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Phenological stages of native Myrtaceae species based on the BBCH scale

Estágios fenológicos de espécies nativas de Myrtaceae com base na escala BBCH

Etapas fenológicas de especies nativas de Myrtaceae según la escala BBCH

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Abstract

The aim of this study was to characterize the development of flowers and fruits in native species of the family Myrtaceae based on the BBCH scale in search for unique and unpublished information about the Brazilian flora. The study was conducted in the Native Fruit Collection of the Federal Technological University of Parana, Campus Dois Vizinhos. We carried out photographic monitoring of eight species of the family Myrtaceae: pitanga tree, araçá-amarelo tree, cereja-da-mata tree, jabuticaba tree, ubajaí tree, guabiju tree, guabiroba tree, and sete-capote tree. The phenological stages follow the general BBCH scale for fruit species, in which the complete cycle of plant development is subdivided into 10 main phases. This study is the first to describe the phenological stages of these species according to the BBCH scale, which facilitates verification of all phases of different vegetative and reproductive stages of the investigated species. Such scales may serve as important and useful tools for appropriate management of orchards, and thereby improved fruit cultivation.

Keywords: *Eugenia uniflora* L; *Psidium cattleianum; Plinia cauliflora; E. myrcianthes; Myrcianthes pungens.*

Resumo

O objetivo deste trabalho foi caracterizar o desenvolvimento de flores e frutos de espécies nativas da família Myrtaceae na escala BBCH, na busca por informações únicas e inéditas sobre a flora brasileira. O trabalho foi desenvolvido na Coleção de Frutas Nativas da Universidade Tecnológica Federal do Paraná, Campus Dois Vizinhos, realizando o monitoramento fotográfico de oito espécies da família Myrtaceae, pitanga, araçá-árvore-árvore, cereja-da-mata, jabuticabeira, ubajaí, guabiju, guabiroba e sete-capote. Os estágios fenológicos seguem a escala geral BBCH para espécies de frutos, em que o ciclo completo de desenvolvimento das plantas foi subdividido em dez fases principais. Os estágios fenológicos dessas espécies foram descritos pela primeira vez no presente estudo de acordo com a escala BBCH, permitindo verificar todas as fases dos diferentes estágios vegetativo e reprodutivo de cada espécie. Tais escalas podem servir como uma ferramenta importante e útil para o manejo correto do pomar, pois servem como parâmetros que auxiliam o fruticultor.

Palavras chave: *Eugenia uniflora* L; *Psidium cattleianum; Plinia cauliflora; E. myrcianthes*; *Myrcianthes pungens.*

Resumen

El objetivo de este trabajo fue caracterizar el Desarrollo de flores y frutos de especies nativas de la familia Myrtaceae en la escala BBCH, en la búsqueda de información única e inédita sobre la flora brasileña. El trabajo se desarrolló en la Colección de Frutos Nativos de la Universidad Tecnológica Federal de Paraná, Campus Dois Vizinhos, realizando el seguimiento fotográfico de ocho especies de la familia Myrtaceae, pitanga, araçá-tree, cherry, jabuticabeira, ubajaí, guabiju , guabiroba y siete mantos. Las etapas fenológicas siguen la escala general BBCH para especies frutales, en la que el ciclo completo de desarrollo de la planta se ha subdividido en diez fases principales. Los estadios fenológicos de estas especies fueron descritos por primera vez en el presente estudio según la escala BBCH, permitiendo verificar todas las fases de los diferentes estadios vegetativos y reproductivos de cada especie. Tales balanzas pueden servir como una herramienta importante y útil para el correcto manejo del huerto, ya que sirven como parámetros que ayudan al fruticultor.

Palabras clave: *Eugenia uniflora* L; *Psidium cattleianum*; *Plinia cauliflora*; *E. myrcianthes*; *Myrcianthes pungens*.

1. Introduction

Brazil stands out as one of the main centers of genetic diversity of wild fruit trees in the world. However, little is known about the vast majority of these species. Native fruit species of the Myrtaceae family are most popular because of their technological potential. They are often found in commercial and domestic orchards and occupy a prominent place in natural ecosystems (Simarelli, 2007), which increases research interest as well as nutritional value and fruit quality, thereby promoting the research and industrialization sector.

All Brazilian species of the Myrtaceae family belong to the tribe Myrteae, which includes species that produce fleshy fruits. This family of woody plants is representative of the vegetation formations of Brazil, especially in the Atlantic Forests (Landrum & Kawasaki 1997). However, few studies have been carried out on native fruits of the Myrtaceae family, even though research, particularly of their phenology, is essential for domesticating these species.

According to Biondi et al. (2007), phenology investigates different phenophases (flowering, fruiting, falling, and sprouting of leaves) on a temporal scale on which it defines the vegetative and reproductive patterns of species. The description of stages of plant growth and development, including monocotyledons, dicotyledons, gramineous plant, and perennials,

has always been a matter of research interest (Morais et al., 2008). Currently, the knowledge of plant phenology aids planning the appropriate times for the re-implementation of agronomic practices, such as fertilizer application and control of pests, diseases, and weeds (Arcila et al., 1998), as well as estimation of harvest seasons, forecast maturation season, and use in breeding programs (Pezzopane et al., 2003).

