

Article

The Phenological Growth Stages of *Sapindus mukorossi* According to BBCH Scale

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Abstract: *Sapindus mukorossi* is a native tree in southern China that has multiple useful functions, including high landscaping, ecological, esthetic, and economic values. More importantly, its fruits are being rapidly developed as raw materials for bioenergy and saponin production in southern China. To provide a standardized phenological description of the species, this study firstly used the BBCH (Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie) scale. In total, eight principal stages—i.e., bud, leaf and shoot development, inflorescence emergence, flowering, fruit development, fruit maturity, senescence and beginning of dormancy—and 58 secondary stages were described. It ranges from vegetative bud dormancy to the onset of the next beginning of the dormancy, using a two-digit numerical coding system. In addition to the descriptions, we provide photographic images of some major developmental stages to standardize morphological characteristics and the phenological observation of *S. mukorossi*. This study will be an asset for biological researches and cultivation management in *Sapindus*, and will provide valuable information for other fruit trees.

Keywords: *Sapindus mukorossi*; BBCH scale; developmental stages; phenology

1. Introduction

Sapindus mukorossi, a member of the Family Sapindaceae, is a multi-functional species with ecological, environmental, social, and economic benefits. It is widely grown as a native ornamental landscaping species in tropical and subtropical regions worldwide [1,2]. The extended summer flowering period, yellow leaves, and golden fruits that are borne in fall and winter make this species an attractive choice for urban forestry establishment in southern China, where trees with leaf colors other than green are rare. *S. mukorossi* trees planted for greening in urban landscapes have strong carbon sequestration abilities, and they are salt- and alkali-resistant [3,4]. The species is a bodhi tree, according to Chinese Buddhism, and its Chinese vernacular name means “no worries”. Thus, *S. mukorossi* has ecological functional, esthetic, and spiritual attributes that make it attractive to urban dwellers. The trees are planted in courtyards, forest parks, along city streets, and in university campuses, parks, popular tourist areas, and temples [1].

Fruit characteristics of *S. mukorossi* are different to confamilial species longan (*Dimocarpus longan*) and lychee (*Litchi chinensis*); its fruits are inedible but have high values in the bioenergy industry, medicine, and domestic chemistry engineering. The oil content accounts for up to 40% of the total

mass of the kernel. Approximately 98% of the oil is stable medium-chain monounsaturated fatty acid, of which oleic and linoleic acids are the major components (>62.5%) [5–8]. The pericarp is rich in triterpenoid saponins and sesquiterpenoids that are widely used in skin care products, and have been developed as a natural source of surfactants [9–12]. Recent research shows that these saponins have the functional activities of hepatoprotective effects, anticancer proliferation, and killing sperm; they are also used for herbicidal and antioxidant [13–16]. These excellent properties make *S. mukorossi* an attractive candidate for further forest development. The species has been included in a Chinese national forestry biomass energy development project that will apply from 2011 to 2020. Several Chinese provinces (e.g., Fujian, Guizhou, Guangdong, Zhejiang Provinces, China) have planted forests on a large scale as raw material sources, and to facilitate many related enterprises. Programs for genetic analysis and selective improvement of species varieties are currently underway, along with developments in planting techniques, studies of biological characteristics, processing and utilization, and the establishment of a sustainable industrial chain [17–20].

S. mukorossi trees can grow to about 30 m in height. They bloom at 4–5 years after seedlings have been planted. The inflorescence is a large terminal panicle growing in a sequence of 1, 2, 3 side axes on the primary axis. The floret is bisexual; each inflorescence contains small functional male and female flowers, which are light yellow to white—and each has five calyxes, five petals, eight stamens, and an ovary comprising 3–5 carpels. Functional male flowers usually bloom before females, although this sequence is sometimes reversed. The main pollinators are species of bees, flies, and butterflies. Fruits are developed over *ca.* six months between June and November in Fujian Province. Development is arrested in one or two carpels in each flower, and in most cases only a single carpel develops a fruit after fertilization. The fruit is green and smooth; white spots appear on the pericarp surface before maturity. At maturity, the fruit is an almost-round drupe. The pericarp becomes yellow-brown and develops a rough surface texture. During its development and maturation period, the fruit enlarges, the seed coats harden, the fruit discolors and, along with several times of physiological fruit, drops [21,22].

