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# Phenological stages of the pomegranate tree (*Punica granatum* L.)

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## Summary

As in other temperate species, the pomegranate tree shows different phenological characteristics through its vegetative cycle in response to changing temperature. This phenology has been studied as a basis for comparisons of the successive stages of growth and reproduction in different geographical areas and conditions. The variety Mollar de Elche was studied, since it is grown on more than 95% of the total area devoted to this crop in Spain. Thirteen phenological-stages were identified during the annual cycle, starting at bud in dormancy and finishing a year later with leaf fall. These stages are denoted using the BBCH General Scale which uses numerical codes to represent particular stages. The code uses a two-digit number to describe the different phenological states and makes it possible to distinguish between principal and secondary stages of development. The duration of stages was measured in days and as accumulated degree-day.

**Key words:** Phenological stages, pomegranate tree

## Introduction

The pomegranate tree (*Punica granatum* L.) originates in central near east (Sánchez-Monge, 1974). It is a temperate species that is now cultivated throughout the Mediterranean region. It requires high summer temperatures to ripen properly so commercial production is limited to coastal areas or those with mild summers (Melgarejo & Martínez, 1989). It can be grown in areas where the winter temperatures drop to −15°C and certain acidic and central Asian cultivars can even survive temperatures of −25°C or −30°C (Aleksandrov, 1950).

The plant's needs during winter are small (Westwood, 1982), and the length of winter dormancy is correlated with temperatures below 16°C (Rozanov & Vorobeva, 1976).

Fleckinger (1945) first studied phenological stages of fruit trees such as pear and apple and represented them graphically. In this scheme the stages of vegetative development of shoots and branches, the thickening of branches and trunk, and the later appearance of flowers and fruit and their subsequent development were defined by descriptions of their external appearance, and each denominated on individual phenological stage (Gil-Albert, 1991).

Bleiholder, van den Boom, Langelüddeke & Stauss (1989) introduced a new nomenclature which described the phenological stages of both herbaceous and woody plants. The new system, BBCH General Scale, unified previous codes which were specific to different botanical families into a general scale applicable to all plants. Stauss (1994) published a more detailed version of this scale. The new method is basically a decimal system which identifies

different development stages by a two digit code. The first digit defines its major stages using values of 0 to 9 while the second digit, also scaled 0 to 9, relates to secondary stages.

The nomenclature has already been used by various authors for different plant families: Zadoks, Chang & Konzak (1974) for cereals; Lancashire *et al.* (1991) for rape, bean and sunflower; Meier *et al.* (1993) for beet; Hack *et al.* (1993) for potato; Meier *et al.* (1994) for fruit with stones and pips, redcurrant and strawberry; Lorenz *et al.* (1994) for vine; Feller *et al.* (1995) for several vegetables, and Agustí *et al.* (1995) for citrus species. Until now their has been no study of the phenological stages of pomegranate.

This paper describes the phenological stages of pomegranate using the traditional nomenclature described by Fleckinger (1945) and other authors for fruit trees, and relates them to the BBCH General Scale.

## Materials and Methods

The pomegranate trees used were of the variety "Mollar de Elche" (Melgarejo, 1993), the most widely grown variety in Spain. They were grown on a plantation belonging to the Polytechnic University of Valencia which lies within the municipal boundaries of Alicante. The trees were produced by vegetative propagation, planted in a 4 m × 3 m pattern, and watered by a system of drip irrigation.

The soil was a clay loam, typical of the region. Rainfall is scarce (about 300 mm per annum), the majority falling in spring and autumn. Mean annual temperature was 19°C with mild winters and hot summers (11°C in January and 28°C in August). According to the agroclimatic classification of Papadakis (Anon., 1986) the climate is subtropical mediterranean, and ideal for pomegranate cultivation.

The different phenological stages of plant growth and bud and fruit development between winter dormancy and leaf fall were defined and described using the traditional procedure of Fleckinger (1945) in which the general stages are designated by letters followed by a number between 1 and 4 to designate the substage. Two consecutive stages should be sufficiently close in time for a bud's evolution to be clearly identified. These stages were related to the BBCH General Scale.

Four healthy trees were chosen at random within the plantation and four branches growing toward each of the four cardinal compass points marked. The development of a single bud on each branch was monitored closely. In addition, all trees in the plantation were inspected to ascertain the predominant growth stage at each visit (every 2 to 4 days until June and then once per week). Photographic records were taken every 2 wk. Measurements and observations were made between December 1991 and December 1992, at which time all the leaves had fallen and the trees were entering their period of winter dormancy. Shoot, flowers and fruit growth was measured during the growth cycle with a Cassio electronic digital gauge (accurate to within 0.01 mm).

