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Phenophases of Pulasan (Nephelium Mutabile Blume) According to the Extended BBCH-Scale for Central Kerala

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Abstract*— Pulasan (Nephelium mutabile Blume), a fruit tree cultivated in the tropics, holds significant value in India, particularly in Kerala, where it is cherished as a homestead crop. This research categorizes its phenological growth phases into seven primary stages—bud development, leaf growth, shoot emergence, inflorescence appearance, flowering, fruit maturation, and ripening—utilizing the extended BBCH-scale. Additionally, the study delineates forty-one secondary growth stages. By analyzing these phenophases in relation to local environmental conditions, this research establishes a fundamental framework for standardizing agronomic practices of Nephelium mutabile Blume. This framework aims to facilitate broader cultivation of this exotic fruit crop, thereby promoting its agricultural significance and enhancing its economic potential in tropical regions.

Index Terms: Pulasan, Sapindaceae, Principal growth stages, Phenology, BBCH.

I. INTRODUCTION

Pulasan (*Nephelium mutabile* Blume) is part of the Sapindaceae family of fruit-bearing trees native to Southeast Asia, particularly Indonesia, Malaysia, and Thailand [11]. Related species like Rambutan are found across Asia in countries such as India, China, Myanmar, and throughout the Malay Peninsula, Borneo, Sumatra, and Java [8], [3]. In Indonesia, Pulasan trees are distributed across Kalimantan, Java, and Sumatra [11], [10], [5]. The name "Pulasan" in Malay derives from the word ‘pulas’, meaning to twist, which describes the method used to open the fruit.

The tree typically grows less than 10 meters tall but can occasionally reach heights of up to 36 meters in its natural environment. Its trunk can grow up to 60 cm in diameter, with buttresses reaching heights of up to 2.4 meters. The leaves are compound, arranged spirally, and composed of 1 to 7 leaflets. These leaflets are elliptical, ranging from 4 to 20 cm in length and 1.7 to 11 cm in width, with a texture that is thin and leathery to papery. The shape of both the leaflet base and tip varies; the base can be blunt, rounded, or narrow (attenuate), while the tip can be short, broad, or obtuse. The upper surface of the leaflet may be glabrous or have short hairs (puberulous) on the midrib, while the underside can be glabrous or covered with fine silky hairs. Domatia, are typically present but may be scarce or absent [7], [1].

Pulasan flowers are grouped in racemes and panicles, situated on axillary or pseudo-terminal stems. Each inflorescence comprises either exclusively male flowers or solely hermaphrodite flowers, which are found on separate trees [4]. Sepals slightly or up to halfway connate, 1—2.75 mm long. Petals absent. Disk glabrous. Stamens 5—8. Pistil 2- (rarely 3-) merous. The fruit is ellipsoid to subglobular, measuring 4 to 6.5 cm in length and 2.5 to 5 cm in width, and is covered with coarse spines that can grow up to 1.5 cm high. These spines are bulbous at the base and often merge together or sometimes have knobby, tongue-shaped appendages. The fruit is fleshy and turns dark red when ripe. It typically grows in rainforests, near rivers, streams, and on slopes at altitudes ranging from 300 to 1950 meters, though it can also occasionally be found in swamps.[7].

The nectariferous pulasan flowers attract pollinators, leading to allogamous reproduction, where hermaphroditic plants assume a female role [4]. Pulasan flowers bloom in response to water stress, similar to rambutan [2], along with high temperatures and decreased humidity. Signs of water stress in trees include inward curling of leaf margins, yellowing, and shedding of mature leaves. New growth typically begins shortly after harvesting on branches that have already produced fruit. Lateral buds below dried-out panicles produce new shoots. Environmental factors such as rainfall, extensive irrigation, pruning, and harvesting promote vegetative growth spurts.

While numerous studies have explored pulasan's fruit morphology, antioxidant activity, and flower morphology, a comprehensive understanding of pulasan development requires a focused investigation into its various phenological growth stages. Similar growth stages have been documented for lychee [13], longan [12] , and rambutan [9] using the extended BBCH scale system. Therefore, this study aims to delineate the phenological growth stages of pulasan according to the extended BBCH scale, aiming to contribute to future research efforts in this area.