Phenology is the study of plant and animal life cycle events in relation to climate and habitat. Phenological observations have been made since the early period of agricultural development [23]. The need for a uniform standard to describe phenological events has become increasingly apparent over the last 80 years. Many efforts have been made to observe and document plant phenological phenomena. The earliest work was focused on apple bud differentiation, it was divided into three stages and 12 phases [24]. Using these observations, the phenology of the pome was described with capital letters from A to I, each with four phases [25]. Subsequently, the first numeric code for cereals was published and refined during the period 1979–1989 [26,27], and more species have been added by the Federal Biological Research Centre for Agriculture and Forestry (BBA) based on the numerical code of Zadoks. As the concept of codes spreads internationally, a new team devised and published the BBCH scale and the extended BBCH scale for general and specific plants [28,29]. The acronym BBCH is derived from the name of the original stakeholder group: Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie. A monograph describing 27 plant species using the extended BBCH scale was published in four languages (English, German, Spanish, French) [23]. Importantly, the European and Mediterranean Plant Protection Organization (EPPOC), the Global Phenological Monitoring Network, and the European Phenology Network adopted the scale as the standard for species protection and phenological observation [23], thereby promoting its international use.

In recent years, the BBCH scale has been widely used to describe the phenology of many crops, such as cereals, colza, rape, bean, and beet [23]. It has also been extended to woody plants, including the lychee [30], longan [31], sugar apple [32], sweet cherry [33], capuli cherry [34], persimmon tree [35], kiwi berry [36], and jackfruit [37]. Meanwhile, the BBCH scale has also been used to describe the life cycles of birds [38], and has been widely applied in forest cultivation, field management, and basic research—e.g., pest control [39], disease control [40], weed control [41], fertilization [42], and pruning [43].

S. mukorossi is a native tree with multiple useful functions in southern China, which has been given more and more attention by landscape designers, environment managers, and plants growers. The current fragmentary understanding of the biological characteristics of different developmental stages, along with improper cultivation and management planning procedures, leads to inappropriate landscaping and slow industrial development. To sufficiently understand the biological characteristics and standardize the phenological observation, we describe the phenological growth stages of *S. mukorossi* using the BBCH scale and provide a series of significant pictures. This study will benefit to cultivation management in *Sapindus* and provide valuable information for other fruit trees.

2. Materials and Methods

2.1. Experimental Site and Plant Material

The experimental site was in Jianning County, Sanming City, Fujian Province, China (26°66' N, 116°85' E) at an averaged elevation of 300 m, where large-scale raw resource forests and four-side trees (trees planted by the side of houses, roads, rivers, and fields) were planted. The preceding 50 years' worth of climate data [44] (<http://data.cma.cn/site/index.html>) indicate that the site has a subtropical monsoon climate, an average temperature of 17.36 °C, a maximum temperature of 36.82 °C (July), a minimum temperature of −4.26 °C (January), and an average relative humidity of 83.88%.

We collected data from an *S. mukorossi* (10–12 years old) stand with quadrangular (4 × 4 m) tree spacing. The trees were managed by appropriate pruning, fertilization, pest control, weed control, and artificially assisted pollination. We randomly selected eight healthy trees and observed 20 central shoots on each. The shoots were located on all four sides of the tree crown. We observed and recorded significant development stages of shoots, from bud dormancy after fruit harvest to the beginning of the next dormancy, for three annual growing seasons (2015–2018).

2.2. The BBCH Scale

The BBCH scale uses a two-digit numerical code: One digit for the principal growth stage (0–9) and another for the secondary growth stage (0–9). The principal growth stages correspond to the 10 main development stages of plant—i.e., vegetative bud development (0), leaf development (1), formation of side shoots/tillering (2), shoot development (3), development of harvestable vegetative plant parts or vegetatively propagated organs/booting (4), inflorescence emergence (5), flowering (6), development of fruit (7), maturity of fruit (8), and senescence and beginning of dormancy (9). The secondary growth stages represent the percentage of growth accounted for, or duration of, each principal growth stage. If some species that have more than one flush in one life cycle, these special development stages can be represented by mesostage (0–9) between principle and secondary stages to yield a three-digit code; 0 and 1 were used to describe the growth and development of the trunk, and 2–9 to describe the development of side shoots.

