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Phenological growth stages of the persimmon tree (*Diospyros kaki*)

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Summary

Detailed crop-specific descriptions and codes are presented for the growth stages of the persimmon tree, contributing to the standardisation of national and international testing systems in fruit growing. Based on the general BBCH-scale, the codes describe growth stages using a two-digit numerical system and differentiate between principal and secondary growth stages to allow separation of developmental steps. Growth stages for bud, leaf and shoot development, inflorescence emergence, flowering, fruit development and fruit maturity are described. A feature of the system is that homologous stages of different crops are presented by the same codes.

Key words: BBCH scale, persimmon, phenology, minor fruit tree species

Introduction

The study of periodic biological events, such as budbreak, flushing, flowering and fruit development, closely regulated by climate and seasonal changes, is called phenology. From a climatological point of view, these phenomena lay the foundation for the interpretation of changes due to bioclimatical factors. From an agronomical point of view, understanding the consequences of a particular microclimate enables the response of the plant to be foreseen. Finally, from an economic point of view, phenological stages allow the prediction of a likely pest outbreak, the need for a specific fertilisation, the application of a hormonal product, etc.

In spite of the obvious importance of these considerations, there was no homogeneous coding to describe the developmental stages of the major cultivated plants and weeds until the beginning of the 1990s. The methods used previously to characterise the stages were usually a combination of letters and numbers (Fleckinger, 1948) without coincidence between different genera for the same developmental stages, thereby making generalisation difficult. However, this approach has been an essential tool for the understanding of fruit tree development, and has been the basis for defining the phenological stages of other plants.

Nevertheless, it became necessary to establish a numerical system to allow standardisation in the description of homologous developmental stages of different crops using the same codes, and allowing computerisation. The first decimal code was published by Zadoks *et al*. (1974) and a further development is the BBCH-scale (Bleiholder *et al*., 1989).

The numerical code consist of two numbers, the first one expressing the major stage and the second one the secondary stage within the course of the specific major stage. However, for some species, the BBCH-scale had some limitations and it was necessary to extend the scale with a third number (mesostadium), between the principal and secondary stages, in order to provide a better description of the phenological stages in these species (Hack *et al*., 1992). The BBCH-scale has been widely accepted in recent years, having been adapted for use in cereals (Lancashire *et al*., 1991), colza, bean and sunflower (Lancashire *et al*., 1991), beet (Meier *et al*., 1993), potato (Hack *et al*., 1993), pome and stone fruit trees, currant and strawberry (Meier *et al*., 1994), grapevine (Lorenz *et al*., 1994), various vegetable crops (Feller *et al*., 1995*a*, *b*), pomegranate tree (Melgarejo *et al*., 1997), citrus (Agustí *et al*., 1997) and loquat tree (Martinez-Calvo *et al*., 1999). All codes published have been compiled in the Spanish language by Bleiholder *et al*. (1996).

In persimmon (*Diospyros kaki* L.f.), there is no specific phenological scale, and until now stages have been defined using the Fleckinger (1948) scale. This scale mainly describes inflorescence development but does not define the bud, leaf, shoot, flower and fruit development processes, which are of importance in a

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fruit crop. In this paper we present the BBCH-scale for the description of the phenological growth stages of the persimmon tree according to the growth stage identification keys for monocolyledonous and dicotyledonous plants (Hack *et al*., 1992).

The persimmon belongs to the family Ebenaceae. There are approximately 200 species in the *Diospyros* genus, including *Diospyros virginiana*, American persimmon, and *Diospyros lotus*, date plum, used as rootstocks for persimmon. The persimmon originated in China but has long been grown in Japan. It belongs to the so-called group of minor fruit tree species that are not widely grown, but are of great importance in the producing areas and for diversification of agro-food production. By 2000, persimmon fruit production was around 1.5 million t, China (51%) and Japan (27%) being the main producer countries (Llácer & Badenes, 2002). Commercial production is also found in areas such as Australia, Brazil, Israel, Italy, New Zealand, Spain and USA, where summers are warm and winters provide sufficient chilling to overcome a short dormancy requirement. The persimmon is well adapted to temperate zones up to 40º latitude.

The persimmon is a species of deciduous trees, 6 m or more in height if unpruned, round and sympodially branched. Axillary buds containing flowering shoots begin development early in the season prior to budburst and flowering. Persimmon flowers appear singly and are hypogynous. Most commercial cultivars are dioecious and bear only female flowers, but some are hermaphrodite and are used as pollinators. However, in the absence of pollination, persimmon can bear parthenocarpic fruit. The fruit has a double-sigmoid growth curve and, characteristically, growth persists during ripening. Persimmons crop on wood produced in the current season. See George *et al*. (1997) and Jackson & Morley-Bunker (1999) for further details.

