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A decimal code to describe the growth stages of sesame (*Sesamum orientale* L.)

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Abstract

A standard description of growth stages for crops/plants is necessary not only for determining and improving cultural practices, but also to facilitate enhanced communication among producers, researchers, and educators. It also could help in unifying experimental results. Many different descriptions of growth stages are currently available for many crops, but there are no codes for sesame (*Sesamum orientale* L.). To define the standard description, common characteristics of sesame genotypes, including main stem node, flower bud appearance, flower bearing and flower opening, and capsule and seed formation, are used. Four principal stages were identified for the crop growth cycle and secondary stages were defined for each principal stage. The three digits stage code uses the first digit to represent the principal stage and the second and third digits shows for the secondary stages. A period "." or a comma "," are used to separate the principal and secondary stage digits. All stages are also documented with hand-drawn illustrations. In this system, a three digit decimal code is assignment to each individual crop development cycle and the complete crop growth and development cycle from seed, as planted, to seed, as harvested, is described. The presented scale is a user friendly tool to recognition of sesame population stages of development. It helps researchers and farmers to choose the best agricultural practices and applying then in farms and research plots.

Keywords: *Sesamum orientale* L.; Pedaliaceae; Oilseed; Growth stages; Development; Flowering; Capsule.

Introduction

Sesame (*Sesamum orientale* L.), synonymous with *S. indicum* L., is an important ancient annual oilseed crop and is commonly grown in the fields of small-holder farmers in the tropics and subtropics. It belongs to the family of Pedaliaceae, consisting of 16 genera and about 60 species (Kobayashi, 1991). There are approximately 38 species in the genus *Sesamum* and most of them are wild (Kobayashi, 1991). Similar to other plants that have been domesticated for a long time, there are many different varieties of *Sesamum indicum* L. that differ considerably in size, form (Figure 1), growth habit, corolla color, and seed size, color and composition (Weiss, 2000).

(a) (b) (c)

Figure 1. Sesame whole plant. (a, b, c) shows different types of sesame whole plant.

The stem of sesame is erect and normally square in section, although rectangular and abnormally wide and flat shapes occur. The stem can be smooth, hairy or very hairy and the stem color is most commonly a darkish green, but can range from light green to almost purple (Weiss, 2000). Stem height usually ranges from 60 to 120 cm (Weiss, 2000), but plants can be as short as 22 cm (Bisht et al., 1998) and as tall as 245 cm; plants with an height of 300 cm have been reported (Weiss, 2000). The number of nodes on the main stem varies between 4 and 65. The branching habit, which is a varietal characteristic, is directly affected by environmental conditions (Weiss, 2000) and the number of branches ranges from 0 to 20.

Sesame leaves vary widely in shape and size, not only among different varieties but also on the same plant. Leaves located on the lower parts of the main stem usually tend to be broad, some times lobed, and the margins are often prominently toothed with the teeth directed outwards (Weiss, 2000). Leaves on the middle part of the stem are lanceolate and sometimes slightly serrate, while the upper leaves are more narrow and lanceolate (Weiss, 2000). Other than leaf shape and size, there are also some differences in leaf arrangement on the main stem. Leaves may be opposite or alternate on the entire plant or be opposite on the lower parts of the stem and alternate on the upper parts.

Sesame is an indeterminate plant with an acropetal flowering habit, in which self-pollinating flowers arise in the leaf axils (Ashri, 1998). The color of the corolla is generally white or very pale pink, but can be much darker to almost purple. The inner surface of the corolla may have red or black spots and occasionally purple or yellow blotches (Weiss, 2000).

The fruit is a capsule, which differs in size and shape among varieties and even on the same plant. The capsule dehisces by splitting along the septa from top to bottom or by means of two apical pores (Weiss, 2000). Some cultivars with indehiscent capsules have been developed and released during the last few years. The ripening pattern of the capsule is similar to flowering pattern, so that the capsules near the stem base normally ripen first.

Due to the indeterminate habit of the sesame plant and dehiscence of the capsules during maturity, it is rather difficult to determine the optimum time to harvest. According to Ashri, (1989) the crop continues to produce leaves, flowers and capsules as long as the weather and soil moisture conditions permit due to its indeterminate growth habit. So, it is common to have several mature capsules on the lower parts of the stem and recently developed capsules near the top of the plant. Therefore, if plants are harvested too early, the seed quality of the entire crop is reduced due to the inclusion of immature seeds. On the other hand, if the plants are harvested too late, then the yield may be reduced due to seed loss through seed fall from the earliest maturing capsules (Day, 2000).

Plant development affects plant characteristics and processes as well as the magnitude of their response to experimental treatments and/or production inputs including fertilizer and irrigation. So, some physiological, biochemical and morphological characteristics of a plant changes in response to transition from one developmental stage to another (Groot et al., 1986).

