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RESEARCH ARTICLE

A general growth stage key for describing trees and woody plants

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Abstract

*B*iologishe *B*undesanstalt, Bundessortenamt and *CH*emical Industry (BBCH) scales are a system for the uniform coding of phenologically similar growth stages of plants, using a two-digit decimal code. Currently, scales exist for a number of tree and woody species grown as crops; however, researchers are often forced to adapt existing scales or create their own when describing other tree or woody species growing as crops or weeds. This paper describes a general BBCH scale for the phenological growth stages of tree and woody species, including plant-specific descriptions and decimal codes covering vegetative and reproductive stages. The scale uses eight of the 10 principal BBCH stages, starting with sprouting/bud development (stage 0) and ending with dormancy (stage 9). This BBCH scale represents a single, standardised growth stage key for describing the growth of needle-bearing and leaf-bearing woody plants and promotes the adoption of the use of BBCH scales more widely. It is expected that the scale will form the basis for the creation of further scales specific for family, genus or species.

Introduction

Those working with agricultural and horticultural crops and their associated weed species need to be able to describe the growth stages of these plants in a readily understood and unambiguous way. Historically, a great many scales have been developed for describing a range of plant types, particularly for economically important crops. However, there were often multiple scales for the same crop and it was difficult to identify analogous codes, and the codes were often a combination of letters and numbers making computerisation difficult. One approach has been to develop a uniform decimal code allowing for standardisation in the description of equivalent developmental stages of different crops using the same codes. As research has extended beyond the realms of 'agriculture', more researchers have begun to recognise the benefits of uniform scales in other areas of plant research, e.g. silviculture, rangeland, pasture and industrial and waste areas.

One internationally recognised system of growth stage keys is based on the *B*iologishe *B*undesanstalt, Bundessortenamt and *CH*emical Industry (BBCH) scale and its associated decimal code that was developed jointly by BASF, Bayer, Ciba-Geigy and Hoechst (Bleiholder *et al.*, 1989) and included a number of economically important crops (Lancashire *et al.*, 1991). The extended BBCH scale (Hack *et al.*, 1992) system provides a uniform coding of phenologically similar growth stages of all monocotyledonous and dicotyledonous plant species.

The BBCH scale describes the entire developmental cycle of plants and is subdivided into 10 clearly recognisable and distinguishable developmental phases. These principal growth stages are described from 0 to 9 in ascending order. The principal growth stages alone are not sufficient to define exactly application or evaluation dates for researchers, as 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, the secondary stages describe points in time or shorter developmental intervals in the major growth stage. The combination of figures for the principal

and secondary stages results in the two-digit code. BBCH scales allow the comparison of individual codes only within one principal growth stage: an arithmetically greater code indicates a plant at a later growth stage. The time span of certain developmental phases of a plant can be exactly defined and indicated by using two stages in which case the codes are connected with a hyphen, e.g. 51-69. The principal growth stages need not proceed in the strict sequence defined by the ascending order of the codes but can also proceed in parallel and are indicated by using a diagonal stroke, e.g. 35/55. BBCH scale descriptions are based on the actual characteristic features of individual plants. If the scale is to be applied to a plant stand, then the description is applied to a minimum of 50% of the plants.

The BBCH scale has been widely accepted in recent years and covers a wide range of plant species. Specific keys for a number of agronomically important crops have been published collectively as a compendium along with a general key for weed species (Hess *et al.*, 1997) all based around the BBCH scale. Specific crop keys that have been developed include a number of 'woody' species, such as pome fruit and stone fruit, and currants (Meier *et al.*, 1994), citrus (Agusti *et al.*, 1995), grapevine (Lorenz *et al.*, 1994), pomegranate tree (Melgarejo *et al.*, 1997), loquat tree (Martinez-Calvo *et al.*, 1999), coffee (Arcila-Pulgarin *et al.*, 2002) and persimmon (Garcia-Carbonell *et al.*, 2002). The advantage of the BBCH scale is its simplicity and ease of use for annual, biennial and perennial plants and that it describes both the vegetative and reproductive stages of plant growth. All keys have been published in English, French, German and Spanish, further increasing the acceptance and use of the BBCH scale (BBA, 2007).

