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Phenological growth stages of loquat tree (*Eriobotrya japonica* (Thunb.) Lindl.)

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Summary

Conservation, characterisation and utilisation of minor fruit tree species is an important objective for diversification of agro-food production. One such fruit tree is the loquat, a tree that originated in China but is well adapted to the Mediterranean area. The conservation and utilisation of suitable germplasm requires an accurate characterisation and evaluation of the material. A first step in characterisation is to use phenotypic traits. This paper describes the phenological growth stages of loquat tree using the extended BBCH scale. Seven principal growth stages (PGS) for bud, leaf and shoot development, inflorescence emergence, flowering, fruit development and fruit maturity and 31 secondary growth stages are described and compared with a previous scale based on Fleckinger classical methodology. An example of application of the extended BBCH scale for characterisation of loquat cultivars from IVIA germplasm collection is reported.

Key words: Germplasm characterisation, minor fruit tree species, BBCH scale

Introduction

Minor temperate and tropical fruit trees have generally been relatively neglected by the scientific and agricultural communities. They have been considered to be low income crops and there has been little genetic improvement of existing cultivars. These crops still maintain a wide genetic base that makes them suitable for cultivation in marginal areas. The conservation, characterisation and utilisation of these minor species is an important objective, allowing diversification of agro-food production by the use of a greater number of species (Morico, Grassi & Fideghelli, 1998). The collection and conservation of suitable species has only just started and much remains to fill gaps in existing collections.

One minor fruit tree species is the loquat (*Eriobotrya japonica* (Thunb.) Lindl.). The centre of origin of *E. japonica* has been accepted as the middle and lower valley of the Daduhe river in China (Zhang, Peng, Cai & Fang, 1993). From there it spread to Japan as an ornamental tree and, later in the 18th century, to the botanical gardens of Paris and Naples through Mauricio Island (Rodríguez, 1983). In the 19th century, selections of cultivars with larger fruits were available, and the fruits were used for human consumption. The loquat is well adapted to the Mediterranean basin, in the same areas that citrus crop are grown (Llácer, Aksoy & Mars, 1995). It is cultivated mainly in China, Japan, India, Pakistan, Madagascar, Reunion Island and Mauricio Island; in Mediterranean countries such as Spain, Turkey, Italy, Greece and Israel; in the United States (mainly California and Florida); and in Brazil, Venezuela and Australia. Within each of these countries the loquat has a narrow distribution range since flowering and fruit set occurs in winter, and it requires a humid and warm climate. Loquats require optimum average temperatures above 15°C, no frosts and no strong winds. The preferred orchard orientation is south to southeast (in the northern hemisphere) at heights lower than 400 m (Rodríguez, 1983).

Spain is the leading country for loquat production in the Mediterranean area. About 3700 ha of orchards produce about 35 000 mt of fruit, more than 50% of total Mediterranean area production. Also, there are many trees scattered in small family orchards or gardens all over the eastern or southern parts of Spain. The Valencia region accounts for 65% of whole Spain's production. About 80% of Spanish production is exported to foreign countries, principally to Italy, Portugal and France (Llácer *et al.*, 1995). To improve loquat culture and preserve genetic resources, a varietal collection of 50 accessions was established in 1993 at the Instituto Valenciano de Investigaciones Agrarias (IVIA); 64 % of which were native to Spain (Espinosa *et al.*, 1997).

The conservation and utilisation of such germplasm requires accurate characterisation and evaluation. A first step is define, by phenotypic markers, visible traits that are highly heritable and are expressed in all en-

vironments (Morico *et al.*, 1998). This includes phenological events such as budbreak, flowering and fruit ripening, which are closely regulated by the seasonal climate. The establishment of the important phenological stages also aids better orchard management and the timing of cultural practices such as thinning, growth regulators application or treatments to control pests, diseases and physiological disorders.

Espinosa *et al.* (1997) defined the phenological stages of the loquat using the classical Fleckinger scale. The BBCH phenological scale (Bleiholder, van den Boom, Langelüddeke & Stauss, 1991; Lancashire *et al.*, 1991) is now the accepted system for a wide range of crops and weeds. The BBCH-scale is a decimal two-digit scale, divided into principal (0 to 9) and secondary growth stages (0 to 9) and based on the well-known cereal code developed by Zadoks, Chang & Konzac (1974). For some crops, a three-digit scale is used. The basic principles of the extended scale were published by Hack *et al.* (1992), since when it has been officially accepted by the European Plant Protection Organization and manuals for different crops, weeds and countries were produced by Bleiholder *et al.* (1996), Hack *et al.* (1997) and Meier (1997).