In addition, phenological studies are necessary to understand the dynamics of ecosystems and plant reproduction as they provide the knowledge about the time of the year when certain plant resources are available to local fauna (Morelatto et al., 2000). However, these characteristics directly influence the gene flow of plants, which is determined by the behavior of floral visitors and evolution of reproductive strategies (Jardim & Kageyama, 1994). This is fundamental for understanding reproductive biology of plants, and it as the basis for studying breeding programs as well as different strategies for the recovery, conservation, and management of degraded or native forests (Danner et al., 2010; Kuaraksa et al., 2011; Maués & Couturier, 2002; Singhal et al., 2011).

Phenological studies are broadly applicable in agronomic practices, as they can be used for the determination of ecoclimatic requirements in agricultural zoning and crop management (Bergamaschi, 2007).

Until the early 1990s, there was no uniform system for describing the stages of development of the most commonly cultivated plants. Previously, these stages were described using a combination of letters and numbers (Fleckinger, 1948). The first decimal code used for attempting to normalize the description of homologous developmental stages of different species was published by Zadoks et al., (1974) using the same codes. This system was further developed into the BBCH scale (Biologische Bundesantalt, Bundessortenamtund Chemische Industrie) proposed by Bleiholder et al., (1989), and the extension of this scale was proposed by Hack et al., (1992). Since then, the BBCH scale became widely accepted for use in numerous species, but no such scale yet exists for application in fruit trees native to, including species belonging to the family Myrtaceae.

The BBCH scale is a system for uniform coding used for phenological identification of the growth phases of all mono- and dicotyledonous plant species (Hack et al., 1992). In the last decades, this scale has been used as a decimal coding system for herbaceous and woody crops (Bleiholder et al., 1989; Lancashire et al., 1991; Hack et al., 1992), and it has been used to characterize all stages of plant development in a wide range of crops, including the genus *Prunus* (Meier 2001). Over the last ten years, the application of the BBCH scale has been extended to fruit trees, such as the caqui tree (García-Carbonell et al., 2002), cherimoya tree

(Cautín & Agustí 2005), goiaba tree (Salazar et al., 2006), kiwi trees (Salinero et al., 2009), manga trees (Hernández Delgado et al., 2011), abacate tree (Alcaraz et al., 2013), pessego tree (Mounzer et al., 2008), and damasco tree (Perez-Pastor et al., 2004). The aim of this study was to characterize the development of flowers and fruits in native species of the family Myrtaceae using the BBCH scale with the goal of providing unique and unpublished information about the Brazilian flora.

2. Methodology

The study was conducted in the Native Fruit Collection of the Universidade Tecnológica Federal do Paraná, Campus Dois Vizinhos. According to Köppen classification, the climate of the area belongs to the mesothermic subtropical humid type (Cfa) with hot summers and no defined dry season. The average temperature of the coldest month is below 18 °C, and that of the hottest month is above 22 °C. The occurrence of frost is frequent, relative air humidity varies between 64% and 74% on average, and rainfall varies between 1,800 and 2,200 mm throughout the year (Maack, 1981).

We studied eight species of Myrtaceae family: *Eugenia uniflora* L. (pitanga tree), *Psidium cattleianum* Afzel. ex Sabine (araçá-amarelo tree), *Eugenia involucrata* DC. (cereja-da-mata tree), *Plinia cauliflora* (DC. Berg) (jabutica tree), *E. myrcianthes* (Nied.) (guabijú tree), *Myrcianthes pungens* (O. Berg.) D. Legrand (guabiju tree), *C. xanthocarpa* (O. Berg.) (guabiroba tree), and *C. guazumifolia* (Cambess.) O. Berg. (sete-capture tree).

Observations of phenophases (flowering and fruiting) were carried out weekly or daily when necessary. In each species, we observed two matrices, and in each matrix, ten branches were marked in alternating points of the crown (basal, median, and apical). The branches were marked and identified with aluminum plates fixed with a string. Through the observations of each phase, a phenological scale was developed, and morphological changes were identified.

The phenological stages followed the general BBCH scale for fruit species, in which the complete cycle of plant development was subdivided into 10 main phases (Hess et al., 1997) (Table 1), which are described using numbers from 0 to 9 (Hack et al., 1992). We characterized the main phenological phases, occurring between the events.

Table 1. Main stages of growth.

Stage	Description
0	Germination/budding
1	Development of the leaf (main stem)
2	Formation of lateral stalks / tillering
3	Elongation of the branches or growth of the leaf rosette / development of the stem (main stem)
4	Vegetative propagation / "adorning" (main stem)
5	Emergence of inflorescence (main stem) / flowering
6	Florescence
7	Development of fruit
8	Fruit or seed maturation
9	Senescence, onset of dormancy

Source: Hess et al. (1997).

3. Results and Discussion

In this study, we identified different phenological stages, such as sprouting, foliar development, flowering and inflorescence development, and fruit growth and maturation. The following ranges included species: *E. uniflora* (Fig. 1), *P. cattleianum* (Fig. 2), *E. involucrata* (Fig. 3), *P. cauliflora* (Fig. 4), *E. myrcianthes* (Fig. 5), *M. pungens* (Fig. 6), *C. xanthocarpa* (Fig. 7), and *C. guazumifolia* (Fig. 8).