Phenology and its response to environmental conditions play a crucial role in the simulation of plant growth either during the entire life cycle or a specific period of the cycle. The importance of phenology is related to its association with many physiological processes, including changes in dry matter partitioning and senescence. Therefore, a clear description of the different stages of a plant's life cycle that is acceptable for plant/crop physiologists and breeders, plant pathologists, entomologists and crop growth modellers will unify the reported results, as it will act as a standard. Using a clear description of the individual phonological stages may facilitate the comparison of results from physiological and crop production studies that are performed in different regions and during different growing seasons (Fehr et al., 1971), since the standardized growth scale has the same meaning during any period of time or for any location and is independent of language (Lancashire et al., 1991). Also, a clear description of the individual crop growth stages has facilitated an improved communication among producers, researchers, and educators concerned with crop growth and development (Boote, 1982). Such a scaling system or growth stage codes should also be appropriate for on-farm use by farmers (Groot et al., 1986), since decisions about agricultural practices, including the applications of fertilizer and pesticides and final harvest, are often related to a particular stage of the crop or plant life cycle (Knott, 1987). For some crops, growth stages descriptions have already been applied successfully to improve a range of cultural practices, including irrigation scheduling, the application of herbicides, insecticides, fungicides and growth regulators, and scheduling of final harvest (Boote, 1982).

Many descriptions of growth stages and crop development keys are currently available, especially for economically important crops such as wheat (*Triticum aestivum,* L.), barley (*Hordeum vulgare*, L.), oats (*Avena sativa*, L.), rye (*Secale cereale* L.) and rice (*Oryza sativa*, L.) (Zadoks et al., 1974; Tottman and Broad, 1987; Waldren and Flowerday, 1979; Counce et al., 2000; Counce et al., 2000; Counce et al., 2000), corn (*Zea mays,* L.) (Hanway, 1963; Groot et al., 1986), soybean (*Glycine max* [L.] Merrill) (Fehr et al. 1971; Fehr and Caviness 1977), peanut (*Arachis hypogaea*, L.) (Boote, 1982), oilseed rape (*Brassica napus*, L.) (Sylvester-Bradley et al., 1984; Sylvester-Bradley, 1985), pea (*pisum sativum,* L.) (Knott, 1987), faba bean (*Vicia faba,* L.) (Knott, 1990), sorghum (*Sorghum bicolor* [L.] Moench) (Vanderlip and Reeves, 1972), cotton (*Gossypium hirsutum*, L.) (Elsner et al., 1979), and sunflower (*Helianthus annuus*, L.) (Schneiter and Miller, 1981). However, no developmental stages have so far been defined for sesame, despite its ancient origin and importance as a cash crop. The goal of this study was to define and develop a growth stage scale for sesame that can be used by scientists for research applications as well as for farmers and crop consultants for on-farm crop management.

Selection of coding system

To describe the various phenological stages of plants, different methods as well as codes have been implemented. For example, Fehr et al. (1971) and Fehr and Caviness (1977) used a combination of letters and numbers to describe both the vegetative and reproductive development stages of soybean. Boote (1982) and Schneiter and Miller (1981) followed a similar approach and introduced peanut and sunflower growth stages, respectively, based on a combination of numbers and letters. These codes use different letters to separate the descriptions of vegetative and reproductive stage. In contrast, Hanway (1963), Zadoks et al. (1974), Knott (1987a, b), Sylvester-Bradley et al. (1984) and Tottman and Broad (1987) used a numbering system to describe the various developmental stages based on either two or three digits. In addition, in the approaches that are based on two digits some differences are present with respect to the identification of the principal and secondary stages. Knott (1987a, b) used three digit numbers, while Tottman and Broad (1987) used two digit numbers. However, none of them used a decimal system. Hanway (1963) used a scale between zero to ten to describe the growth stages of maize. Groot et al. (1986) used zero to nine with periods to separate the secondary stage digits, while Sylvester-Bradley et al. (1984) used commas for this purpose.

Table 1. Primary stages of the sesame growth scale.

Code	Description
0	Germination and emergence
1	Vegetative stage
2	Flowering stage
3	Capsule and seed formation

Table 2. Detailed description of the primary and secondary stages of sesame growth.

Code		Description
0	Germination and emergence	
0.00		Dry seed
0.01		Imbibed seed
0.02		Radicle emergence
0.03		Appearance of hairy roots
0.04		Hypocotyls arc is present
0.05		
0.06		
0.07		Folded cotyledons on the soil surface
0.08		
0.09		Fully open cotyledons on the soil surface
1	Vegetative stage	
1.01		First node on main stem is visible (other than cotyledon's node)
1.02		Second node on main stem is visible
1.03		3rd node on main stem is visible
1.04		4rd node on main stem is visible
1.05		5rd node on main stem is visible
1.06		6rd node on main stem is visible
1.07		7rd node on main stem is visible
1.08		8rd node on main stem is visible
1.09		9th node on main stem is visible.
2	Flowering stage	
2.01		First flower bud appears in the leaf axil
2.02		Calyx and pedicle is visible
2.03		Corolla is still inside calyx
2.04		
2.05		Corolla is greater than calyx tips and still closed
2.06		
2.07		Corolla tip is open
2.08		
2.09		Corolla is detached from the base and is ready to fall.
3	Capsule and Seed formation	
3.01		At least one flower has a developing capsule, which is covered by calyx. The capsule is less than 5 mm in length.
3.02		At least one flower has a growing capsule, which is taller than calyx tips. It is usually greater than 5 mm in length.
3.03		At least one flower has a growing capsule with small transparent visible seeds, filled with transparent liquid.
3.04		
3.05		At least one flower has a growing capsule with semi-transparent visible seeds filled with semi- transparent liquid
3.06		Seeds of at least a capsule are in real shape. Seeds are white non-transparent which filled with viscose milky liquid. Cotyledons are not apparent by pressing seeds
3.07		At least a capsule is in real shape. Cotyledons are apparent by pressing seeds but soft.
3.08		
3.09		At least two capsules of middle parts of main stem capsule bearing zone has seeds with dark seed line or dark tip