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II. MATERIALS AND METHODS

Forty Pulasan trees were initially screened, from which 10 healthy, consistently fruiting trees, (budded pulasan trees) aged 12 years, were selected from the Homegrown Biotech farm in Kottayam, Kerala, India. Phenological observations were conducted on these trees to monitor various growth stages. The orchard, situated at 9°30'6" N latitude, 76°49'6" E longitude, and 64 m above sea level, experiences a tropical warm humid climate. Climate conditions include an average maximum temperature of 32°C, average minimum temperature of 23°C, and annual rainfall of 3130 mm.

Observations on vegetative, reproductive, and fruit development were documented between October 2022 and August 2024. A total of 60 branches (5 from each of the 10 trees) with 170 buds were marked and observed at intervals of one to two weeks, depending on the growth stage, following the extended BBCH scale [6]. The study utilized seven of the ten principal growth stages (PGS) based on the BBCH scale, including vegetative bud development (stage 0), leaf development (stage 1), shoot development (stage 3), inflorescence development (stage 5), flower development (stage 6), fruit development (stage 7), and fruit maturity (stage 8). Additionally, secondary growth stages were also documented.

III. RESULTS

The study provides a description of the phenological growth stages of Pulasan using an extended BBCH scale. (Table 1).

Table I: Description of the phenological growth stages (PGS) of Pulasan on BBCH-scale.

BBCH code	Description
PGS- 0: Vegetative bud development	
011	Beginning of bud swell
017	Beginning of bud break
019	End of bud break
PGS- 1: Leaf development	
110	First leaves separated
111	First leaves unfolded
113	More leaves unfolded
119	All leaves unfolded: all leaflets fully expanded
PGS- 3: Shoot development	
310	Beginning of shoot extension
311	10% of final shoot length
313	30% of final shoot length
317	70% of final shoot length
319	90% or more of final shoot length
PGS- 5: Inflorescence emergence	
510	Reproductive buds dormant
511	Beginning of reproductive bud swell
512	Panicle axes begin to elongate
513	Beginning of panicle development
515	50% of final inflorescence length
519	End of inflorescence extension
PGS- 6: Flowering	
610	First flowers open
615	50% flowers open
617	70% flowers open 619 90% flowers open
PGS- 7: Fruit development	
710	No ovary growth still visible
711	Initial ovary growth. First physiological fruit abscission
712	20% of final fruit size. Beginning of ovary growth

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Vol 11, Issue 8, August 2024

BBCH code	Description
713	30% of final fruit size
715	50% of final fruit size. Seed is covered by aril
717	70% of final fruit size. Aril becomes fleshy
719	90% or more of final fruit size
PGS- 8: Fruit maturity	
810	Skin colour changes from green to dark red
819	Physiological and harvest maturity.

A. Principal growth stage 0: vegetative bud development

The initial vegetative buds became visible approximately 2–4 weeks following fruit harvesting. This timeframe typically fell during the monsoon season, occurring between July and August, depending on when the fruits were harvested. (Fig. 4).

010–Vegetative buds dormant: The foliar buds are completely closed and covered with brownish scales.

011–Beginning of bud swell: The foliar buds begin to swell and open with bud scales starting to separate (Fig. 1).

013–End of bud swell: The brownish scales have fully separated, and light green buds begin to emerge.

017–Beginning of bud break: The tips of the compound leaves, which are dark copper in color, become just visible (Fig. 1).

019–End of bud break: The buds are fully burst, making the shoot tip clearly visible, and the first compound leaves start to slightly separate (Fig. 1).

B. Principal growth stage 1: leaf development

Leaf development begins in August and is completed within 50–60 days.

110–First leaves separate: The leaflets of the first compound leaf start to emerge (Fig. 1).

111–First leaves visible: All leaflets of the first compound leaf unfold and spread away from the shoot, reaching about 10% of their full size (Fig. 1).

113–More leaves unfold: Leaves appear light green and petioles become visible, with leaflets at about 30% of their full size (Fig. 1).

115–First leaves fully expanded: The first leaflets reach nearly 100% of their full size.

