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Phenological growth stages of the rubber tree *Hevea brasiliensis* (Willd. ex Adr. de Juss.) Muell.-Arg.: Codification and description according to the BBCH Scale

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Abstract

The detailed description of growth stages of useful plants followed by adequate codification facilitates communication between scientist and practicians if e.g. new findings of science have to be transferred to management procedures or if experiences made at one growing site have to be adapted to another. We describe the growth stages of the world wide grown rubber tree (Hevea brasiliensis) to prepare the basis for production management, comparisons of epidemiological studies of disease, of growth patterns under different environmental factors and of genetically clone specific parameters. The codification follows the “Extended BBCH - Scale”, a numerical system which differentiates between principal, secondary and tertiary growth stages. Each growth stage presented from seed germination to crown development and harvest is correlated with general management practices. This scale will be of great help to rubber growers and scientists around the world for more efficient planning of management practices and experiments.

Key words:, Rubber, Rubber tree, BBCH Scale, Growth stages, Phenological development

INTRODUCTION

Native to the South American Amazon region the rubber tree (*H. brasiliensis*) was introduced to many other tropical regions of the world at the beginning of the 20th century. Ranging from subtropical wet to tropical dry and to tropical wet forest life zones, the rubber tree (2n = 36, 34, 72), is reported to tolerate annual precipitation of 10 to 43 dm, annual temperature of 23.1 to 27.5°C. There are many improved varieties and cultivars in areas where the rubber tree is cultivated commercially. Tapping begins when trees are 5–8 years old, depending on the area, and increases every year until a maximum at about 20 years, then the yield can sustain for 40–50 years or more. Average yields for unselected trees were about 300–450 kg latex/ha; bud-grafted trees of approved clones produce 700–2,000 kg latex/ha in improved plantations. Rubber is produced round the year, with great fluctuations from month to month.

The knowledge of the phenology of the crop is, therefore, important for the correct timing of management practices such as fertilizer application, disease, pest, and weed control among others. No uniform code for these existing descriptions was used and, furthermore, they refer to single growth stages like leaf development and no effort has been realised to establish a full description of rubber growth stages for a generalized use. Consequently, this paper deals with the application of the “Extended BBCH-scale” and its decimal code for the description of rubber tree growth stages with practical relevance.

MATERIAL AND METHODS

Data presented in this analysis were collected by literature evaluation where specific authors are cited or base on own unpublished data of the authors. The own data base on observations made especially in the Amazon region of Brasil between 1987 and 1998, when developing polyculture systems for the plantation cultivation of rubber tree (Lieberei et al. 1989, Feldmann, 1990; Feldmann et al. 1995, Feldmann et al. 1999). Seed material used was mainly of maternally defined clone Fx 25; grafted stumps were of clone Fx 3925, Fx 4098, IAN 6158 and RRIM 600.

The “BBCH scale” (Bleiholder et al. 1991) and the “Extended BBCH scale” (Hack et al. 1992) considers 10 principal growth stages (syn. “macro stages”) numbered from 0 to 9. For the rubber tree, these initiate with the germination of seeds (Growth Stage 0). The vegetative growth is considered under two principal growth stages corresponding to leaf development

(BBCH 1), and elongation of the stem (BBCH 3). Inflorescence emergence and flower development are considered under BBCH 5. Flowering (BBCH 6), development of fruit (BBCH 7), ripening of the fruit and seed (BBCH 8) and harvest (BBCH 9) complete the scale. Development of vegetative harvestable (BBCH 4) parts is considered as well. Secondary growth stages are also numbered from 0 to 9 which correspond to ordinal or percentage values of development. Tertiary growth stages allow the description of important steps of development within a single secondary growth stage. Consequently, they are numbered from 0 to 9 like the principal and secondary growth stages. In the most of the descriptions already published (Meier 1997) it was not necessary to describe the plant development in such detail. In the rubber tree, especially the leaves underlie a pattern of development which is of importance for the plant protection management because young leaves have different resistance behavior against the main fungal disease than well developed mature leaves.

