The BBCH system to coding the phenological growth stages of plants-history and publications

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Übersichtsarbeit

Uwe Meier[1], Hermann Bleiholder[2], Liselotte Buhr[3], Carmen Feller[4], Helmut Hack[5], Martin Heß[6], Peter D. Lancashire[7], Uta Schnock[8], Reinhold Stauß[9], Theo van den Boom[10], Elfriede Weber[11], Peter Zwerger[1]

The BBCH system to coding the phenological growth stages of plants – history and publications –

Das BBCH-System zur Codierung der phänologischen Entwicklungsstadien von Pflanzen – Geschichte und Veröffentlichungen –

Abstract

The growth stages of development of many cultivated plants have been described by numerous scientists according to the principles of the extended BBCH scale within the last 19 years. The BBCH scales are now well-known worldwide and are used by research, administration and practise in agriculture and horticulture, as in the phenology as an integrative science in environment, meteorology and climatology.

This fact indicates that the basic objectives and hope have been reached, justifying the practical approach taken by the authors of this scale. The BBCH scale is a contribution to improve the communication between different groups of scientists and to allow the interchange of data and scientific results in a transparent way. The BBCH scales have turned out helpful and practical. The aim to cause the harmonisation in the application of decimal codes for the description of the phenological growth stages of plants and weeds was reached. They also fulfilled the hope of the initiators to contribute with it to the improvement of the international agrarian-scientific and interdisciplinary communication.

This paper will describe the history and background of the BBCH scales. The original publications are described and explained with reference of the original literature sources. The paper will describe the different area of use of the scales and list the different scientific disciplines using them. The worldwide success of the BBCH scales is the work of many scientists around the globe.

Key words: BBCH scale, phenological growth stages, BBCH publications, BBCH history

Zusammenfassung

Die Entwicklungsstadien der wichtigsten Kulturpflanzen wurden in den vergangenen 19 Jahren von zahlreichen Wissenschaftlern nach den Prinzipien der erweiterten BBCH-Skala beschrieben. Die BBCH-Skalen sind inzwischen weltweit bekannt und werden von Wissenschaft, Administration und Praxis in Landwirtschaft und Gartenbau ebenso genutzt, wie in der Phänologie als integrative Wissenschaft im Bereich Umwelt, Meteorologie und Klimatologie.

Institute
Julius Kühn-Institut – Bundesforschungsinstitut für Kulturpflanzen, Braunschweig[1]
formerly BASF AG , Limburgerhof[2]
formerly Biologische Bundesanstalt für Land- und Forstwirtschaft, Kleinmachnow[3]
Institut für Gemüse- und Zierpflanzenbau, Großbeeren/Erfurt[4]
formerly Bayer CropScience GmbH, Leverkusen[5]
Bayer CropScience GmbH, Industriepark Höchst, Frankfurt[6]
Bayer CropScience GmbH, Monheim[7]
Bundessortenamt (BSA), Hannover[8]
Landesamt für Natur und Umwelt des Landes Schleswig-Holstein, Flintbek[9]
formerly Bayer CropScience GmbH, Leverkusen[10]
formerly BASF AG, Limburgerhof[11]

Correspondence
Prof. Dr. Peter Zwerger, Julius Kühn-Institut – Bundesforschungsinstitut für Kulturpflanzen 38104 Braunschweig, Germany, Messeweg 11/12, E-Mail: peter.zwerger@jki.bund.de

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Diese Tatsache weist darauf hin, dass Zielsetzung und Hoffnung, die seit dem Beginn der Arbeit damit verbunden waren, sich erfüllt haben. Die BBCH-Skalen haben sich als hilfreich und praktisch erwiesen. Das Ziel, die Harmonisierung in der Anwendung von Dezimalcodes für die Beschreibung der phänologischen Entwicklungsstadien von Kulturpflanzen und Unkräutern herbeizuführen, wurde erreicht. Sie erfüllten auch die Hoffnung der Initiatoren, damit zur Verbesserung der internationalen agrarwissenschaftlichen und interdisziplinären Kommunikation beizutragen.

In der vorliegenden Arbeit soll die Geschichte der BBCH-Skalen aufgezeigt werden, weil diese Einblick in die Hintergründe ihrer Entstehung und Entwicklung erlaubt. Alle Original-Publikationen werden mit ihren Literaturquellen zusammenfassend dargelegt. Die Arbeit soll die unterschiedliche Nutzung der BBCH-Skalen in den verschiedenen wissenschaftlichen Disziplinen dokumentieren. Es soll deutlich werden, dass der weltweite Erfolg der BBCH-Skalen vielen Wissenschaftlern rund um den Globus zu verdanken ist.

Stichwörter: BBCH-Skala, phänologische Entwicklungsstadien, BBCH-Publikationen, BBCH-Geschichte

Introduction

Phenology is the study of plant and animal life cycle events, which are triggered by environmental changes. Wide ranges of phenomena are included, from first opening of leaf and flower buds, to insect hatching and migration of birds are all examples of phenological events. Each one gives a measure of the environment as experienced by the affected organism. Thus, phenological events are ideal indicators of the impact of local and global changes in weather and climate on the earth's biosphere.