Materials and Methods

Plant material consisted of 43 accessions from the germplasm collection at the IVIA located in Moncada (Valencia, Spain), latitude 39° 34' N, longitude 00° 24' W. Data were recorded from two to three adult trees (4–5 yr old) per accession. Twenty five of those accessions were native cultivars. All trees were grafts onto seedlings planted at 3 × 2 m in an orchard on a sandy loam soil of pH 7.8. The mean annual rainfall at this location is 430 mm (230 mm between April and October) and the average temperature is 16.4°C (19.9°C between April and October). The height above sea level is 55 m. The orchard was watered by drip irrigation as required.

All measurements and observations were made over two growing seasons, from September to September in 1996/1997 and from October to June in 1997/1998. Measurements were made two-three times per wk between September and May, and once per wk from June onwards. Representative trees were photographed to illustrate the primary and secondary phenological stages.

Results

Phenological stages of loquat tree (Extended BBCH scale)

The phenological stages of loquat tree according to growth stage identification keys for mono- and dicotyledonous plants (Hack *et al.*, 1997) are presented. The vegetative phase of the loquat tree lasts from the preceding autumn to the summer. The generative phase occurs in autumn and winter and there is no clearly demarked phase of leaf fall. Leaf senescence occurs throughout the year. To distinguish events during the vegetative phase, three mesostages (1–3) are used corresponding to autumn, spring and summer growth, respectively. Mesostage 0 is used for the generative phase.

Principal growth stage 0: Bud development

010 Dormancy in autumn: leaf buds are closed and covered by brown scales and grey-whitish fuzz (Fig. 1: 010).
011 Beginning of leaf bud swelling; bud scales begin to elongate and separate.
013 End of leaf bud swelling.
017 Beginning of bud break: first green leaf tips just visible (Fig. 1: 017).
019 Green leaf tips between 5 and 10 mm above bud scales.

020 Dormancy in spring: leaf buds are closed and covered by brown scales and grey-whitish fuzz.
021 Beginning of leaf bud swelling; bud scales begin to elongate and separate.
023 End of leaf bud swelling.
027 Beginning of bud break: first green leaf tips just visible.
029 Green leaf tips between 5 and 10 mm above bud scales.

030 Dormancy in summer: leaf buds are closed and covered by brown scales and grey-whitish fuzz.
031 Beginning of leaf bud swelling; bud scales begin to elongate and separate.
033 End of leaf bud swelling.
037 Beginning of bud break: first green leaf tips just visible.
039 Green leaf tips between 5 and 10 mm above bud scales.

Principal growth stage 1: Leaf development

110 Autumn growth: green leaf tips more than 10 mm above bud scales; first leaves separating (Fig. 1: 110).
111 First leaves unfolded.
115 More leaves unfolded, but not yet at full size (Fig. 1: 115).
119 First leaves fully expanded.

120 Spring growth: green leaf tips more than 10 mm above bud scales; first leaves separating.
121 First leaves unfolded.
125 More leaves unfolded, but not yet at full size.
129 First leaves fully expanded.

Fig. 1. The major phenological growth stages of loquat tree

130 Summer growth: green leaf tips more than 10 mm above bud scales; first leaves separating.
131 First leaves unfolded.
135 More leaves unfolded, but not yet at full size.
139 First leaves fully expanded.

Principal growth stage 3: Shoot development

311 Beginning of shoot growth in autumn: axes of developing shoots visible (Fig. 1: 311).
315 Shoots about 50% of final length.
319 Shoots about 90% of final length (Fig. 1: 319).
321 Beginning of shoot growth in spring: axes of developing shoots visible.
325 Shoots about 50% of final length.
329 Shoots about 90% of final length.
331 Beginning of shoot growth in summer: axes of developing shoots visible.
335 Shoots about 50% of final length.
339 Shoots about 90% of final length.

Principal growth stage 5: Inflorescence emergence

500 The thicker inflorescence buds are closed and covered by green scales
501 Beginning of swelling of inflorescence buds; bud scales begin to separate (Fig. 1: 501).
503 Bud burst: beginning of development of flower cluster.
504 Branches of flower cluster begin to elongate (Fig. 1: 504).
505 Flower cluster fully expanded; some terminal flower buds begin to swell.
507 Beginning of flower bud break: sepals

slightly open, first white petals just visible (Fig. 1: 507).

