



Phenological growth stages of saffron plant (*Crocus sativus* L.) according to the BBCH Scale

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Abstract

Phenological studies are important for understanding the influence of climate dynamics on vegetative growth, flowering and fruiting on plants and can be used in many scientific subjects, such as Agronomy, Botany and Plant Biology, but also Climatology as a result of the current global interest in climate change monitoring. The purpose of the detailed specific culture descriptions of the principal growth stages in plants is to provide an instrument for standardization of data recording. To date, there was no coding method to describe developmental stages on saffron plant (*Crocus sativus* L.). Because of the increasing world-wide interest on this crop, a novel growth development code based on the BBCH extended scale is proposed in this paper. Six principal growth stages were set up, starting from sprouting, cataphylls and flowers appearance, plant appearance and development, replacement corms development, plant senescence and corm dormancy. Each principal growth stage is subdivided into secondary growth stages. Descriptive keys with illustrations are included to make effective use of the system.

Additional key words: developmental phases; replacement corm; nomophylls; cataphylls.

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Saffron spice is obtained from dried stigmas of *Crocus sativus* L. plant and it is appreciated because of its colouring, flavouring and aroma capacity (Carmona *et al.*, 2006). It is the most expensive world-wide spice and thus it has been called “the red gold” (Poggi, 2009). Saffron-growing in Spain has been world-wide referenced both in yield and quality; in fact, the best quality saffron spice is globally recognized to be produced in the Region of Castilla-La Mancha, Spain (Carmona *et al.*, 2006). Seasonal weather changes are significant in these Mediterranean climate areas, and saffron plants have been able to develop survival mechanisms coping with adverse conditions derived from higher or lower temperatures as well as extreme drought events (Wareing & Phillips, 1981; Pérez Bueno, 1988).

In cultivated plants, phenological studies have traditionally been carried out with the aim of agricultural application to determine the optimal time to apply fertilizers, crop protection products (herbicides, fungi-

cides and insecticides) and plant growth regulators, pruning, pollination techniques, obtaining propagation material and decision making for the best harvest time.

Until the early 1990s, there was not a homogeneous code to describe the growth stages in most plants and crops. Zadoks *et al.* (1974) published the first decimal code aiming at standardizing the phenological development stages description for similar cereal crops by using the same codes. Further development derived in the BBCH (Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie) scale proposed by Bleiholder *et al.* (1989) and in the extended BBCH-scale proposed by Hack *et al.* (1992). Since then, the extended BBCH-scale has become a world-wide coding system commonly used to integrate phenology in agricultural, horticultural, environmental and meteorology and climatic studies (Meier *et al.*, 2009). It has been broadly accepted for its use in many crops like cereals (Lancashire *et al.*, 1991), sugar beet (Meier *et*

al., 1993) or *Citrus* spp. (Agustí *et al.*, 1997). The extended BBCH-scale is a system for a uniform coding of phenologically similar growth stages of all mono- and dicotyledonous plant species carried out by a work team referenced by Enz & Dachler (1997). The entire developmental cycle of the plants is subdivided into ten clearly recognizable and distinguishable longer-lasting developmental phases. These ten principal growth stages alone are not sufficient to define exactly application or evaluation dates, since they always describe time spans in the course of the development of a plant. Secondary stages are used if points of time or steps in the plant development must be indicated precisely. In contrast to the principal growth stages they are defined as short developmental steps characteristic of the respective plant species, which are passed successively during the respective principal growth stage. They are also coded by using a second digit with figures from 0 to 9.

The characterization of the phenological stages is essential for saffron crop production since cultural practices such as application of crop protection products and herbicides, transplanting and tillage rely to a large extent on correctly checking certain stages (Vela *et al.*, 2013). Several authors have deeply described the morphology and annual cycle of saffron plant (Chrungoo *et al.*, 1983; Botella *et al.*, 2002; Carmona *et al.*, 2006; Poggi, 2009) whilst Molina *et al.* (2005) codified the phenological stages of saffron inflorescence buds. Nevertheless, there are currently no universally used keys to describe the entire development cycle of this plant.

ITAP (Agronomy Technical Institute of Albacete) and the University of Castilla-La Mancha have been working on agronomy research of saffron crop since 1994, particularly on plant breeding, pathology, mechanic cultivation practices, corm processing and flower forcing methods, as related to its influence on saffron spice quality (ITAP, 2013). Basing on this background, the objective of this paper was to describe the phenological growth and developmental stages of saffron plant according to the extended BBCH-scale to effectively supplement other studies on saffron cultivation.