The steps identified in the investigated species are described in Table 2.

Table 2. Phenological stages found for native fruit trees according to the general BBCH scale.

Main stage 0: Bud development
0.0 - The buds are in winter numbness or resting period;
0.1 - The buds are at the beginning of their development, latent;
0.2 - The buds begin to swell;
0.3 - The swelling of the buds ends;
0.7 - The buds begins to open or sprout;
0.9 - The buds start to show green edges.
Main stage 1: Leaf development
10 - The first leaves separate from the shoots;
11 - Development of the first leaf or pair of true leaves;
12 - Development of the second leaf or pair of true leaves;
13 - Development of the third leaf or pair of true leaves;
14 - Development of the fourth leaf or pair of true leaves;
... The stages continue until....
19 - Development of nine or more leaves or a pair of true leaves.
Main stage 3: Stem elongation and bud development
32 - The stem reaches 20% of its length or final diameter;
33 - The stem reaches 30% of its length or final diameter;
35 - The bud reaches approximately 50% of its length and final diameter;
... The stages continue until...
39 - The stem reaches the maximum of its final length or diameter.
Main Stage 5: Development of the floral organ
51 - Visible flower buds;
52 - Flower buds visible;

55 - First individual flower buds visible (without opening);

56 - The petals grow, and the sepals cover about half of the corolla;

59 - First visible petals.

Main stage 6: Flowering

60 - Flowers open;

61 - Beginning of flowering: approximately 10% of the flowers are open;

62 - 20% of the flowers are open;

63 - 30% of the flowers are open;

64 - 40% of the flowers are open;

65 - Full bloom: 50% of the flowers are open / first petals dry and fall off;

67 - Flowering reaches the end / most petals and anthers have fallen off;

68 - All petals and anthers have fallen off;

69. End of flowering, fruit visible.

Stage 7: Fruit formation

70 - First fruits visible;

72 - 20% of the fruits reach the specific size of the species or 20% of their final size;

75 - 50% of the fruits reach the specific size of the species or 50% of their final size;

76 - 60% of the fruits reach the specific size of the species or 60% of their final size;

78 - 80% of the fruits reach the specific size of the species or 80% of their final size;

79 - The fruits reach the average size of the species.

Stage 8: Fruit ripening

81 - Beginning of fruit maturation or coloring;

85 - Continuation of fruit coloring;

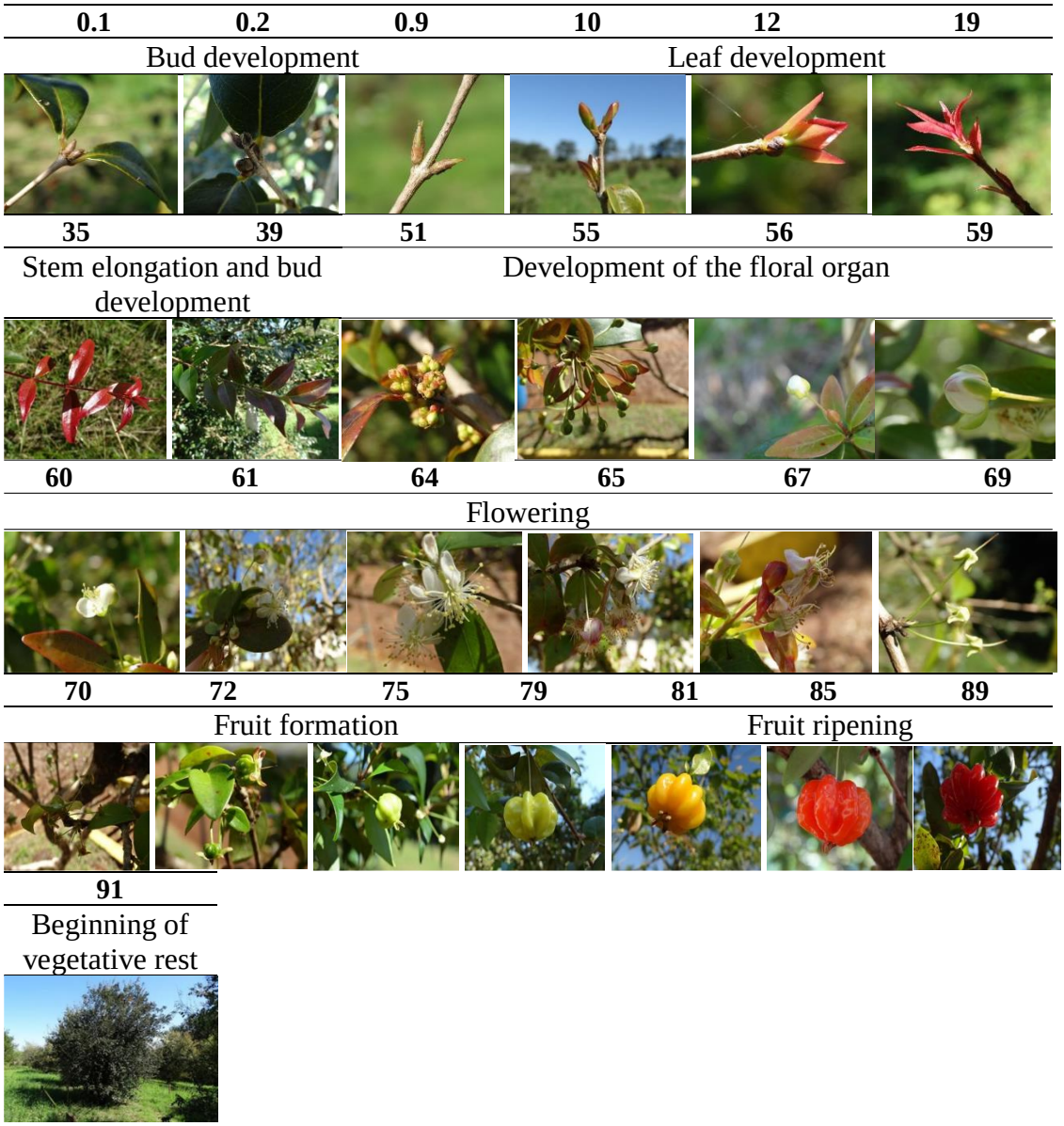
89 - Full maturation. Cessation of the typical fruit coloration. The fruits fall easily.

