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Description of Different Growth Stages of *Sesamum indicum* L. Using the Extended BBCH Scale

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Abstract: The extended Biologische Bundesanstalt and Chemische (BBCH) scale and its associated decimal code were used to describe the different growth stages of *Sesamum indicum* L. The study focused on different primary and secondary plant growth phases from germination to senescence. The use of a two-digit decimal code allowed the identification of the principal growth stages and their respective secondary stages. This approach suggests that this could be of great help to sesame growers and researchers for efficient planning of both management practices and experimental designs.

Key words: Congo-Brazzaville, plant growth phases, extended BBCH scale, fruit, germination, phenology, senescence, *Sesamum indicum* L., ripening

INTRODUCTION

The Pedaliaceae includes about 16 genus and 60 species, of which *Sesamum* is the major genus group. The sesame is an annual plant that is 10-20 cm high and rarely reaching 180 cm. The stem is obtusely quadrangular and finely pubescent to glabrescent. The leaves are heteromorphic and grow on either opposite or alternate position on branches. Flowers come in different colors and the most common are either white, pink, or mauve-pink. Fruits are oblong capsules with small oval and yellowish seeds (Kafiriri and Deckers, 2001). Sesame is self-pollinating, although differing rates of cross pollination have been reported by Yermanos (1980), Ashri (2007) and Sarker (2004). The pollinisation process occurs at the time the flowers open (Kafiriri and Deckers, 2001; Langham, 2007). The species *Sesamum indicum* L. is cultivated in Europe, Asia, America and Africa. By 2001, the estimated land area used for sesame production was about 2-2.5 million ha (India), 1 million ha (China), 0.6 million ha (Birmanian) 0.5 million ha (Soudan) and 0.25 million ha (Mexico). In Africa, Soudan leads in sesame production, followed by Nigeria, Somalia, Ouganda and Ethiopia (Kafiriri and Deckers, 2001).

Sesame is an important oil seed crop. The seed has excellent nutritional value having high and unique protein composition making them a nearly perfect food. The seeds by expression yield a fixed oil consisting essentially of the glycerides of oleic acid and linoleic acid with preparations of stearin, palmitin and myristin.

Liquid fatty acids are present to about 70% solid fatty acid 12-14% (Rakipov, 1987; Kafiriri and Deckers, 2001). Knowledge of the phenology of the crop is important for the correct timing of management practices such as fertilizer application and disease, pest and weed control. Several descriptions of the growth stages of this plant can be found in the literature (Kang *et al.*, 1985; Mulkey *et al.*, 1987; Langham, 2007) and as is the case for the majority of cultivated plants, there is no unified and standard description approach. Most papers refer to specific growth stages, but no effort is usually made to establish a full description that could lead a framework of growth stages for general use.

Since the proposal of Zadoks *et al.* (1974) of a decimal code for the description of growth stages for cereals, there has been a growing interest in the extension of these general principles for the description of the growth stages of many other crops (Agusti *et al.*, 1997; Gonzales *et al.*, 2002; Cautin and Augusti, 2005). In recent years and based on the above mentioned proposal, a uniform decimal code, known as the BBCH-scale, was developed by Bleiholder *et al.* (1991) and Lancashire *et al.* (1991). A more advanced scale, the extended BBCH-scale was proposed later by Hack *et al.* (1992) and Hess *et al.* (1997). Subsequently, Meier (1997) published the "BBCH-monograph" for 27 crops and weeds. According to this universal scale, by using phonological criteria and a consistent set of numeric codes, it is possible to establish a uniform coding that describes the growth stages of a large number of plant

species. In this paper, we take advantage of the extended BBCH-scale and its decimal code to provide a description of the growth stages of the sesame plant.

MATERIALS AND METHODS

This study was conducted using *S. indicum*, an annual plant with a wide variety of specimen and sizes ranging from 0.5-2 m. In this research effort, seeds from *S. indicum* were first collected from Okouesse in the central portion of the Republic of Congo and taken to the experimental site located in Brazzaville, the capital city of the Republic of Congo (4°16'8"; 15°11'10"). Experimental studies were conducted on a study site located on the University of Brazzaville's campus. The study area is characterized by a short dry season from June to September and a rainy season from October to May. It is worth to note that the rainy season is not uniform as it is interrupted by a 2-month period (January and February) of very little to no precipitation. Overall, the annual precipitation averages 1370 mm per year, while the average temperature is about 25.3°C.

