Texas Cooperative Extension
The Texas A&M University System

Productive Rotations on Farms in Texas
PROFIT

B-6137
7-03

Sorghum Growth and Development

Thomas Gerik, Brent Bean and Richard Vanderlip*

Sorghum is well-adapted to Texas, and its ability to yield consistently in harsh environments makes it popular with growers. Although a perennial plant by nature, grain sorghum is customarily grown as an annual crop. Knowing how the sorghum plant develops is important in understanding how to manage the crop.

Recognizing Key Plant Structures

Understanding crop growth and development begins with knowing its structures and anatomy. Key plant structures are shown in Figure 1. The first leaf visible at emergence is the coleoptile leaf. It differs from all of the other leaves in that it has a rounded leaf tip. The leaf collar marks the junction of the leaf blade and sheath and appears when the leaf is fully developed. Each leaf sheath originates at its own node on the plant stalk. The sheath surrounds and strengthens the stalk (culm). The flag leaf is the last to emerge on the plant and is considerably smaller than the other leaves. The panicle (head) emerges from the flag leaf sheath and is supported by the portion of the stalk called the peduncle.

From Planting to Emergence

The time from planting to emergence (usually 5 to 10 days) depends on the growing conditions — soil temperature and moisture; the depth of planting and, to some extent, seed vigor. Slow emergence often results in uneven, skimpy plant stands and decreased yield. Before emergence, the plant is totally dependent on food reserves in the seed from the endosperm for survival. Slow emerging plants risk depleting these reserves, which are important to early plant growth in the days immediately following emergence. Some of the factors that adversely affect emergence and early plant growth are:

- **Cool, Wet Soil.** Plants prefer warm, moist soil for germination and emergence. Cool, wet soils promote the development of diseases. The ideal temperature for sorghum germina-

*Professor, Texas Agricultural Experiment Station, Temple, TX; Professor and Extension Agronomist, Texas Cooperative Extension, Amarillo, TX, The Texas A&M University System and Professor, Kansas State University, Manhattan, KS

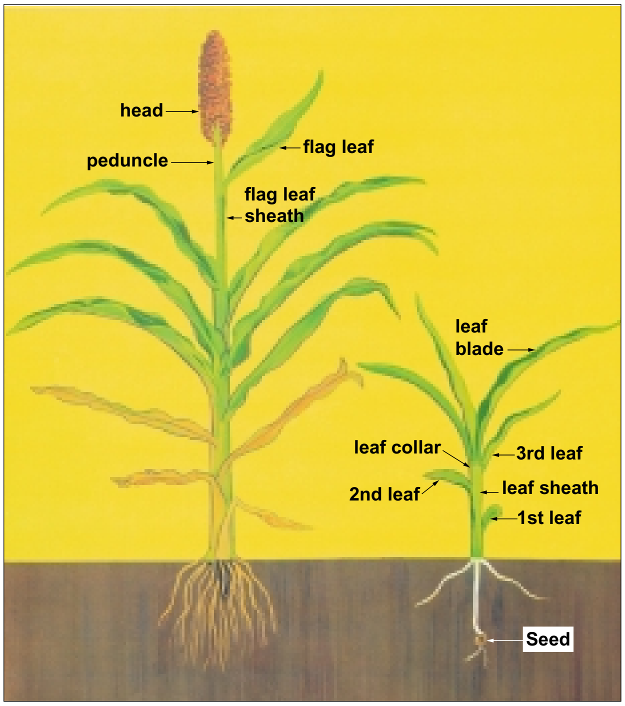

Figure 1. Typical grain sorghum plants at physiological maturity (left) an a 3-leaf growth stage (right).

tion and emergence is 70 degrees F. Although germination can occur at temperatures below 50 degrees F, emergence is delayed. For optimum germination and emergence, delay planting until the 5-day average daily soil temperature at the two-inch depth reaches 60 degrees F. In central and south Texas, predominantly dark color soils and higher frequency of warm spring temperatures allow growers to begin planting when soil temperatures are 50-55 degrees F. If planting in cool, wet soils cannot be avoided, plant shallow and use fungicide seed treatments.