The codes can be compared, and higher code numbers denote greater progression within the same principal stage. Simultaneously developing stages can be separated by a solidus—e.g., leaf development and shoot development (13/33). Coding for forest stands always includes a hyphen between the latest and earliest stages—e.g., 56–63 [23].

3. Results

We used observations and recordings of the phenological stages of *S. mukorossi* to determine when and how the vegetative and reproductive organs grew and developed over the life cycle (Figure 1). Eight principal stages were used to describe the phenology of *S. mukorossi* (Table 1). Stage 2 (formation of side shoots or tillering) and stage 4 (development of harvestable vegetative plant parts or vegetative propagated organs/booting) were inappropriate for this plant's morphology. We incorporated only the first flush in the two-digit coding system, because a second vegetation flush is rare in adult trees.

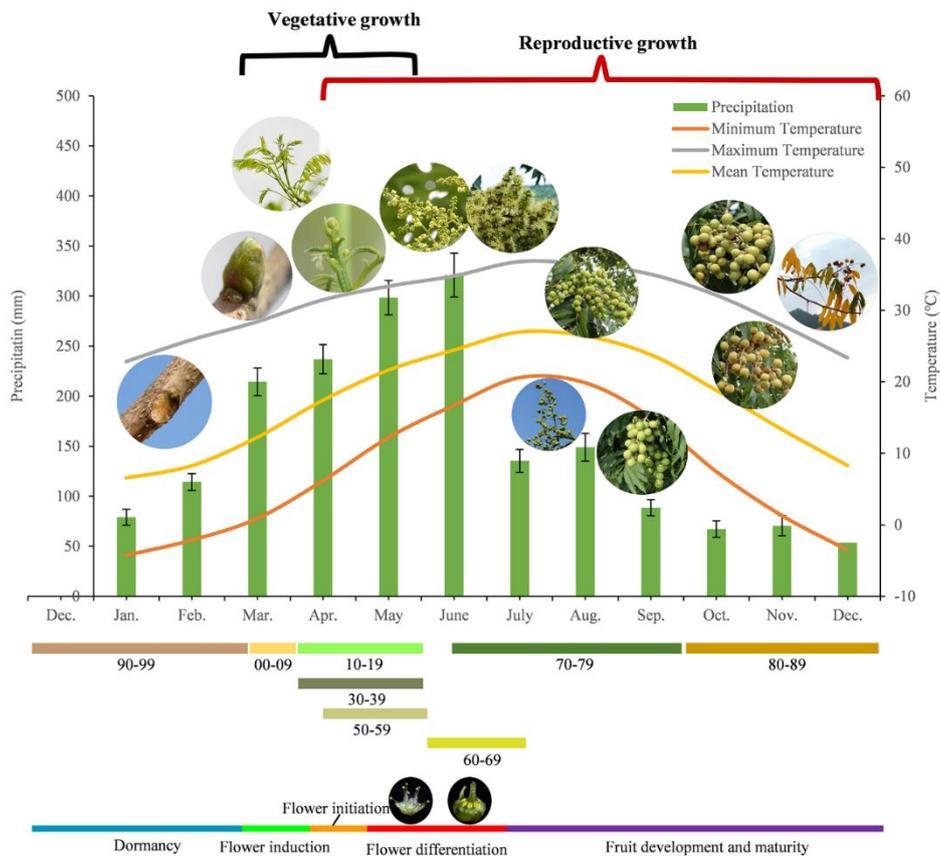


Figure 1. Main phenological growth stages of *S. mukorossi* according to the BBCH scale. Time elapsed in each stage (horizontal bars), 50 years’ average data of precipitation and mean, maximum, and minimum temperatures.

Table 1. Phenological growth stages of *S. mukorossi* according to the BBCH scale.