Although a number of the keys published to date covered species that could be described as 'woody', none of the scales provided sufficiently exact description to fully reflect the many other tree and woody plant species that are being dealt with in ongoing research. Researchers often construct their own scales, continue to use older non-uniform scales or are obliged to adapt the existing scales such as those of pome fruit and of citrus or the general scale. This has led to the potential for global researchers interpreting the scales in different ways, leading to inconsistency and loss of comparability in research. The following scale attempts to unify the description for needle-bearing and leaf-bearing woody species (either as crop or weed species). Without such a scale, researchers will continue to encounter difficulties in interpretation of other research. Although this is a general scale, the authors also believe it can form the basis for future scales specific for family, genus or species for trees and woody plants.

Materials and methods

Information was gathered from Europe, Latin America, North America and the Pacific of the plant genera and species that were regularly being examined in plant protection research but were not easily covered by the extended general BBCH scale for monocotyledonous and dicotyledonous plants, adaptation of crop-specific scales or the general weed scale. This resulted in an extensive list (Table S1) representing the enormity of the challenge of providing a single uniform growth scale. It was also clear that, like the general scale, separation of some codes for needle-bearing and leaf-bearing species would be necessary.

A draft scale was proposed, and for those stages where the description would benefit, an illustration based on photographs of the stages was produced.

Stages of trees and woody plants

Scale characteristics

Trees and woody plants may exhibit proleptic (most temperate woody species) or sylleptic (many tropical species and a few temperate species, e.g. some *Populus*) bud growth. Many species can also exhibit both forms of growth depending on cultural and environmental conditions. Similarly, they may also exhibit monopodial (indeterminate) or sympodial (determinate) growth. Despite this, the proposed BBCH scale can be applied to all types as its application relies on the description of the plant at a particular moment in time. It is for this reason that BBCH scales already exist for proleptic trees (apple), sylleptic (citrus), sympodial (pomegranate and persimmon) and monopodial types where the same codes and descriptions are equivalent for each type.

The proposed scale uses eight of the 10 principal stages, starting with sprouting/bud development (stage 0) and ending with dormancy (stage 9) (Table 1). Stage 2 (formation of side shoots) was omitted as the scale is restricted to the description of the main stem only as tree and woody plant branching can be so extensive that it goes beyond the scope of a BBCH scale and is better described by the use of tree architectural models. Stage 4 (development of harvestable vegetative plant parts or vegetatively propagated organs) was omitted as it is not relevant to the woody plants covered by the scale. The secondary stages are numbered 0 to 9, being related to the ordinal or percentile stages of growth. Thus, value 5 of the principal growth stage 6 (flowering) represents 50% of flowers open – code 65. In other cases, the values of secondary stages indicate qualitatively different stages within a principal stage, e.g. 03 is the end of bud swelling.

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Table 1 Description of the phenological growth stages of woody species

Code[a]		Description
Principal growth stage 0: sprouting/bud development		
00		Dormancy: buds closed and covered by scales
01		Beginning of bud swelling
03[b]		End of bud swelling
07		Beginning of sprouting or bud breaking; shoot emergence
09		Buds show green tips
Principal growth stage 1: leaf and needle development		
10[b]	LB	Green leaf tips 10 mm above the bud scales
	NB	Needle elongation
11	LB	First leaves unfolded
15[b]	LB	More leaves unfolded, but not yet at full size. First leaves unfolded
	NB	Needle elongation, 50% developed
17	LB	Most leaves unfolded on majority of tree
19[b]	LB	Leaf expansion complete
	NB	Needle elongation complete
Principal growth stage 3: stem elongation		
30[b]		Beginning of stem elongation
31		Stem about 10% of final length
33		Stem about 30% of final length
35		Stem about 50% of final length
3.		Stages continuous till …
39[b]		Stem about 90% of final length; cessation of stem growth
		Principal growth stage 5: inflorescence emergence
51		Inflorescence or flower buds visible
55		First individual flowers visible but still closed
59		First flower petals visible (in forms with petals)
Principal growth stage 6: flowering (main shoot)		
60		First flowers open
61		Beginning of flowering, 10% flowers open
62		20% of flowers open
63		30% of flowers open
64		40% of flowers open
65		50% of flowers open, full flowering: first petals may be fallen
67		Flowering finishing; majority of petals fallen or dry
69	LB	End of flowering: fruit set visible
	NB	End of flowering
Principal growth stage 7: fruit/cones development		
72		Fruit/cones 20% of final size
75		Fruit/cones 50% of final size
78		Fruit/cones 80% of final size
79[b]		Fruit/cones final size
Principal growth stage 8: fruit/cones ripening		
89		Fruit/cones fully ripe
Principal growth stage 9: senescence, beginning of dormancy		
91[b]		Shoot growth completed; foliage still green and terminal buds developed
92[b]	LB	Beginning of leaf discoloration
93	LB	Beginning of leaf fall
95	LB	50% of leaves fallen
97	LB	End of leaf fall

LB, leaf bearing; NB, needle bearing.