The observation and recording of phenological events has a long tradition. XIAOQIU (2003) reports ancient records and literature, such as observations taken for up to 3000 years in China.This tradition is in close connection with the observation of the weather and its dependence on the seasons. Human knowledge and activities connected to what is now called phenology are probably as old as civilisation itself. Surely, soon after farmers began continuously to dwell in once place – planting seeds, observing crop growth and carrying out the harvest year after year – they quickly became aware of the connection of changes in their environment to plant development.

The history of phenology and its importance in the present and in the future is described by more than 50 scientists from different disciplines in the book of SCHWARTZ (2003) *Phenology: In integrative environmental science*. Bruns, Chmielewski, van Vliet (2003) and MEIER (2003) develop the relationship to modern agriculture, they recommend the BBCH system and the traditional meteorology and climatology.

History of the BBCH coding system

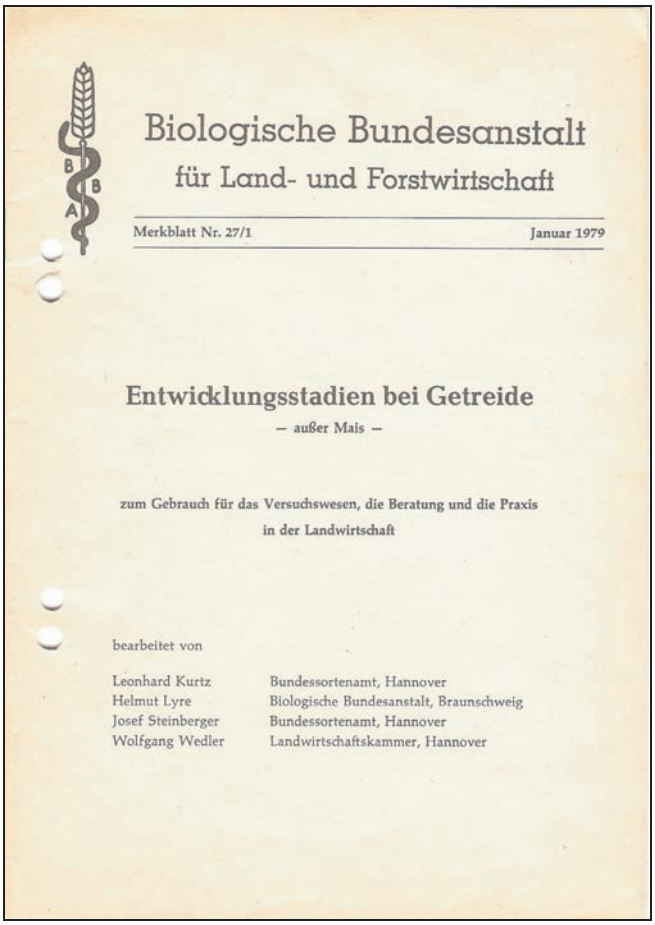
Like all scientific branches, the agricultural plant sciences are increasingly integrated into international networks. The exchange of new findings as a result of the work of international project teams needs a common understanding of the terms in use.

The need for a common understanding of terminology is also important for the description of the phenological growth stages of plants. The BBCH scheme is a good basis to satisfy this scientific demand.

During the past 70 years numerous authors have published descriptive development stage scales for different individual plant species. TROITZKI (1925) studied the correlation between the occurrence and control of the apple blossom weevil (*Anthonomus pomorum* L.) and the phenological development of flower buds. The author divided the bud formation of the apple into three stages and twelve phases. This initial development scale for pome fruits was also used by KLEMM (1937) and SOENEN (1951, 1952) for their documentation on plant protection. On the basis of the work of TROITZKI (1925), FLECKINGER (1948) described the phenological development stages of pome fruit. He assigned the capital letters from **A** to **I** to the main stages and differentiated them by numbers from 1 to 4. This classification was widely used in science and practice until 1994. Based on the scale of FEEKES (1941), LARGE (1954) published the first numeric code for cereals. ZADOKS et al. (1974) presented an adjusted and refined numeric decimal scale for cereals and rice which is still in use by plant breeders.

The increasing international interconnections in crop research and the increasing electronic data processing of trial results required an international system with a standardised description and coding of the development stages of plants.