117–All leaves are fully unfolded and expanded.

119–Leaves mature: Leaves mature, changing color from light green to green (Fig. 1).

Fig. 1. Phenological growth stages of Pulasan according to the extended BBCH scale (PGS-0,1,3,)

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Vol 11, Issue 8, August 2024

Fig. 2. Phenological growth stages of Pulasan according to the extended BBCH scale (PGS-,5,6,7,8)

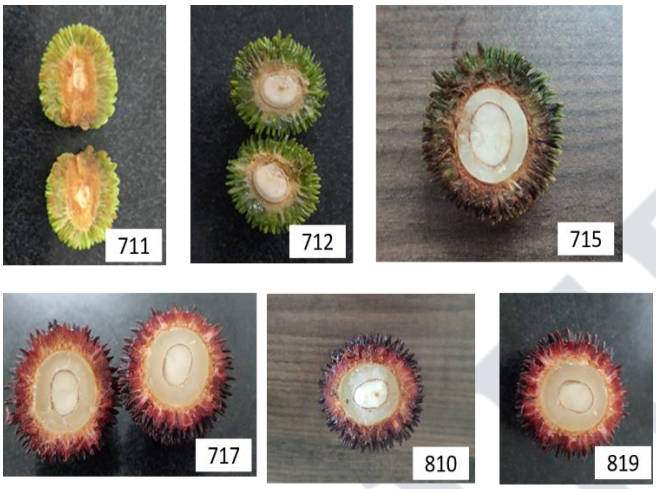

Fig. 3. Cross section of Rambutan displaying the fruit development and maturity as per the extended BBCH scale.

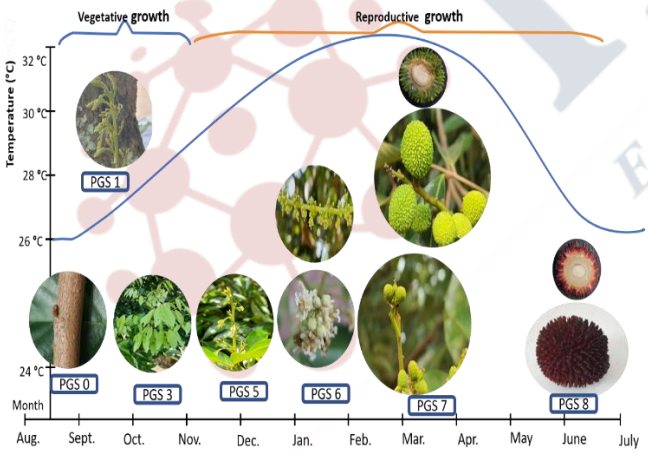

Fig. 4. Principal growth stages (PGS) of pulasan corresponding to average monthly temperatures in Kottayam, Kerala, India.

C. Principal growth stage 3: shoot development

Shoot development progresses alongside leaf development before the onset of inflorescence and flower development.

310–Beginning of shoot growth: extension of shoots and axes become visible (concurrently with stage 110) (Fig. 1).

311–10% of the final shoot length (concurrently with stage 113).

313–30% of the final shoot length (concurrently with stage 117) (Fig. 1).

315–50% of the final shoot length (concurrently with stage 119).

317–The shoot has reached 70% of its final length (Fig. 1).

319–The shoot has reached 90% of its final length.

D. Principal growth stage 5: Inflorescence emergence

Pulasan flowers are grouped in racemes and panicles, situated on axillary or pseudo-terminal stems. Each inflorescence comprises either exclusively male flowers or solely hermaphrodite flowers, which are found on separate trees [4]

The development of reproductive buds and the subsequent emergence of inflorescences took place from late December to late January, following a dry spell. (Fig. 4)

510–Reproductive buds dormant: The inflorescence buds are fully closed and covered with brownish scales.

511–Beginning of the reproductive bud swell: The brownish scales start to separate, making the flower buds visible (Fig. 2).

512–Panicle axes begin to elongate: The panicle axes start to extend, and the folded primary leaves become apparent (Fig. 2).

513–Beginning of panicle development: The primary branches of the panicle become visible (Fig. 2).

