Characterizing phenology of sorghum hybrids in relation to production management for high yields*

SS Rao, M Elangovan, AV Umakanth and N Seetharama**

National Research Centre for Sorghum, (ICAR) Rajendranagar, Hyderabad 500 030 (AP), India;
**e-mail: ssrao@nrcsorghum.res.in

Abstract: Phenology and growth stages of sorghum hybrid grown under semi-arid tropical regions of India are described in this paper. The phenology and growth stages have been characterized on the standard scale of "0" to "9". Identification of correct phenology and growth stages and their timing based on crop development phases results in better crop management decisions in seed production plots. Tropical commercial sorghum hybrid CSH 16 growth stages namely emergence, 3-leaf stage, 5-leaf stage, growing point differentiation (panicle initiation), flag leaf visible, boot, 50% flowering, soft dough, hard dough, and physiological maturity have been characterized on a scale of "0" to "9" scale. Parents of kharif sorghum hybrids and commercial varieties also follow almost the similar scheme of growth and development. To achieve the targeted grain yields of hybrids and their parents' identification of correct growth stages, and their timing will help in proper timing of application of production inputs and management practices at appropriate stage of crop development. Also, using these crop growth stages, the sensitive stage of crop for insect pests and diseases could be identified for appropriate management practices, which helps the farming community to reduce the cost of cultivation but at the same time realize high yield potentials.

Introduction: Sorghum [*Sorghum bicolor* (L.) Moench] is the principal cereal grown for food ,fodder, fuel and fiber around the world in over 45.8 m ha, with production and productivity of 59.6 m t and 1.30 t ha^{-1}, respectively (FAO, 2004). In India, it is cultivated over 9.50 m ha with a production of 7.73 m t and productivity of 0.77 t ha^{-1}. The major production constraints that reduce sorghum productivity are abiotic (nutrient and drought stresses, excess water, temperature extremities, etc.), biotic (shoot fly, stem borer, head bugs, grain mold, foliar diseases, charcoal rot, etc.).

Vanderlip and Reeves (1972) described the temperate sorghum growth stages on a scale of 0-9. However, the duration of these stages varied according to the climatic conditions, latitude, date of planting, temperature, photoperiod, etc. Eastin (1972) reported three simplified sorghum growth stages, i.e., i) planting to panicle initiation (GS1), ii) panicle initiation to flowering (GS2), and iii) flowering to physiological maturity (GS3). However, the variation in growth stages of temperate sorghum described by Vanderlip and Reeves (1972) is inadequate to characterize the Indian tropical sorghums, where the growing conditions and seasons are different from those of temperate countries. Rao *et al* (2004) have characterized the phenology and growth stages of tropical sorghum hybrids which are described in this paper.

Identification of growth stages and their duration

Stages of Indian semiarid tropical sorghum development on a '0' (emergence) to '9' (physiological maturity) have been characterized to determine the duration to each growth stage including their time interval between stages are presented in Table 1. However, the duration of these growth stages may vary with planting date, genotype and location (latitude).

* Presented at the of NRCS-ICRISAT Learning Program on Sorghum Hybrids Parents and Hybrids Research and Development, 6 - 17 February 2007, NRCS and ICRISAT, Hyderabad.

Stage 0 (Emergence): Emergence is considered to have occurred when the seedlings are seen above the soil surface. This can be identified when the coleoptile is visible at the soil surface, which takes about 4 days. Furthermore, sorghum emergence will vary depending on depth of planting, soil moisture, and temperate conditions, compaction of soil, and seed vigor.

Management guide: Planting should be timed to synchronize adequate moisture in the top 0-15 cm soil profile to enable good emergence. Planting within 10 days after the onset of monsoon avoids shoot fly infestation. While the use of pre-emergence herbicide, atrazine (@1.0 kg ha^{-1}) immediately after planting will prevent weed growth. Light sprinkler irrigation, if available, weakens the crust and allow rapid seedling emergence.

Table 1. Identification of growth stage characteristics in sorghum.

Growth stage Number	*Days from Emergence*	*Duration (days)*	*Identification characteristics*
0	0	0	*Emergence:* Coleoptiles visible at soil surface (first leaf is seen with a round tip).
1	6	6	*3-leaf stage:* Collar of 3rd leaf visible.
2	16	10	*5-leaf stage:* Collar of 5th leaf visible.
3	32	16	*Growing point differentiation (panicle initiation):* Approximately 9-leaf stage by previous criteria.
4	50	18	*Flag leaf visible:* Tip of flag leaf (final leaf) visible in the whorl.
5	60	10	*Boot:* Head extend into flag leaf sheath.
6	68	8	*50% flowering:* Half of the plant has completed pollination from the tip to down.
7	80	12	*Soft dough:* Squeezing kernel between fingers results in little or no milk.
8	96	16	*Hard dough:* Seed cannot be compressed between fingers.
9	106	10	*Physiological maturity:* Black layer (spot) appears on the hilum, at the base of the seed.

N.B. Planting to emergence takes 4 days.