Stage 9: Beginning of vegetative rest

91 - Sprouts have completed their development and leaves acquire their full green coloration.

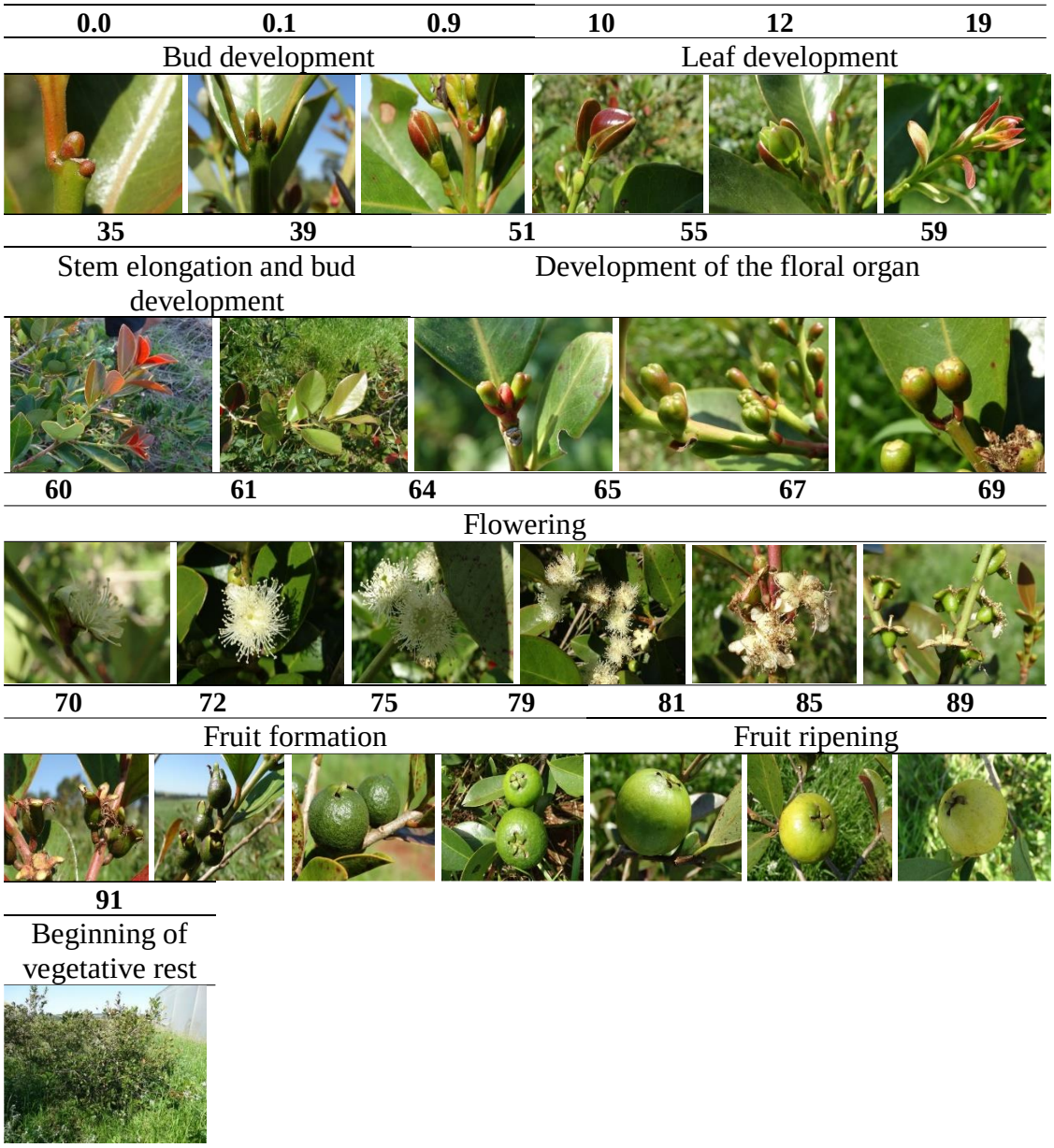
Source: Authors.