The BBCH-scale describes the pattern of development independent of variation in timing single growth stages are reached. Therefore, the scale can be applied to all cultivated species of Hevea, varieties or clones and regions they are cultivated in.

RESULTS

Principal growth stage 0: Germination

H. brasiliensis shows recalcitrant seed storage characteristics, i.e. the seeds are killed by desiccation. Consequently, seeds are collected and sown fresh in BBCH 02 (Fig 1). Seed longevity in moist storage conditions is short. They lose viability rapidly (within only 7–10 days). In some cases this short period can be extended to 4–6 weeks, if the seeds are packed in charcoal powder or sawdust with 15–20 % moisture in special containers. Seeds germinate in 1–2 weeks (BBCH 03), depending on climatic conditions and freshness of seed. Scarification can be done at BBCH 02 with concentrated sulphuric acid for 2-5 min or by filing the seed coat. The removal of seed covering structures, i.e. seed coat and micropylar cap are supporting the germination (Fig. 1). A detailed description of the BBCH - Growth Stages of seeds and germination is presented in Table 1 and Figure 1.

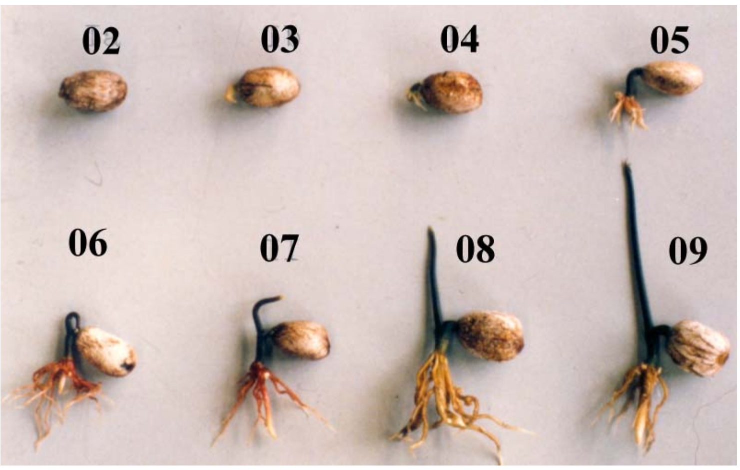


Fig. 1 BBCH Growth Stages 0: Germination of seed of *H. brasiliensis*

Table 1: Codification and description of BBCH principal and secondary growth stages. Principal growth stage 0: Germination of seeds

Code	**Description**
00	Seed fresh, mature seed directly after liberation from the fruit; seed coat and micropylar cap intact
01	Beginning seed swelling
02	Seed turgescent; micropylar cap broken
03	Horizontal emergence of the hypocotyl (3-7mm)
04	Radicula formation: vertical downwards torsion of radicula
05	Crown root formation
06	Advanced germination: beginning differentiation of root system; formation of tap root and intense growth of surrounding crown roots
07	Emergence of plumule; slow growth of tap root (< 2cm)
08	Erection of epicotyl; ramification of crown roots; intense prolongation of tap root (> 3cm)
09	Bud formation of first true leaves; slow continuation of tap root and crown root prolongation

Important management practices are related to BBCH 0. Already before sawing the seeds in BBCH 02, inoculation of the seed bed with growth promoting microorganisms (e.g. mycorrhizal fungi and beneficial bacteria) is suitable. To save inoculum this procedure can be carried out in BBCH 05, too. The first piquering normally is taking place in BBCH 08, latest in BBCH 09.

Principal growth stage 1: Leaf development

Typical for a series of other tropical trees like *Theobroma spp.* is the leaf flushing modus of rubber tree. At the apex of stem or branches 7-11 leaves are flushed from one bud at the same time but developing slightly differentially. These leaves are flushing regularily or irregularily and are the main target of disease. A detailed description of the BBCH - Growth Stages of Leaf development is presented in Table 2 and Figure 2.