BBCH Code	Description
Principal growth stage 0: Bud development	
00	Bud dormancy
01	Beginning of bud swelling
03	End of bud swelling
05	First green bud scale visible
07	Beginning of bud burst
09	End of bud burst
Principal growth stage 1: Leaf development	
10	First compound leaves separate
11	First leaves unfold and petiole elongate
12	More leaves unfold: First compound leaves at 20% of their final area
13	More leaves unfold: First compound leaves at 30% of their final area
14	More leaves unfold: First compound leaves at 40% of their final area
16	More leaves unfold: First compound leaves at 60% of their final area
19	All leaves unfold and petiole elongates to final size
Principal growth stage 3: Shoot development	
30	Beginning of shoot elongation: Shoot axis visible
31	10% of final shoot length
32	20% of final shoot length
33	30% of final shoot length
34	40% of final shoot length

Table 1. Cont.

35	50% of final shoot length
36	60% of final shoot length
38	80% of final shoot length
39	90% or more of final shoot length
Principal growth stage 5: Inflorescence emergence	
50	Beginning of reproductive bud swelling
51	End of bud swelling and bud burst
52	Primary axis elongation
53	First side axes elongate about 30% of their final length
54	First side axes elongate about 40% of their final length
56	First side axes elongate about 60% of their final length
57	First side axes elongate about 70% of their final length
58	First side axes elongate about 80% of their final length
59	First side axes elongate about 90% or more of their final length
Principal growth stage 6: Flowering	
60	First flowers bloom
61	Beginning of flowering
63	Early flowering: 30% of flowers bloom
65	Full flowering
69	End of flowering
Principal growth stage 7: Fruit development	
70	No ovary development
71	Early ovary growing
72	20% of the biggest fruit size
75	50% of the biggest fruit size
76	60% of the biggest fruit size
77	70% of the biggest fruit size; the second physiological fruit drop occurs
78	80% of the biggest fruit size
79	90% of the biggest fruit size
Principal growth stage 8: Maturity of fruit and seed	
81	Beginning of maturity
82	Pericarp becomes wrinkled
85	Pericarp turns a little golden yellow and transparent
87	Advanced maturity
89	Fruits are fully developed and mature
Principal growth stage 9: Senescence and beginning of dormancy	
90	Shoots and leaves stop development
91	Beginning of leaf discoloration
92	Leaves begin to fall
93	Most leaves turn yellow: 30% leaves fall
94	40% leaves fall
95	50% leaves fall
97	All leaves fall
99	Dormancy

3.1. Principal Growth Stage 0: Bud Development

The buds remained dormant until late February in the observed site, and they expanded in a short time to middle March (Figure 1). Besides, floral induction simultaneously happened in this period.

00. Bud dormancy: Bud is flat, closed, and covered by brown scales above surface (Figure 2).

01. Beginning of bud swelling: Bud begins to swell in mid to late February, about two months after harvest; the main bud is a little higher than the bud scales on both sides.

03. End of bud swelling: Bud swells and reaches the final size; the brown bud scales separate and small tips of greenish-yellow villous bud scales are visible.

05. First green bud scales visible: Brown bud scales are completely separated and parts of greenish-yellow villous bud scales are visible (Figure 2).

07. Beginning of bud burst: Buds continue to elongate, greenish-yellow villous bud scales are fully exposed, and the outermost bud scales divide (Figure 2).

09. End of bud burst: The buds reach the final length and stop elongating. All the bud scales are opened, and 5 mm of leaf tip can be seen among the bud scales (Figure 2).

