UNITED SORGHUM CHECKOFF PROGRAM

CENTRAL & SOUTH TEXAS PRODUCTION GUIDE

SORGHUM THE SMART CHOICE

Welcome to the United Sorghum Checkoff Program's Central and South Texas Production Guide. We have integrated research from various sources to produce an easy-to-use guide that can help farmers manage their crop more efficiently. Sorghum has tremendous potential to return a profit to your farm, and Sorghum Checkoff work will only improve that potential over time. As you manage your sorghum, keep these tips in mind:

- Choose a hybrid appropriate for your region and conditions. Check with your extension service for unbiased data as well as your seed company representative.
- Set a realistic yield goal, and apply the appropriate amount of fertilizer to meet that goal.
- Use an integrated weed management strategy that starts with pre-emergence herbicide, and then apply an appropriate post treatment as needed.

By following a few guidelines, you'll be amazed at what this crop can do for you. We strive to help you make sorghum more profitable for your operation. Remember, every situation is a bit different, so contact your local county extension office, land-grant university or other area sorghum farmers to help you get the most out of this water-sipping crop.

Funded by:
United Sorghum Checkoff Program

SORGHUM CHECKOFF

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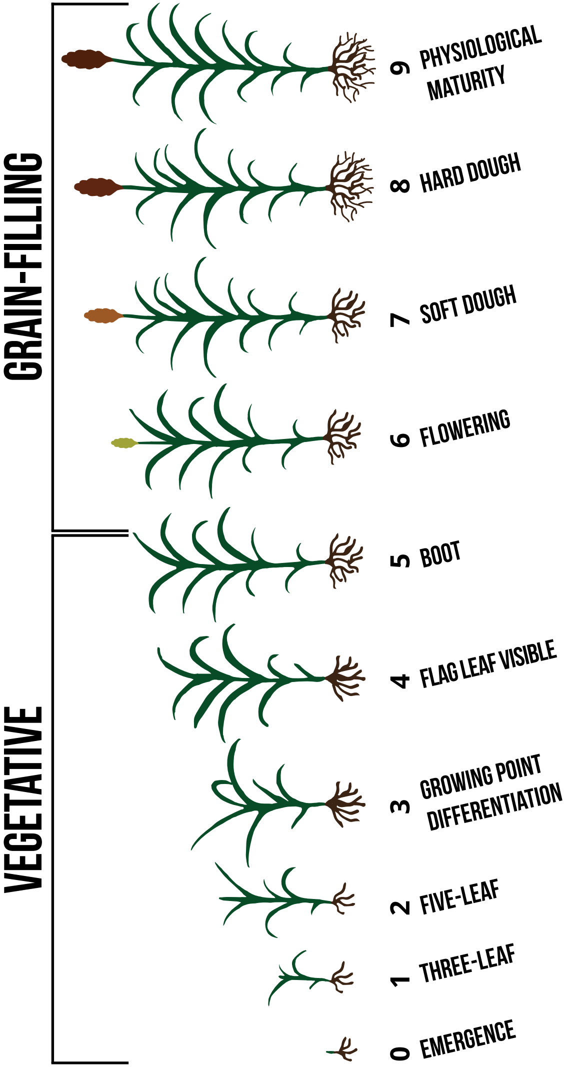
TOPIC PAGE

GROWTH STAGES

It is important to understand the various developmental stages of sorghum to aid in making critical management decisions. The stages are based on key points of sorghum growth used to describe sorghum from planting to maturity. There are 10 recognized stages in sorghum starting with emergence (Stage 0) to physiological maturity (Stage 9).

An excellent publication on sorghum growth and development was published by Kansas State University titled “How a Sorghum Plant Develops." The publication provides excellent pictures of the different growth stages as well as graphs of cumulative nutrient uptake. The 10 crop growth stages are listed on the next few pages along with timely management suggestions for each stage.


