruit maturity at harvest.

Furthermore, the unique quality characteristics of Musang King durian could offer valuable insights for breeding programs. By understanding the genetic basis of its high sugar content, low water content, and superior flavor, breeders can work to develop new cultivars with similar or enhanced traits. Future studies could explore the molecular mechanisms behind these characteristics, particularly the genes involved in sugar metabolism and water transport, as these could inform future agricultural practices and genetic improvements for durian cultivation (Figure 8).

3.5 Physiological disorders

The development of Musang King durian from fruit set to harvest revealed several physiological disorders that significantly impacted fruit quality and commercial value. Around 70 DAFS, symptoms such as flesh hardening and discoloration began to appear, affecting 16.7% of fruits (Figure 9f). These symptoms progressed by 84 DAFS, accompanied by fruit burning, a disorder characterized by the external drying and blackening of fruit segments, rendering them inedible. Flesh hardening and discoloration, affecting both internal and external parts of the fruit, resulted in brownish-black segments with a water-containing membrane, while unaffected segments retained their light yellow color and soft texture.

At harvest, the most prevalent disorders were flesh hardening and discoloration (30.0% per fruit), isolated flesh hardening (13.3%), and fruit burning (6.7%) (Figure 9b and c). On average, 28.1 ± 10.6 of fruit locules and 18.0 ± 9.6 of segments exhibited flesh hardening and discoloration, while 30.6 ± 14.4 of locules were affected by fruit burning, and 25.5 ± 10.2 displayed flesh hardening (Table 3). Mild cases resulted in yellowish-brown segments, but severe symptoms led to black discoloration and significantly reduced edible quality. The combination of these disorders diminished the fruit's marketability, posing challenges for both local and export markets where premium quality is expected.

These physiological disorders are influenced by multiple environmental and agronomic factors [4,36]. High soil moisture and heavy rainfall during the late stages of fruit development, as well as nutritional imbalances, are potential contributors. Similar findings were reported by

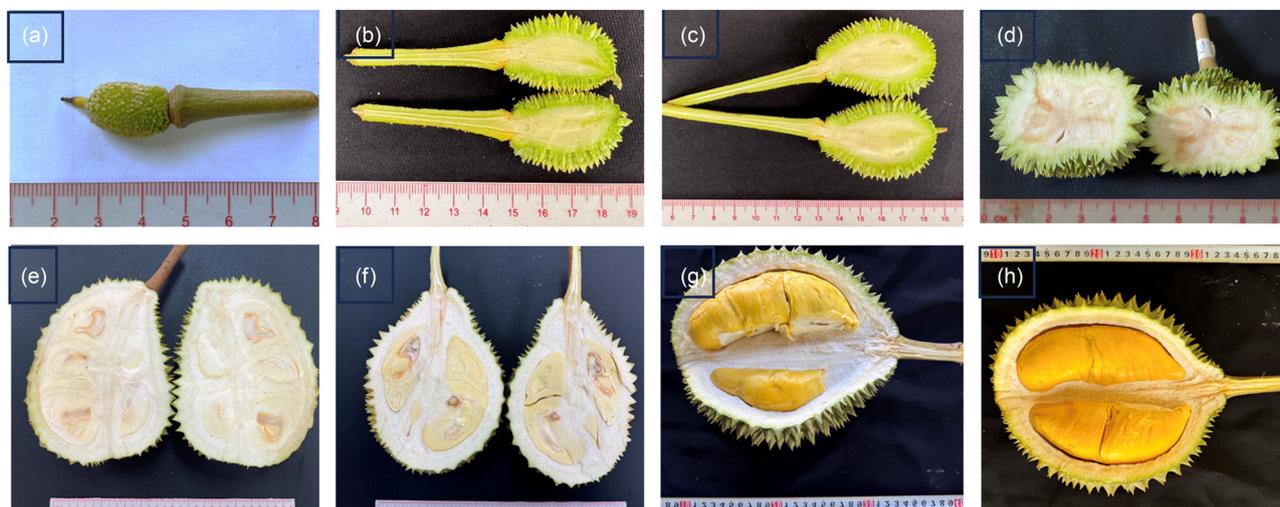


Figure 8: Fruit development of Musang King durian from fruit set to harvest in Phong Dien District, C n Thơ City: (a) after fruit set, (b) 14 DAFS, (c) 28 DAFS, (d) 42 DAFS, (e) 56 DAFS, (f) 70 DAFS, (g) 84 DAFS, and (h) 90 DAFS. Source: Created by the author.