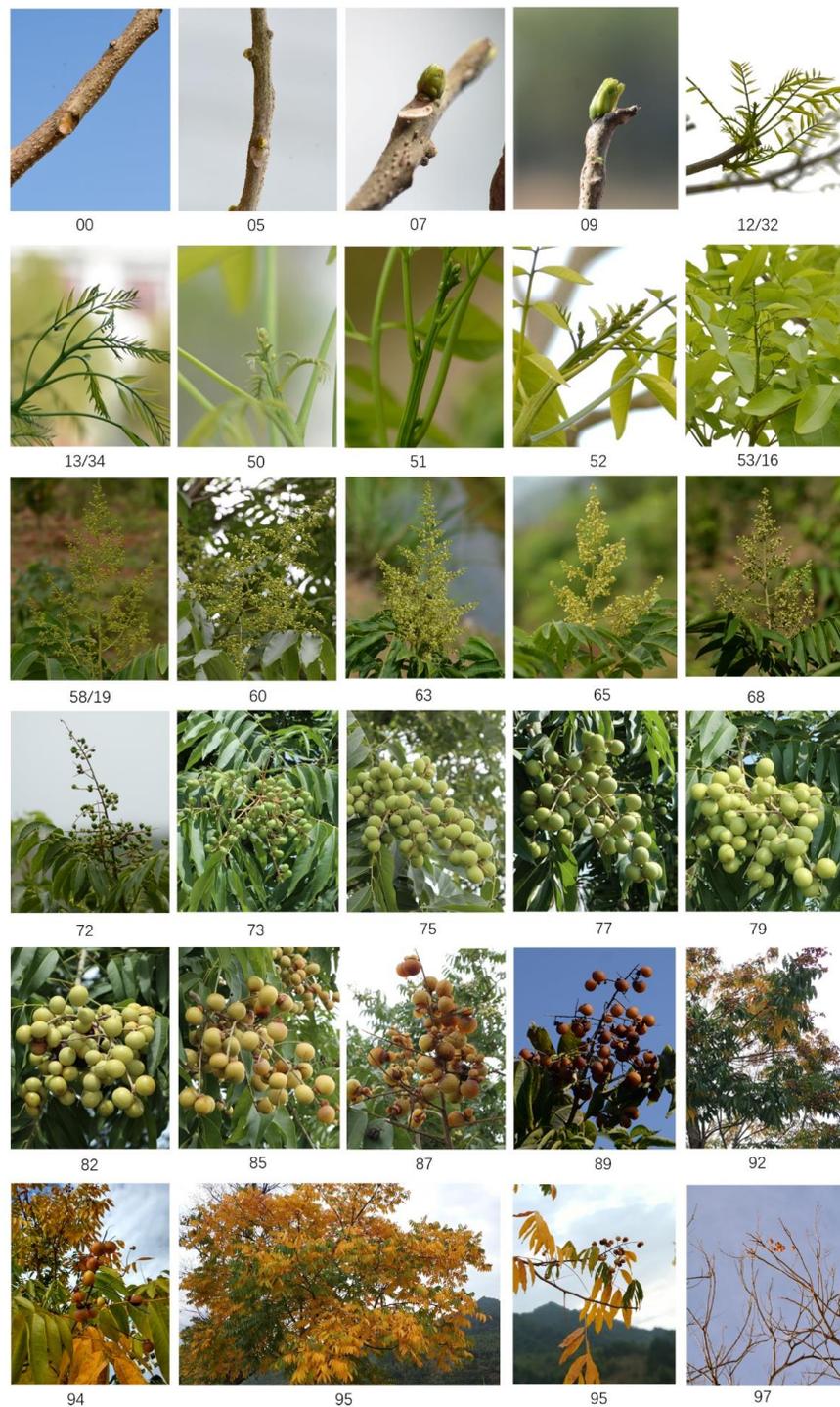


Figure 2. Phenological growth stages of *S. mukorossi* according to the BBCH scale.

3.2. Principal Growth Stage 1: Leaf Development

Leaf growth and development spend about two months from early March to May (Figure 1). Leaves stop developing before blooming.

10. First compound leaves separate: Green leaf cluster is 5 mm higher than bud scales, first compound leaves separate from the principal axis, leaflets on the first compound leaf are folded.

11. First leaves unfold and petiole elongates: Leaflets on the first compound leaves unfold and petiole elongates about 10% of final length.

12. More leaves unfold: More compound leaves separate from the principal axis and the leaflets are unfolded; leaflets of first compound leaves are at 20% of their final area (Figure 2).

13. More leaves unfold: Most (90%) compound leaves separate from the principal axis and leaflets continue to unfold; leaflets of first compound leaves are 30% of their final area (Figure 2).

14. More leaves unfold: All compound leaves separate from the principal axis and more leaves are unfolded; leaflets of first compound leaves are 40% in their final area.

16. More leaves unfold: Leaflets of first leaves grow to 60% of final area. Leaflets and petioles become hardened.

19. All leaves unfold and petiole elongates to their final size: The color of leaflets turns from light green to dark green and become thick (Figure 2).