Prior to planting, the top 10cm of surface soil was well mixed with a hoe. Then, furrows of about 9.30 x 1.70 m were made using shovels. Furrows were separated by empty spaces of about 0.7 m and the surface of each furrow was "leveled" using a rack. To avoid the formation of deep depressions in which water could accumulate and lead to the death of growing plants, experimental plots were well-homogenized and leveled following the method described by Kafiriri and Deckers (2001). The planting was finally done along well-defined transacts in the month of April. Approximately 4 seeds were placed in small holes and covered with loose soil. For each furrow, three transacts were used. Finally, after germination, a total of 50 plants were chosen for observational studies.

RESULTS AND DISCUSSION

Scale characteristics: The extended BBCH scale [16, 18] considers 10 principal growth stages numbered from 0-9. For the sesame plant, we begin with the germination of seeds, or shoot development in cuttings or stumps (stage 0). This stage is then followed by vegetative growth considered under 3 macro-stages corresponding to leaf development in seedlings in the nursery or on branches (stage 1), formation of branches (stage 2) and elongation of branches (stage 3). Next are inflorescence emergence and flower development (stage 5), flowering (stage 6), development of fruit (stage 7), ripening of the fruit and seed (stage 8) and senescence (stage 9). Note that the development of vegetative harvestable parts corresponding to stage 4 was not considered because it does not apply to the sesame plant.

The secondary growth stages are also numbered from 0-9 and are related to ordinal or percentage values of

growth. For example, for leaf development (stage 1), the fifth true pair is assigned a value of 5 and its identification in the scale will be 15; for branch elongation (stage 3), when 20 nodes are present, a value of 2 is given and its identification in the scale will be 32. In the sesame manner, if 10% of flowers are open, this characteristic is given a value of 1 within the principal stage 6 (flowering) and will be defined as 61 in the scale. For fruit ripening, the change of color was the criteria chosen, thus, stage 88 corresponds to fruits fully yellow and ready for picking and the stage 89 means that fruits are over ripe or decaying.

The descriptions presented below are valid for sesame growth under average climatic conditions in the study area: that is a temperature of 17-23°C, monthly rainfall of at least 120 mm and less than 13.5 h of day light. Although some variation in the timing of the growth stages occurs among cultivated species and regions, the scale can still be applied under these generalized circumstances.

Description of the phenological growth stages for the studied sesame plants

Principal growth stage 0: germination, vegetative propagation, bud development:

- 00: Dry seed (2.5 mm long, 2 mm large and 3 mg weight); beige color (Fig. 1).
- 01: Beginning of seed imbibitions, beige color, no radical visible, no shoots and no callus visible.
- 03: Seed imbibitions complete; small swelling and whitish in color and the radical is not yet visible.
- 05: Seed radical protrusion and hooking are visible (Fig. 1).
- 06: Elongation of radical; formation of root hairs and lateral roots on germinated seeds; formation of root hairs and lateral roots on cuttings.
- 07: Hypocotyls with cotyledons breaking through the seed coat; cuttings have formed shoots and branched roots.
- 09: Emergence: seedlings have emerged from soil and show the hypocotyls with cotyledons still enclosed in the parchment (Fig. 1).

Principal growth stage 1: leaf development on main shoot of the young plant and branches:

- 10: Cotyledons completely unfolded. First pair of true leaves separating on branch (see Fig. 1).
- 11: First leaf pair unfolded, not yet at full size and exhibit a light green color.
- 12: 2 leaf pairs unfolded, not yet full size; the third leaf pair from apex is light green.
- 13: 3 leaf pairs unfolded, not yet full size; the third leaf pair from apex is still light green.
- 14: 4 leaf pairs unfolded. The fourth leaf pair from apex is light green and has reached full size.
- 15-18: Five to 8 leaf pairs unfolded.
- 19: Nine or more leaf pairs unfolded (see Fig. 1).