The Federal Biological Research Centre for Agriculture and Forestry (BBA) published from 1979 until 1988 the leaflet series 27 (MEIER, 1985) (Fig. 1). The structure of the individual scales was in general based on the publication of ZADOKS et al. (1974). The BBCH coding system is an advancement of the Zadoks coding system, because it includes mono- and dikotyledoneous plants. A major disadvantage of the scales published by BBA was the missing direct comparability of homologous growth stages. By comparing the scales of different crops it can be shown that for the same growth stage a common code is missing. For example for the stage "full flowering" in maize it is stage 65, in rape it is stage 64, in sugar beet this stage is missing and grapes are already in full flower at stage 23. For trialists this is an enormous disadvantage in their daily work. During the period, 12 booklets were published with descriptions of the growth stages of individual cultivated plants. Each scale published by the BBA was based on the development characteristics of the plant described with the scale; no homology between the crops was achieved. At the same time the "Nachrichtenblatt für den Pflanzenschutz in der DDR" between 1985 and 1989 published the BBA codes of the crops on the reverse of the journal cover. Members of the Academy of Agricultural



Biologische Bundesanstalt
für Land- und Forstwirtschaft

Merkblatt Nr. 27/1 Januar 1979

Entwicklungsstadien bei Getreide
– außer Mais –

zum Gebrauch für das Versuchswesen, die Beratung und die Praxis
in der Landwirtschaft

bearbeitet von

Leonhard Kurtz Bundessortenamt, Hannover
Helmut Lyre Biologische Bundesanstalt, Braunschweig
Josef Steinberger Bundessortenamt, Hannover
Wolfgang Wedler Landwirtschaftskammer, Hannover

Fig. 1. The first leaflet No. 27/1: Groth stages of cereals – except maize (Entwicklungsstadien bei Getreide – außer Mais).

Sciences of the GDR in Bad Lauchstädt worked out a coordinated decimal code (KDC) for numerous crops, and published them as a booklet (BUHTZ et al., 1990).

The second group consisted of staff members from four chemical companies which have been doing research in the agricultural field for decades. This group worked out a common scale for the description of the phenological growth stages for mono- and dicotyledonous plants. This concept was published by BLEIHOLDER et al. (1989) and presented at the 47. Deutsche Pflanzenschutztagung (BLEIHOLDER et al., 1990). This was the first time a uniform growth scale for mono- and dicotyledonous plants was published . The first publication of the BBCH codes of some specific crops (BLEIHOLDER et al., 1989) quickly generated interest and was distributed internationally. This concept was then published in Spain (BLEIHOLDER et al., 1991), Brazil (BLEIHOLDER et al., 1991) and Great Britain (LANCASHIRE et al., 1991).

In 1991 the different working groups formed a new common working group. The first outcome of this cooperative work was the publication of the principles of the enhanced general BBCH scale (HACK et al., 1992). Since 1992 members of this working group have published "extended BBCH scales for specific crops" with experts in each crop in various scientific magazines.

The descriptions of development stages for important crops were summarised in the book "BBCH-Monograph. Growth stages of plants – Entwicklungsstadien von Pflanzen – Estadios de las plantas – Développement des Plantes" edited by MEIER (1997). The monograph describes the phenological development stages of 27 crops and wild plants in four languages (English, German, Spanish, French). In a separate book, ADAMCZEWSKI and MATYSIA (2005) published the BBCH scales in Polish, after GASOWSKI and OSTROWSKA (1993) had published the BBCH scales for the first time in Polish. BBCH scales of numerous crops and weed were translated into the Russian and few in Ukrainian language and were published in specific crop production monographs by Spaar (Tab. 3). Compendiums were also published in different languages by Ciba-Geigy, Novartis and BASF (see Compendia) to help the trialists in the field easily identify the growth stages. These various publications contributed considerably to the world-wide practical use of the BBCH system in plant research and other disciplines such as climatology, and it solved interdisciplinary communication problems.

A very important step for the international acceptance of the BBCH codes in plant protection was the recognition of the BBCH system by the European and Mediterranean Plant Protection Organization (EPPO). The EPPO

Tab. 1. Principal growth stages

Stage	Description
0	Germination / sprouting / bud development
1	Leaf development (main shoot)
2	Formation of side shoots / tillering
3	Stem elongation or rosette growth / shoot development (main shoot)
4	Development of harvestable vegetative plant parts or vegetatively propagated organs / booting (main shoot)
5	Inflorescence emergence (main shoot) / heading
6	Flowering (main shoot)
7	Development of fruit
8	Ripening or maturity of fruit and seed
9	Senescence, beginning of dormancy