To facilitate and simplify data recording and processing, our scale was designed based on the numbers from zero to nine. To provide more detail, the scale was divided into primary and secondary stages, also, based on numbers. Finally, a three digit system with a separating period between the first and second and third digits (0.00) was implemented. This separator could either be a period "." or a comma ",". This scale solved some of the problems of previous scales for data entry to datasheets and also provides adequate space for secondary stages, which is flexible for both American and European systems. For example, in entering codes into spreadsheet-based programs that are related to "Imbibed seed," e.g. 001, or "Emergence," e.g. 004, based on Knot's (1987 a, b) scales for faba bean and/or pea, some problems might arise as some software programs consider 001 and 004 as 1 and 4. Although programming solutions are available to overcome this problem, it is inconvenient and creates additional work.

In the proposed growth stage system for sesame, the first digit represents the principal growth stage and the second and third digits represent the differences that occur within principal stages, e.g. the secondary stages. Although the growth stage is represented as a decimal number, it should not be concluded that it has the usual arithmetic properties, except that the decimal numbers represent an increase in the arithmetic value of the code through the continuous progression of plant development. Therefore, the arithmetic difference between codes has no meaning, but a large value of a code indicates a plant at a later growth stage. So, sorting codes into numerical order will thus arrange the order of plant development (Lancashire et al.,1991).

Selection of common plant characteristics

A standard growth stage code to identify the various growth stages must be broadly applicable to a wide range of genotypes and be applicable for different cultural and climatic conditions. Therefore, such codes must be based on typical and common development characteristics of a plant (Knott 1987, Lancashire et al., 1991). As mentioned previously, the sesame plant is very diverse, both among different plants and within the same plant. Therefore, developmental characteristics that have less variability among and within plants as well as in different climate and management conditions should be selected for defining the growth stage code. Otherwise, reference to variable characteristics in describing sesame growth stages will result in a system that is not applicable to all genotypes and conditions. Zadoks et al. (1974) stated that growth stages must be easily recognizable under field circumstances without specialized equipment or size measurement and the scale should explain the complete plant life cycle. Therefore, using some characters such as the genetic variation of isozymes as studied by Isshiki and Umezaki (1997), will not helpful. Hanway (1963) stated that the growth stages should relate to the important transitional periods of the plant life cycle and should occur regularly throughout the life cycle to permit growth staging at various times during the growing season.

In this study, we selected germination and emergence, vegetative stage, flowering, and capsule and seed formation as the principal stages to describe growth and development of sesame. Similar to other crop development scales, this system refers to the development of the main stem of an individual plant only.

As stated previously, sesame has opposite and alternate leaf arrangements, either on the same plant or on different plants. Therefore, considering the leaf number on the main stem as criteria for plant growth might be confusing. We did not consider the leaf number in this scale, to avoid the ambiguity associated with the definition of "a true leaf" and to avoid the size characteristic of leaves, which are used in several other crops. It helps a researcher to avoid having to measure the degree of completion of previous leaves, since sesame has different leaf sizes and shapes on the vertical plant profile, which changes in size during development. Also, reference to percentage of a phenomenon, such as flowering, could be confusing and hard to determine. Reference to percentage of final size of a plant component is not a convenient characteristic. Because it may imply that the final number of a plant component, e.g., stem or capsule, be known at the time of evaluation. Clearly, it is not possible to predict the future precisely for any individual plant or even crop, but an experienced technician will know the expected (average) performance of a species or cultivar for a range of growth conditions (Lancashire et al., 1991). It also decreases the universality of the scale or staging system, since in most research studies some student are involved who have inadequate experience as an expert technician. Using the term "percentage of potential," as used by Sylvester-Bradley et al. (1984) was also excluding because of the same reason. For the proposed system, the node number of the main stem was considered as one of the criteria for describing vegetative development. Also, the sesame scale directed to the way to comprise phenomena with already happened event when comparison was necessary.