- **Crusting.** Strong crusts, typically 0.25 to 0.5 inches thick, hinder a plant's ability to emerge. Crusts typically form after hard rain and when weather — warm temperature, low humidity and high winds — promotes very rapid soil drying. Soils with high content of fine sand and silt more readily form crusts than coarse sand and clay textured soils. Light tillage with a rotary harrow or sprinkler irrigation can sufficiently weaken crusts to allow the plants to emerge. Cropping systems that leave large amounts of plant residue on the soil surface, such as no- till or conservation tillage, help reduce soil crusting.
- **Herbicide Injury.** Pre-emergent chloroacetamide herbicides (e.g. Dual, Lasso, Frontier) are widely used to control weeds in sorghum. However, they can significantly injure the crop if rainfall moves the herbicide to a depth where it can be absorbed by the roots and shoots as they emerge from the seed. In severe cases, the plants may not emerge from the soil but will try to leaf out under the soil surface. Once emerged, the leaves may not unfurl properly and appear twisted, with the leaf tips being trapped in the whorl. In addition, plants may be stunted with purple leaf sheaths and leaf margins. Sorghum can recover from this injury if good growing conditions quickly return. Injury is accentuated in cool or crusted soils, since the plant emerges slowly and absorbs more herbicide. Seed treated with herbicide seed safeners (e.g. Concept) must be used if these herbicides are to be applied but do not guarantee the crop will completely escape injury when adverse weather or planting conditions are encountered.

Growth Stages

Once grain sorghum emerges, the plant develops in a predictable manner characterized by three distinct growth stages — GS I, GS II and GS III. A medium-maturity hybrid requires approximately 32 to 35 days to pass through each stage, depending on the hybrid and environmental conditions. Modern hybrids are insensitive to day length, meaning their rate of development is primarily driven by temperature.

Growth Stage I

This first growth stage, GS I, is characterized by vegetative growth. The plant develops its vegetative structures, leaves and tillers, which ultimately support grain formation and growth. Because modern hybrids are insensitive to day length, the duration of GS I largely depends on air temperature and the number of leaves genetically predisposed to form on the hybrid's main stalk. The more leaves formed by the hybrid, the longer maturity (e.g., more time is required from planting to harvest) and greater its potential to produce forage and grain. Early-maturing hybrids typically produce 15 leaves per plant, while medium- and late-maturing hybrids produce 17 and 19 leaves each.

Stages within GS I are characterized by the number of leaves with visible collars. The smaller of the two plants in Figure 1 is at the 3-leaf stage because the collars of the first, second and third leaves are visible. In this example, all or portions of six leaves can be observed, but because only three collars are visible, it is considered to be in the 3-leaf stage.

Sorghum can tolerate high degrees of stress from drought, hail and freezing temperatures in GS I with little adverse affect on yield. But insect pests, if untreated, can irreparably harm the crop. Abnormally dry and/or cool weather promotes the development of damaging pests such as corn leaf aphids, greenbugs and chinch bugs. Most post-emergent herbicides are applied during GS I. Follow label directions carefully to prevent crop damage.

Prolonged cool, cloudy weather in GS I may also cause a purple coloring on leaf sheaths and blade margins, and the blades can develop an interveinal yellow striping (chlorosis). The purple color occurs from the accumulation of anthocyanin in the tissue and results from insufficient phosphorous uptake or from the plant's inability to move sugars from the leaf blade. Leaf striping is often caused from insufficient iron or zinc uptake. Symptoms usually disappear when favorable temperatures return. Iron and zinc deficiencies will be more pronounced in high calcareous soil.