GRAIN-FILLING
VEGETATIVE
9 PHYSIOLOGICAL MATURITY
8 HARD DOUGH
7 SOFT DOUGH
6 FLOWERING
5 BOOT
4 FLAG LEAF VISIBLE
3 GROWING POINT DIFFERENTIATION
2 FIVE-LEAF
1 THREE-LEAF
0 EMERGENCE

Emergence (Stage 0)

The plant is visible when the first leaf (coleoptile leaf) breaks through the soil surface. The coleoptile leaf is shorter than the later emerging leaves and has a rounded leaf tip. Emergence time can range 3-14 days and will depend largely on soil temperature, moisture, seeding depth and seedling vigor.

Three-Leaf (Stage 1)

The collar of the third leaf is visible (once a leaf's collar forms the leaf no longer expands). This stage occurs 10-15 days after emergence, depending on weather conditions. The plant is typically 3-4 inches tall.

Five-Leaf (Stage 2)

The collar of the fifth fully expanded leaf is visible. This stage occurs approximately 20-25 days after emergence and when plants are 7-9 inches tall. The growing point is at or just below the soil surface. Many post herbicides should be applied at or before this time. Side-dress fertilizer applications are best made now or over the next 10-15 days.

Growing Point Differentiation (GPD)(Stage 3)

The growing point can now be found above the ground, and the number of seeds per head will be determined over the next couple of weeks. The plant is now entering a rapid period of growth. This stage typically occurs 30-40 days after emergence and when the plant is 12-15 inches tall.

One or two of the bottom leaves may have been lost, and tillers may now be present originating at the base of the plant. Prior to GPD, the plant can withstand considerable stress with minimum effect on yield. However, stress during GPD can affect the potential number of seeds per head that can be set at flowering. Plants should be adequately fertilized prior to this stage. This is a key stage to apply irrigation if available and if soil moisture conditions are dry.

Flag Leaf Visible (Stage 4)
The last leaf to emerge prior to heading is called the flag leaf. This leaf is shorter than the preceding leaves. The plant is considered to be in the flag leaf stage when the leaf tip is visible in the whorl. The last two or three leaves will fully expand during this period.

Boot (Stage 5)
Leaf collars of all leaves are now visible. The sorghum head or panicle can be located just below the flag leaf collar enclosed in the flag leaf sheath. The sorghum head is now being pushed up through the flag leaf collar by the upper stalk known as the peduncle. The length of the peduncle can be affected by stress at this time and is influenced by hybrid genetics. With most grain sorghum hybrids the boot stage occurs 50-60 days after emergence. Moisture stress during boot and for the next 14 days will significantly lower yield.

Heading (Not Official Stage)

Sorghum is considered headed when 50 percent of the heads (panicles) in a field are visible.

Flowering (Stage 6)

Flowering is the most critical stage in the life of the sorghum plant. A plant begins flowering (blooming) from the top of the panicle and progresses downward. A field of sorghum is considered to be in the flowering stage when blooming has progressed halfway down the panicle in 50 percent of the plants. The peduncle is still elongating, and it typically takes 4-9 days for a single head to complete the flowering process. Hybrids are rated on their maturity largely based on the length of time it takes to reach the flowering stage.

Milk (Not Official Stage)

Grain begins forming as soon as flowering (pollination) is complete. The grain or kernel quickly expands and contains a milky fluid. The sorghum is now in what is often referred to as the grain fill period that will not be completed until physiological maturity is reached.

Soft Dough (Stage 7)

The soft dough stage is reached when the grain can still be crushed between the thumb and index finger but no longer contains a milky liquid. Starch is rapidly accumulating, and 50 percent of the grain's final weight has been achieved. Stress at this time can significantly lower yield. Whole plant moisture is approximately 65-68 percent once the soft dough stage has been reached and is typically when sorghum is harvested for silage. Grain has colored by the end of the soft dough stage.

Hard Dough (Stage 8)

At the hard dough stage grain has reached 75 percent of its final dry weight, and nutrient uptake is almost complete. The grain can no longer be crushed between the thumb and index finger. Water stress during this time tends to promote lodging.