Tab. 2. Original publications

Crops and weeds	**Scientific name**	**Original publication**	**Year**
Apricot tree	*Prunus armeníaca* L:	PÉREZ-PASTOR, A. M. et al. (english)	2004
Edible musaceae	*Musa* × *paradisiaca* L:	GONZALES, R. et al. (english)	2002
Beta beet	*Beta vulgaris* L. spp.	MEIER, U. et al. (german)	1993
Cereals	*Triticum sp., Hordeum vulgare,*	WITZENBERGER, A. et al. (german)	1989
	Avena sativa, Secale cereale	LANCASHIRE, P.D. et al (english)	1991
Maize	*Zea maize* L:	WEBER, E., H. BLEIHOLDER (german)	1990
		LANCASHIRE, P. D. et al. (english)	1991
Rice	*Oryca sativa* L:	LANCASHIRE, P. D. et al. (english)	1991
Faba bean	*Vicia faba* L:	WEBER, E., H. BLEIHOLDER (german)	1990
		LANCASHIRE, P. D. et al. (english)	1991
Sunflower	*Helianthus annuus* L:	WEBER, E., H. BLEIHOLDER (german)	1990
		LANCASHIRE, P. D. et al. (english)	1991
Oilseed rape	*Brassica napus* L:	WEBER, E., H. BLEIHOLDER (german)	1990
		LANCASHIRE, P. D. et al. (english)	1991
Citrus fruits	*Gen. citrus*	AUGUSTI, M. et al. (spanish)	1995
		AUGUSTI, M. et al. (french)	1997
Coffee	*Coffea* spp.	ARCILA-PULGARÍN, J. et al. (english)	2002
Cotton	*Gossypium hirsutum* L:	MUNGER, P. et al. (english)	1998
North American ginseng	*Panax quinquefolius* L:	PROCTOR, J. T et al. (english)	2003
Grapevine	*Vitis vinifera* ssp. *vinifera* L:	LORENZ, D. H. et al. (german)	1994
		LORENZ, D. H. et al. (english)	1995
Hop	*Humulus lupulus* L:	ROSSBAUER, G. et al. (german)	1995
Loquat tree	*Eriobotrya japonica* L:	MARTÍNEZ-CALVO, J. et al. (english)	1999
Pea	*Pisum sativum* L:	WEBER E., H. BLEIHOLDER (german)	1990
		LANCASHIRE, P. D. et al. (english)	1991
		FELLER, C. et al. (german/ english)	1995b
Olive tree	*Olea europaea* L.	SANZ-CORTÉS, F. et al. (english)	2002
Peanut	*Arachis hypogaea* L.	MUNGER, P. et al. (english)	1998
Persimmon tree	*Diospyros kaki* L.	GARCÍA-CARBONELL, S. et al. (english)	2002
Pome fruit, apple	*Malus domstica* Borkh.	MEIER, U. et al. (german)	1994
Pome fruit, pear	*Pyrus communis* L.	MEIER, U. et al. (german)	1994
Stone fruit, cherry	*Prunus cerasus* L..	MEIER, U. et al. (german)	1994
Stone fruit, plum	*Prunus domestica* L.. ssp.*domestica*	MEIER, U. et al. (german)	1994
Stone fruit, peach	*Prunus persica Batsch* L.	MEIER, U., et al. (german)	1994
Cherimoya tree	*Annona cherimola* Mill.	CAUTÍN, R. et al.	2005
Pomgranate tree	*Punica granatum* L.	MELGAREJO, P. et al. (english)	1997
Currant, black	*Ribes nigrum* L..	MEIER, U. et al. (german)	1994
Currant, red	*Ribes rubrum* L.	MEIER, U. et al. (german)	1994
Strawberry	*Fragaria x ananassa* Duch.	MEIER, U. et al. (german)	1994
Potato	*Solanum tuberosum* L.	HACK, H. et al. (german)	1993
Quince tree	*Cydonia oblonga* Mill.	MARTÍNEZ-VALERO, R. et al. (english)	2001
Raspberry	*Rubus idaeus* L.	SCHMIDT, K. H. et al. (german)	2001
Soybean	*Glycine max* L. MERR.	MUNGER, P. et al. (english)	1997
Bulb vegetables, onion	*Allium cepa* L.	FELLER, C. et al. (german / english)	1995a
Bulb vegetables, leek	*Allium porrum* L.	FELLER, C. et al. (german / english)	1995a
Bulb vegetables, garlic	*Allium sativum* L.	FELLER, C. et al. (german / english)	1995a
Bulb vegetables, shallot	*Allium ascalönicum* auct. Non L.	FELLER, C. et al. (german / english)	1995a
Root and stem vegetables, carrot	*Daucus carota* L.. ssp. *sativus*	FELLER, C. et al. (german / english)	1995a
Root and stem vegetables, celeriac	*Apium graveolens* L. var. *rapaceum* Gaud.	FELLER, C. et al. (german / english)	1995a
Root and stem vegetables, kohlrabi	*Brassica oleracea* L. var. *gongylodes*	FELLER, C. et al. (german / english)	1995a