Long, sunny days with temperatures below 65 degrees F favor tiller appearance on basal nodes (nodes at the base of the plant) of plants at the four- and six-leaf stage. Plant densities of fewer than three plants per row-foot promote tillering, while more than four plants per foot suppresses tillering. Panicles of tillers are smaller and flower later than those on the main stalk. Basal tillers formed at this stage can compensate somewhat for losses in plant emergence. Some hybrids have a tendency to tiller more than others.

Growth Stage II

The second growth stage, GS II, is the period when reproductive structures of the panicle form and the maximum number of seed per plant are set. It is considered the most critical period for grain production, because seed number per plant accounts for 70 percent of sorghum's final grain yield. Anything that impedes panicle development during this period reduces the number of seed to be formed, which lowers grain yield.

GS II begins with **"panicle initiation"** and continues to flowering. The initiation of the panicle is marked by the appearance of protrusions (seen as raised bumps) on the surface of the plant's growing point about 30 to 35 days after emergence (Figure 2). These are the primordial structures that ultimately form the panicle branches, which later differentiate into spikelet branches and floral structures responsible for seed set and grain formation. They are easily identified with the naked eye by vertically splitting the stalk with a sharp knife and locating the growing point when 7 to 10 leaves have fully developed (e.g., note one to three leaves may have been lost, since the lower leaves die and fall off as the plant grows, making correct identification of the leaf stage more difficult). Use the coleoptile leaf (small, round tipped) as leaf number one. If it is not present, use the number of nodes at the base of the plant to determine the correct leaf stage. The first internode (lowest on the plant) that can be observed is internode four. This will be approximately one-fourth inch long. An internode is the portion of the stalk between nodes. Subsequent internodes will be progressively longer if good growing conditions exist. The leaf sheath of leaf five originates from node five. All other leaves can easily be identified using leaf five as a reference.

If sorghum is being grown under irrigation, it is important that the crop not be allowed to stress at the beginning of this stage when the potential number of seed per plant is being set. Following panicle initiation, the plant abruptly stops forming new leaves and begins to form the plant's reproductive structures. Although panicle initiation marks the moment when the plant attains its max-

Figure 2. The growing point of sorghum following panicle initiation. Far right: A growing point one day after panicle initiation with raised bumps developing into primary panicle branches. Center and left: Growing points 5 and 7 days after panicle initiation containing secondary and tertiary primordial branches.

imum leaf number, only one-third of the leaf area has formed (Figure 3). The remaining leaf area develops as the panicle and floral parts form during GS II, a period of rapid growth. Side-dress nitrogen applications should occur prior to this event, so soil fertility is not limiting when the crop most needs it.

The **flag leaf** is the last leaf to emerge from the whorl. It is smaller than the other leaves and positioned directly below the panicle. When the flag leaf collar appears, the plant is in the **boot stage** (Figure 4). The sorghum panicle development is complete and primed for flowering, and the plant has attained its maximum leaf area and accumulated approximately 60 percent of its total dry matter. Severe drought stress at this time can impede panicle exertion from the boot and lead to incomplete flowering (anthesis), seed set and loss in grain yield. The crop's water requirements are greatest

Figure 3. The appearance of grain sorghum at the panicle initiation growth stage.

at this time, so growers with irrigation are advised to ensure there is sufficient water for panicle exertion, flowering and seed set. Sorghum is considered **headed** (Figure 5) when panicles are visible on 50 percent of the plants in the field.

The development of the panicle, its floral structures and the remaining leaf area is extremely sensitive to drought and stresses caused by greenbugs, corn leaf aphids and chinch bugs. Stress reduces the number of florets and, ultimately, the number of seed in the panicle for grain formation. Furthermore, applications of 2,4-D- or dicamba-containing products after panicle initiation can injure and reduce seed number and yield. Cultivation should be avoided after panicle initia-

Figure 4. Grain sorghum plant at the boot stage.

Figure 5. Grain sorghum at the heading stage.

tion to prevent pruning the expanding root system and losing soil water and nutrient uptake.