## Results

The growth stages, the phenological codes and duration are given in Table 1 and also in Fig. 1.

The pattern of development of individual buds of marked trees generally matched that of the whole plantation even though flowering was dependant on the position and orientation of the branches on the tree. There was no appreciable difference between buds for the duration of the successive phenological stages.

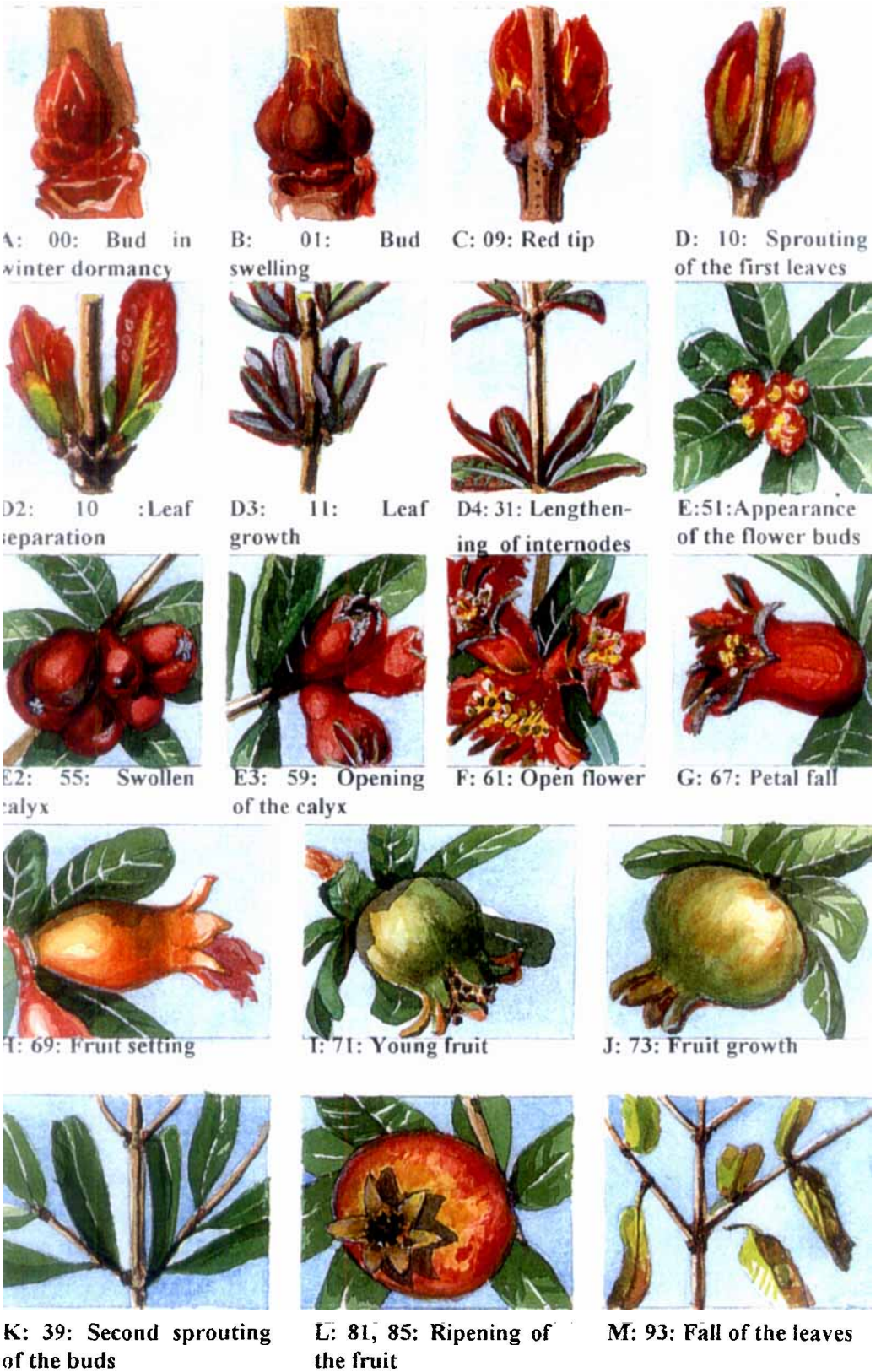


Fig. 1. Phenological stages of development of the pomegranate (*Punica granatum* L.) from bud to leaf fall.