Tab. 2. Continue

Crops and weeds	Scientific name	Original publication	Year
Root and stem vegetables, chicory	*Cichorium intybus* L. var. *foliosum*	FELLER, C. et al. (german / english)	1995a
Root and stem vegetables, radish	*Raphanus sativus* L.. ssp.	FELLER, C. et al. (german / english)	1995a
Root and stem vegetables, swede	*Brassica napus* L. ssp. *Rapifera Metzg.*	FELLER, C. et al. (german / english)	1995a
Root and stem vegetables, scorzonera	*Scorzonera hispanica* L.	FELLER, C. et al. (german / english)	1995a
Leaf vegatables (forming heads), cabbage	*Brassica oleracea* L. var. *capitata f. alba and rubra*	FELLER, C. et al. (german / english)	1995a
Leaf vegatables (forming heads), chinese cabbage	*Brassica chinensis* L.	FELLER, C. et al. (german / english)	1995a
Leaf vegetables (forming heads), lettuce	*Lactuca sativa* L. var. *capitata*	FELLER, C. et al. (german / english)	1995a
Leaf vegetables (forming heads), endive	*Cichorium endivia* L.	FELLER, C. et al. (german / english)	1995a
Leaf vegetables, spinach	*Spinacea oleracea* L.	FELLER, C. et al. (german / english)	1995a
Leaf vegetables, loosehead lettuce	*Lactuca sativa* L.. var. *crispa*	FELLER, C. et al. (german / english)	1995a
Leaf vegetables, kale	*Brassica oleracea* L. var. *sabellica*	FELLER, C. et al. (german / english)	1995a
Brussels sprout	*Brassica oleracea* L. var. *gemmifera* DC./Zenk.	FELLER, C. et al. (german / english)	1995a
Cauliflower	*Brassica oleracea* L. var. *botrytis*	FELLER, C. et al. (german / english)	1995a
Broccoli	*Brassica oleracea* L. var. *italica* Plenck	FELLER, C. et al. (german / english)	1995a
Cucumber	*Cucumis sativus* L.	FELLER, C. et al. (german / english)	1995b
Melon	*Cucumis melo* L.	FELLER, C. et al. (german / english)	1995b
Pumpkin, marrow, squash	*Cucurbita pepo* L.	FELLER, C. et al. (german / english)	1995b
Calabash	*Cucurbita pepo* L. var. *giromontiina*	FELLER, C. et al. (german / english)	1995b
Water-melon	*Citrullus* var. *vulgaris Schad.*	FELLER, C. et al. (german / english)	1995b
Tomato	*Lycopersicum esculentum* Mill.	FELLER, C. et al. (german / english)	1995b
Aubergine	*Solanum melongena* L.	FELLER, C. et al. (german / english)	1995b
Paprika	*Capsicum annuum* L.	FELLER, C. et al. (german / english)	1995b
Bean	*Phaseolus vulgaris* var. *nanus* L.	FELLER, C. et al. (german / english)	1995b
Trees and woody plants	*several species*	FINN, G. A. et al. (english)	2007
Winter linseed	*Linum usitatissimum* L.	SMITH, J. M. et al. (english)	1998
Weeds		HESS, M. et al. (english)	1997

(2004, 2006) made the BBCH code mandatory for all official plant protection trials.

The BBCH scale

The BBCH scale is a system for a uniform coding of phenologically-similar growth stages of all mono- and dicotyledonous plant species. It results from teamwork between scientists of

- the German Federal Biological Research Centre for Agriculture and Forestry (BBA)[1],
- the German Federal Office of Plant Varieties (BSA),
- the German Agrochemical Association (IVA) and
- the Institute for Vegetables and Ornamentals

[1]By now: Julius Kühn-Institute (JKI). Federal Research Centre for Cultivated Plants

The decimal code, which is divided into principal and secondary growth stages, uses the basic structures described by ZADOKS et al. (1974) for cereals and rice and was adapted to other monocotyledonous crops and described for use for dicotyledonous and perennial crops and wild plants. The abbreviation BBCH derives from **B**iologische Bundesanstalt, **B**undessortenamt and **CH**emical industry.

The basic principles of the scale

- The general scale forms the framework within which the individual scales are developed. It can also be used for those plant species for which no special scale is currently available.
- Similar phenological stages of each plant species are given the same code.
- For each code, a description is given, and for some important stages, drawings are included.
- For the description of the phenological development stages, clear and easily recognised (external) morphological characteristics are used.

