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Phenological growth stages of biquinho pepper according to the BBCH scale

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ABSTRACT. Biquinho pepper has been gaining prominence on the national scene because of its sweet taste and low pungency. Therefore, this study aimed to describe the phenological growth stages of biquinho pepper according to the BBCH scale. Based on this general scale, biquinho pepper showed 9 of the 10 principal stages (germination, leaf development, formation of side shoots, shoot development, development of the harvestable vegetative parts of the plant, flowering, fruit development, coloring or ripening of fruits and senescence). In addition, 25 secondary growth stages have also been described. The study will act as a tool for adoption of better crop management practices (nutrient management, irrigation scheduling, monitoring of management of pests and timely harvest of fruits).

Keywords: *Capsicum chinense* Jacq; development stages; phenology.

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Introduction

The biquinho pepper (*Capsicum chinense* Jacq.) is a species that presents small round fruits forming a beak. The fruits have low pungency and are characterized as sweet fruits that can be consumed *in natura* or processed (Heinrich, Ferraz, Ragassi, & Reifschneider, 2015). It is grown all over the country, and produced almost exclusively by small and medium producers or family farmers, who can sell the fruit either fresh or processed (such as jams, canned or dehydrated), adding greater value to the product (Labigaline, Sala, Gomes, Corsini, & Rossi, 2020). Recent studies with biquinho pepper were developed in Brazil (Rodrigues et al., 2021), but there is still a lack of research about the phenological growth stages in this crop production.

Phenological scales have been used to describe plant development (Ramírez & Davenport, 2020). The characterization of the phenological stages is essential for biquinho pepper crop production since cultural practices such as application of crop protection products and herbicides, transplanting and tillage, rely to a large extent on correctly checking certain stages (Vela, Salinero, & Sainz, 2013).

Until the early 1990s, there was not a homogenous code to describe the growth stages in most plants and crops. Zadoks, Chang and Konzak (1974) published the first decimal code aiming at standardizing the phenological development stages description for similar cereal crops by using the same codes. Further development derived in the BBCH (Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie) scale proposed by Bleiholder, Van Den Boom, Langelüddecke and Stauss (1989) and in the extended BBCH scale proposed by Hack et al. (1992). Since them, the extended BBCH scale has become a world-wide coding system commonly used to integrate phenology in agricultural, horticultural and environmental studies (Meier et al., 2009).

This scale generally consists of 10 principal stages (0-9), which are further divided into 10 secondary (0-9) growth stages. So far, the BBCH scale has been widely used with many crop species, such as cereals, colza and bean (Lancashire et al., 1991). Fruit bearing plants, such as guava (Salazar et al., 2006), kiwifruit (Salinero, Vela, & Sainz, 2009), mango (Delgado et al., 2011), avocado (Alcaraz, Thorp, & Hormaza, 2013), cape gooseberry (Ramírez, Fischer, Davenport, Pinzón, & Ulrichs, 2013), lychee (Wei et al., 2013), and sugar apple (Liu et al., 2015).

The system has been extensively used to describe the phenological stages of diverse species, but there is no phenological description of biquinho pepper. In this context, the objective of this work is to describe the phenological growth stages of biquinho pepper according to the BBCH scale and thereby to supplement the future studies.

Material and methods

The study area was located in Marmeleiro, Paraná, Brazil (26º08'56"S and 53º1'36"W, 654 m a.s.l). The soil is classified as Latossolo Roxo (Dark-red Latosol) (Empresa Brasileira de Pesquisa Agropecuária [Embrapa], 2018). The climate in this site is Cfa, humid subtropical (Aparecido, Rolim, Richetti, Souza, & Johann, 2016). The experiment was carried out from January 23, 2019 to May 18, 2019.

Six uniform and healthy plants were randomly selected labelled and monitored through the crop cycle.

Biquinho pepper was implanted in January 2019 and plants were cultivated at a spacing of 0.6 x 0.5 m, without an irrigation system. All cultural practices typically recommended for biquinho pepper cultivation were performed.

Codification and description of different growth stages were carried out using BBCH scale. Phenological evaluation of principal and secondary growth stages were performed through periodical visits to the production sites according to the following schedule: four times a week between January and February and twice a week from march onward.

The phenological stages were defined considering the appearance of plant specific organs, which has the advantages of simplicity and easy identification in the field and defines the beginning and the end of the phenological stage of the crop (Streck, Bosco, Michelon, Walter, & Marcolin, 2006).

To illustrate representative key phenological stages, a collection of pictures for biquinho pepper were taken and recorded by using a camera. At the end of the study period, the best pictures illustrating important phenological stages were chosen and used in the codification and description of both vegetative and reproductive phenology.

In this study, nine of ten principal growth stages based on the existing BBCH scale were used for describing biquinho pepper, starting with germination (stage 0), leaf development (stage 1), formation of side shoots (stage 2), shoot development (stage 3), development of the harvestable vegetative parts of the plants (stage 4), flowering (stage 6), fruit development (stage 7), coloring or ripening of fruits (stage 8) and senescence (stage 9). The main secondary growth stages were also described.