Stage 1 (3-leaf stage): Seedling had three fully expanded leaves, and the collar of 3 leaves is clearly visible, which occurred 6 DAE (Table1) and the seedling grew to a height of 20 cm.

Management guide: Since seedlings are quite small with less leaf area and poor weed control during this stage can seriously reduce the crop yields. First manual weeding should be undertaken during this stage to promote seedling growth and conserving soil water. Seedlings are infested by shoot fly at this stage.

Stage 2 (5-leaf stage) : It can be identified by the appearance of visible collar in all the 5 leaves, continuous visibility of first leaf with round tip, and takes 16 days from emergence (Table1).The seedling thus said to be entered in to 'grand period of growth'. The plant grew to a height of 50 cm.

Management guide: Shoot fly, weed competition, nutrient, and water stress reduce the crop stand. Prolonged cold, wet, and cloudy weather causes purple coloring on the leaf sheath and blades, besides iron chlorosis. Crop should be thinned to one seedling per hill to reduce competition for soil water. Soil application of carbofuan 3G (20 kg ha^{-1}) or phorate10G (15 kg ha^{-1}) for shoot fly; and need-based application of carbofuran 3G or phorate 10G inside the plant whorls (@ 8 and 12 kg ha^{-1}) at 30 and 45 DAE protects the plant from stem borer damage.

Stage 3 (Panicle initiation stage): This stage occurred at 32 days after emergence, when the growing point is seen transforming from vegetative (leaf producing) to reproductive phase (panicle producing) (Table 1). Planst have grown to a height of 95-100 cm. Panicle initiation can be identified by splitting the stalk with a sharp knife and observed under compound microscope. During this stage, plant develops 9-10 leaves, depending upon maturity group, and the basal 2-3 leaves may become senesced. Culm growth increases rapidly following this stage.

Management guide: Growth and nutrient uptake are rapid during stage 3. Side-dressing of nitrogen fertilizer is recommended to hasten the panicle growth. Intercultivation and second weeding enables to promote root growth and conserve the soil water. The crop may be susceptible to spotted stem borer resulting in deadhearts due to larval damage to the growing tip or tunneling, which can be checked with the application of carbofuran granules inside the plant whorls as indicated earlier.

Stage 4 (Flag leaf (final leaf) visible): This stage takes about 50 days from emergence, and 18 days from stage 3, and can be identified by observing the appearance of tip of flag leaf in the whorl (Table 1). Plants showed rapid leaf and culm elongation during this stage. All the leaves except the top 3-4 were expanded, and the basal 3-5 leaves were lost due to senescence. Plant grew to a height of 115-120 cm.

Management guide: Severe water, nutrient and insect stresses will reduce the potential seed number $plant^{-1}$. Intercultivation should be avoided to prevent pruning of expanding root system, loss of soil water, and nutrient uptake. Continuous tunneling by the spotted stem borer inside the stem may delay the emergence of flag leaf.

Stage 5 (Boot stage): This can be identified as a swollen flag leaf sheath enclosing the panicle which gives the appearance of boot shape (Table 1). This stage takes about 60 and 10 days from emergence and stage 4, respectively. Flag leaf was the last leaf to emerge from the whorl. Panicle development was completed, and plant reached with maximum leaf

area. Plants have grown to a height of 125-130 cm tall. Plant experiences high water demand, hence maximum water use. Also, the plant response to irrigation was the greatest at this stage, if severe drought stress was prevailing.

Management guide: Rapid culm elongation continues. Severe drought stress during stage 5 may shorten the peduncle length and prevent complete exsertion of the panicle. This may lead to incomplete pollination and affect the seed set. In view of stalk tunneling by stem borer, either panicle exsertion may be affected or delayed. Irrigation under severe drought stress over a period of >10 days helps to realize maximum yields.

Stage 6 (50% flowering): It can be identified when half the plants in the field are in anthesis, and takes about 68-70 days from emergence and 8 days from stage 5 (Table 1). Plant has grown to a height of 150-160 cm. Flowering typically started in 5-7 days after panicle exsertion and progressed from the tip to bottom of the panicle. Plant is at 50% flowering means that 50% of the anthers exserted out on 50% of the plants in the field. Flowering duration (from starting to end) usually takes 4-9 days.

Management guide: At this stage, any limitation in plant size or leaf area could no longer be corrected. Severe drought stress at flowering could result in blasting and poor seed filling. Choosing correct maturity cultivar and planting period is important, so that the flowering should not coincide with terminal drought conditions. During this stage, sorghum midges will get attracted due to flowering panicles, and lay eggs inside the florets resulting in blasting of panicles without seed setting. Head bug infestation also overlaps affecting grain development. Both these pests can be prevented by spraying of endosulfan 35EC or carbaryl 50 SP (@ 1 L in 500 Lt water ha^{-1}).

Stage 7: (Soft dough stage): Following flowering, seed development progressed from milk through soft dough stage, which can be identified when kernel is squeezed between fingers for the presence of little or no milk. It takes about 80 and 12 days from emergence and flowering, respectively. This stage had signaled the end of culm elongation. About 8 to 10 functional leaves were present and this may vary with the cultivar. Plants reached to about 170 cm tall.