Figure 1. Phenological stages of the *Eugenia uniflora* L. using the nomenclature for fruit species according to the general BBCH scale.



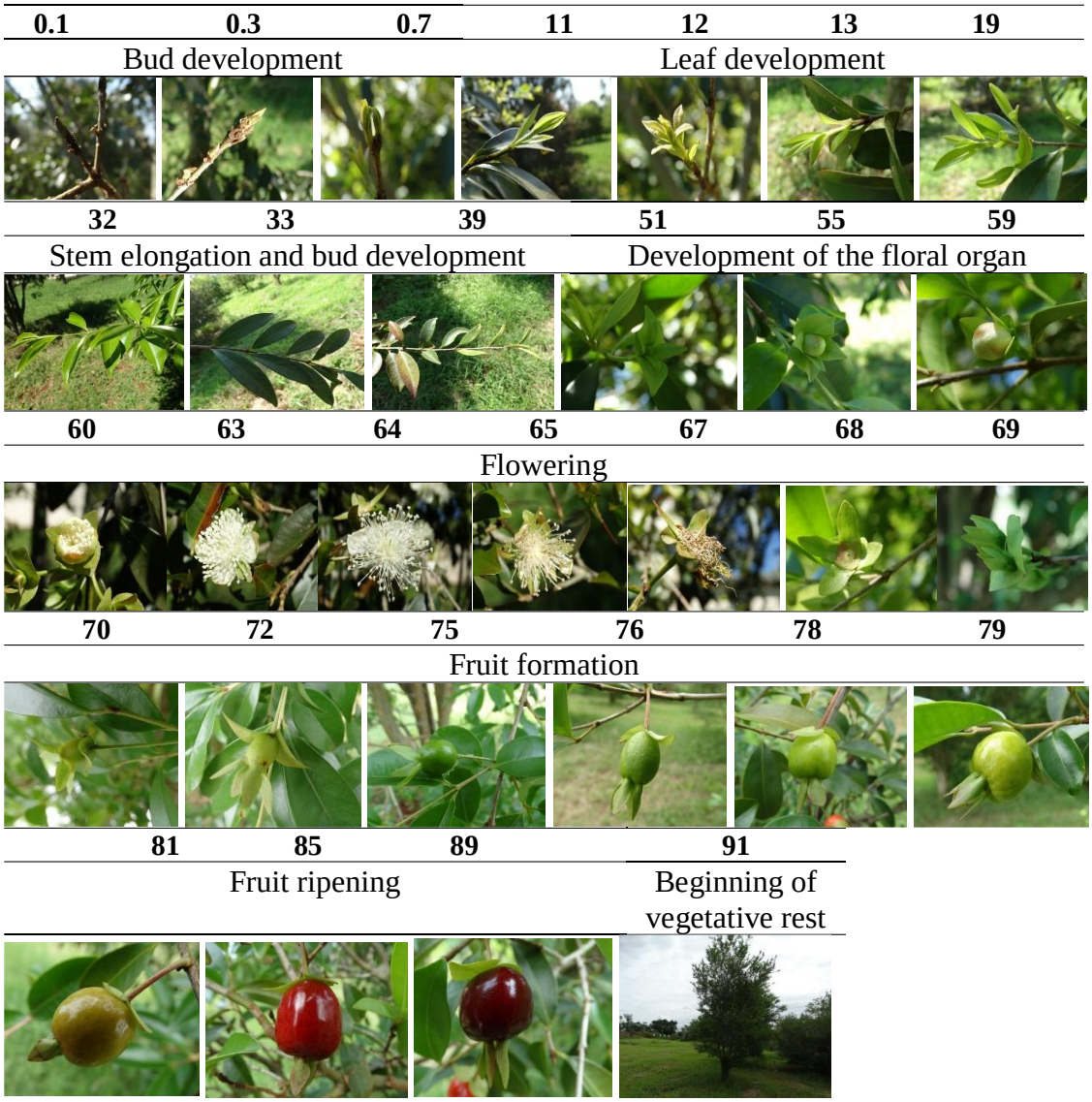
Source: Authors.

Figure 2. Phenological stages of the *Psidium cattleyanum* using the nomenclature for fruit species according to the general BBCH scale.