[a]No code letter is used if the description applies to both plant groups.

[b]One or more illustrations are available (Fig. 1).

In keeping with all BBCH scales, the proposed scale allows for the description of principal growth stages that may proceed in parallel and are indicated by using a diagonal stroke, e.g. 35/55. Similarly, a plant stand may also occur at a range of stages at any particular point in time and is described by using two stages in

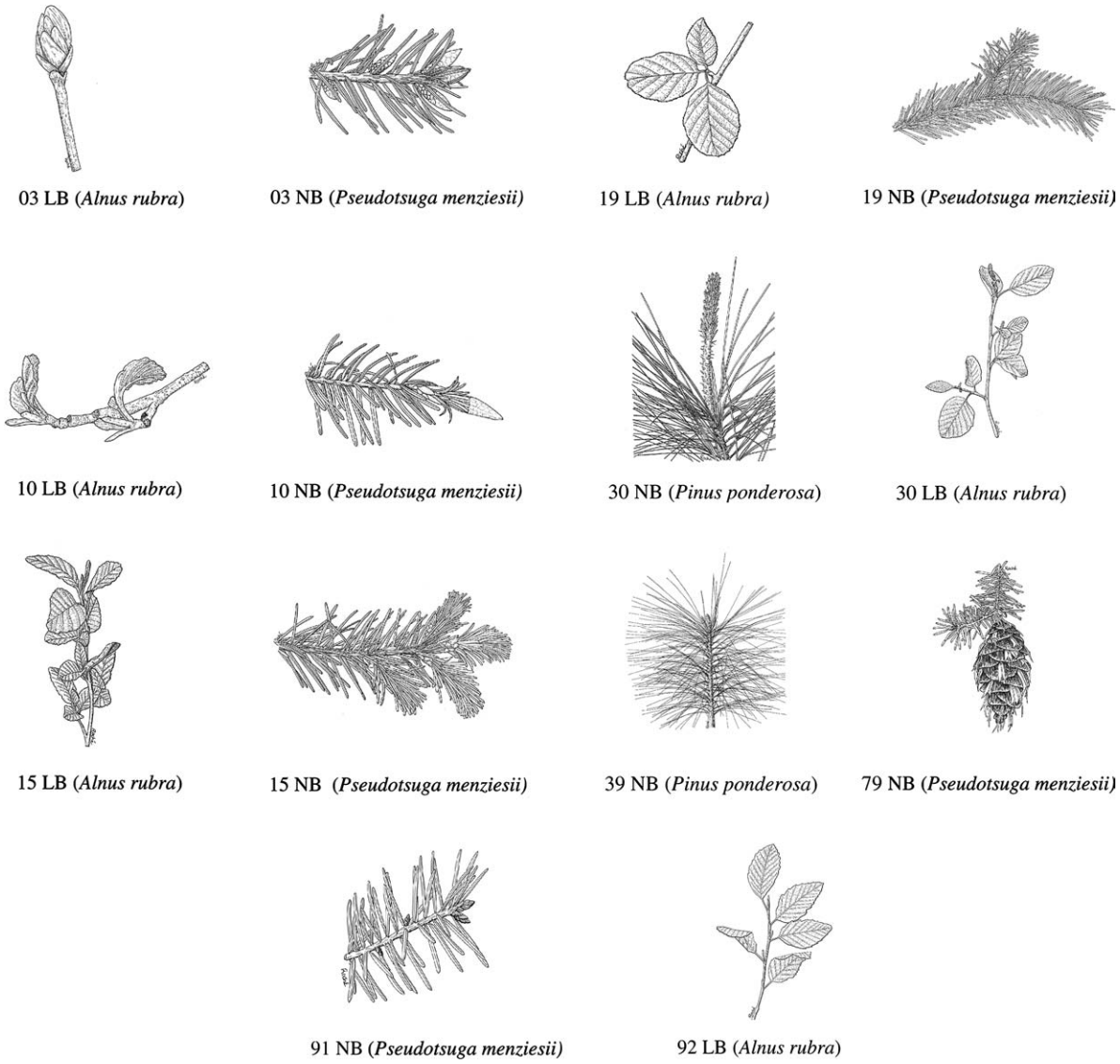

Figure 1 Main phenological growth stages of tree and woody species. The illustrations are renderings of specific growth stages described in the general phenological BBCH growth stage key for describing trees and woody plants. The caption for each illustration refers to the specific numerical growth stage and plant type (leaf or needle bearing) and the scientific name of the species used.

which case the codes are connected with a hyphen, e.g. 51-69.

Discussion

The authors propose that the BBCH scale is a further step forward in achieving uniformity of growth stage descriptions and wish to encourage the adoption of the use of BBCH scales more widely. In covering such a wide range of species, it is possible that some woody species still will not easily fit into the scale. Researchers are encouraged to publish separate scales or modifications to this scale to further encourage the adoption of the BBCH system.

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References

Agusti M., Zaragoza S., Bleiholder H., Buhr L., Hack H., Klose R., Stauss R. (1995) Escala BBCH para la descripcion de los estadios fenologicos del desarrollo de los agios (Gén Citrus). *Levante Agrícola*, **3**, 189–199.

Arcila-Pulgarin J., Buhr L., Bleiholder H., Hack H., Meier U., Wicke H. (2002) Application of the extended BBCH scale for the description of the growth stages of coffee (*Coffea* spp.). *Annals of Applied Biology*, **141**, 19–27.

BBA (2007) *Growth Stages of Mono- and Dicotyledonous Plants – BBCH Monograph*. URL http://tinyurl.com/26j3b3 [accessed on 27 April 2007].

Bleiholder H., van den Boom T., Langelüddeke P., Stauss R. (1989) Einheitliche Codierung der phänologischen Stadien bei Kultur- und Schadpflanzen. *Gesunde Pflanzen*, **41**, 381–384.