509 Most flowers with petals, forming a hollow ball.

Principal growth stage 6: Flowering

600 First flowers open.

601 Beginning of flowering: *c.* 10 % of flowers open (Fig. 1: 601).

605 Full flowering: at least 50 % of flowers open, first petals falling (Fig. 1: 605).

607 Flowers fading: majority of petals fallen (Fig. 1: 607).

609 End of flowering: all petals fallen (fruit set).

Principal growth stage 7: Fruit development

701 Fruit size *c.* 10 % of final size (Fig. 1: 701).

705 Fruit size *c.* 50 % of final size.

709 Fruit size *c.* 90 % of final size (Fig. 1: 709).

Principal growth stage 8: Maturity of fruit

801 Beginning of fruit colouring (colour break).

805 Increased, cultivar-specific fruit colouring (Fig. 1: 805).

807 Fruit ripe for picking (Fig. 1: 807).

809 Fruit ripe for consumption: fruit has typical taste and firmness.

Comparison of phenological scales

The above BBCH phenological stages for loquat are compared below with those defined by the Fleckinger scale (Espinosa *et al.*, 1997).

Fleckinger scale		*BBCH Scale*
A:	Dormant bud	500
B:	Swelling bud	501
C_1:	Bud burst	503
C_2:	Cluster development	504
C_3:	Cluster fully expanded	505
D:	Petals just visible	507
E:	Stamens just visible	600
F:	Flowering	601, 605
G:	Petals fallen	607
H:	Fruit set	609
I:	Development of fruit	701, 705, 709

Example of application of the extended BBCH scale for characterisation of cultivars

Fig. 2 shows a phenogram using the BBCH scale for the phenological stages relating to flower and fruit development for the earliest (Cardona) and latest (San Filipparo) cultivars in the collection. This illustrates the variation between cultivars. Data are the averages of three growing seasons. Table 1 summarises the intervals between stages in days.

The duration of the phenological stages differed between cultivars. The beginning of swelling of the inflorescence bud (code 501) and the beginning of flowering (code 601) occurred between 2–6 wk earlier in Cardona than San Filipparo, the start of fruit development was 11 wk earlier, and fruits matured 4½ wk earlier. In total, fruit maturation in Cardona and San Filipparo occurred within 227 and 243 days from the beginning of inflorescence bud swelling, respectively (Table 1). The other cultivars in the collection were intermediate between these two cultivars.

Table 1. *Durations in days of the phenological stages of flower and fruit development in the earliest (Cardona) and latest (San Filipparo) varieties of loquat in the IVIA collection*

	Phenological stages				
Variety	501–601	601–701	701–801	801–809	Total
Cardona	40	56	104	27	227
San Filipparo	71	87	64	21	243

Fig. 2 also shows the dates of beginning of leaf development in autumn, spring and summer (codes 110, 120 and 130, respectively). Leaf development in Cardona started 8 days earlier than in San Filipparo in autumn, 25 days earlier in spring, and 21 days earlier in summer.

Discussion

The loquat tree differs from other *Rosaceae* fruit tree species in that it has persistent leaves, three flushes of growth per year, flowering occurs during autumn and winter, and fruit harvest occurs during spring.

Other authors have focused on a single cultivar to define phenological stages (Melgarejo *et al.*, 1997). The use of the BBCH scale in this study has allowed all cultivars of the loquat collection to be described. Using data for more extensive collections has advantages. For instance, the range of cultivars allows to find principal and secondary stages in different varieties at the same time, which implied only one observation per week and contributed to a better description.

The BBCH scale has several advantages over the Fleckinger scale in fruit crops. The Fleckinger scale has only 11 stages which mainly describe inflorescence development (PGS 5). It does not define the flowering and fruit development processes (PGS 6 and 7) particularly well. Also, there are no descriptions of bud, leaf and shoot development (PGS 0, 1 and 3), or fruit maturity (PGS 8). Many growth regulators or pesticide applications are applied during these stages and they are completely defined by the new digital extended BBCH scale.

The extended BBCH scale has allowed varieties in the IVIA loquat collection to be better characterised. It has established, for instance, that the inflorescence development and flowering stages (PGS 5 and 6) are longer in late varieties than early ones. On the other