515–Inflorescences 50% of final length: The secondary branches of the inflorescence are visible (Fig. 2).

517–Inflorescences 50% of final length: Elongation of the secondary branches is noticeable, and tertiary branches begin to appear.

519–End of inflorescence extension: The tertiary branches are fully developed, the pedicels of individual flowers have elongated, and the flowers are separate and close (Fig. 2).

E. Principal growth stage 6: flowering

Flowering persisted for approximately 30 to 40 days, starting in early January and lasting through February. (Fig. 4)

610–First flowers open: Depending on the tree, either hermaphrodite flowers or male flowers begin to open (Fig. 2).

611–Beginning of flowering: 10% of the flowers in a panicle have opened.

613–Early flowering: 30% of the flowers in a panicle are open.

615–Mid bloom: 50% of the flowers in a panicle are open (Fig. 2).

617–Full flowering: More than 50% of the flowers are open, fading begins, and initial fruit set starts (Fig. 2).

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Vol 11, Issue 8, August 2024

619–End of flowering: 90% of the flowers are open, sepals dry and fall off, and fruit set occurs due to insect cross-pollination (Fig. 2).

F. Principal growth stage 7: fruit development

The number of ovaries could be two, three, or occasionally five, with two ovaries being by far the most frequent structure observed, occurring exclusively in hermaphrodite flowers. In staminate flowers, the anthers open during anthesis, whereas in hermaphrodite flowers, they remain closed. Typically, stamens in hermaphrodite flowers remain attached to the flower until it ripens, usually for about a week, after which they typically drop off. However, in several instances where flowers developed into fruit, the stamens remained attached until the flower reached four weeks of age and had developed into a young fruit. [4]

710–No ovary growth still visible: Spinterns begin to emerge on the fruit (Fig. 2).

711–Initial ovary growth: The first physiological fruit abscission stage begins, with spinterns reaching 20% of their final length (Fig. 2).

712–20% of final fruit size: Ovary growth commences, one carpel aborts while another starts growing (fig. 3)

713–30% of final fruit size: The second physiological fruit abscission stage occurs, and spinterns reach about 50% of their final length (Fig. 2).

715–50% of final fruit size: Aril development begins around the seed, and spinterns reach their full length (Fig. 2)

718–80% of final fruit size: The fruit's skin becomes rough, the aril becomes fleshy and thicker, and color development starts in spinterns from top to bottom.

719–Final fruit size: The fruit reaches its maximum size and aril thickness (Fig. 2).

G. Principal growth stage 8: fruit maturity

The fruiting and harvesting stages mirrored the flowering period, with the time from flowering to fruit maturity spanning approximately 120 to 130 days. The trees were ready for harvest from early June to early July. Pulasan fruits start out green when immature and gradually turn dark red as they ripen.

810–Physiological maturity: The fruit develops a slightly rough skin and reaches the typical size for its cultivar. This stage corresponds with stage 718.

811–Beginning of fruit ripening: The fruit changes color from green to dark red.

815–Advanced ripening: The fruit reaches its characteristic rind and spintern color.

819–Harvest maturity: When fruits are fully ripened, they have a smooth surface, reach their final size, and are ready for consumption and harvest. Figure 3 shows a cross-section of Pulasan fruit depicting its development and maturity. (Fig. 3).

IV. DISCUSSION

The growth stages of Pulasan were described using the BBCH (Biologische Bundesansalt Bundessortenamt und Chemische industrie) scale comprising seven principal stages starting from the vegetative bud development followed by leaf development, shoot development, inflorescence emergence, flowering, fruit development and ending with fruit maturity. Each of these stages also encompasses secondary growth phases specific to pulasan. Flower buds completed development during the reproductive bud stage, with flowering occurring after dry periods, influenced by factors like drought stress, terminal maturity, and tree health. In central Kerala, especially in Kottayam flowering typically spans December to February, with a single observed season. Flowering lasts 30-40 days, and fruit development to maturity takes approximately 130-140 days. This study not only defines but also describes these stages comprehensively using an extended BBCH scale, offering a foundation for future studies on Pulasan's agronomic and ecophysiological aspects, potentially fostering its cultivation expansion.

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