Fungal or bacterial diseases are the major problems for rubber growers during rubber cultivation. About 90 species of pathogens are known to attack *Hevea* trees, the most prevalent ones being the following: *Microcyclus ulei* (Rubber tree leaf blight), *Thanatephorus cucumeris* (Mancha areolada), *Botryodiplodia elactica* and *B. theobromae*, *Colletotrichum gloesporeoides* (Anthracnosis) *Colletotrichum heveae* (leaf spot), *Oidium heveae* (powdery mildew), *Gloeosporium heveae* (die-back), *Phytophthora palmivora* (leaf-fall and die-back), and *Corynespora cassiicola* (leaf fall).

Harmful insects and acarides are e.g. *Erinnyis ello* (Mandarova), *Aleurodicus cocois* (White Fly), *Atta* spp. (Sauva), termites, *Diabrotica speciosa*, *Ceratoma* spp., *Tenuipalpus heveae* and finally *Thrips* spp.

Fig. 2 BBCH Growth Stages 1: Leaf development of *H. brasiliensis*

Table 2: Codification and description of BBCH secondary and tertiary growth stages of rubber tree. Principal growth stage 1: Leaf development

Code	**Description**
110	Bud burst of first leaf whorl, leafs upstanding, folded, sprout not canopy elongated
111	First leafs of the whorl beginning to unfold, with petioles in a 90° angle to sprout, leaf length <1,5 cm, surface turning downwards, colour green, start-
112	All leafs of the first whorl unfolded, turned downwards, sprout starting to elongate, largest leafs <2,5cm; colour green to red
113	Largest leafs >2,5cm, reddish, green nerves visible, surface gleaming; beginning elongation of petioles
114	Largest leafs >3,5cm, reddish, green nerves visible, surface gleaming; proceeding elongation of petioles
115	Largest leafs >6,5cm, reddish, green nerves visible, surface gleaming; elongation of petioles finished
116	Continuation of leaf area increase; starting colour change to light green; surface smooth, leafs hanging downwards
117	Leaf area increase of the latest leaf of the first whorl finished; colour light green; surface smooth, leafs hanging downwards, sprout elongation finished
118	Starting change of colour to dark green; starting consolidation of leafs, leafs starting to come up
119	Leafs dark green, consolidated, positioned 45°-90° to sprout
12	Development of the second to fifth whorl
15	Development of the fifth to tenth whorl
16	10-33 % of the canopy have leafs in growth stage 112 to 115
17	33-66 % of the canopy have leafs in growth stage 112 to 115
19	66-100 % of the canopy have leafs in growth stage 112 to 115

Leaf pathogens attack the tree depending on the leaf developmental stage or without respect to the growth stage. They are controlled by a variety of sprays applied by spray or dusting techniques at certain growth stages or degrees of infestation.

Already in BBCH 111 rubber growers begin with the monitoring of leaf pathogens. In BBCH 112 decision making for application of chemical control agents in nurseries takes place and in BBCH 113 the application of plant protection products in nurseries may start finishing with the last application of plant protection products in nurseries at BBCH 117 (Fig. 2). If the occurrence of pathogens is related to specific developmental stages of the leaves (like *Microcyclus ulei*) BBCH 14 would be important for decision making for application of bio control or chemical control agents in plantations, reaching BBCH 15 would initiate application of plant protection products and BBCH 16 would indicate frequent application of plant protection products.

Principal growth stage 2: not relevant

Principal growth stage 3: Stem elongation

The growth stages described are mainly characterizations of diameter and height of the developing sprout and trunk (Table 3).