3.3. Principal Growth Stage 3: Shoot Development

Shoot and leaf development occur simultaneously. Shoots stop growing when the inflorescence is completely developed (Figure 1).

30. Beginning of shoot elongation: Shoot axis is visible and starts to develop when the first compound leaves separate. This stage simultaneously occurs with 10.

31. 10% of final shoot length: The shoots elongate and become thick; some small white spots are visible on the surface.

32. 20% of final shoot length: The shoots elongate and grow thicker. This stage simultaneously occurs with 11 (Figure 2).

33. 30% of final shoot length: The shoots continue to elongate and grow thicker.

34. 40% of final shoot length: The shoots elongate and grow thicker. This stage simultaneously occurs with 13 (Figure 2).

35. 50% of final shoot length: The shoots elongate and grow thicker. This stage simultaneously occurs with 14.

36. 60% of final shoot length: The shoots continue to elongate and grow thicker. This stage simultaneously occurs with 15.

38. 80% of final shoot length: The shoots continue to elongate and grow thicker. This stage simultaneously occurs with 16.

39. 90% or more of final shoot length: The shoots are thickened, hardened, and have completed development. The white spots are densely covered on the surface and the shoots are gray-green. This stage simultaneously occurs with 17.

Sometimes a few trees have one more flush; the first side shoots grow during summer at the end of June (320–329), and the second shoots develop from the end of August to September (330–339). The side shoots are usually shorter and thinner than the first developed shoots, and appear to bear no flowers or fruits. These phenomena and development periods resemble those of lychee in southern China and longan in Spain [30,31].

3.4. Principal Growth Stage 5: Inflorescence Emergence

During the period of shoot elongation, inflorescences emerge and develop in parallel with the growth of leaves from late March to mid-May (Figure 1).

50. Beginning of reproductive bud swelling: Reproductive buds appear in the axils of first 2–4 compound leaves and swell like “yellow dots” (Figure 2).

51. End of bud swelling and bud burst: Bud reaches full size; the bud bracteoles separate and gradually turn to light green (Figure 2).

52. Primary axis elongation: Bud axes elongate to 20% of final length and develop to primary axis of the inflorescence (Figure 2).

53. First side axes elongate about 30% of their final length: Secondary side axes appear on the first side axes. Some first side axes constantly appear at the top of inflorescences; stipules of first side axes are unfolded and develop into complete compound leaves or turn yellow and fall off (Figure 2).

54. First side axes elongate about 40% of their final length: Secondary side axes continually extend and tertiary axes are visible.

56. First side axes elongate about 60% of their final length: Secondary and tertiary side axes continuously develop; floret buds become visible and start to develop.

57. First side axes elongate about 70% of their final length: Secondary and tertiary side axes continuously develop; first developed floret buds continue to expand and green sepals separate.

58. First primary side axes elongate about 80% of their final length: First side axes develop more closely to the final length. First developed floret buds expand and expose a little part of white or faint yellow petals; the gender of florets can be distinguished by naked-eye (Figure 2).

59. End of all three axes elongation: The inflorescences develop and reach their final size; first developed florets reach their largest size. This stage simultaneously occurs with 19.

3.5. Principal Growth Stage 6: Flowering

The flowering stage starts in early or mid-May (Figure 1), with year to year variations. It lasts an average of 34 days for plantation, and 21 days for individual trees in three years. During the flowering process, some small floret buds may also form at the top of each side axis of the inflorescence and at the base of each floret group.

60. First flowers bloom: A few functional male or female flowers bloom (Figure 2).

61. Beginning of flowering: 10% of flowers open, functional male flowers fall off after flowering.

63. Early flowering: 30% of flowers open, petals and sepals of functional female flowers fall off after blooming, while ovaries turn dark green and start to expand (Figure 2).

65. Full flowering: More than 50% of flowers have opened. Most trees show two types of flowers, and some trees show only male flowers. This stage is the best time to admire the beauty of flowers, bees, butterflies, and other flower-visiting insects on the inflorescences (Figures 2 and 3).

69. End of flowering: 90% or more of flowers have opened. All the opened functional female flowers have set fruits, but all the opened functional male flowers fall off except for a few flowering florets.