Germination and emergence: stage 0

The growth stage key starts with the first primary stage: Germination and Emergence. The stage was divided into ten secondary stages, starting with dry seeds, followed by absorption of water, seed imbibition, and radicle emergence. The end of this stage is defined by the full opening of the cotyledons (Figure 2l). The cultivated dry seed was considered as the starting point of the sesame life cycle, from planting to final harvest and represented by code 0.00 (Figure 2a). After planting, the dry seeds will absorb water and then swell. These well imbibed seeds which still have no radicle, coded as 0.01 (Figure 2b, c). After swelling and living seeds, a radicle will grow and emerge from the seed coat, i.e., code 0.02 (Figure 2d, e, f). The appearance of hairy roots represents code 0.03 (figure 2g). The emerged radicle continues to grow and forms an arc in order to allow for the cotyledons to reach the soil surface. The appearance of the arc in the radicle is coded as 0.04 (Figure 2h,i). The process for the cotyledons to reach the soil surface takes time, as it depends somewhat on other parameters, such as soil temperature, texture and soil moisture. Code 0.07 represents the situation that the folded cotyledons are visible on the soil surface and in some situations the cotyledons are still covered with the seed coat (Figure 2j). When the cotyledons reach the soil surface, they start to unfold. The stage of fully unfolded cotyledons on the soil surface is coded as 0.09. The unfolding of the cotyledons is the final event of the primary stage 0 and it is an indication that the vegetative stage will start soon.

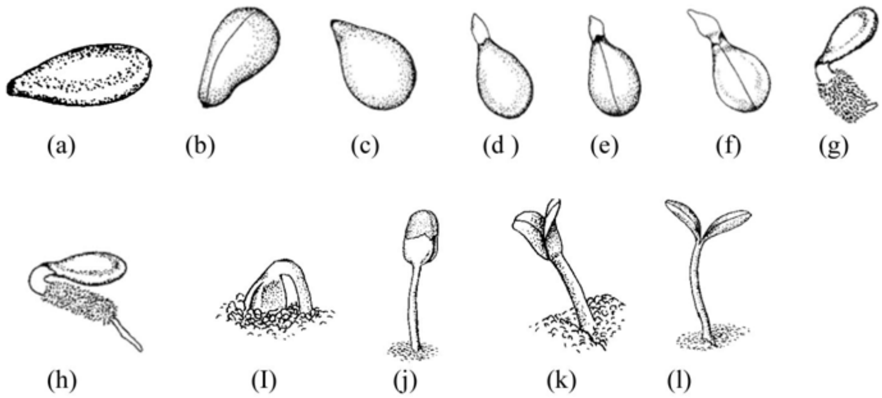

Figure 2. Germination and emergence stage. (a) Dry seeds (code 0.00), (b, c) imbibed seed (code 0.01); (d, e, f) radicle emergence (code 0.02); (g) appearance of hair roots (code 0.03); (h, i) Hypocotyls arc is present (code 0.04); (j, k) Folded cotyledons on soil surface (code 0.07); and (l) fully opened cotyledons (code 0.09).

Vegetative stage: stage 1

The vegetative stage starts when the first node other than the cotyledonary node, appears on the "main stem" and visible by eye. (Figure 3a). This stage is indicated by code 1.01. Although there are no branches at this stage, the "main stem" is emphasized to show that the scale refers to main stem only and not to branches. During the vegetative stage, the plant canopy develops by producing leaves and stems. The duration of this stage depends on environmental conditions, including air temperature and photoperiod and of course the genetic background. This code allows users to record more than nine nodes in situations that the post vegetative stage occurs with a delay. However, under normal condition with commercial cultivars, the post vegetative stage, including flowering, will occur prior to the formation of 9 nodes. The secondary growth stage codes for vegetative stage refer to the number of visible main stem nodes. Therefore, code 1.01 (Figure 3a) represent a plant with one visible main stem node. Similarly, code 1.02 (Figure 3b, c) and 1.03 (Figure 3d) represent plants with two and three visible nodes on the main stem. Up to 99 nodes could be counted using the second and third digits of the vegetative stage code. The vegetative stage terminated with the appearance of the first flower bud on the main axil.

Flowering: stage 2

The appearance of the fist flower bud defines the start of flowering and the post vegetative stage. Flower buds form in the leaf axils and they change to a flower through various distinct visual alterations. These changes, which are reflected by the second and third digits start with the appearance and growth of a calyx and corolla, followed by a change in the color of the corolla. For the complete flower, pollination and fertilization will occur under suitable conditions, usually before opening of the corolla. In most cases, the abortion of the corolla is an indicator of a successful fertilization. Under suitable conditions, the fertilized flower will produce a capsule and form seeds. We decided to not categorize the post-vegetative stages as reproductive stage, because the appearance of the flower bud or even the opening of the flower does not necessarily mean reproduction. Also, in some situations flowers do not ultimately result in a capsule and seed. We, therefore, classified the post vegetative stages into two distinct stages, including flowering and seed and capsule formation.