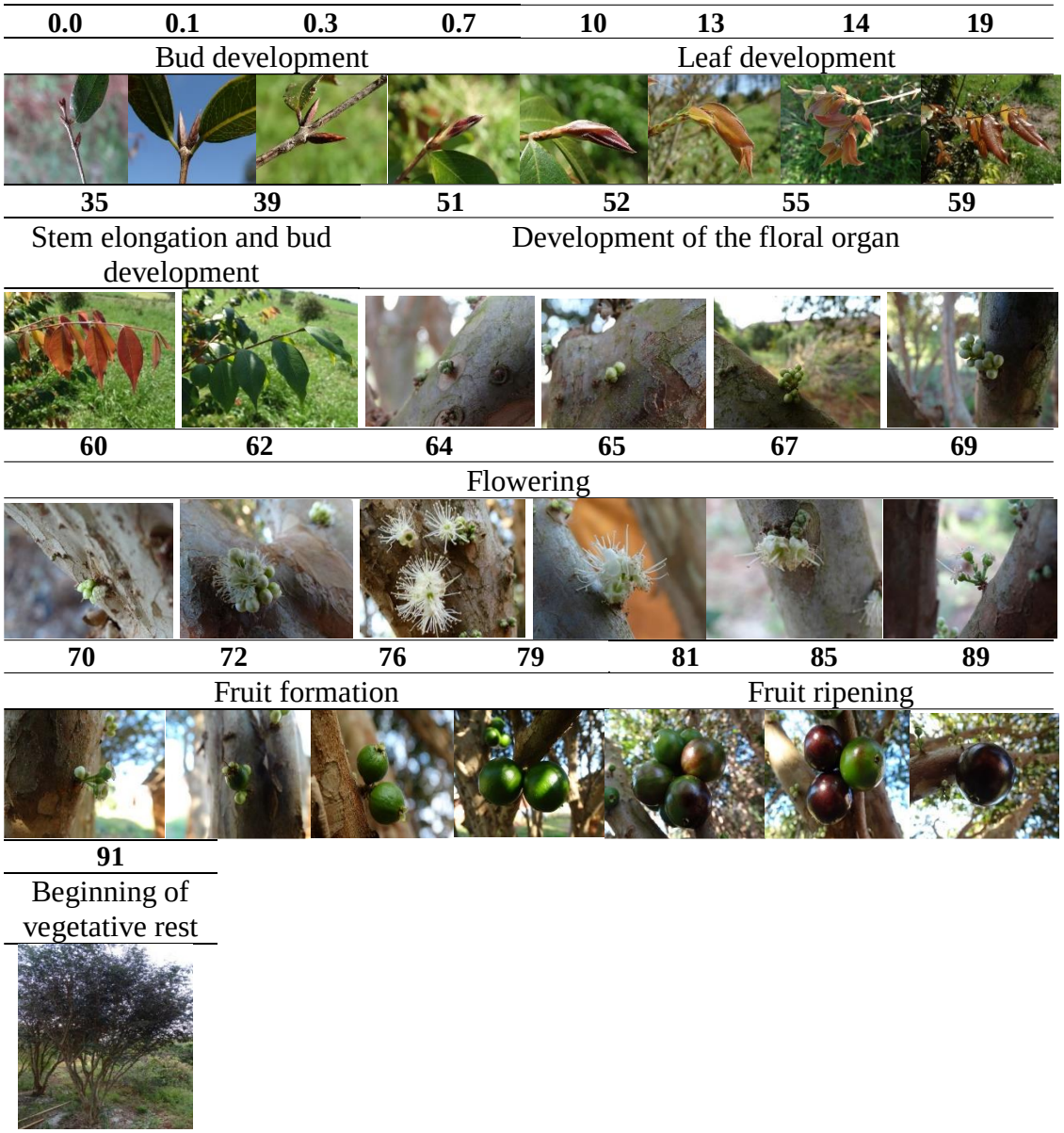
Source: Authors.

Figure 3. Phenological stages of the *Eugenia involucrata* DC. using the nomenclature for fruit species according to the general BBCH scale.



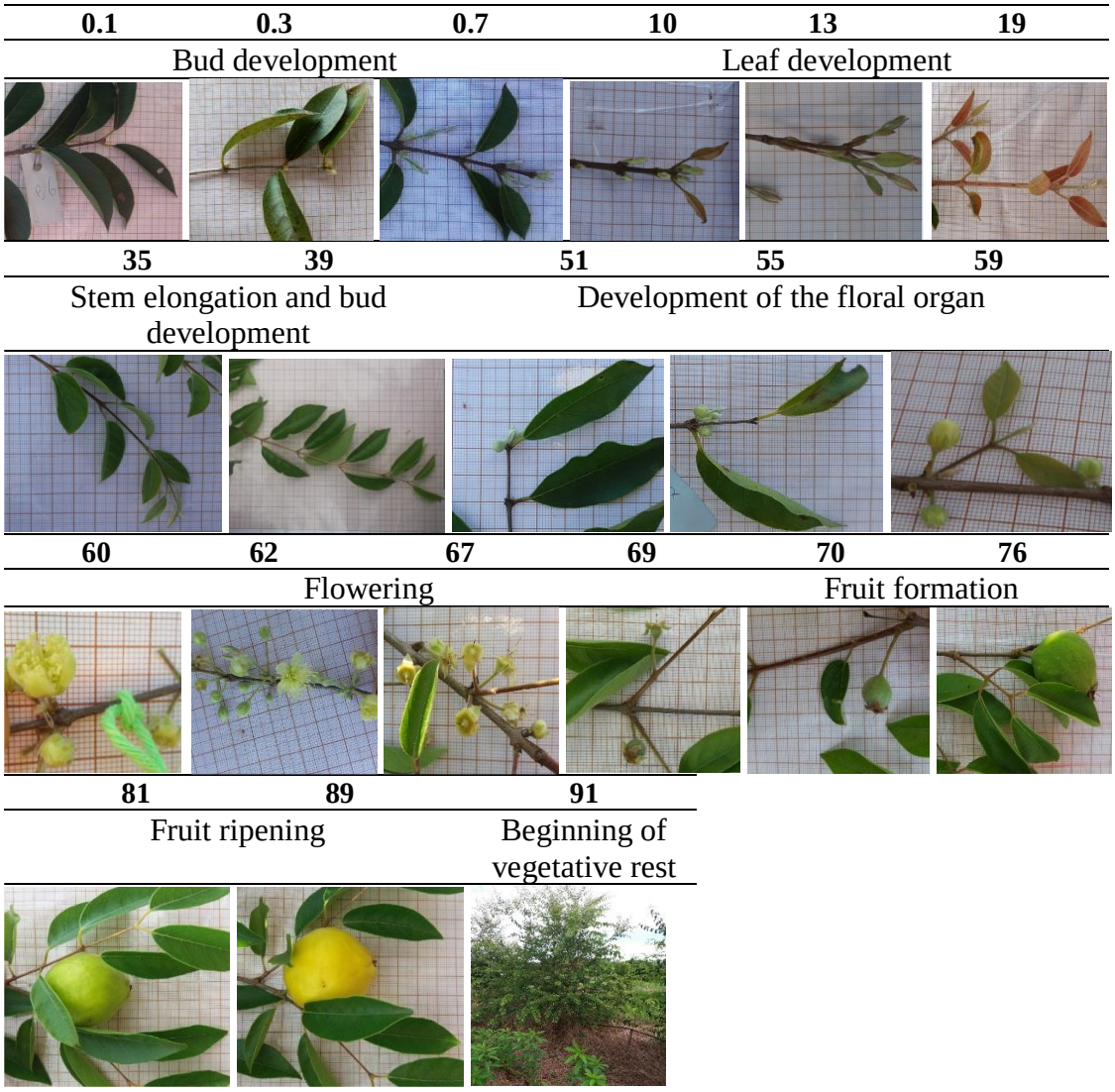
Source: Authors.