Tab. 3. Phenological growth stages of plants in Russian and Ukrainian language

- Growth stages of oilseed rape (BBCH-Code). Ed. SPAAR, D.: production of rape. Moskau 1996, p 120-122 (russian)
- The general extended BBCH-scale of phonological growth stages of plants (BBCH-Code). Rape and turnip rape. Production, harvest and use. Moskau: DLV Agrodelo 2007, p 281-183 (russian)
- Growth stages of potato. Development of the tuber (BBCH-Code). Ed. SPAAR, D.: Potato production. Moskau 1997, p 227-231 (russian)
- Growth stages of potato. Development of the tuber (BBCH-Code). Ed. SPAAR, D.: potato, production, harvest, storage. Moskau, DLV Agrodelo 2007, p 394-398 (russian)
- Growth stages of potato. Development of the tuber (BBCH-Code). Ed. SPAAR, D.: potato, production, harvest, storage. Kiew 2006, p 418-422 (ukrainian)
- Growth stages of maize (BBCH-Code). Ed. SPAAR, D.: maize, production, harvest, conservation, use. Moskau, DLV Agrodelo 2006, p 294-297 (russian)
- Growth stages of cereals (BBCH-Code). Ed. SPAAR, D.: production of cereals. Moskau 1998, p 320-323 (russian)
- Growth stages of cereals (BBCH-Code). Ed. SPAAR, D.: production of cereals. Moskau: DLV Agrodelo 2008, p 566-571 (russian)
- Growth stages of pea (BBCH-Code). Ed. SPAAR, D.: Grain legumes. Minsk 2000. p 238-241 (russian)
- Growth stages of faba bean (BBCH-Code). Ed. SPAAR, D.: Grain legumes. Minsk 2000. p 242-244 (russian)
- Growth stages of soy bean (BBCH-Code). Ed. SPAAR, D.: Grain legumes. Minsk 2000. p 245-250 (russian)
- Growth stages of phaseolus bean (BBCH-Code). Ed. SPAAR, D.: Grain legumes. Minsk 2000. p 251-253 (russian)
- Growth stages of sunflower (BBCH-Code). Ed. SPAAR, D.: Summer oil plants Minsk 1999. p 261-264 (russian)
- Growth stages of rape (BBCH-Code). Ed. SPAAR, D.: Summer oil plants Minsk 1999. p 651-267 (russian)
- Growth stages of linseed (BBCH-Code). Ed. SPAAR, D.: Summer oil plants Minsk 1999. p 268-269 (russian)
- Growth stages of sugarbeet (BBCH-Code). Ed. SPAAR, D.: production of sugarbeet Minsk 1998. p 178-181 (russian)
- Growth stages of sugarbeet (BBCH-Code). Ed. SPAAR, D.: sugarbeet. production, harvest and storage. Moskau: DLV Agrodelo 2006, p 268-271(russian)
- Growth stages of sugarbeet (BBCH-Code). Ed. SPAAR, D.: sugarbeet. production, harvest and storage. Kiew: DLV Agrodelo 2005, p 299-302 (ukrainian)
- Growth stages of weed species (BBCH-Code). Ed. SPAAR, D.: plant protection in sustainable systems of agriculture. Torshok 2003, Vol. 2, p 212-224 (russian)
- Growth stages of vegetables, pome,- stone- and berry fruits and grape and weed species (BBCH-Code). Ed. SPAAR, D.: Ecologisation of plant protection of in the vegetable,- fruit- and grapeproduction. Vol. 2, 2005, Sankt-Petersburg-Puschkin p 162-228 (russian)

SPAAR, D. (Ed.): Seed and plants of agricultural crops. Vol. 2, Berlin 2001 (russian):

Growth stages of cotton (BBCH-Code), p 279-282

Growth stages of hop (BBCH-Code), p 299-30

(translation and editor: Dieter SPAAR)

- Except where stated otherwise, only the development of the main stem is taken into consideration.
- The growth stages refer to representative individual plants within the crop stand. Crop stand characteristics may also be considered.
- Relative values relating to species- and/or variety-specific ultimate sizes are used for the indication of sizes.
- The secondary growth stages 0 to 9 correspond to the respective ordinal numbers or percentage values. For example stage 3 could represent: 3rd true leaf, 3rd tiller, 3rd node or 30% of the final length or size typical of the species or 30% of the flowers open.
- Post harvest or storage treatment is coded 99.
- Seed treatment before planting is coded 00.

Organisation of the BBCH scale

The entire developmental cycle of the plants is subdivided into ten clearly recognizable and distinguishable longer-lasting developmental phases. These principal growth stages are described using numbers from 0 to 9 in ascending order. The principal growth stages are described in Tab. 1. Owing to the very many different plant species there may be shifts in the course of the development or certain stages may even be omitted.

The principal growth stages need not proceed in the strict sequence defined by the ascending order of the figures, but can occasionally also proceed in parallel. If two or more growth stages proceed in parallel, both can be indicated by using a diagonal stroke (example 16/22). If only one stage is to be indicated, either the more advanced growth stage must be chosen or the principal growth stage of particular interest, depending upon the plant species.

The 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

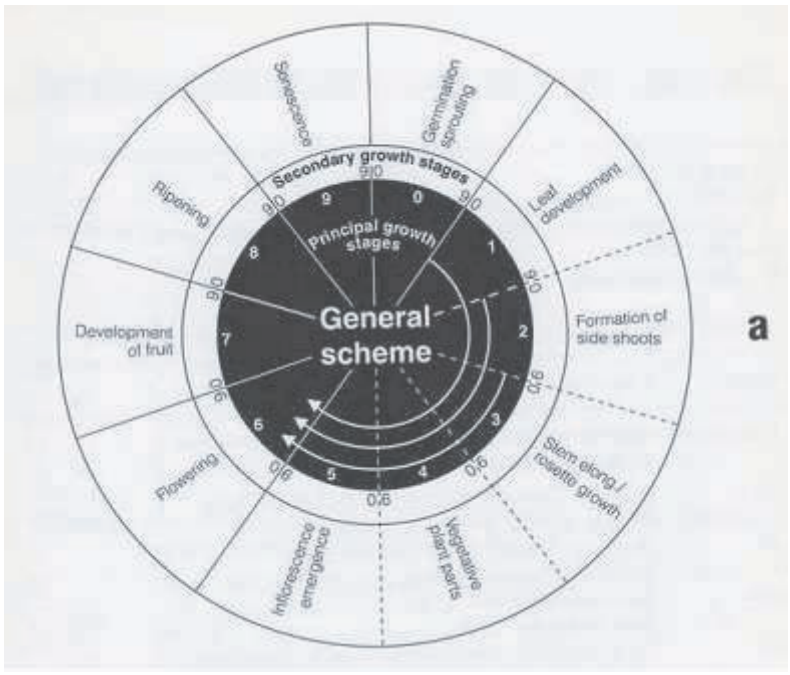


Fig. 2a. Subdivision of the developmental cycle of plants into principal and secondary stages.

