



Phenological growth stages of mango (*Mangifera indica* L.) according to the BBCH scale

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ABSTRACT

Codes and detailed crop-specific descriptions are presented for the growth stages of the mango tree, contributing to the standardization of international testing systems in fruit growing. Based on the general BBCH-scale, the one for mango uses 7 of the 10 principal stages (0–9), thus growth stages for bud, leaf and shoot development, inflorescence emergence, flowering, fruit development and fruit maturity are described. Secondary stages (also from 0 to 9) are numbered related to ordinal or percentage values of growth. The scale also uses mesostages, between the principal and secondary stages, to distinguish the different vegetative flushes and the principal terminal inflorescence emergence from the later axillary one, subsequent to terminal flowering failure. A feature of the system is that homologous stages of different crops are presented by the same codes.

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1. Introduction

The mango (*Mangifera indica* L.) belongs to the family Anacardiaceae. There are 69 species in the *Mangifera* genus (Kosterman and Bompard, 1993), including *M. laurina*, used as a rootstock for mango, *M. sylvatica*, cold resistant, *M. pajang*, producing easy peeling fruit, and *M. caesia* for extracting fruit juice. The mango originated in the Assam area between India and Burma (now Myanmar), where there are still several wild populations, but also could be native of the lower slopes of the Himalayas or even from areas close to Nepal or Butan (Kosterman and Bompard, 1993). This species has been cultivated from ancient times and it is estimated that was domesticated from 6000 years ago (Hill, 1952). It is now cultivated in tropical and subtropical regions of the world, in over 100 countries, from 33° south latitude in South Africa to 36° north latitude in Spain. According to FAO statistics (www.fao.org) the total production for 2009 is estimated at 35×10^6 t, being the second tropical fruit in terms of world production and imports, just located behind the banana, and the fifth of all fruits (also exceeded in volume by citrus, grapes and apples). Nevertheless, these figures are not accurate since FAO grouped under the same heading mango, mangosteen and guava, both very minor crops, particularly mangosteen, compared with mango. Galán Saúco (2009) provides a review of botanical and economic characteristics of mango, its environmental

requirements and growing practices. The mango is a species of ever-green trees, 10 m in height when unpruned and reaching up to 40 m under tropical conditions. Leaves are simple, 8–40 cm long, from light green to copper-red or purplish in colour when young, gradually turning to dark green, and persisting on the tree for up to 4–5 years before shedding. Mango produces several vegetative flushes during the year. In climates with well-defined seasons, those occurring during summer and autumn are more conducive to flowering the following winter–early spring. The terminal buds of the stem, but also in certain conditions in axillary ones (i.e. fail of initial flowering), produces a panicle containing 300–6000 hermaphrodite and male flowers, number and sex ratio depending upon the cultivar. Hermaphrodite flowers are small (5–10 mm diameter), pentamerous (rarely 4 or 7 sepals and petals), with green sepals and petals pinkish white in colour, with only one functional stamen and four staminodes, and one-celled ovary attached to a nectary disc, with one lateral style, and a simple stigma. The male flower is essentially the same with the absence of the ovary. Flowers reach full bloom in 25–30 days after initiation. The fruit is a drupe variable in size, shape, colour and weight (200 g – 2 kg). Fruit possess a single seed, either monoembryonic or polyembryonic, enclosed in a hard endocarp with fibres extending into the flesh. For further details see Kosterman and Bompard (1993), Nakasone and Paull (1999) and Galán Saúco (2009).

Knowledge of the periodic biological events of a particular crop – bud break, flushing, flowering, and fruit development – is an important tool for its agronomical management. Until the early 1990s there was no standardized coding of these phenological stages,

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most of these were described based on Fleckinger scale (Fleckinger, 1948), using alphanumerical combinations and dealing exclusively with inflorescence development. In 1972, Aubert and Lossois proposed a letter-based phenological scale for mango, describing five stages for shoot and nine stages for inflorescence development, and in 1991 Oosthuysen described a panicle development scale with 18 numerical stages from dormant bud to fruit set.

In 1989, Bleiholder et al. developed a two-digit decimal coding system for angiosperms, the BBCH-scale (*Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie*). This scale uses 10 principal stages (0–9), divided each one in 10 secondary (0–9) growth stages; a three digits “extended BBCH-scale” (Hack et al., 1992) was proposed for certain crops. Today, both BBCH scales are widely employed – for grains, rape and sunflower, vegetables (beans, beet, and potato), pome and stone fruits, citrus, grape, strawberry, currant, pomegranate, coffee, olive, Musaceae, persimmon, cherimoya, etc. – but such scales have not yet been employed for specifically describe mango development. A feature of the system is that homologous stages of different crops are presented by the same codes. Therefore, as these scales appear to have systematic advantages over the classical Aubert and Lossois (1972) system, the present work was set up using the extended BBCH-scale.

