Scientia Horticulturae 130 (2011) 536–540

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

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

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ARTICLE INFO

Article history:
Received 25 April 2011
Received in revised form 22 July 2011
Accepted 26 July 2011

Keywords:
Anacardiaceae
Botanical coding system
Developmental stages
Tropical fruit tree species

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.

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 evergreen 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 monoembrionic o polyembrionic, 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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doi:10.1016/j.scienta.2011.07.027

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 Oosthuyse 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 Bundesantalt, 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 has 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

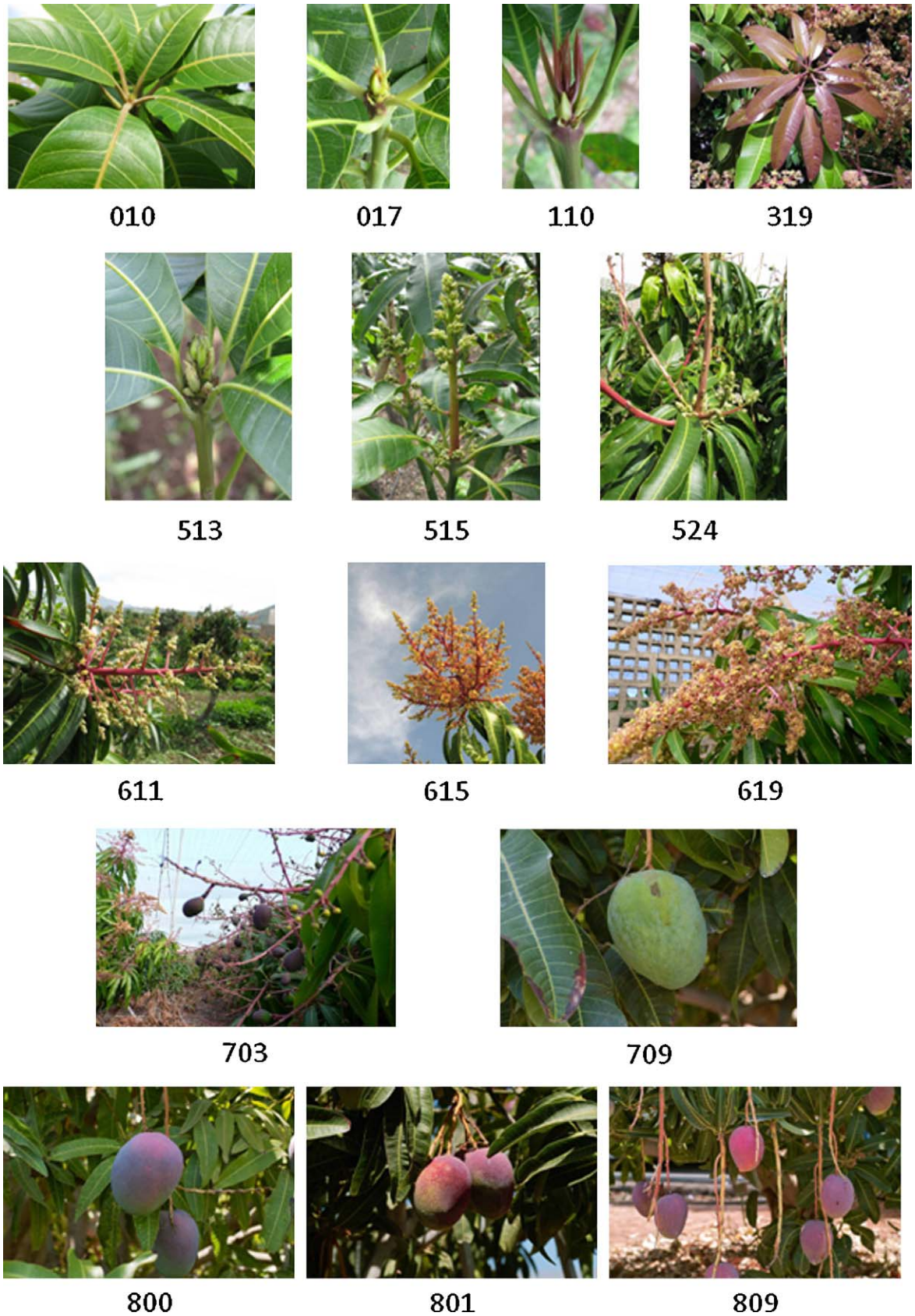

Fig. 1. Some of the primary and secondary phenological growth stages of mango tree according to BBCH-scale.