3.6. Principal Growth Stage 7: Fruit Development

The fruit development only relates to female flowers for the abortion of opened functional male flowers. This stage starts from early June to mid-September in the observed site (Figure 1).

70. No ovary development: This stage occurs during the flowering time for functionally female flowers, in which petals and sepals do not fade and green ovaries have three plump carpels.

71. Early ovary development: The ovary turns dark green, petals and sepals around it wither and fall off after fertilization. Fruits expand to about 10% of final size and the first fruit drop occurs.

72. 20% of the biggest fruit size: Only 1–2 carpels continually expand, and the others grow slowly or stop developing. Some white spots appear on the surface of the pericarp (Figure 2).

73. 30% of the biggest fruit size: The fruit continually expands and only one carpel develops normally for most of fruits (Figure 2).

75. 50% of the biggest fruit size: Fruits continue to develop and become spherical in shape; white spots are still visible on the smooth pericarp surface (Figure 2).

77. 70% of the biggest fruit size: The fruits continually expand, but the speed is slowing down due to the fruits coming into the core-hardening period. Testa turns from green to yellowish-green and hardens. The second physiological fruit drop begins (Figure 2).

78. 80% of the biggest fruit size: The fruits and seeds grow slowly, testa becomes black and harder.

79. 90% of the biggest fruit size: The green fruits are big enough and smooth on the surface, the third physiological fruit drop begins (Figures 2 and 3).



Figure 3. Ornamental and ecological value of different phenological stages in *S. mukorossi*. (A)–(B) Blooming functional male flowers on large yellow panicle inflorescences; (C)–(D) Bee and butterfly pollination; (E)–(H) Developing fruits and golden yellow fruits in the mature stage; (I)–(K) Landscaping with *S. mukorossi* along roadsides in summer and fall in southern China; (L)–(O) *S. mukorossi* trees in stone forest and parkland of Stone-Forest Scenic Spot in Yunnan Province; (P)–(R) Fully turned yellow leaves of *S. mukorossi* in the courtyard of the Guangxi Eco-engineering Vocational and Technical College, Temple of Marquis Wu and Yuanhua Forestry Biotechnology Co., Ltd.

3.7. Principal Growth Stage 8: Maturity of Fruit and Seed

Maturity of fruit and seed takes place from late September to late December, with little difference among trees and locations (Figure 1). This stage is the best viewing time of this species for golden fruits and leaves (Figure 2).

81. Beginning of maturity: Fruits keep plump, pericarps turn yellow.

82. Pericarp becomes wrinkled: Pericarps start to become wrinkled and yellow, which results in the fruits becoming smaller than before (Figure 2).

85. Great change in pericarp: The pericarp turns a little golden yellow and becomes transparent with luster, showing the black seeds inside (Figure 2).

87. Advanced maturity: Fruits become more mature; pericarps turn more golden-yellow and are more wrinkled and transparent, the kernels become light yellow without too much moisture (Figure 2).

89. Fully developed and mature: Pericarps turn tawny, more wrinkled, and harder; kernels are light yellow to creamy. The fruits are mature for harvesting (Figure 2).

3.8. Principal Growth Stage 9: Senescence and Beginning of the Dormancy

Senescence and the beginning of the dormancy synchronously happen with process of fruit maturity or after harvest, with little difference among trees and locations. This stage is the most beautiful period for the trees for their golden leaves (Figure 3).

90. Shoots and leaves stop development: Shoots stop growing and the color of leaves remain dark green.

91. Beginning of leaf discoloration: A few leaves irregularly turn yellow on different sites of the crown (Figure 2).

92. Leaves begin to fall: More leaves turn yellow and some leaves begin to fall (Figure 2).

93. 30% leaves fall: Most leaves turn yellow.

94. 40% leaves fall: Most leaves turn yellow and some mature fruits start to fall.

95. 50% leaves fall (Figure 2).

97. All leaves fall, only very few fruits remain on the crown (Figure 2).

99. Dormancy: The trees completely enter into dormant period.

4. Discussion

As reported for other deciduous species [32–36,45,46], the one-year life cycle of *S. mukorossi* spanned eight major stages: bud development, leaf development, shoot development, inflorescence emergence, flowering, fruit development, maturity of fruit and seed, and senescence and beginning of dormancy. In addition, we described a total of 58 secondary developmental stages.