Physiological Maturity (Stage 9)

Grain has now achieved its maximum dry weight. Physiological maturity is recognized by a dark spot or black layer on the bottom of the kernel. Grain moisture content typically ranges 25-35 percent. Dessicants can now be safely used to aid in harvest without reducing grain yield.

Determining Leaf Stage

Grain sorghum leaves are numbered by counting the fully expanded leaves with a developed collar. Once sorghum has produced about five fully expanded leaves counting can become difficult. This is because lower leaves will begin to die and will start falling off the plant. When counting leaves, keep in mind leaves alternate from one side of the stalk to the other. Also keep in mind the first leaf is a short leaf with a rounded tip that will likely have fallen off the plant within 25 days of emergence.

APPROXIMATE DAYS TO EACH GROWTH STAGE

Boot	Heading	Flowering	Milk	S. Dough	H. Dough	PM

3-5 → 5 → 5 → 14 → 10 → 10-14

GRAIN SORGHUM YIELD COMPONENTS

Sorghum yield is based on three factors: number of heads, number of seeds per head, and seed size and test weight. Although these factors may compensate for each other, the number of seeds per head is the greatest component of yield.

FREEZE DAMAGE & HAIL INJURY

Assessment and formulas used by crop insurance adjusters can get complicated, but yield loss predictions are based on the stage of growth and the amount of plant damage. Plant damage includes both direct damage and leaf defoliation. Direct damage is made up of stand reduction and stalk and head injury.

For the first 30 days after emergence, sorghum can withstand significant damage from a late, light freeze or from hail damage and recover without significant yield loss. This is because the growing point is below or very close to the soil surface. Early hail-damaged sorghum has surprisingly little loss in yield potential provided the plants remain healthy. For example, 50 percent leaf removal five weeks after germination (near growing point differentiation) reduces yield potential by about 5 percent. Losses are substantially higher for older plants, especially if bruising of the stalk occurs leading to broken stalks or disease infection. Yield loss from leaf defoliation reaches its maximum at the bloom stage (Table 1).

It is best to wait 7-10 days after an early to mid-season hail event to assess damage. Under good growing conditions the sorghum plant will often put on new growth in just a few days. Early in the season even if a few plants are killed, leaving a skip in the row, yield will be compensated for by an increase in tillering or increased head size of the surrounding plants.

An early freeze during grain fill can have a major effect on yield. Grain at the soft dough stage has only accumulated about 50 percent of its final weight and at the hard dough stage about 75 percent of its final weight.

TABLE 1. YIELD LOSS DUE TO LEAF DEFOLIATION (NEB G86-812)

Growth Stage	Percent Defoliation		
	30	50	70
Boot	18	31	53
Bloom	19	33	57
Milk	13	22	38
Soft Dough	7	12	21

HYBRID SELECTION

Selecting the correct hybrid is the first step in successfully producing grain sorghum. In variety trials the difference in yield between the highest and lowest yielding hybrids can be significant. Environment will play an important role in how any given hybrid will perform, for this reason it is critical that hybrids be adapted to Central and South Texas. Key resources for hybrid adaptability and performance are local extension and seed company trials. Since conditions will vary from year to year, it is a good idea to examine a hybrid's performance over multiple years before making the decision to plant significant acres to a new hybrid. **Maturity, standability, insect and disease resistance, weathering panicle type, and head exertion are all important characteristics to consider in selecting a sorghum hybrid.**

<u>Maturity</u>

A well adapted, longer-maturing hybrid will almost always out-yield a well adapted shorter-maturing hybrids provided long periods of drought are avoided and length of growing season is adequate. However, full-season and even medium-long maturity hybrids in Central and South Texas (unless irrigated in the Lower Rio Grande or Coastal Bend) can exhaust available moisture in dry years resulting in reduced yields. Any late-planted grain sorghum production in the Blacklands faces the task of reaching maturity prior to the onset of cold nighttime temperatures, which are often more detrimental to a sorghum crop than when an actual killing frost occurs. This negates the potential yield benefit of longer-maturity hybrids. Furthermore, late-planted sorghum in North Texas faces poor drying conditions prior to harvest. Planting two or three hybrids with slightly different maturities is a good way to protect against short term adverse environmental conditions greatly affecting the total yield of a given field.