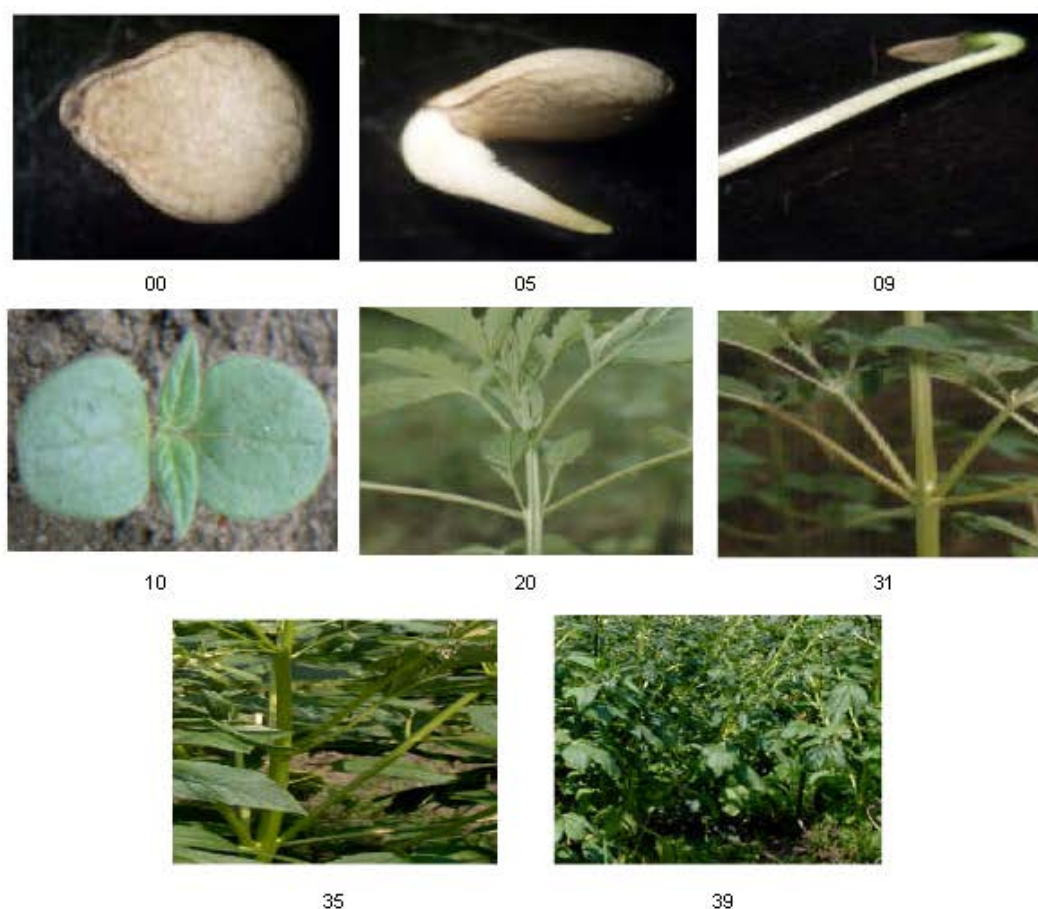


Fig. 1: Vegetative growth stages (00-39) of *Sesamum indicum* L. plant

Principal growth stage 2: formation of branches:

- 20: First pair of primary branches is visible (Fig. 2)
- 21: Ten pairs of primary branches visible
- 22: Twenty pairs of primary branches visible
- 23: Thirty pairs of primary branches visible

Principal growth stage 3: branch elongation:

- 30: Beginning of branch growth; axes of developing shoots visible.
- 31: Branches about 10% of final size (see Fig. 1).
- 32: Branches about 20% of final size.
- 35: Branches about 50% of final size (Fig. 1).
- 39: Branches about 90% of final size (Fig. 1).

Principal growth stage 5: Inflorescence emergence:

- 50: Inflorescence buds are closed in leaf axils.
- 51: Inflorescence buds swelling in leaf axils (Fig. 2).
- 53: Inflorescence buds burst; no flowers visible
- 57: Flowers visible, still closed (Fig. 2)
- 58: Flowers visible, still closed, petal 1.5 cm long and white.
- 59: Flowers with petals elongated (3 cm long), still closed and white in color (Fig. 2).