120 Leaf tips more than 10 mm above bud scales.
121 First leaves unfolded.
125 More leaves unfolded; petioles visible.
129 All leaves completely unfolded and expanded.

3.3. Principal growth stage 3: shoot development

First vegetative flush

311 Beginning of shoot growth: axes of developing shoots visible, about 10% of final length.
312 Shoots about 20% of final length.
315 Shoots about 50% of final length (Aubert and Lossois: vegetative stage E).
319 Shoots about 90% of final length (Fig. 1).

Second vegetative flush

321 Beginning of shoot growth: axes of developing shoots visible, about 10% of final length.
322 Shoots about 20% of final length.
325 Shoots about 50% of final length (Aubert and Lossois: vegetative stage E).
329 Shoots about 90% of final length.

3.4. Principal growth stage 5: inflorescence emergence

Principal flowering

510 Buds closed and covered with green or brownish scales.
511 Beginning of bud swelling, scales begin to separate (Aubert and Lossois: flowering stage A).
513 Bud burst: first floral *primordia* just visible, panicle development begins (Aubert and Lossois: flowering stage B) (Fig. 1).
514 Panicle axis begins to elongate. Leaves are visible in mixed panicles.
515 Flowers are visibly separated, secondary axes begin to elongate (Aubert and Lossois; flowering stage D) (Fig. 1).
517 Secondary axes elongated, flowers buds are swollen, and first light green to crimson petals tips visible in some flowers. In mixed panicles, leaves have reached final length.
519 End of panicle development: secondary axis fully developed, many flowers with green to crimson petals tips visible and some opened. Leaves fully developed in case of mixed panicles.

Secondary flowering

520 Axillary flower buds of the apical dome are closed and covered with green or brownish scales.
521 Beginning of bud swelling, scales begin to separate (Aubert and Lossois: flowering stage A).
523 Bud burst: first floral *primordia* just visible, panicle development begins (Aubert and Lossois: flowering stage B).
524 Panicle axis begins to elongate. Leaves are visible in mixed panicles (Fig. 1).
525 Flowers are visibly separated, secondary axes begin to elongate (Aubert and Lossois; flowering stage D).
527 Secondary axes elongated, flowers buds are swollen, and first light green to crimson petals tips visible in some flowers. In mixed panicles, leaves have reached final length.
529 End of panicle development: secondary axis fully developed, many flowers with green to crimson petals tips visible and some opened. Leaves fully developed in case of mixed panicles.

3.5. Principal growth stage 6: flowering

Principal flowering

610 First flowers open.
611 Beginning of flowering: 10% of panicle flowers open (Fig. 1).
613 Early flowering: 30% of panicle flowers open.
615 Full flowering: more than 50% of panicle flowers open (Aubert and Lossois: flowering stage E) (Fig. 1).
617 Flower fading. Majority of petals fallen or dry.
619 End of flowering. All petals fallen or dry. Fruit set. (Fig. 1).

Secondary flowering

620 First flowers open.
621 Beginning of flowering: 10% of panicle flowers open.
623 Early flowering: 30% of panicle flowers open.
625 Full flowering: more than 50% of panicle flowers open (Aubert and Lossois: flowering stage E).
627 Flower fading. Majority of petals fallen or dry.
629 End of flowering. All petals fallen or dried. Fruit set.

3.6. Principal growth stage 7: fruit development

701 Fruits at 10% of final size, styles still visible. Beginning of physiological fruit drop (Aubert and Lossois; fruit set stage A).
703 Fruits at 30% of final size. End of physiological fruit drop (Aubert and Lossois: fruit set stage B) (Fig. 1).
705 Fruits at 50% of final size.
709 Fruit at standard cultivar size, shoulders fully developed, flesh creamy green in colour (Fig. 1).

3.7. Principal growth stage 8: maturity of fruit

800 Physiological maturity: fruit fully developed, flesh pale yellow colour (Fig. 1).
801 Beginning of skin colour change (Fig. 1).
809 Fruit colour fully developed. Fruit ripe for consumption, with correct firmness and typical taste. Beginning of fruit senescence (Fig. 1).

This extended BBCH-scale for mango has advantages over the one of Aubert and Lossois (1972), especially because it is more complete, describing stages for bud, shoot and leaf development, inflorescence emergence, flowering, and fruit growth and ripening, while that of Aubert and Lossois (1972) only focused on shoot and panicle development. This BBCH-scale also distinctly separates the various vegetative flushes occurring in the mango, as well as the terminal and axillary flowerings. All of which is important for the correct timing of general orchard management, particularly for disease and pest management, physiological disorders and weed control, flowering inhibition and effectiveness of fertilizers and PGRs application.

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