The study of saffron plant phenology described in this paper is based on twenty years field observation records (from 1993 to 2013) which were collected from many farming crops and many field experiments, with plant material of different ages and cultivated at different sites across the Albacete province, Spain (lat. of $38.7 \pm 0.75^\circ\text{N}$; elevation range: 610–870 m asl), by the ITAP Department of Agricultural Technology Extension and Transfer (ITAP, 2013). A field experiment was carried out in the campaign 2012-13 to better describe in

detail the phenological stages of the saffron plant. The sample plot was located in a traditional farming area of Balazote, Spain (lat. $38^\circ55'\text{N}$, long. $02^\circ06'\text{W}$, 740 masl), under continental mediterranean climate conditions, with winters of type avena/oats warm and summers of type maize; the temperature regime is temperate to warm and the humidity regime is dry mediterranean (Papadakis, 1961). The soil is classified as Haplic-calcisol in the FAO system and Typic-Calcixercept according to USDA.

The sampling plot was representatively selected from traditional farms growing saffron crop for commercial use. It was planted in September 2011 on a 6,000 m² plot, according to proper tillage commonly used in the area (de Juan & Lozano, 1991). Corms were planted at 15 cm depth in rows 50 cm apart and planting density of 40 plants/m². Planting material derived from local ecotypes of saffron corms. Although the farm has sprinkler irrigation infrastructure, it was never used during this trial because the rainfall (248.5 mm) from November to April was sufficient to cope with the crop water requirements. Phenology observation was carried out daily over the whole plot. The phenological stage was assigned as that of most of the plants, in any case, at least more than 50%, which had reached that stage (López, 2004) and the most representative plants were photographed to describe the most significant phenological stages. Furthermore, destructive data collection was recorded every fortnight, that is 13 sampling dates, with three replicates, from October 1, 2012 to May 9, 2013, covering the period from sprouting up to senescence of the above-ground plant part. Each sampling consisted on pulling out all the entire plants, with the exception of roots, in 0.5×0.4 m² plots (10-12 sampled plants) randomly delimited.

With a view to unifying the criteria existing to describe the saffron plant cycle, the terms *mother corm*, *replacement corm* or *daughter corm* and *cataphyll* are utilized in this paper basing on Mathew (2003) and Negbi (2003).

According to field observations and following the basic principles of the extended BBCH-scale, a phenological scale describing the entire developmental cycle of saffron (*Crocus sativus* L.) is proposed.

The study of the biological cycle of saffron plant starts with the corm in dormancy stage, apparently showing neither morphological change, nor external growth, although there do exist internal physiological and morphogenetic changes (Le Nard & De Hertogh, 1993). Once the corm leaves the dormancy, fibrous caulogenic roots form a root plate at the base, one or more shoots subsequently emerge with the leaves and flowers wrapped by the cataphylls. This currently happen under the case study environmental conditions from

Table 1. Growth stages of saffron plant following the extended BBCH-scale

Stage	Principal growth stage	Sub-stage	Secondary growth stage
0	Sprouting		
		00	Dormant mother corm. Apical and lateral sprouts are not developed yet.
		01	Beginning of bud swelling.
		03	Bud swelling complete
		05	Roots appearing from the corm.
		07	Beginning of bud sprouting.
		08	Shoots visible under the soil surface.
		09	Emergence: Shoots (cataphylls) breaking through soil surface.
1	Leaf development (assessed at plant level)		
		10	Leaves (nomophylls) sprouting and unfolding from cataphylls.
		11	Leaves (nomophylls) growth at 10% of final length.
		12	Leaves (nomophylls) growth at 20% of final length.
		1X	Leaves (nomophylls) growth at X0% of final length, continues with the same scheme until sub-stage 18
		19	Leaves (nomophylls) growth at 90% of final length.
4	Development of replacement corms		
		41	Growth of replacement corms at 10% of final size.
		42	Growth of replacement corms at 20% of final size.
		4X	Growth of replacement corms at X0% of final size, continues with the same scheme until sub-stage 48.
		49	Growth of replacement corms at 90% of final size.
5	Appearance of flower cataphylls		
		50	Beginning of flower cataphylls. Stigmata are visible at the basal part of the stem.
		55	Flower cataphylls emerging.
		57	Flower cataphylls visible above ground, enveloped by its bracts.
		59	Flower cataphylls still closed.
6	Flowering		
		60	First flower tepals visible.
		61	10% of maximum flower mass reached.
		63	30% of maximum flower mass reached.
		65	50% of maximum flower mass reached.
		67	70% of maximum flower mass reached.
		69	End of flowering.
9	Plant senescence		
		91	Leaves (nomophylls) development completed, foliage still green.
		93	Leaves (nomophylls) apices beginning to discolour.
		95	50% of leaves yellowish.
		96	Roots have dried out and can fall easily.
		97	Leaves senescence. Leaves fully discoloured and beginning plant resting. Mother corm fully dry.
		98	Leaves fall off the corm.
		99	Replacement corms fully formed.