Figure 4. Phenological stages of the *Plinia cauliflora* (DC. Berg) using the nomenclature for fruit species according to the general BBCH scale.



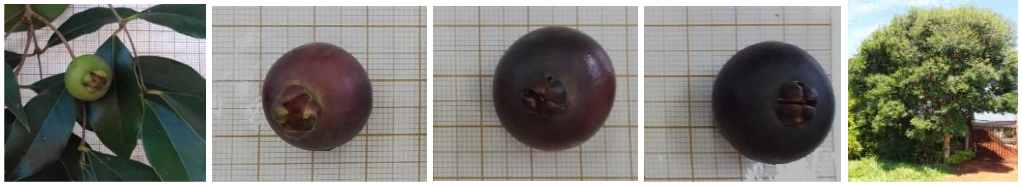
Source: Authors.

Figure 5. Phenological stages of the *Eugenia myrcianthes* (Nied.) using the nomenclature for fruit species according to the general BBCH scale.



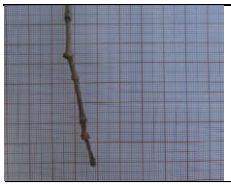
Source: Authors.

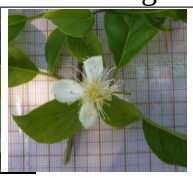
Figure 6. Phenological stages of the *Myrcianthes pungens* (O. Berg.) D. Legrand using the nomenclature for fruit species according to the general BBCH scale.

0.1	**19**	**39**	**51**	**55**	**59**
Bud development	Leaf development	Stem elongation and bud development	Development of the floral organ		
					
60	**64**	**65**	**67**	**68**	**69**
Flowering					
					
75	**81**	**85**	**89**	**91**	
Fruit formation	Fruit ripening			Beginning of vegetative rest	
					

Source: Authors.

Figure 7. Phenological stages of the *Campomanesia xantocarpa* (O. Berg.) using the nomenclature for fruit species according to the general BBCH scale.