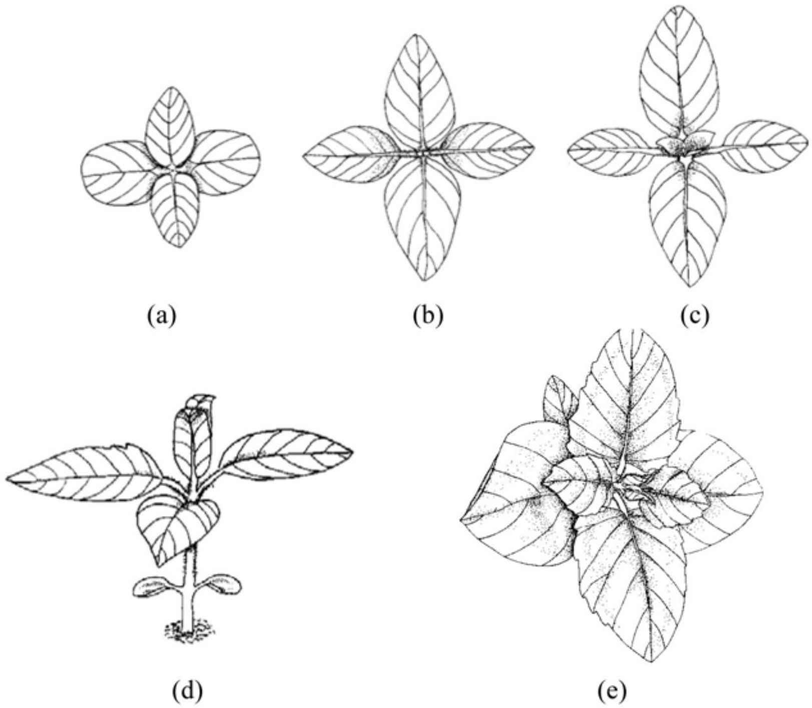

Figure 3. Vegetative stage. (a) Plant with first node on main stem (code 1.01); (b, c) second node on main stem (code 1.02); (d) 3rd node on main stem is appear (code 1.03). (e) 6th node on main stem is appear (code 1.06).

The flowering stage start with code 2.01 which means the appearance of the first flower bud in any leaf axil. The buds will grow and the calyx and/or pedicle will appear, coded as stage 2.02. In Stage 2.03, the corolla is inside the calyx (Figure 4a). The corolla will grow and emerge out of calyx tip, which is coded as 2.05. However, during stage 2.05, the calyx tip is still closed (Figure 4b, c, d). Finally, the corolla tips will open and the flower is ready for cross-pollination, coded as stage 2.07 (Figure 4e). It will take from 33 to 89 days from planting, i.e., stage 0.00, to the first opened flower, i.e., stage 2.07. After fertilization, a visible change in the color of the corolla color is also evident. Soon after this event, the corolla detaches and, in some cases, abscises (code 2.09). This is also defines the end of flowering stage. Under suitable condition, the flower remains on the plant and a capsule will start to develop. The diameter and length of the capsular will start to increase, and after some times it will emerge from the tips of the calyx.

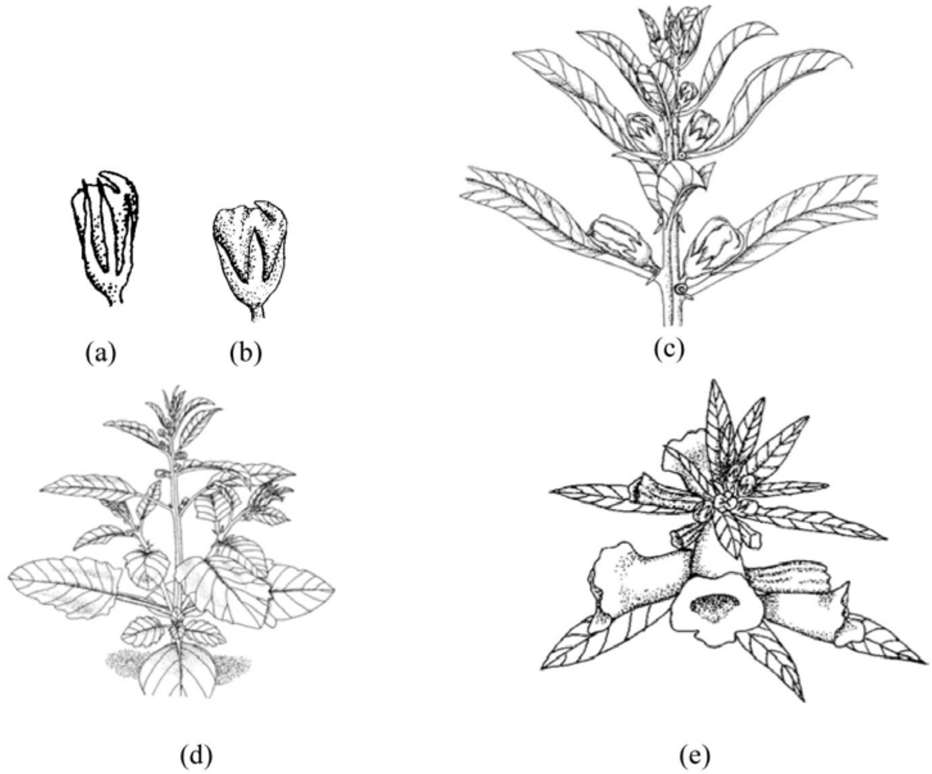

Figure 4. Flowering stage. (a) Calyx and corolla are easily visible and corolla is inside the calyx (code 2.03); (b, c, d) corolla is grater than calyx tip and still closed (code 2.05); (e) corolla tip is open (code 2.07).