Vegetative growth spanned three principal stages at our location in southern China: bud (00–09), leaf (10–19) and shoot (31–39) development. The growth cycle of *S. mukorossi* differed from those of loquat and lychee trees in southern China; these latter species have a period of dormancy in winter after completing the growth of shoot and then start the reproductive period in the spring of next year. Vegetative growth of *S. mukorossi* extended from late February to late May, about three months after three months' dormancy in winter, having some differences among years and sites with different meteorological conditions. For example, in the same observed site in Fujian province, the buds began to swell in mid-February in 2013, in early March in 2014, and late February in 2018 [21]. A single flush of vegetative growth occurred in most trees. One to three flushes of vegetative growth occurred frequently in young trees, adult trees without blooming, or the trees with few fruits for physiological fruit drop.

The reproductive stage began with the emergence of the panicle. The first morphological features of flower initiation were small "yellow dots" that appeared at the axils of the leaf (51); these closely resembled the "whitish millet" of lychee (53). In lychee trees, shoots and leaves fully develop in the autumn and the "whitish millet" appear in spring, after a period of dormancy, for southern

China. While “yellow dots” appeared during the growth process of shoots and leaves in spring of *S. mukorossi*. This distinction may be related to the shedding of flowers and small fruits due to inadequate carbohydrate accumulation in *S. mukorossi*. Flower induction, flower initiation, floral organ development, and the blooming period were markedly influenced by temperature. Thus, trees at our site bloomed from May 22 to mid-June in 2017 (26 days), but for only 17 days in 2018 from mid-May to the beginning of June. This significant reduction in the blooming period during 2018 was related to a decline in temperature to near 0 °C on March 10 during flower induction.

Like longan and lychee, *S. mukorossi* had far more functional male than female flowers, and the two types of flowers bloomed at different times [30,31]. While it varies in the confamiliar member *Xanthoceras sorbifolia*, in which male and female flowers bloom synchronously on the same shoot. Besides, the sex ratio of female to male for *X. sorbifolia* is higher than *S. mukorossi* [47]. The sex ratio imbalance increases the probability of inefficient pollination and low harvest yields in these species.

The anatomy, cytology [48], microRNAs [49], physiological phytohormones and nutrients [50], temperature and humidity [31], and other factors influencing flower induction and floral differentiation have been investigated in lychee, longan, and *X. sorbifolia* over many years. Studies have also examined the regulation of the flowering period and the gender ratio in these resembled species, via exogenous hormone spraying and potassium chlorate (KClO₃) application [51–53]. The heavy fruit drops, cracking, and decay which occur during the fruit development (70–79) and maturation (80–89) periods of *S. mukorossi* are also close to lychee and longan. Physiological, biochemical, and molecular approaches have been used to investigate the causes of these phenomena in longan and lychee [53–57]. In comparison, *S. mukorossi* has been little studied in these fields. In further research, projects about inflorescence development, bisexual flower development and differentiation, fruit development, synthesis of aliphatic acid, and saponin for pericarp should be paid more attention to guide the cultivation of high efficiency raw material forests.

5. Conclusions

This study gave a unified standard for describing the phenology of *S. mukorossi*. In contrast to other procedures [21,22], application of the extended BBCH scale allowed for more accurate and scientific description of the morphological characteristics of *S. mukorossi* in different developmental stages. More importantly, this description is widely applicable to *S. mukorossi* plants located in diverse sites and climatic conditions. This study described the first application of a numerical coding system to *S. mukorossi*; it should prove useful for scientific investigators and technical operators, and may facilitate convenient communication between researchers of *S. mukorossi* located in different parts of the world. The scale is easy to understand and has potential applicability to scientific research, tree collection and cultivation management of urban forests. In addition, the scale could also be applied to the areas of pest/disease control, fertilization, pruning, artificial supplementary pollination, and harvesting, thereby advancing the cultivation of raw material forests and producing higher multi-functionalities of ecological, landscaping, esthetic, spiritual, and economic benefit.

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