Growth Stage III

The third and final growth stage is grain filling, called GS III. It begins with **flowering** and continues until dry matter accumulation in the grain stops with the appearance of a **black-layer** near the point of the seed attachment in the floret. Flowering typically begins when yellow anthers appear at the tip 5 to 7 days after panicle exertion (Figure 6). Over the next 4 to 9 days, anthers appear incrementally and develop down the panicle. The crop is in full flower (bloom) when 50 percent of the anthers on 50 percent of the plants in the field have emerged.

Environmental stress from heat or drought does not usually affect pollination, but herbicide drift prior to, during or immediately following pollination can interfere with seed set and severely reduce yield. The sorghum midge, a common insect pest in central and south Texas, is damaging at this stage, laying its egg in the floret and killing the developing seed. One midge per panicle can lower grain yield 10 to 20 percent. Examine plants for other pests, such as greenbugs on the leaves and head worms in the panicles, at this stage.

Figure 6. Grain sorghum head at the beginning of the flowering stage.

After flowering, plant development centers on grain formation. Sugars, amino acids and proteins produced in the leaves and roots are rapidly transported to the kernel and converted to starch and protein. Seed development progresses from **milk** to **soft dough** to **hard dough** to **physiological maturity** over a 25- to 45-day period after flowering, depending on hybrid and environmental conditions. Kernels reach their maximum size (volume) about 10 days after flowering — the **milk stage**. The seed is soft, and a white milk-like liquid is obtained when kernels are squeezed. The **soft dough stage** occurs 15 to 25 days after flowering, when approximately 50 percent of the grain weight is accumulated — the kernel can be squeezed between the fingers with little or no liquid present. Sorghum for silage is typically harvested at the soft dough stage when the plant has lost several lower leaves. The plant is quite susceptible to bird feeding at this time. Eight to 12 functional leaves are usually present at soft dough.

The **hard dough stage** occurs when the grain cannot be compressed between the fingers. The grain has accumulated approximately 75 percent of its dry matter. Plants are most susceptible to lodging (falling over) at this time, resulting from severe drought, plant diseases (charcoal rot) and stalk-boring insects.

The seed is physiologically mature when a **black-layer** (Figure 7) appears immediately above the point of kernel attachment in the floret near the kernel base. The kernel is approximately 30 to 35 percent moisture and attains its full dry weight when the black-layer appears. Grain can be harvested at 20 percent moisture without mechanical damage but must be dried to below 14 percent to be safely stored in bins without drying equipment. Kernels can lose up to 5 percent of the dry matter present at black-layer if the crop fully dries in the field. This is because the kernels continue to convert sugars and amino acids into starch and protein, losing carbon dioxide through respiration until the kernels dry to a water content of approximately 15 percent.

Figure 7. A physiologically mature sorghum kernel at 35 percent moisture with recently formed black-layer (left), compared to a sorghum kernel at 13 percent moisture from panicle ready for mechanical harvest.

Kernel size and weight varies in sorghum, typically ranging from 2.0 to 4.5 millimeters in diameter (Figure 8). On average, kernels weigh about 25 grams per 1,000 seed (18,000 seed per pound) but can range from 13 to 40 grams per 1,000 seed (e.g., 11,300 to 33,600 seed per pound). Kernel size and weight depend on the plant's ability to accumulate dry matter during GS III. Weather, soil fertility and available soil water influence final size and weight of kernels. Eighty-five percent of the dry matter produced by the plant during GS III goes directly to grain. Only 15 percent of final grain weight originates from dry matter produced during GS I and GS II. Hybrids with high seed numbers typically have low seed weights (e.g., high numbers of seed per pound) and vice-versa. An early freeze or severe drought during the soft dough stage will drastically cut dry matter production, resulting in shriveled, light grain.