Figure 9: Physiological Disorder in Musang King Durian: (a) normal durian fruit; (b) durian fruit with burning seed coat (Aril tip burn); (c)–(e) durian fruit with hardened flesh and discoloration; and (f) durian segment with hardened flesh at 70 DAFS. Source: Created by the author.

Table 2: Quality characteristics of Musang King Durian in Phong Dien District, Can Tho City

Fruit quality characteristics	Lowest	Highest	Average	SD
°Brix (%)	30.0	35.0	33.1	1.9
TSS (%)	20.3	26.2	23.9	1.8
Water content (%)	45.6	57.1	50.2	3.8
Starch content (%)	10.9	13.1	12.1	0.8
Total sugar content (%)	10.2	14.5	12.5	1.4

Nakasone and Paull [8], who noted that excessive water availability before harvest can exacerbate fruit quality issues by disrupting the plant’s physiological processes. High moisture levels may lead to localized anaerobic conditions within the

fruit tissues, causing oxidative stress and cell damage, which manifest as discoloration and hardening. Moreover, nutrient deficiencies or imbalances, particularly in potassium and calcium, can impair cell wall integrity and sugar transport, further exacerbating these disorders [4].

Effective agronomic management is essential to mitigate these disorders and ensure consistent fruit quality. Strategies include optimizing irrigation schedules to avoid waterlogging, especially during critical growth stages, and implementing drainage systems in regions prone to heavy rainfall. Additionally, precise fertilization strategies tailored to durian’s nutritional requirements can address potential nutrient deficiencies and reduce susceptibility to physiological disorders. For instance, maintaining a balanced supply of

Table 3: Physiological disorders in Musang King durian at harvesting time in Phong Dien district, Can Tho city

Fruit quality indicators	Segments with hard flesh or discoloration (Avg ± SD)	Pulp units with burning seed coat (Aril tip burn) (Avg ± SD)	Segments with hard flesh (Avg ± SD)
Fruit with physiological disorders (%)	30.0 ± 18.9	6.7 ± 14.5	13.3 ± 17.2
Locules with physiological disorders (%)	28.1 ± 10.6	30.6 ± 14.4	25.5 ± 10.2
Segments with physiological disorders (%)	18.0 ± 9.6	13.5 ± 6.7	16.9 ± 7.5
Pulp with physiological disorders (%)	17.4 ± 12.1	6.5 ± 4.7	14.5 ± 9.1

potassium and calcium may enhance cell wall strength and mitigate discoloration and hardening.

The timing and methods of fruit handling also play a critical role [37]. Overexposure to sunlight during late development stages may contribute to fruit burning, necessitating canopy management practices to provide adequate shading without compromising photosynthesis. Post-harvest storage conditions should also be optimized to minimize further quality degradation caused by physiological stresses.

4 Conclusion and recommendations

4.1 Conclusion

The flowering process of Musang King durian occurs 49 DAB emergence, lasting 7 days, with a peak blooming period from day 2 to day 4, predominantly during 16–17 h. The fruit set rate reached 93%, and fruit development spans 90 DAFS, with the highest fruit drop rate (35.0%) occurring between 0 and 14 DAFS. Durian fruits undergo three growth stages: slow growth (0–28 DAFS), rapid growth (28–70 DAFS), and maturation/ripening (70–90 DAFS). Flesh development begins at 42 DAFS, with rapid growth peaking at 56 DAFS.

At harvest, the average fruit weight is $2,161.8 \pm 74.7$ g, with the edible portion comprising 24.8% of the total weight. Physiological disorders, such as hardened flesh, discoloration, and aril tip burn, are first observed at 70 DAFS (16.7%) but become more pronounced by harvest, with incidences of 30.0, 6.7, and 13.3%, respectively. Affected flesh accounts for 17.4, 6.5, and 40.4% of total disorders, respectively. The fruit's biochemical composition at harvest includes total sugar content (12.5%), starch content (12.1%), σ Brix (33.1), TSS (23.9%), and water content (50.2%). These findings provide essential insights into the growth, development, and postharvest quality of Musang King durian, contributing to optimizing cultivation practices.

4.2 Recommendations

Further studies should focus on mitigating physiological disorders and reducing fruit drop through improved nutrient management, irrigation practices, and preharvest treatments. Investigations into the genetic and environmental factors affecting fruit quality and physiological

disorders will help enhance the commercial value and yield of Musang King durian. Developing specific guidelines for optimal harvest timing and postharvest handling is also critical to maintaining fruit quality and market competitiveness.

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