Capsule and seed formation stage: stage 3

The best visible criterion to evaluate this stage is the development of the body of the capsule and the seed coat face characters. The appearance of the capsule with visible grooves which surround the calyx is beginning of the "capsule and seed formation" stage, coded as stage 3.01. In sesame, the individual flower has a small calyx that is divided into several segments that measure 3 to 7 mm in length (Yermanos, 1980). However, during stage 3.01 the initial capsule is usually less than 5 mm in length. During its growth, the length of the capsule increases and then emerges from the tips of the calyx, coded as stage 3.02 (Figure 5a). The capsules in this stage are usually longer than 5 mm. In sesame, the capsule and seeds partially grow simultaneously. Stage 3.03 is determined by small transparent seeds inside the capsule; the seeds are filled with a transparent liquid. The appearance of the seed then changes to semi-transparent white and the seeds are filled with a semi-transparent liquid, coded as stage 3.05 (Figure 5b). During stage 3.06 the white non-transparent seeds are filled with a viscose milky liquid. During this stage, the cotyledons are not hard and well shaped. Therefore, pressing the seed between fingers exposes only a milky liquid and no cotyledons are visible. However, feeling and exposing hard and well shaped seed cotyledons by pressing between fingers represents higher degree of plant development which coded as 3.07. In the stage, the soft cotyledons become visible by pressing a seed between fingers. By progress in plant and therefore seed development, appearance of seed coat surface including seed coat color, changes. Code 3.09 was described as a stage in which sesame seeds dark line is visible on one side of a seed. In the stage also black tip is present in the seed hilum area. To reach the code, seeds of at least two capsules should have such characters. Only capsules located in the middle part of capsule bearing zone of main stem must be consider. Code 3.09 is the end of the stage and therefore the development scale.