Table 1. *Growth stages, phenological codes and duration of the pomegranate tree*

| Growth stage | Fleckinger code | BBCH code | Duration days | Duration °C days |
|---|---|---|---|---|
| Bud in winter dormancy | A | 00 | 61 | — |
| Bud swelling | B | 01 | 11 | 12 |
| Red tip | C | 09 | 6 | 25 |
| Sprouting of first leaves | D | 10 | 6 | 21 |
| Leaf separation | D2 | 10 | 4 | 20 |
| Leaf growth | D3 | 11 | 12 | 44 |
| Lengthening of internodes | D4 | 31 | 119 | 1228 |
| Appearance of the flower buds | E | 51 | 3 | 21 |
| Swollen calyx | E2 | 55 | 11 | 88 |
| Opening of calyx | E3 | 59 | 3 | 24 |
| Open flower | F | 61 | 6 | 59 |
| Petals fall | G | 67 | 2 | 27 |
| Fruit setting | H | 69 | 10 | 129 |
| Young fruit | I | 71 | 17 | 182 |
| Fruit growth | J | 73 | 90 | 1323 |
| Second bud sprouting | K | 39 | 45 | 700 |
| Fruit ripening | L | 81, 85 | 35 | 366 |
| Leaf fall | M | 93 | 57 | — |

The duration of each phenological stage was measured in days and heat units starting at the beginning of bud development. The heat units were measured as the sum of the differences between mean daily temperatures and a base temperature of 10°C which corresponds to the temperature at which bud development is activated (Baldini, 1992). The use of heat units allows comparisons to be made across different years and geographical areas.

## Phenological stages of development

*A: 00: Bud in winter dormancy*

The bud is greyish brown and completely closed, deeply linked to the twig and sharply pointed at its tip.

*B: 01: Bud swelling*

The bud swells and becomes paler and rounder in shape.

*C: 09: Red tip*

The bud opens to show the new shoot, which is spear shaped and has a red tip.

*D: 10: Sprouting of the first leaves*

The first leaves appear; they are furled and are bright red with a pale midrib green and the rest of the leaf is bright red.

*D2: 10: Leaf separation*

The new leaves separate.

*D3: 11: Leaf growth*

Leaves grow in length and width, and change colour from bright red to light green.

*D4: 31: Lengthening of internodes*

Internodes lengthen and shoot growth is rapid.

*E: 51: Appearance of the flower buds*

Flower buds appear among the leaves on shoots, being greenish at first, but becoming red after a few days. The sepals are visible and close together.

*E2: 55: Swollen calyx*

The buds increase in size, and become pear-shaped; the differences between male and hermaphrodite flowers becomes apparent in the shape and the colour of the calyx; the terminal branches bud together with several flowers, usually abscises.

*E3: 59: Opening of the calyx*

The sepals open, to show the folded red petals inside. Toward the end of this stage, petals unfold and the pistil anthers become visible.

*F: 61: Open flower*

The calyx opens totally and the protruding petals, which are folded and purple, unfold over the sepals. The petals seem to be inserted between every two sepals, on their inner side, giving the impression of alternating petals and sepals. The anthers of the stamen change to deep yellow when the pollen is ripe and capable of fertilising. It is during this stage that pollination takes place.

*G: 67: Petal fall*

Petals wither and fall; the calyx turns colour from red to orange-red; stamens bend toward the longitudinal axis of the flower and the anthers become greyish-yellow. The terminal part of the style withers.

*H: 69: Fruit setting*

The fertilised ovary grows in size and the base of the calyx swells; the stamens wither and the fruit slam changes from orange-red to greenish brown.

*I: 71: Young fruit*

The fruit increases in size rapidly and the colour turns from greenish brown to green.

*J: 73: Fruit growth*

The fruit enlarges almost to its final size through cell enlargement; the sepals form a crown, the dry stamen being inside.

*K: 39: Second bud sprouting*

Resumption of shoot growth on the tree.

*L: 81, 85: Fruit ripening*

The fleshy seeds change from white to pinkish-red or red; the skin of the fruit changes from green to greenish yellow, and finally to brownish-yellow with reddish patches.

*M: 93: Leaf fall*

The leaves turn yellowish, and fall; and when complete, winter dormancy starts.

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