Figure 1. Selected principal and secondary phenological growth stages of annual cycle of saffron (*Crocus sativus* L.) corresponding to sprouting (0: 00, 05, 07, 09), leaf development (1: 10), appearance of flower cataphylls (5: 55), flowering (6: 60, 61, 65, 69) and senescence (9: 97), according to the extended BBCH-scale.

the second fortnight of October on. The above-ground plant growth derived from sprouting is due to available reserves in the corm. Flowering occurs from the second fortnight of October to the first fortnight of November (ITAP, 2013), and previously to leaf appearance or

simultaneously, since saffron is a hysteroanthous plant (Plessner *et al.*, 1989) whose flowers open before its leaves depending on the environmental conditions (Mathew, 1982). Later on, leaves and roots keep on growing along the period of vegetative activity (Oromí,

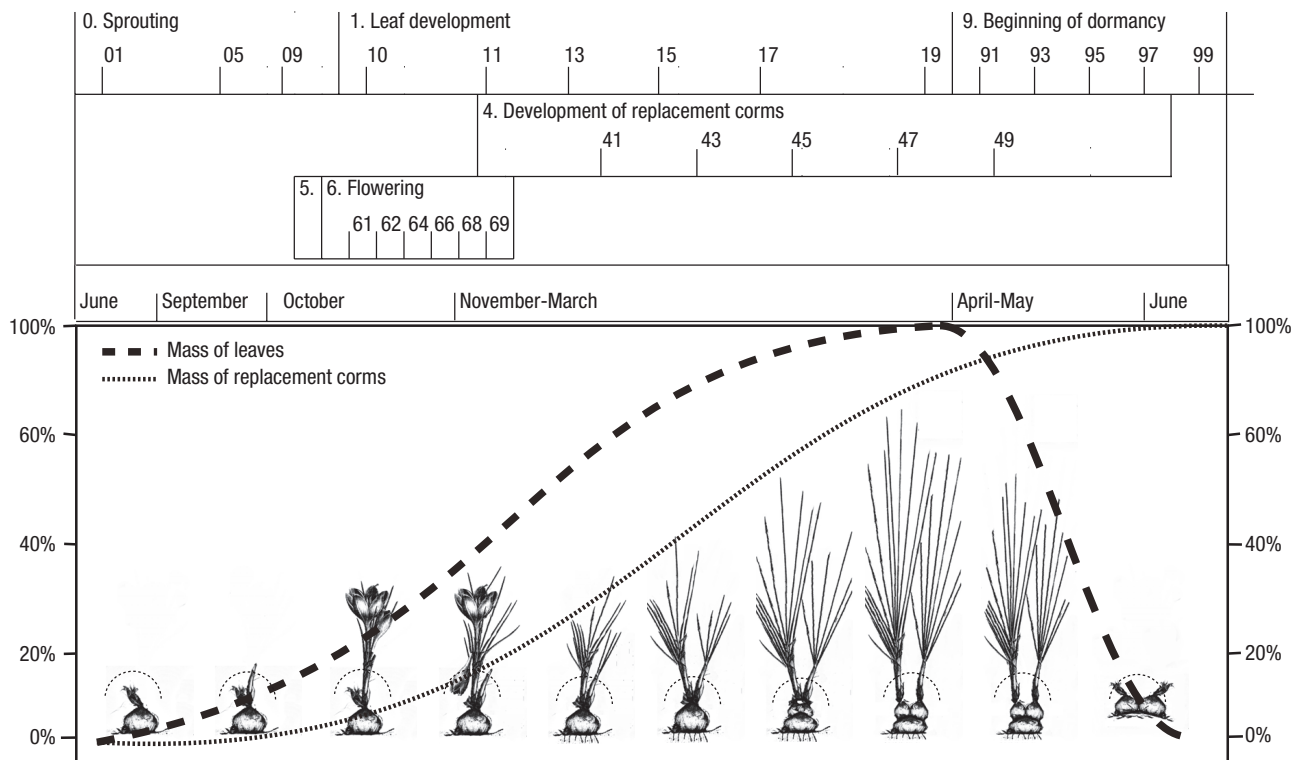


Figure 2. Scheme of the annual cycle and the principal growth stages of saffron (*Crocus sativus* L.) on a monthly basis, according to the extended BBCH-scale in Albacete, Spain, based on ITAP (2013). The dash line shows the trend of leaf mass (%) and the dot line, the trend of corm mass (%).

1992). The base of shoots begins to swell forming the daughter corms while the mother corm depletes its reserves. In spring, as diurnal temperatures increase and soil moisture decrease, the mother corm roots die and break away, photoassimilates move from the leaves to the corms and the leaves start to senesce from the apex to the base; the daughter corms are fully developed and ready for latency.

For the saffron plant, growth begins with bud swelling and sprouting. The vegetative period is represented by three principal growth stages corresponding to leaf development, development of replacement corms and plant senescence. The reproductive period covers appearance of flower cataphylls and flowering.

Some stages of the extended BBCH scale do not apply to saffron plant and must be omitted, like BBCH stage 2 which is related to the formation of side shoots or tillering, BBCH stage 3, which relates to stem elongation or rosette growth or shoot development (main shoot) and finally BBCH stages 7 and 8 which are related to the development and ripening of the fruit/seeds respectively, since *Crocus sativus* L. is a sterile triploid form making its flowers unable to produce viable seeds for independent sexual reproduction.

Secondary growth stages are referred to by a second digit in the code (numbered from 0 to 9) and corre-

spond to ordinal or percentage values of plant development. For example, for corms development (stage 4), the scale represented the growth share (%) related to the final size.