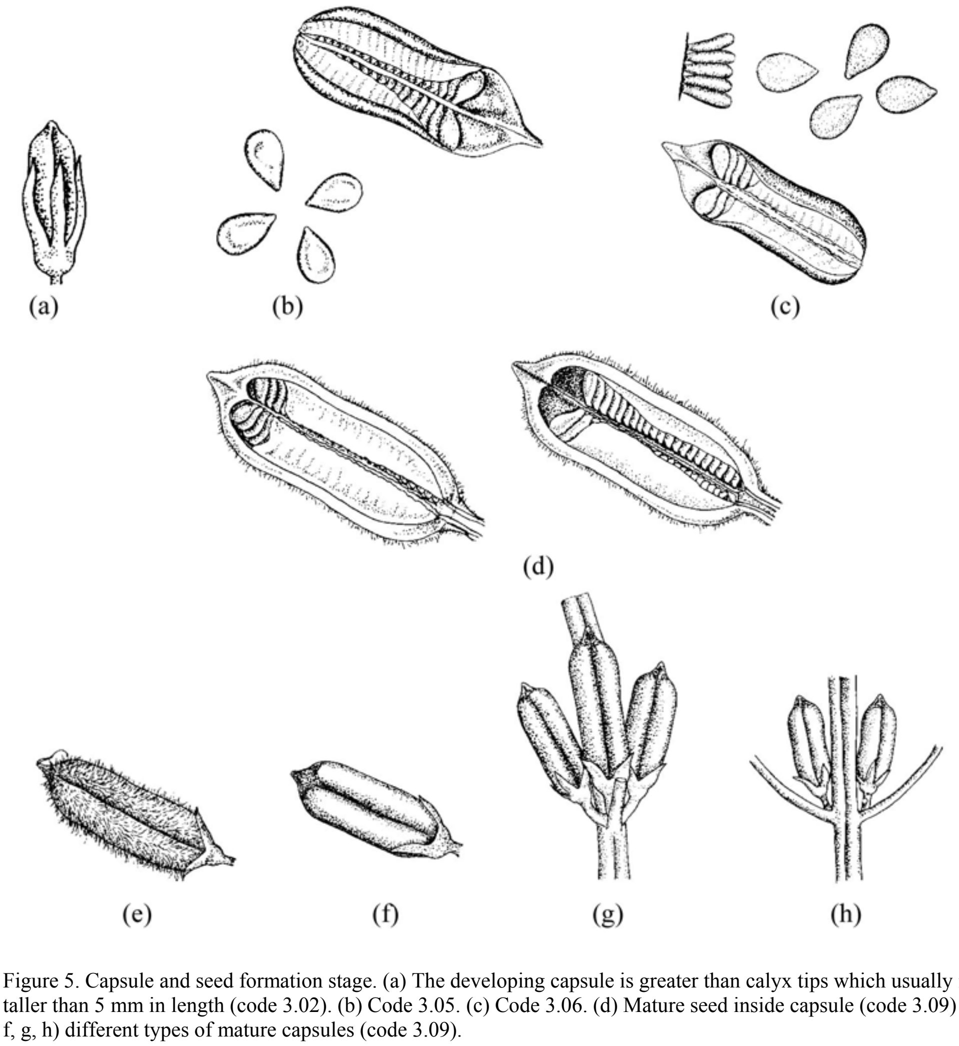

Figure 5. Capsule and seed formation stage. (a) The developing capsule is greater than calyx tips which usually is taller than 5 mm in length (code 3.02). (b) Code 3.05. (c) Code 3.06. (d) Mature seed inside capsule (code 3.09) (e, f, g, h) different types of mature capsules (code 3.09).

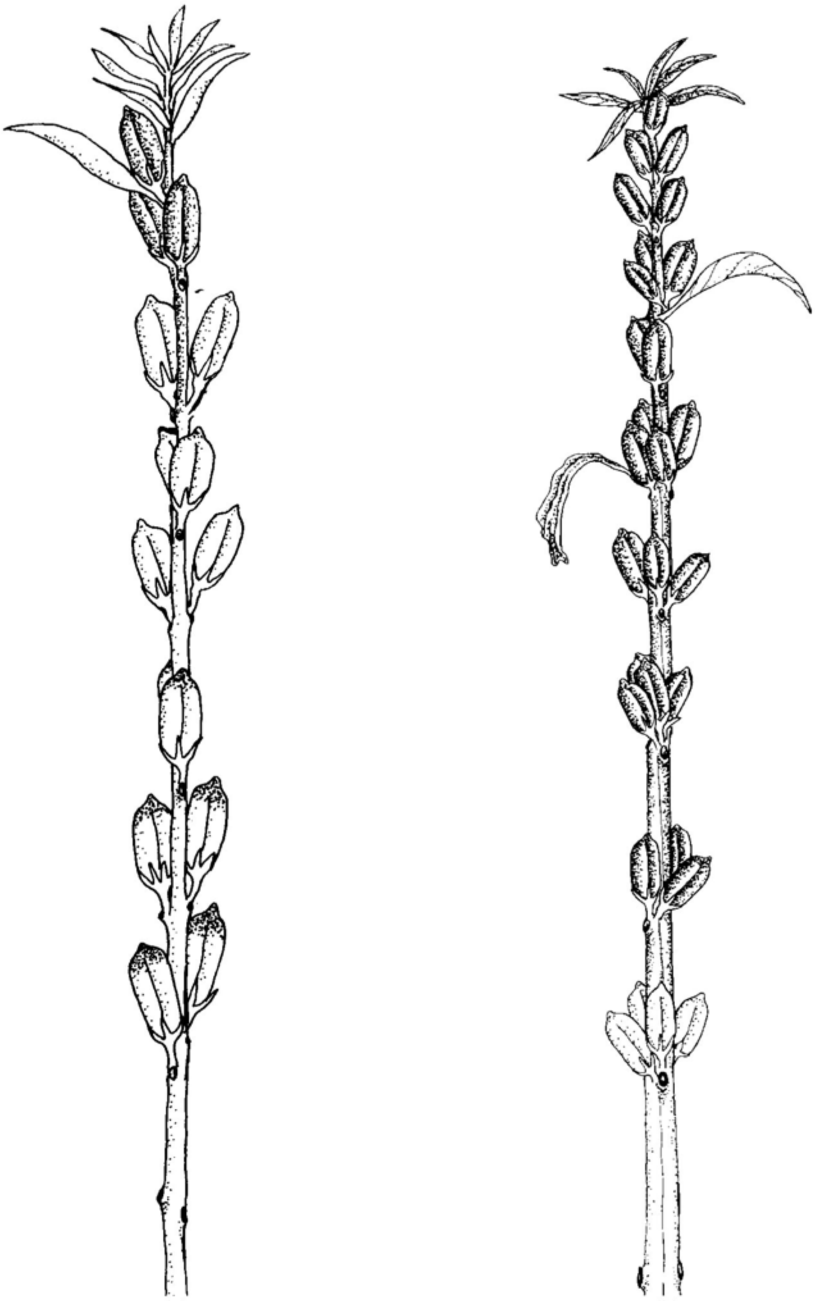

Figure 6. (a, b) Mature plant (code 3.09). Most leave already fall down. Some capsules have black tips.

Recognition of sesame population stage at field

A scale that defines both vegetative and reproductive development should not only be applicable to plants that are grown in research plots, but also to farmer's field. The best way to determine the developmental stage of either a field or an individual research plot is determining the growth stage of a sample plant population and extrapolation of the population's stage to the entire field or plot. The criterion for determining the growth stage of a population is when more than 50% of the population has advanced to the next stage. For example, a plot is in stage 3.01 when at least 50% of plants have reached this growth stage. Therefore, the application of the scale for either a field or a plot is based on the frequency of the growth stage codes in a sample population or the entire population.