Table 3: Codification and description of BBCH principal and secondary growth stages - Principal growth stage 3: Stem elongation

Code	Description
30	Stem >1,5m high, 2cm circumference in 5cm height
31	Stem 1,5m high, 4cm circumference in 5cm height
32	Stem 1,5-2m high, <10cm circumference in 5cm height
33	Stem 2-3m high, >10cm circumference in 1,50 height
35	Stem 40cm circumference in 1m height
39	Stem >100cm circumference in 1m height

Budded seedlings are 1–1.3 m tall in 6 months. Then plants are uprooted in BBCH 32, the stem cut back to 45–60 cm, the taproot to 45–70 cm, and the lateral roots to 0-10 cm. As well in BBCH 33 young trees may be budded a second time, if a disease resistant crown has to be established (“crown budding”).

The primary production of latex - the cultivation of *H. brasiliensis* trees and tapping of latex – is mainly related to the development of the stem, especially to stem elongation and stem thickening. Five to eight years will pass before the young rubber trees are ripe for production reaching BBCH 35. Once in production and dependent on the intensity of tapping, rubber trees continue to supply latex for 20 years or longer (BBCH 39), after which the old trees are dug up and new trees replanted in their place (compare Tab. 9). The *Hevea* wood is used in the furniture industry as well as in other trades (BBCH 99).

Principal growth stage 4: Development of harvestable vegetative propagated organs

Principal growth stage 4 describes the development of scions on seedlings.

Buds are collected from seedling trees or selected clones. Seedlings are grafted at BBCH 40. Relevant management practices are control measures like success control of budding procedure, repetition of the process or plant protection. At the end, after reaching BBCH 49, the budded seedling is ripped out for production of budded stumps (BBCH 32).

Table 4: Codification and description of BBCH principal and secondary growth stages: Principal growth stage 4: Development of harvestable vegetativily propagated organs

Code	**Description**
40	Seedling grafted with bud from scion
41	Beginning callus formation
45	End of callus formation
49	Bud and seedling tidely fixed

Principal growth stage 5 and 6: Inflorescence emergence and flowering

H. brasiliensis is a monoecious plant with unisexual flowers arranged in the same inflorescence. The inflorescence is a panicle of separate staminate and pistillate flowers borne in the axils of basal leaves of new shoots that grow out after wintering. In large inflorescences, we can find nearly 3,000 male flowers with an approximate proportion of one female to 60 male flowers (Bouychou 1963).

Table 5: Codification and description of BBCH principal and secondary growth stages. Principal growth stage 5: Inflorescence emergence

Code	**Description**
51	Inflorescence buds visible
55	Half of inflorescence emerged
59	Inflorescence fully emerged

Table 6: Codification and description of BBCH principal and secondary growth stages: Principal growth stage 6: Flowering

Code	**Description**
60	First flowers open
61	Beginning of flowering: 10% flowers open
63	30% flowers open
65	Full flowering: 50% flowers open
67	Flowering finishing: majority of petals dry or fallen
69	End of flowering: fruit set visible

Concurrently with the elongation of the inflorescence buds are developing. In the continuously evolving inflorescence buds at branches of the inflorescence are therefore in a more advanced growth stage. Consequently, several different growth stages of flowers can be found in one inflorescence. Figure 3 shows such differences in an inflorescence.

Principal growth stage 7 and 8: Development of fruit and seed ripening

From the practical point of view growth stages BBCH 7 and 8 (Table 7 and 8) are important only for harvesting sufficient seeds for new seedling production. The rubber grower is monitoring (from BBCH 71 on) whether an infection by Phytophthora spp. takes place which sometimes might endanger the seed production. The description of the ripening process illustrate the figure 4. After ripening the seeds are scattered under the mother plants and are collected there (BBCH 89).

Fig. 3 BBCH Growth Stages 5 & 6: Inflorescence emergence and flowering of *Hevea spp.*

Table 7: Codification and description of BBCH principal and secondary growth stages. Principal growth stage 7: Development of fruit

Code	Description
71	10% of fruits have final size
73	30% of fruits have final size
75	50% of fruits have final size
77	70% of fruits have final size
79	Nearly all fruits reached final size

Fig. 4 BBCH Growth Stages: Ripening of fruit and seed of *H. brasiliensis*

Table 8: Codification and description of BBCH principal and secondary growth stages. Principal growth stage 8: Ripening of fruit and seed

Code	Description
81	Beginning of ripening
85	Advanced ripening and starting fruit browning
87	Starting fruit flesh degradation
89	Beginning fruit abscission and seed liberation

Principal growth stage 9: Senescence and death

Already after 15-20 years of tapping the trees begin to loose their productivity. Depending on several economical considerations the tree decaying in latex production will then be cut and the stem sold as rubber wood (BBCH 99) while the crown will remain as mulch in the plantation.