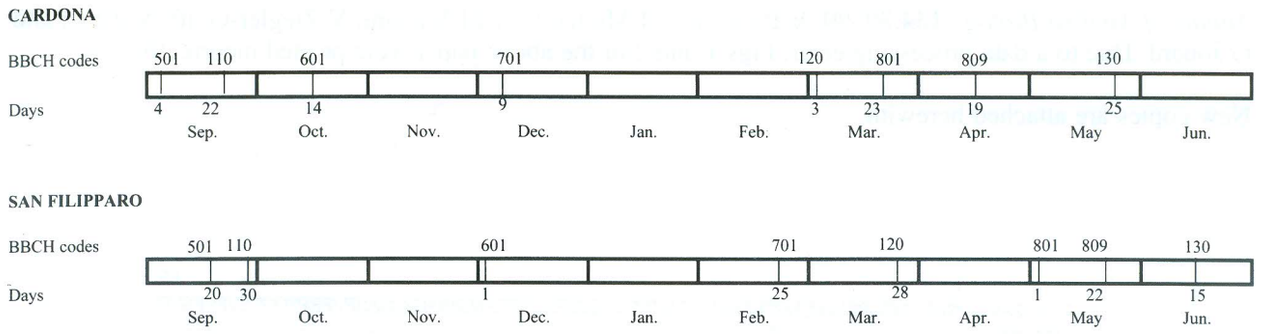

Fig. 2. Varietal differences in the phenological stages of flowering and fruit and leaf development in the loquat. Comparisons of the earliest (Cardona) and latest (San Filipparo) varieties in the IVIA collection

hand, the fruit growth and maturity stages (PGS 7 and 8) take longer in early varieties than in late ones (Fig. 2; Table 1). This is probably because the fruit development of early varieties takes place in winter and fruit ripening in March-April, when average temperatures are lower than in May, when the late varieties ripen.

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References

Bleiholder H, van den Boom T, Langelüddeke P, Stauss R. 1991. Codificación uniforme para los estadios fenológicos de las plantas cultivadas y de las malas hierbas. *Phytoma España* **28**:54–56.

Bleiholder H, Buhr L, Feller C, Hack H, Hess M, Klose R, Meier U, Stauss R, van den Boom T, Weber E. 1996. Compendio para la identificación de los estadios fenológicos de especies mono- y dicotiledóneas cultivadas, escala BBCH extendida. BASF AG, Germany. **ISBN 3–926138–17–3.**

Espinosa E, Martínez-Calvo J, García S, Badenes M L, Llácer G. 1997. Fenología y caracterización fenológica de variedades de níspero japonés. *Actas de Horticultura* **15**:425–430.

Hack H, Bleiholder H, Buhr L, Meier U, Schnock-Fricke U, Weber E, Witzenberger A. 1992. Einheitliche Codierung der phänologischen Entwicklungsstadien mono- und dikotyler Pflanzen - Erweiterte BBCH-Skala, Allgemein-. *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes* **44**:265–270.

Hack H, Bleiholder H, Buhr L, Feller C, Hess M, Klose R, Lancashire P, Meier U, Munger Ph, Stauss R, van den Boom T, Weber E. 1997. Compendium of Growth Stage Identification Keys for Mono- and Dicotyledonous Plants, Extended BBCH scale. 2nd Edition. Novartis AG, Switzerland. **ISBN3–9520749–3–4.**

Lancashire P D, Bleiholder H, van den Boom T, Langelüddeke P, Stauss R, Weber E, Witzenberger A. 1991. A uniform decimal code for growth stages of crops and weeds. *Annals of Applied Biology* **119**:561–601.

Llácer G, Aksoy U, Mars M. 1995. Underutilized fruit crops in the Mediterranean region. *Cahiers Options Méditerranéennes* **13**:110.

Meier U. 1997. Growth stages of plants, Entwicklungsstadien von Pflanzen, Estadios de crecimiento de las plantas, Stades de dévelopément des plantes. BBCH-Monograph, Blackwell Wissenschafts-Verlag Berlin, Wien: 622 pp. **ISBN 3–8263–3152–4.**

Melgarejo P, Martínez-Valero R, Guillamón J M, Miró M, Amorós A. 1997. Phenological stages of the pomegranate tree (*Punica granatum* L.). *Annals of Applied Biology* **130**:135–140.

Morico G, Grassi F, Fideghelli C. 1998. Horticultural genetic diversity: conservation and sustainable utilisation and related international agreements. *World Conference on Horticultural Research, Rome, June 1998, Discussion Text, Working Group 2*, pp. 55–63.

Rodríguez A. 1983. El cultivo del níspero y el valle del Algar-Guadalest. *Sociedad Cooperativa de Crédito de Callosa de Ensarriá (Alicante)*: 262 pp.

Zadoks J C, Chang T T, Konzac C F. 1974. A decimal code for the growth stages of cereals. *Weed Research* **14**:415–421.

Zhang H Z, Peng S A, Cai L H, Fang D Q. 1993. The germplasm resources of the genus *Eriobotrya* with special reference on the origin of *E. japonica* Lindl. *Plant Breeding Abstracts* **63**:772.

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