Garcia-Carbonell S., Yague B., Bleiholder H., Hack H., Meier U., Agusti M. (2002) Phenological growth stages of the persimmon tree (*Diospyros kaki*). *Annals of Applied Science*, **141**, 73–76.

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.

Hess M., Barralis G., Bleiholder H., Buhr L., Eggers T.H., Hack H., Stauss R. (1997) Use of the extended BBCH-scale – general for the descriptions of the growth stages of mono- and dicotyledonous weed species. *Weed Research*, **37**, 433–441.

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

Lorenz D.H., Eichorn K.W., Bleiholder H., Klose R., Meier U., Weber E. (1994) Phänologische Entwicklungsstadien der Weinrebe (*Vitis vinifera* L spp. *vinifera*). Codierung und Beschreibung nach der erteweitergen BBCH-Skala. *Viticulture and Enology Science*, **49**, 66–70.

Martinez-Calvo J., Badenes M.L., Llácer G., Bleiholder H., Hack H., Meier U. (1999) Phenological growth stages of loquat tree (*Eriobotrya japonica* (Thunb.) Lindl.). *Annals of Applied Biology*, **134**, 353–357.

Meier U., Graf H., Hack H., Hess M., Kennel W., Klose R., Mappes D., Seipp D., Strauss R., Streif J., Van den Boom T. (1994) Phänologische Entwicklungsstadien des Kernobstes (*Malus domestica* Borkh. und *Pyrus communis* L.), des Steinobstes (*Prunus*-Arten), der Johannisbeere (*Ribes-Arten*) und der Erdbeere (*Fragaria* × *ananassa* Duch.). *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes*, **46**, 141–153.

Melgarejo P., Martinez-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.

Supplementary material

The following supplementary material is available for this article:

Table S1. An extensive listing of woody genus/species considered when developing the scale and to which it can be applied; the listing includes scientific name, common name where available and European and Mediterranean Plant Protection Organization (EPPO) code.

This material is available as part of the online article from: http://www.blackwell-synergy.com/doi/abs/10.1111/j.1744-7348.2007.00159.x

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