Table 9: Codification and description of BBCH principal and secondary growth stages: Principal growth stage 9: Senescence and death

Code	Description
91	10-33% of the canopy have decaying, yellowish, senescent, falling leafs
93	33-66% of the canopy have decaying, yellowish, senescent, falling leafs
96	66-100% of the canopy have decaying, yellowish, senescent, falling leafs
97	Beginning decay of plant productivity
99	maximum economically acceptable age of tree. Harvest of *Hevea* wood

The genus *Hevea* tends to have regular leaf fall in the dry season. Irregular leaf fall occurs mainly in the rainy season. Furthermore inhomogeneous leaf fall can occur. In such a case only a part of the canopy falls after senescence of the leaves while an other part of the canopy develops new leaf flushes (Growth Stage 1) at the same time. Development of leaves is described in principal growth stage 1 (Table 1). Within the growth stage 9 we describe the leaf fall behavior of *Hevea* clones as well. The gradual state of the leaf fall is described with the growth stages 91-96.

APPLICATIONS

Example 1: Integration of BBCH codes in a generalized IPM-concept of *Hevea spp.*

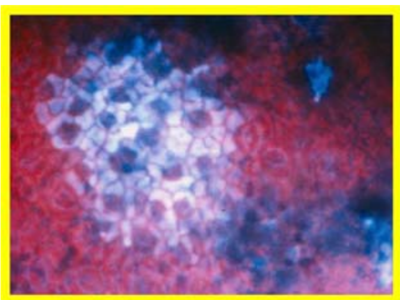
Sawing at BBCH 0-0

Monitoring of pathogens at BBCH 1-4

Preparation of budded stumps at BBCH 3-2

Crown bud. 3-3; Spraying 3-5; Tapping 3-6

Example 2: Studying host-pathogen interrelationships of Hevea spp. at defined developmental stages



Studying occurrence of physiological changes in leaves (here: clone Fx4098 at BBCH 1-3-5)

Studying epidemiology of disease (here: clone RRIM 600 at BBCH 1-4-6 after mycorrhizal treatment)

Comparison of plant reaction after breeding (here: clone Fx4098 X *H. pauciflora* at BBCH 1-3-8)

DISCUSSION

Since the the first BBCH publication (Lancashire et al. 1991) and the publication about the general BBCH standards from Hack et al. (1992), there has been a growing interest on the extension of these general principles for the description of the growth stages of world main crops including monocotyledons, dicotyledones, gramineae and perennials (Bleiholder et al. 1991), most of them summarized by Meier (1997) published in a the “BBCH-Monograph” with 27 crops and weed in English, German, Spanish and French.

This paper on the phenology of *Hevea* describes for the first time the developmental stages of a tropical tree with a leaf flushing modus which is representative for a hug number of tropical perennials. As an example, the growth stages should be easily applied to the genus *Theobroma*. Furthermore, the detailed description of leaf development is very useful in case of irregular leaf fall, because principal growth stage 1 and 9 integrate the whole cycle o a leaves from bud to senescence.

With the codes provided here a much better basis of communication exists not only for practicians around the tropics, but as well for scientists working on specific aspects of the rubber tree: can the exact flowering date or intensity tell something about shifts in climate? Can the physiological changes at certain developmental stages of the leaves serve as indicators for shortening the breeding process? Do different clones react to fertilizers differently with respect to their growth pattern? Which phenotypic plasticity does one specific clone have growing in different parts of the world?

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