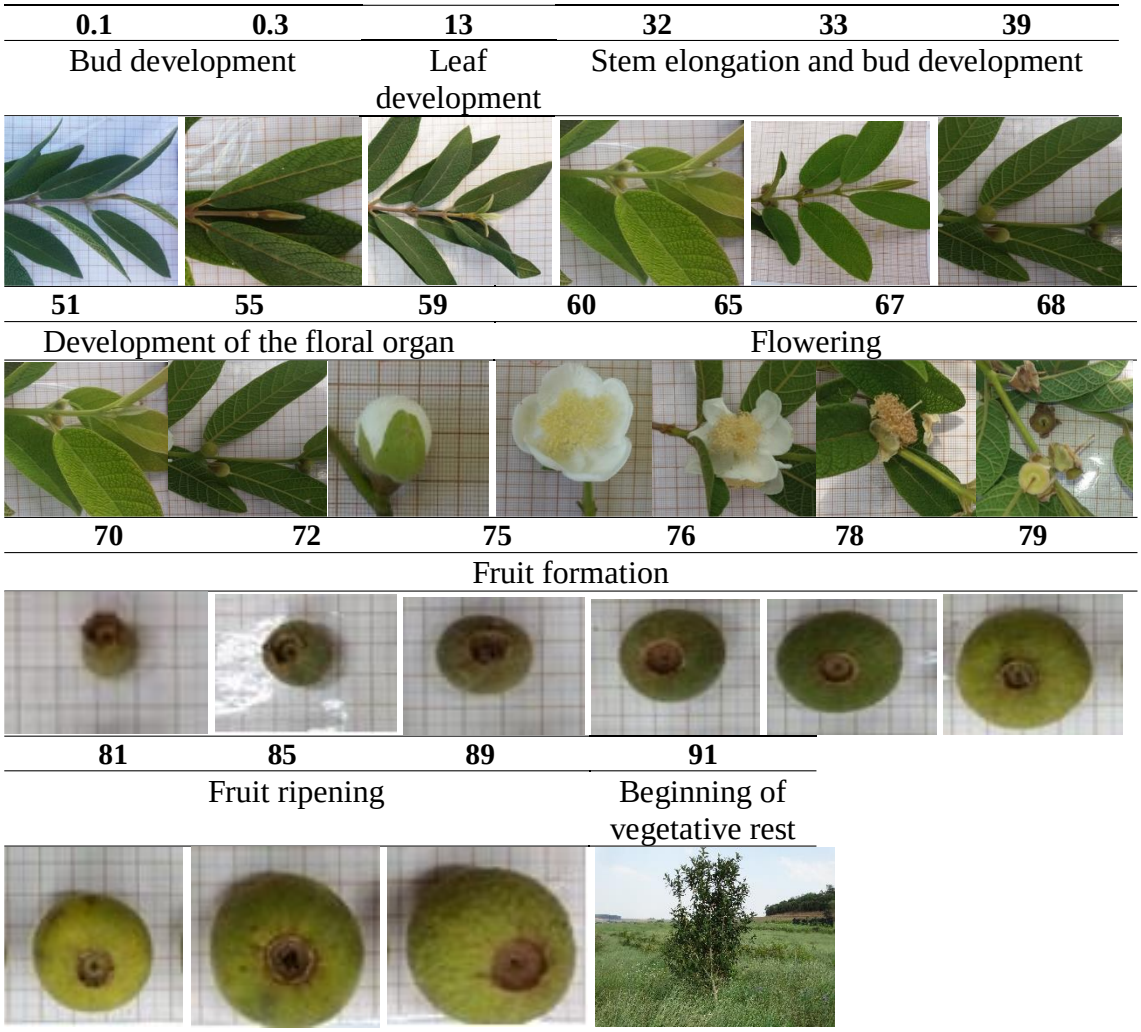
0.1	**0.7**	**11**	**51**	**59**
Bud development		Leaf development	Development of the floral organ	
				

64	**65**	**69**	**81**	**85**	**89**
Flowering			Fruit ripening		
					

91
Beginning of vegetative rest


Source: Authors.

Figure 8. Phenological stages of the *Campomanesia guazumifolia* (Cambess.) O. Berg. using the nomenclature for fruit species according to the general BBCH scale.



Source: Authors.

In general, for the investigated species, we found that the reproductive stage begins during the period of apical meristem differentiation. During this stage, flower buds appear, and anthesis (floral opening) occurs. At this moment, with the stamens stretching, the sepals and petals open simultaneously. Thereafter, fertilization takes place, the stamens fall off, and the stigma curvature increases along with an increase in ovary volume, giving rise to the formation of fruit. The petals then fall off and the sepals close again, marking the end of the flowering stage and beginning of the reproductive stage. The fruits of both begin their development with green coloring and finish maturation with red to dark red (*Eugenia uniflora* and *E. involucrata*), yellow (*Psidium cattleianum* and *Eugenia myrcianthes*), purple to dark purple (*Plinia cauliflora* and *Myrcianthes pungens*), orange (*C. xanthocarpa*), and light

yellowish green coloration (*Campomanesia guazumifolia*). In this phase, the process of physiological maturation is finalized and the fruits acquire darker coloring, tending to brown, initiating the dispersion process. Finally, the onset of vegetative rest occurs.

The phenological stages of these species according to the BBCH scale were described here for the first time, making it possible to verify all phases of different vegetative and reproductive stages of each species. Such scales may serve as an important and useful tool for appropriate management of orchards, as they serve as parameters that help the fruit growers. However, adaptation occurred because in the true scaffold, the period of dormancy (as previously mentioned) was observed, a fact that these native fruit trees were not present.

The expansion of native fruit production has led the producers to increasingly adapt to new management techniques which require prior knowledge of phenology. This study provides this knowledge about the harvest and can indicate the climatic potential of a certain region for the cultivation and production of the investigated species. In addition, these parameters are important in the planning of direct crosses and for assisting in the determination of cultural practices, such as thinning out, fertilization, and irrigation. It is believed that this is the first step in the cultivation of these fruit trees on a commercial scale, as such information is essential for any fruit culture (Pedro Júnior et al., 1993).

4. Conclusions

The phenological stages of *Eugenia uniflora*, *Psidium cattleianum*, *Eugenia involucrata*, and *Plinia cauliflora*, *E. myrcianthes*, *Myrcianthes pungens*, *Campomanesia xanthocarpa*, and *C. guazumifolia* according to the BBCH scale were described here for the first time, differentiating the vegetative and reproductive stages. These descriptions are highly valuable as they provide basic information about these fruit tree species and their cultivation practices.

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