Maturity is measured by days to half bloom and physiological maturity. How hybrids are classified into maturity groups can vary by company. Days to half bloom and physiological maturity will depend greatly on weather since maturation is driven by heat accumulation and to lesser extent day length. South Texas crop testing results mostly represent planting dates from mid-February at Weslaco to about March 25 at College Station; note individual years will vary greatly in days to bloom from one year to the next. Early planting combined with cool, wet weather can delay the time to half bloom by as much as two weeks. Hybrids may advance more quickly to half bloom when it is dry versus ample rainfall or irrigation.

For North and Central Texas, when planting is delayed into July, choose a hybrid that will allow the sorghum to reach black layer 1-2 weeks before the area's average killing frost. This allows for sorghum maturation without significant risk to yield or test weight if a freeze occurs up to 10 days earlier than average.

Standability

All sorghum hybrids will lodge under the right conditions. However, genetics do play a significant role in the standability of a hybrid. Drought stress and limited moisture conditions can lead to charcoal and other stalk rots which cause lodging, especially when plant populations are high. Gulf Coast wind and the history of damaging storms make standability ratings a particularly important characteristic to consider.

Drought Tolerance

Central and South Texas can experience significant periods of drought in any given year. Selecting a hybrid with good drought tolerance is important, particularly on sandy soils with less water-holding capacity. Some yield potential may be given up with those hybrids with the greatest drought tolerance, but they may yield more consistently over multiple years.

Insect and Disease Resistance

In recent years, sugarcane aphid has become the insect of most concern. Hybrids with resistance or tolerance to the sugarcane aphid should be considered. It is important to note even though a hybrid is considered to have some tolerance to sugarcane aphid scouting of these hybrids will still be necessary and insecticide applied if threshold levels are reached.

Stalk rot diseases can be an issue in Central and South Texas leading to lodging prior to harvest. Many companies rate their hybrids on charcoal and fusarium stalk rot. These ratings should be considered when selecting a hybrid, especially under dryland conditions. Anthracnose and other foliar diseases can occasionally be an issue but seldom reduce yield.

Weathering

Extended periods of rainy weather once sorghum grain has reached maturity can lead to mold growth or even sprouting of the grain. When possible, adjust planting date to avoid historical wet periods at harvest. Seed companies may also be able to provide information on their hybrids that are able to withstand weathering better than others. Farmers are encouraged to harvest their crop when conditions are suitable to avoid late-season weathering issues.

Head Exertion

Many companies rate hybrids for head exertion, the extent to which the head emerges from the boot. In some hybrids, the peduncle may not elongate enough to fully expose the head when soil moisture is limiting during heading. With poor head exertion, the portion of the head still wrapped in the sheath of the flag leaf can have poor seed set or may be more susceptible to grain molds if rains come after pollination and grain fill. Good head exertion will also improve harvestability and lessen the need for grain cleaning following harvest.

Suggested Hybrid Maturity Selection

Frequently, the selection of hybrid maturity is based on fitting hybrid maturation with available water, whether it be rainfall or irrigation, and the timing of both. Overstretching available water can diminish yield potential for longer-season hybrids. In general, for both South Texas and all of the Texas Blacklands, Texas AgriLife Extension does not recommend either full-season hybrids or early season-hybrids. The former can indeed increase risk of not fully maturing due to drought. Yield potential of the latter is a significant drop off from even the medium maturity hybrids.

Lower Rio Grande Valley and Coastal Bend

Due to less rainfall than other areas, medium and medium-early hybrids may work best. Seed companies routinely enter many medium-long hybrids in Texas AgriLife Research Crop Testing trials in this area, but irrigated producers should be cautious about extending hybrid maturities to medium-long unless they are sure they will irrigate more heavily.