Materials and Methods

Data were recorded from adult trees (5 yr old) of *D. kaki*, cvs. 'Rojo Brillante' and 'Sharon', grafted onto seedlings, planted 3 × 3 m apart and grown in a loamy sand soil with furrow irrigation. Trees were located in an experimental orchard at the Universidad Politécnica of Valencia (Spain), latitude 39º 28' N, longitude 00º 22' W and altitude 13 m.

Five trees of each cultivar were used for observations.

Measurements and observations were carried out over two growing seasons (1999-2000 and 2000-2001), from February to November.

Phenological Stages of the Persimmon Tree

Scale characteristics

For fruit trees, the BBCH-scale uses eight of the 10 principal stages, starting with shoot growth (stage 0) and ending in initiation of dormancy (stage 9). Three principal growth stages are assigned to vegetative growth, which describe bud development (stage 0), leaf development (stage 1) and shoot growth (stage 3), the latter being shared with flower development (stage 5). Flowering (stage 6), fruit growth (stage 7) and maturity of fruit (stage 8) complete the code.

The secondary stages are also numbered from 0 to 9, being related to ordinal or percentile values of growth. Hence, value 1 of the principal stage of growth 6 (flowering) represents 10% of flowers in anthesis and its identification will be 61. Likewise, the value 5 of the principal stage 7 (fruit development) represents fruit at about 50% of final size, and will be defined, therefore, as 75. In other cases, the values of secondary stages indicate qualitatively different stages within a given principal phenological stage; thus, within the flowering stage, the beginning of the anthesis (60) and flowers withered state (67) are identified.

Description of the phenological growth stages of persimmon

Principal growth stage 0: Bud development

00 Dormancy: leaf buds are closed and covered by greenish scales and a grey-white fuzz
01 Beginning of leaf bud swelling: bud scales begin to elongate (Fig. 1)
02 Elongation of leaf bud. Terminal bud aborts
03 End of leaf bud swelling: greenish-brown scales slightly separated
07 Beginning of bud burst: first green leaf tips just visible
08 Green leaf tips continue growing and separating the scales (Fig. 1)
09 Green leaf tips about 5 mm above bud scales

Principal growth stage 1: Leaf development

10 First leaves separating: brownish scales slightly opened; leaves emerging
11 First leaves unfolded
15 More leaves unfolded, but not yet at full size (Fig. 1)
16 All leaves unfolded, but not yet at full size
19 First leaves fully expanded

Principal growth stage 3: Shoot development

31 Beginning of shoot growth: axes of developing shoots visible
25 Shoots about 50% of final length
39 Shoots about 90% of final length

Principal growth stage 5: Inflorescence emergence

51 Inflorescence buds swelling: buds closed, greenish-brown scales visible
52 End of inflorescence bud swelling: elongated scales with pubescent edges
53 Bud burst: scales begin to separate; beginning

01

08

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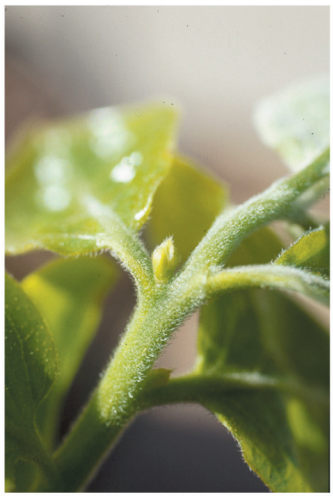

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89

Fig. 1. The major phenological growth stages of the persimmon tree

of peduncle elongation (Fig. 1)
54 Sepals visible, but still united (green bud)
55 Flowers still closed; sepals begin to separate (Fig. 1)
56 Flower petals elongating; peduncle elongating
57 Sepals open: petal tips visible; flowers with cream-coloured petals, still closed
59 Most flowers with petals forming a hollow ball

Principal growth stage 6: Flowering
60 First flowers open
61 Beginning of flowering: about 10% of flowers open
65 Full flowering: 50% of flowers open (Fig. 1)
67 Flowers fading (Fig.1)
69 End of flowering

Principal growth stage 7: Fruit development
71 Fruit set: beginning of ovary growth; green ovary surrounded by dying petal crown, petals begin to fall; beginning of fruitlet abscission (Fig. 1)
72 Fruit about 20% of final size (Fig. 1)
73 Beginning of physiological fruit drop
75 Fruit about half of final size
77 Fruit about 70% of final size. Light green fruit: end of physiological fruit drop (Fig. 1)
79 Fruit about 90% of final size

Principal growth stage 8: Maturity of fruit and seed
81 Beginning of fruit colouring (Fig. 1)
85 Fruit ripe for commercial picking; fruit has not yet variety-specific colour
87 Advanced ripening; increase in intensity of variety-specific colour
89 Fruit ripe for consumption; fruit has typical taste and firmness; fruit loses astringency; beginning of fruit senescence (Fig. 1)

Principal growth stage 9: Senescence. Beginning of dormancy
91 Shoot growth complete; foliage fully dark green
93 Beginning of senescence of old leaves; leaves fall
97 Winter rest period. All leaves fallen.

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