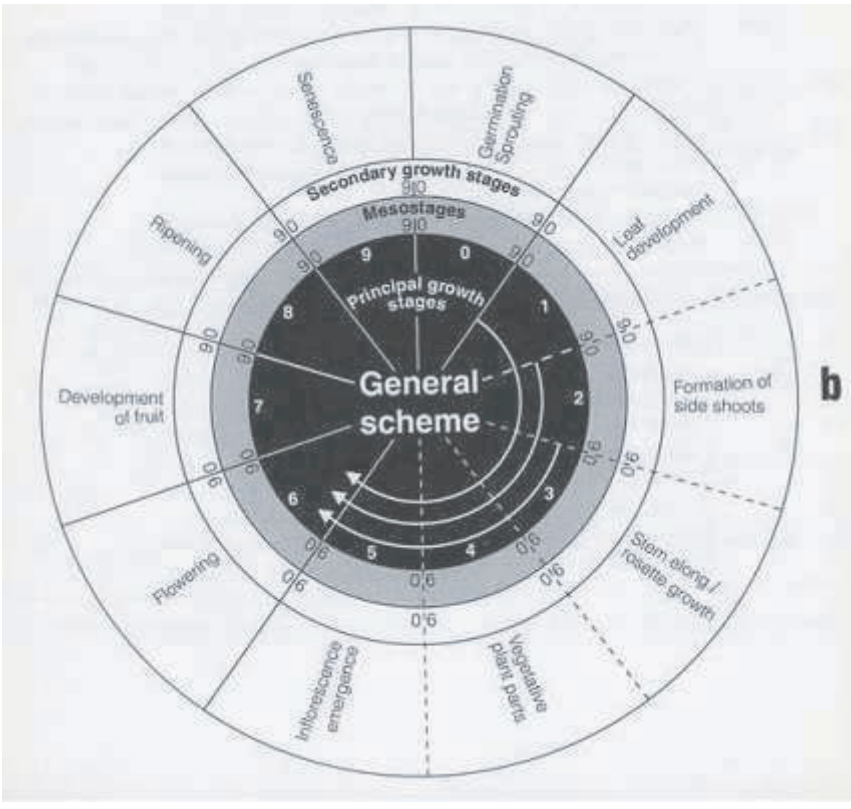


Fig. 2b. Subdivision of the developmental cycle of plants into principal, meso- and secondary stages. The mesostages are inserted between the principal and the secondary stages.

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 the figures 0 to 9. The combination of figures for the principal and the secondary stages, results in the two-digit code. The two-digit code (Fig. 2a) is a scale which offers the possibility of precisely defining all phenological growth stages for the majority of plant species. Only in the case of some plant species (e.g. cucumber, onion, potato, tomato, banana) is further subdivision necessary within a principal growth stage beyond that possible using the secondary stages from 0 to 9. For these cases a three-digit scale (Fig. 2b) is presented alongside the two-digit scale. This involves the inclusion of the

so-called mesostage between the principal and the secondary stage, which provides a further subdivision with figures 0 and 1 describing the development on the main stem and figures 2 to 9 that of the side shoots 2nd to 9th order. In this way up to 19 leaves can be counted on the main stem or the branching can be described.

The 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. Sorting codes into numerical order therefore allows a listing in order of the stage of plant development.

The time span of certain developmental phases of a plant can be exactly defined and coded by indicating two stages. For this purpose two codes are connected with a hyphen. Thus, for instance, the code 51 - 69 describes the developmental phase from the appearance of the first inflorescence or flower buds until the end of flowering. This allows the computer-supported monitoring of crop stands.

For a uniform coding which covers the maximum number of plant species, it is necessary to use primarily phenological criteria rather than homologous or analogous stages. Thus, for instance, germination of plants from true seed and sprouting from buds are classified in one principal growth stage, the principal growth stage 0, even though they are completely different biological processes.

In the BBCH scales the descriptions are based on the actual characteristic features of the individual plant. If the scales are used for the definition of the development stage of a plant stand, the description should apply to at least 50% of the plants. Greater differences in the course of the development of different plant groups have to be taken into consideration for the description of the general scale. This problem is dealt with by offering several definitions for one specific stage wherever the formulation of a uniform text is impossible. The following letters show to which plant group the respective definition refers.