Principal growth stage 6: flowering:

- 60: First flowers open and white color (Fig. 2)
- 61: 10% of flowers open
- 63: 30% of flowers open
- 65: 50% of flowers open
- 67: 70% of flowers open
- 69: 90% of flowers open

Principal growth stage 7: fruit development:

- 70: Fruit set; fruit visible as small capsule.
- 71: Beginning of capsule growth. Fruit have reached 10% of final size (Fig. 2).
- 73: Fruit about 30% of final size
- 75: Fruit about 50% of final size
- 77: Fruit about 70% of final size (Fig. 2).
- 79: Fruit about 90% of final size. Physiological maturity is complete (Fig. 2).

Principal growth stage 8: ripening of fruit and seed:

- 81: Beginning of fruit color change from pale green to yellow (Fig. 3).
- 85: Increase in fruit color intensity, fruit not yet ready for picking.

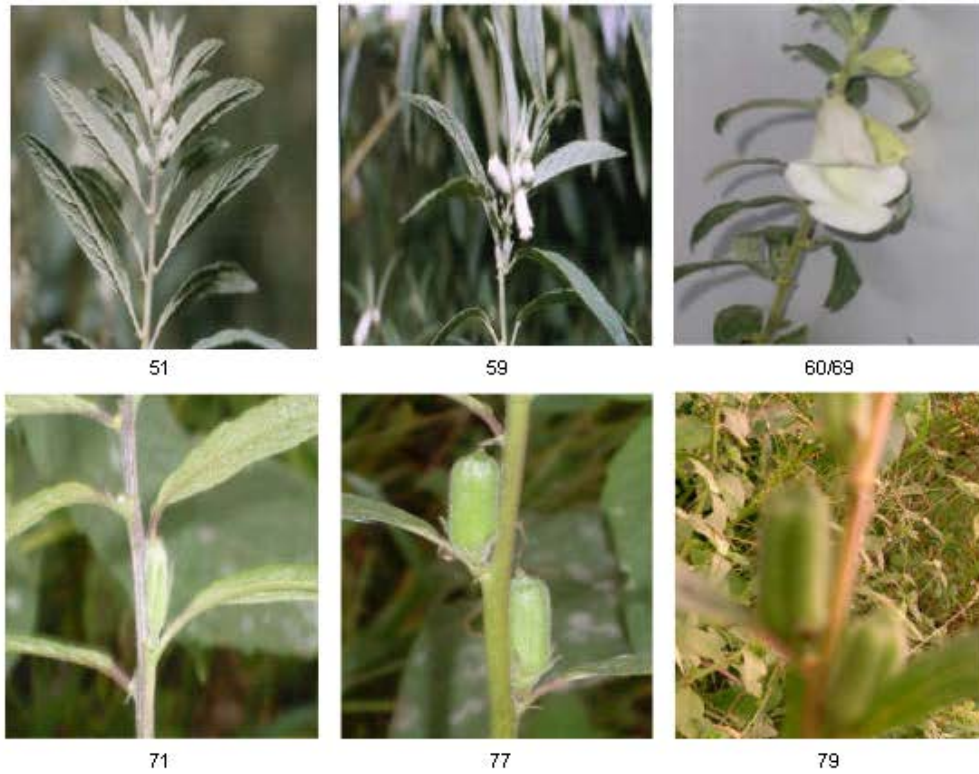


Fig. 2: Reproductive growth stages (51-79) of *Sesamum indicum* L. plant



Fig. 3: Ripening and drying phases (79-98) of *Sesamum indicum* L.

- 88: Fruit is fully-ripe and ready for picking.
89: Over ripe; beginning drying (Fig. 3).

Principal growth stage 9: senescence:

- 90: The shoots have completed their development (Fig. 3).
93: Older leaves change from deep green to yellow (Fig. 3).
94-98: Leaves falling (Fig. 3).
99: Storage treatments

Conclusion: The use of the extended BBCH scale and a two-digit decimal code allowed the identification of the principal growth stages and their respective secondary stages. This method can be used by sesame growers as well as researchers for efficient planning in both management practices and experimental designs.

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