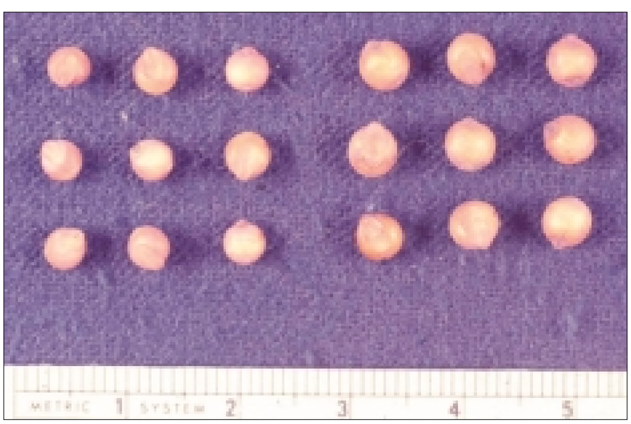

Figure 8. the typical range in kernel size of grain from a sorghum panicle (in millimeters/centimeters).

If growing conditions are favorable when grain is physiologically mature, tillers often emerge from the plant's upper and lower nodes. These tillers, if left unchecked, produce small amounts of additional grain and increase grain moisture to levels unacceptable for immediate sale, storage or delivery, delaying harvest several weeks. This delay often results in substantial degradation in grain quality, reducing grain price and farm income. Tillering is suppressed when growing conditions are unfavorable at harvest. Nevertheless, in central and south Texas, mechanical stalk destruction or chemical crop termination may be required to thwart tiller development and crop regrowth after harvest. Applying glyphosate when the black-layer appears on 50 percent of grain prevents the development of tillers following grain maturation and accelerates grain drying and harvest.

Predicting Sorghum Development Based on Air Temperature

Grain sorghum follows a predictable pattern of growth from planting through GS III. The timing and duration of each growth stage are closely related to air temperature and the genetic background (maturity) of the hybrid. Because daily minimum and maximum temperatures vary from year to year and between locations, the number of calendar days from planting to emergence, panicle initiation, flowering and black-layer varies and is not a good predictor of crop development. As a result, thermal time more reliably estimates crop development than the number of calendar days. It is estimated as the cumulative number growing degree units (GDU) between growth stages, e.g. from planting to emergence, to panicle initiation and so forth. For grain sorghum, GDUs accumulated each day are calculated as follows:

$$\text{GDU} = \frac{\text{daily max. air temp.} + \text{daily min. air temp.}}{2} - \text{Base Temp.}$$

The base temperature or lower temperature limit of sorghum development is 50 degrees F, while the upper limit is 100 degrees F. Air temperatures greater than 100 degrees F are entered as 100 degrees F, and temperatures less than 50 degrees F are entered as 50 degrees F. For example, if a crop experiences a day with the maximum daily temperature of 94 degrees F and a minimum temperature of 65 degrees F, the number of growing degree units for the day is 29.5.

$$\text{Example: } \frac{94 + 65}{2} - 50 = 29.5 \text{ GDU}$$

The key growth stages of sorghum and the cumulative GDUs (from planting) required to reach each growth stage is illustrated in Table 1. Because sorghum hybrids differ in maturity, the table illustrates cumulative GDUs expected for early and late maturing hybrids.

Table 1. Cumulative growing degree units (F) from planting to successive growth stages for short and long season grain sorghum hybrids.

Growth Stage	Cumulative GDUs (F)	
	Short Season Hybrid	Long Season Hybrid
Planting		
Emergence	200	200
3-leaf	500	500
4-leaf	575	575
5-leaf	660	660
Panicle Initiation	924	1365
Flag Leaf Visible	1287	1470
Boot	1683	1750
Heading	1749	1890
Flowering	1848	1995
Soft Dough	2211	2310
Hard Dough	2508	2765
Black Layer	2673	3360

Produced by Agricultural Communications, The Texas A&M University System

Extension publications can be found on the Web at: http://tcebookstore.org
Visit Texas Cooperative Extension at: http://texasextension.tamu.edu

Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture. Chester P. Fehlis, Director, Texas Cooperative Extension, The Texas A&M University System.
2.500 copies, New