Graphical representations

All publications about the growth stages of crops and weeds include illustrations. The BBCH stage which are important for the production of the specific crop were always drawn. The important BBCH stages of each crop are always illustrated and assigned a code. Heinz SCHLOBACH (BBA Braunschweig) drew the illustrations for the leaflet series 27. Ernst HALWASS, a graphic artist from Nossen in Germany, drew most of the illustrations using a very high quality dot technique (Fig. 3).

Important scopes of uses of the BBCH scale

Taking agricultural sciences and practice as a basis, other disciplines may be able to benefit from this standard. It is applicable to areas such as botanical science, agricultural insurance and phenological observations by meteorological and climatology services.

Uses in agriculture. In the improvement of the international communication in agricultural practice and science

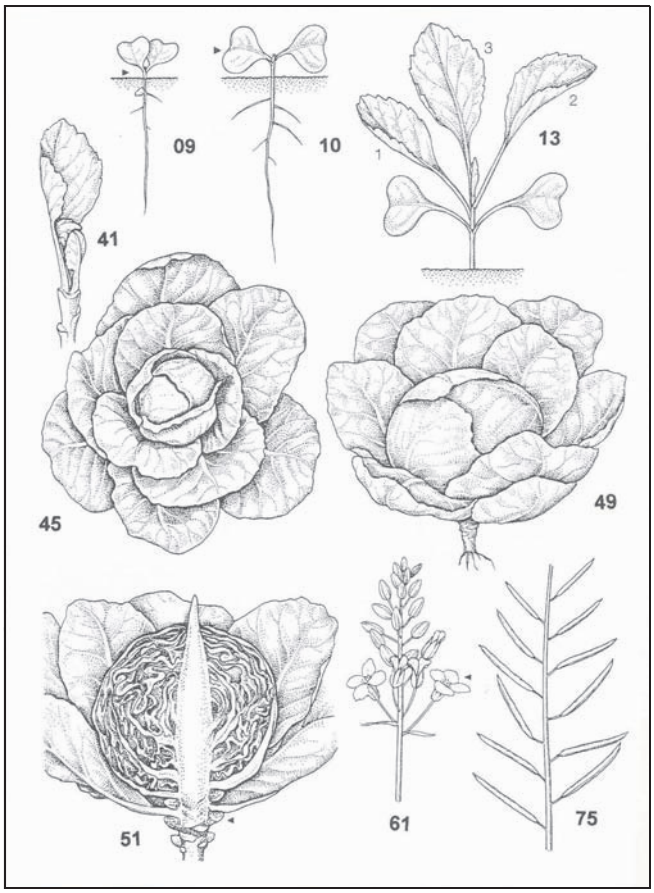


Fig. 3. Illustration of the important stages of leaf vegetables – forming heads – (example).

- In plant protection to define the use pattern of a chemical.
- In plant protection field trials the BBCH scale is recommended to define the application and assessment timing.
- In plant breeding to define the main aspect of a variety like ripeness, earliness and maturity to be in the situation to correlate this data with days after sowing/ planting or with the date.
- In agricultural field testing to define the application timing of nutrients, of plant protection applications and the assessment times (EPPO 2004)

The BBCH code is included as a check list in several IT-Systems for reporting and analysis of agricultural field trial data. ARM and PIAF (GYLLING and STRATMANN, 2007; MICHEL et al. 2007; SCHMIDTKE and ZINK 2007) are two commercial systems in which the BBCH coding system is integrated as check lists.

Uses in meteorology and climatology. In the field of phenological observation as a branch of climatology there has been little international standardisation – as opposed to the measurement of meteorological parameters. Traditional phenologists in Europe, North America and China have taken notice of the BBCH codes and accepted them as helpful. In meteorology and climatology it is now pos-

sible to correlate data to a specific phenological growth stage (BRÜGGER and VASSELLA, 2003 a, b; BRUNS and VAN VLIET, 2003). Phenological phases reflect among other things the environmental characteristics of the climate in the region where they occur. Consequently, long series of phenological observations may be used for the detection of climate variability or climate change. The main objective of the action is to establish a European reference data set of phenological observations that can be used for climatological purposes, especially climate monitoring, and detection of changes.

The *Global Phenological Monitoring programme* (Intern. Society of Biometeorology) is fully compatible with the BBCH system. The *International Phenological Garden* and many other national programmes provide a comparison between the *BBCH* codes and their definitions. The *European Phenological Data Platform for Climatological Applications* (COST 725) hosted by the Austrian *Central Institute of Meteorology and Geomagnetism* (ZAMG) in Vienna manages its phenological data using the corresponding *BBCH* codes (KOCH et al., 2006). The *Guidelines for Plant Phenological Observations* of *World Meteorological Organisation* (WMO) highly recommend the phase definition according to the *BBCH codes* in a chapter of its own (KOCH et al., 2007). For the reasons of continuity in traditional plant phenology, however, it will still take some time before BBCH phases are fully adopted.

Uses in agricultural insurance to describe the growth stages of the damaged plants (MEIER and LANGNER, 1997).

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BBCH-scale as PDF-file in four languages:
BBCH german
BBCH englisch
BBCH french
BBCH spanich

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