Results and discussion

Based on phenological observations, nine principal growth stages were identified in biquinho pepper out of 10 stages given in the BBCH scale. A total of 25 secondary stages were described.

The phenological growth stages according to the BBCH scale for biquinho pepper are depicted in Table 1 and Figures 1-9 as follows.

On February 7, 2019, the seeding of biquinho pepper was carried out in trays, and after 19 days (February 26, 2019), germination began, with the beginning of root formation (Figure 1A), and seed imbibition (Martinelli, Andrzejewska, Salis, & Sulas, 2015), after 3 days, the breakage of the seed coat has already occurred with the appearance of the cotyledon leaves (Figure 1B) and 5 days after the beginning of germination the cotyledonary leaves were visible, and they were already completely opened (Figure 1C).

Germination describes seed germination until the cotyledons or epicotyl appear above the soil surface. Seed germination begins with seed imbibition (secondary stage 01) (Enriquez-Hidalgo, Cruz, Teixeira, & Steinfort, 2020), and germination ends with the emergence of the cotyledons or first true leaf (stage 9, Table 1; Figure 1). After the germination stage, the cotyledon leaves are already well developed.

Leaf development begins when cotyledons are already fully unfolded (stage 10, Figure 2), and it is determined by the number of visible basal leaves (Martinelli et al., 2015). The number of leaves per plant determines the current principal growth stage (Table 1). After germination and emergence, the cotyledonary leaves are already well developed and their main development begins, with the appearance of the first primary leaf, with a light green color. After 21 days, the growth of the second primary leaf begins, and it also presents a light green color, making it possible to see the first open leaf.

Table 1. Phenological growth stages of biquinho pepper according to the BBCH scale.

BBCH code	Description
Principal growth stage 0:	Germination
01	Initiation of seed imbibition
03	Seed imbibition completed
09	Emergence of cotyledons or epicotyl through the soil
Principal growth stage 1:	Leaf development
10	Cotyledons fully unfolded
11	First true leaf, leaf pair, or whorl unfolded
Principal growth stage 2:	Formation of side shoots
24	4 lateral shoots visible
25	5 lateral shoots visible
26	6 lateral shoots visible
Principal growth stage 3:	Shoot development
31	Beginning of shoot development
33	30% of final shoots length
35	50% of final shoots length
39	90% of final shoots length
Principal growth stage 4:	Development of the harvestable vegetative parts of the plant
41	10% of maximum biomass reached
49	90% of maximum biomass reached
Principal growth stage 6:	Flowering
61	Beginning of flowering
62	20% of flowers open
65	Full flowering
Principal growth stage 7:	Fruit development
72	Sepals beginning to fall
73	Second fruit fall
79	90% of final fruit size
Principal growth stage 8:	Coloring or ripening of fruits
81	Beginning of fruit coloring
83	30% of fruits show typical fully ripe color
86	60% of fruits show typical fully ripe color
87	Fruit ripe for picking
Principal growth stage 9:	Senescence
91	Shoot growth completed; foliage still fully green

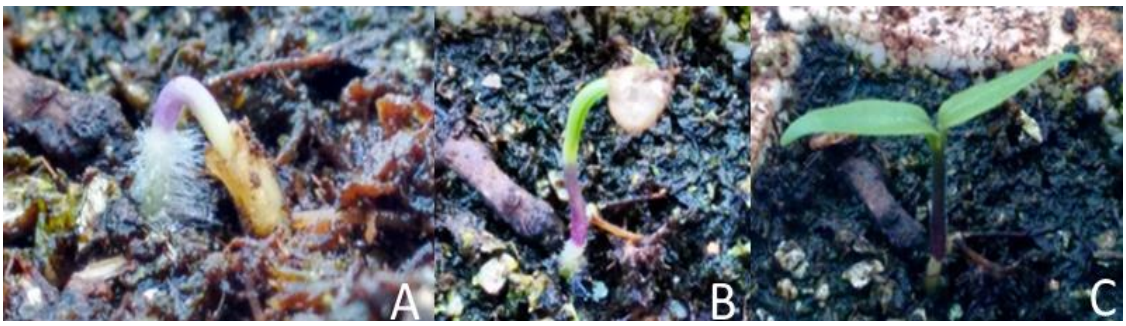

Figure 1. Principal growth stage 0: Germination according to the BBCH scale. (A) stage 1, (B) stage 3 and **(**C**)** stage 9.

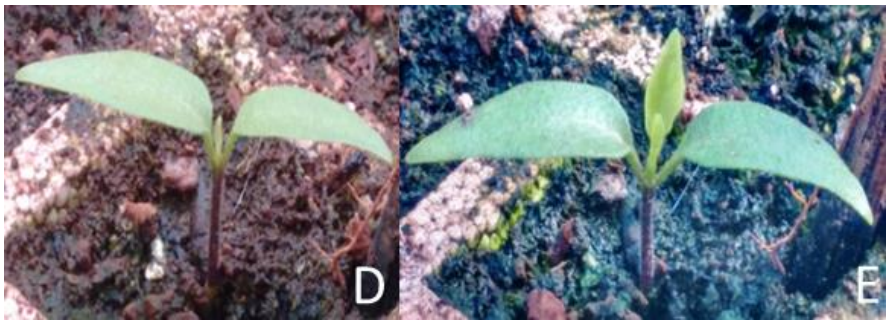

Figure 2. Principal growth stage 1: Leaf development according to the BBCH scale: (D) stage 10 and (E) stage 11.