Management guide: Crop yields depend on the rate of biomass accumulation and duration to grain fill. Drought stress at this stage depresses the rate of grain growth. High humid conditions following flowering result in grain mold, and cause loss in grain weight and quality. Head bug population buildup may increase rapidly, if unchecked, which may result shriveling of grain and also predispose the seed to grain mold infections. Suitable chemical control measures such as malathion 10D (@ 20 kg ha^{-1}) ensure protection from this pest. Bird menace becomes a problem, if the crop is not planted *en bloc*.

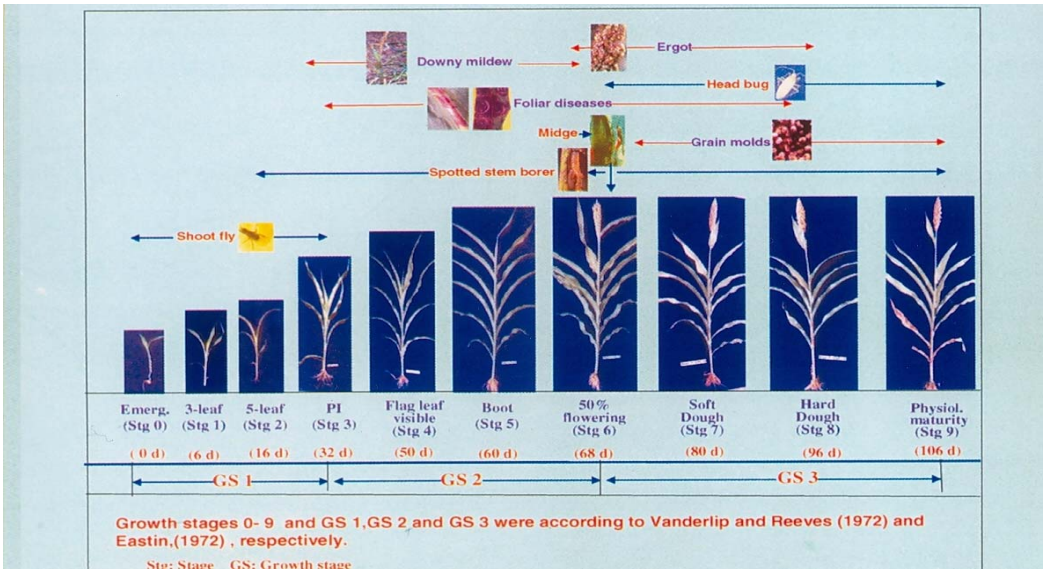
Stage 8 (Hard dough stage): At this stage, the seed cannot be compressed between fingers, and took about 96 and 16 days from emergence and stage 7, respectively (Table 1). Plants were susceptible to lodging due to charcoal rot and moisture stress. Lodging also occurs by defoliation due to insect pests & diseases during flowering through hard dough stage. Also heavy rain or hail driven by wind may cause stalks to lodge.

Management guide: Severe drought stress and charcoal rot infection if occurs leads to either lodging or incomplete seed filling. During this stage, because of extensive stem tunneling by the borer, the root system may also be predisposed to charcoal rot infections. Cloudy weather with prolonged wet spells of rain during this stage causes in discoloration and loss in grain weight resulting in grain molds.

Stage 9: (Physiological maturity): This stage can be identified when a dark spot (black layer) appears at the basal portion of seed whose appearance signals the end of photosynthate supply to the seed. Physiological maturity occurred in about 106 days from emergence and 10 days after hard dough stage. However, Further, seed moisture content at this stage varies between 25% and 35% and seeds gain maximum dry weight. The crop could be harvested at 20% moisture content, but must be dried to 14% moisture content for safe storage. On an average, 1000 seed weight was 25 g, but may range from 13 to 40 g. Seed size and weight depends on the plant's ability to accumulate biomass during grain-fill stage.

Management guide: To reap the maximum yields and quality of marketable produce, harvest the crop immediately after physiological maturity to avoid the grain mold incidence and crop lodging. Grain mold incidence to some extent can be controlled by spraying captan (0.3%) plus dithane M-45 (0.3%) thrice at 10 day intervals during grain filling stage. Harvested grain can be predisposed to storage pests when kept for long term storage. Thus, the seed may be treated with malathion 10% dust (@ 2 g kg^{-1} seed) to protect from storage pests.

Figure 1. Pictorial view of occurrence of insect pests and diseases at various growth stages



References:

1. FAO (Food and Agriculture organization), 2004: http://faostat.fao.org/faostat/notes/citation.
2. Rao SS**,** Seetharama N, Kiran Kumar KA, and Vanderlip RL. 2004. Characterization of Sorghum Growth Stages. NRCS Bulletin Series no.14. National Research Centre for Sorghum, Rajendranagar, Hyderabad 500 030, (AP), India.20 pp.
3. Vanderlip RL and Reeves HE, 1972. Growth stages of sorghum. *Agron J* **64**:13-16