Hence, the extended BBCH-scale proposed for saffron plant only considers 6 out of the 10 principal growth stages, starting with *Sprouting* (Stage 0) and ending with *Beginning of dormancy* (Stage 9). Four principal growth stages are involved in vegetative development: *Sprouting* (Stage 0), *Leaf development* (Stage 1), *Development of replacement corms* (Stage 4) and *Plant senescence* (Stage 9). The remaining two principal stages are related to flowering: *Appearance of flower cataphylls* (Stage 5) and *Flowering* (Stage 6).

The entire phenological cycle identified for saffron plant is characterized in Table 1. It is highly recommended to follow this key with Figures 1 and 2, showing the annual cycle of saffron plant following the extended BBCH-scale as proposed. Figure 2 shows that some stages overlap or run concurrently in the saffron plant cycle (for instance, leaf appearance and flowering, among others); thus, it is recommended that both stages should be noted separating their codes by a forward slash.

Álvarez-Ortí *et al.* (2003) already described the phenological cycle into six stages according to the

morphological and physiological characteristics observed, although this classification suits the plant cycle, it is not scaled nor coded for agricultural applications. The BBCH scale proposed in this paper for saffron plant will help farmers and technicians to efficiently cultivate and manage saffron crop. Furthermore, it will facilitate the exchange of information, knowledge and experiences among the scientific community by unifying criteria to describe the growth and development stages regardless the area where it might be cultivated. Negbi (2003) referred that the timing of the transition from vegetative to reproductive shoot apex differs in Azerbaijan and Russia, Kashmir or Israel. In Spain it happens in April-May and flower organs are formed in June-July (ITAP, 2013). Crop practices scheduling might be compared and adapted to local situations according to regular phenological codes. It must be outlined that there is variability in dating and duration of the presented growth stages in the study area, but these are mainly due to different agronomy and climate conditions and not to local ecotypes of saffron which are not present in Spain so far (Alonso *et al.*, 2007).

The extended BBCH-scale for saffron plant is introduced in this paper for the first time. It can be broadly applicable because it describes the total of six principal phenological stages for sprouting (stage 0), leaf appearance (stage 1), replacement corm development (stage 4), flower cataphylls appearance (stage 5), flowering (stage 6) and beginning of dormancy (stage 9). These data should facilitate more effective management of saffron orchards, defining the optimal time to carry out the different agricultural tasks and particularly irrigation practices, because the crop coefficients are directly related to the phenological stages.

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