Conclusion

A decimal growth stage system was defined and presented to express sesame development from the seed at planting to the seed at harvest maturity. Common and objective characteristics and traits were used for defining each stage using three digit codes. The sesame growth stage code was defined as four primary stages and up to 99 potential secondary growth stages for each primary stage. To determine the growth stage of a sesame plant, the common criteria should only be applied to the main stem. The growth stage system is applicable to determine developmental stage of a single and/or a plant population. Application of the system in the field is based on the frequency of the growth stage occurrence of a sample of representative plants or the entire plant population. Using the system helps researchers and farmers in application of inputs and treatments. Also, it makes comparison and use of research finding which obtained in different parts of the world as the scale unifies developmental descriptions.

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References

Ashri, A., 1998. Sesame breeding. In: Janick, J. (Ed.), Plant breeding review. John Wiley and Sons, Inc., pp: 179-228.

Bisht, I.S., Mahajan, R.K., Loknathan, T.R., Agrawal, R.C., 1998. Diversity in Indian sesame collection and stratification of germplasm accessions in different diversity groups. Gen. Res. Crop Evol. 43, 325-335.

Boote, K.J., 1982. Growth stages of peanut (*Arachis hypogaea* L.). Peanut Science 9, 35-40.

Counce, P.A., Keisling, T.C., Mitchell, A.J., 2000. A uniform, objective, and adaptive system for expressing rice development. Crop Sci. 40, 436-443.

Day, J.S., 2000. Development and maturation of sesame seeds and capsules. Field Crops Res. 67, 1-9.

Elsner, J.E., Smith, C.W., Owen, D.F., 1979. Uniform stage descriptions in upland cotton. Crop Sci. 19, 361-363.

Fehr, W.R., Caviness, C.E., 1977. Stages of soybean development. Ames, Iowa State University of Science and Technology.

Fehr, W.R., Caviness, C.E., Burmood, D.T., Pennington, J.S., 1971. Stage of development descriptions for soybeans, *Glycine Max* (L.) Merrill. Crop Sci. 11, 929-931.

Groot, J.J.R., Kropff, M., Vossen, F.J.H., Spitters, C.J.T., Rabbinge, R., 1986. A decimal code for the developmental stages of maize and its relation to accumulated heat units. Netherlands J. Agric. Sci. 34, 67-73.

Hanway, J.J., 1963. Growth stages of corn (*Zea mays* L.). Agron. J. 55, 487-492.

Knott, C.M., 1987. A key for stages of development of the pea (*Pisum sativum*). Ann. Appl. Biol. 111, 233-244.

Knott, C.M., 1990. A key for stages of development of faba bean (*Vicia faba)*. Ann. Appl. Biol. 116, 391-404.

Kobayashi, T., 1991. Cytogenetics of sesame (*Sesamum indicum*). In: Tsuchiya, T., Gupta, R.K. (Eds.), Chromosome engineering in plants: Genetics, breeding, evolution. Elsevier Science Publishing Company Inc. Amesterdam, pp: 581-592.

Lancashire, P.D., Bleiholder, H., Van Den Boom, T., Langelüddeke, P., Strauss. R., Weber, E., Witzenberger, A., 1991. A uniform decimal code for growth stages of crops and weeds. Ann. Appl. Biol. 119, 561-601.

Schneiter, A.A., Miller, J.F., 1981. Description of sunflower growth stages. Crop Sci. 21, 901-903.

Sylvester-Bradley, R., 1985. Revision of a code for stages of development in oilseed rape (*Brassica napus* L.). Asp. Appl. Biol. 10, 395-400.

Sylvester-Bradley, R., Makepeace, R.J., Broad, H., 1984. A code for stages of development in oilseed rape (*Brassica napus* L.). Asp. Appl. Biol. 6, 399-419.

Tottman, D.R., Broad, H., 1987. The decimal code for the growth stages of cereals, with illustrations. Ann. Appl. Biol. 110, 441-454.

Vanderlip, R.L., Reeves, H.E., 1972. Growth stages of sorghum (*Sorghum bicolor* (L.) Moench.). Agron, J. 64, 13-16.

Waldren, R.P., Flowerday, A.D., 1979. Growth stages and distribution of dry matter, N.P., and K in winter wheat. Agron. J. 71, 391-397.

Weiss, E.A., 2000. Oilseed crops. 2nd edition, Blackwell Science Ltd., Oxford.

Yermanos, D.M., 1980. Sesame. In: Fehr, W.R., Hadley, H.H. (Eds.), Hybridization of crop plants. American Society of Agronomy and Crop Science Society of America, Madison, Wisconsin, USA, pp. 549-563.

Zadoks, J.C., Chang, T.T., Konzak, C.F., 1974. A decimal code for the growth stages of cereals. Weed Research 14, 415-421.