Principal growth stage 2 describes the formation of side shoots (Figure 3). In biquinho pepper, the appearance of side shoots starts after the leaf development and before the shoot development. This main stage begins with the first primary apical side shoot being visible (Herraiz et al., 2015). This growth stage concerns the formation of side shoots derived from apical buds of the main stem, which form the crown (Cardoso, Lopes, Dotto, Pirola, & Giarola, 2021). In biquinho pepper this stage is characterized by a development of four to six primary apical side shoots.

Figure 3. Principal growth stage 2: Formation of side shoots: (F) stage 24, (G) stage 25 and (H) stage 26.

The shoot development in biquinho pepper began with epicotyl growth was followed by a monopodial phase of a main shoot growth (Figure 4) (Feldmann & Rutikanga, 2021). Shoot development proceeds in parallel with leaf development of the harvestable vegetative parts of the plant and flowering (Muhamed & Kurien, 2018).

Figure 4. Principal growth stage 3: Shoot development: (I) stage 31, (J) stage 33, (L) stage 35 and (M) stage 39.

This stage (Development of the harvestable vegetative parts of the plant, Figure 5, stage 4) describes the biomass accumulation of the whole plant, including leaves, stems, flowers and fruits. It is annotated as a percentage of the final plant biomass based on a dry matter basis. This stage overlaps with the rest of the phenological stages from leaf development (stage 1) until fruit ripening (stage 8), when naturally growth is stopped (Enriquez-Hidalgo et al., 2020).

Figure 5. Principal growth stage 4: Development of the harvestable vegetative parts of the plant: (N) stage 41 and (O) stage 48.

Reproductive development is marked by the plant's ability to produce flowers, and is the result of changes that take place in the bud meristem that are induced by an internal and external stimulus (De Marco, Martins,

Herter, Crosa, & Nava, 2021). The main growth stage 6, corresponding to flowering, identified three more sub-stages (Figure 6), namely: P (stage 61) beginning of flowering, characterized by the presence of at least one floral bud on the main and secondary stem; Q (stage 62) described as the phase when 20% of the floral buds are shown; and R (stage 65) when the total of floral buds is opened, which is the final phase.

Figure 6. Main growth stage 6: Flowering: (P) stage 61, (Q) stage 62 and (R) stage 65.

The development of fruit (Figure 7) (stage 7) begins when the first fruit of the first infructescence reaches the typical size (stage 71) (Acosta-Quezada et al., 2016). The time required to reach the final size after fruit set is variable and depends on the cultivar and climatic conditions (Pringle & Murray, 1991).

Figure 7. Principal growth stage 7: Fruit development: (S) stage 72, (T) stage 73 and (U) stage 79.

The maturation stage of biquinho pepper is a relevant factor regarding the attribute of fruits, since it directly influences the composition of ripening, varying the biochemical composition during conception and construction (Abud et al., 2018).

This stage (Coloring or ripening of fruits) describes the maturation of the first emerged fruit, characterized by water loss and color change from yellow to red. This stage starts when the fruit is yellow with high water content (stage 81) and is followed by the biquinho pepper starting to red and lose water. The next stages are defined when 30, 60 and 70% of the biquinho pepper is ripe (Figure 8).

The biquinho pepper is an aesthetically beautiful plant, therefore, it is widely used in the decoration of environments. The red coloration of the exocarp reaches the highest values of length, diameter and thickness (Jorge et al., 2018). The flowering and fruiting of the biquinho pepper occurs continuously, and fruits can be found on the plant at different stages of maturation (Araújo et al., 2018).

Figure 8. Principal growth stage 8: Coloring or ripening of fruits: (V) stage 81, (X) stage 83, (Y) stage 86 and (W) stage 87.

Senescence is a quite obvious stage, with highly visual changes (Bihan, Coson, Rollin, & Rollin, 2020). At the end of senescence in biquinho pepper there is a loss of water and mass (Figure 9). When biquinho pepper are ripe for the harvest (stage 87) the majority of the leaves are hydrated and light green. Stage 91 describes the harvested product to which post-harvested or storage treatments are applied. In addition, the discoloration of the leaves of the biquinho pepper is included in the senescence.

Figure 9. Principal growth stage 9: Senescence: (Z) stage 91.

Conclusion

The use of the BBCH scale allowed a precise description of the phenological stages of biquinho pepper in a pioneering study in Brazil.

The codification proposed here is based on a standardized description of biquinho pepper and will be a useful tool for farmers and researchers facilitating scientific communications at international level.

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