2. Materials and methods

2.1. Plant material

Data were collected from adult trees (15–30 years old) of *M. indica* L. grafted onto Gomera-1 rootstock, planted 6 m × 5 m apart, drip irrigated and fertilized as required, located in the Instituto Canario de Investigaciones Agrarias (ICIA) mango collections. These collections, composed by 91 accessions of cultivars representative of most parts of the world, are located in Tenerife at latitude 28° 13' N and longitude 16° 50' W, with a dry tropical climate according to Köppen classification (Köppen, 1936) or warm tropical according to Papadakis classification (Papadakis, 1966), with an average daily temperature of 21 °C, an average of daily minimum temperature of 18 °C, an average of daily maximum temperature of 25 °C, an average daily relative humidity of 70%, and total year rainfall of 155 mm.

Measurements and observations were carried out during several growing seasons in a frequency depending on the stage, from two to three times per week to once each 15 days. Developmental stage and morphological characteristics of each developing organ was recorded and compared between growing seasons and cultivars.

2.2. Scale characteristics

For mango tree, the BBCH-scale uses 7 of the 10 principal stages, starting with vegetative bud dormancy (stage 0) and ending in full maturity of the fruit (stage 8). Three principal growth stages are assigned to vegetative growth, which describe bud development (stage 0), leaf development in seedlings in nursery or on tree branches (stage 1) and shoot growth elongating the branches (stage 3). Other two stages are assigned to flowering, describing inflorescence emergence (stage 5) and flowering (stage 6). Fruit development (stage 7) and fruit maturity (stage 8) stages complete the code. Development of rosette leaves (stage 2), vegetative harvestable parts (stage 4) and senescence (stage 9) are not considered because they do not apply in mango.

The vegetative phase of the mango usually lasts from the preceding autumn to the summer, with rest periods between two vegetative flushes. To distinguish the separate events of the vegetative phase, several mesostages (1 to *n*) describes the different vegetative flushes during the season; in our description only two

of them (1 and 2) are used, as indicative. Two mesostages (1 and 2) are used for coding inflorescence emergence and flowering, in order to distinguish the principal terminal flowering from the later axillary one, subsequent to terminal flowering failure.

The secondary stages are also numbered from 0 to 9, being most related to ordinal or percentage values of growth. Hence, value 3 of principal stage 6 (flowering) is assigned when 30% of flowers open and its identification will be 613. Likewise, stage 705 identifies the value 5 of the principal stage 7 (fruit development), which represents fruit at about 50% of final size. In other cases, the values of secondary stages indicate qualitatively different stages within a given principal phenological stage. For example, value 3 of principal stage 5 (inflorescence emergence) of secondary flowering (mesostage 2) indicates first floral primordial just visibly and the beginning of the new (second) panicle development, and is identified as 523.

3. Results and discussion

Description of the principal phenological stages of mango tree according to growth stage identification keys for mono and dicotyledonous plants (Hack et al., 1992) are presented and compared with the classical Aubert and Lossois (1972) phenological scale.

3.1. Principal growth stage 0: bud development

First vegetative flush

- 010 Dormancy: leaf buds are closed and covered by green or brownish scales (Aubert and Lossois: vegetative stage A) (Fig. 1).
- 011 Beginning of leaf bud swelling: bud scales begin to separate.
- 013 End of leaf bud swelling: scales completely separated, light-green buds emerged (Aubert and Lossois: vegetative stage B).
- 017 Beginning of bud break: light green to dark coppery tan leaf tips just visible (Aubert and Lossois: vegetative stage C) (Fig. 1).
- 019 Bud break: light green to dark coppery tan leaf tips visible 5–10 mm above bud scales (Aubert and Lossois: vegetative stage D).

Second vegetative flush

- 020 Dormancy: leaf buds are closed and covered by green or brownish scales (Aubert and Lossois: vegetative stage A).
- 021 Beginning of leaf bud swelling: bud scales begin to separate.
- 023 End of leaf bud swelling: scales completely separated, light-green buds emerged (Aubert and Lossois: vegetative stage B).
- 027 Beginning of bud break: light green to dark coppery tan leaf tips just visible (Aubert and Lossois: vegetative stage C).
- 029 Bud break: light green to dark coppery tan leaf tips visible 5–10 mm above bud scales (Aubert and Lossois: vegetative stage D).

3.2. Principal growth stage 1: leaf development

First vegetative flush

- 110 Leaf tips more than 10 mm above bud scales (Fig. 1).
- 111 First leaves unfolded.
- 115 More leaves unfolded; petioles visible.
- 119 All leaves completely unfolded and expanded.

Second vegetative flush

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