Upper Gulf Coast (Victoria to Houston) and Up to I-10

Plant medium-long and medium maturity hybrids. Medium-long and medium maturity hybrids are generally recommended for this region unless planting date is significantly delayed.

San Antonio Region

For some irrigated but mostly dryland to the west, rainfed to the east, plant medium and medium-long hybrids (the latter more appropriate if irrigated). For rainfed conditions in the area, lower seeding rates and shorter maturities (medium and medium-early) are recommended as one moves west from about Gonzales to Hondo and Uvalde.

Central to North Texas

For the most part, medium-long and medium maturity hybrids perform best in this region. Medium-early maturity hybrids might be appropriate in a few instances when later planting concerns raise the possibility of increased sorghum midge potential, but yield potential will be reduced.

Summary

The surest way to select hybrids that will perform well on your farm is to:

- Spend sufficient time searching for improved hybrids.
- Look at hybrids from several companies.
- Look at a broad base of information on hybrids

of interest. Avoid reliance on only one source of hybrid performance information. Use results from company tests, county strip trials and university performance tests to select a small set of hybrids to try on your farm.

- Try this subset of hybrids on a small scale and keep harvest records. This is becoming easier every year with the widespread use of guidance/auto-steer technology and yield monitors. Be sure to replicate comparisons in such a way that you can be confident of your conclusions.
- Plant two or more hybrids of differing maturity to spread out risk from adverse weather conditions.
- Keep alert for new insects or diseases that might threaten sorghum and plant resistant hybrids as needed.

PLANTING

Row Spacing

Depending on the area, predominant row spacing is 30, 36, 38 or 40-inch rows. A few producers use 15-inch or 20-inch rows on occasion by either drilling or using an inter-plant planter. Research in San Patricio County and Temple shows increased yields with 30-inch row spacing versus wider rows. Making rows 30 inches instead of 38-40 inches can help shade the soil faster and reduce weed growth. Further research in the Coastal Bend and Uvalde (Table 4) regions show narrower row spacing has fairly, consistently produced slightly higher yields (seeding rate held the same). Planting with a row planter verses a drill typically results in better seed placement and uniform emergence. However, advances in new drill technology have narrowed this gap.

One Texas AgriLife Extension test in the Corpus Christi area found grain sorghum yields increased 10-26 percent by planting narrow rows (less than 20 inches) compared to conventional row spacing (38-40 inches), except under severe drought (where lower seeding rate likely would have a stronger impact). All tests were held at the same seeding rate for narrow and conventional rows.

Seed Treatments

If one of the short residual herbicides metolachor, acetochlor or dimethenamid is planned for weed control, seed must be treated with Concep III seed safener. Historically many growers have elected not to use an insecticide seed treatment, however, an insecticide treatment provides relatively cheap protection from early season insect infestations.

Planting Date

The planting window is restricted at the beginning of the season by soil temperature as well as cool air temperatures that can slow growth. Quick germination and emergence occur when the soil temperature is 70°F. However, sorghum can be planted once soil temperatures are above 60°F when warm weather is expected for the next few days. The end of the planting window is influenced by the risk of sorghum midge and flowering/ maturation under hotter conditions with reduced rainfall in July and August. Texas AgriLIfe Extension suggests the following planting date windows for various regions in Tables 3 and 4. However, local experience in any given area is important in choosing a planting date.

TABLE 2. IRRIGATED SORGHUM SEEDING RATE AND ROW SPACING FROM FIVE YEARS OF TESTING AT UVALDE

Plants per Acre	Estimated Seeds per Acre at 75% Establishment	Row Spacing	
		26 in.	38 in.
		Yield (lb/acre)	
27,000	36,000	3,560	2,910
41,000	55,000	4,080	3,030
55,000	73,000	4,790	3,200
76,000	101,000	4,810	3,730

TABLE 3. RANGE OF SUGGESTED EARLY (6-10 DAY RANGE), PREFERRED, AND LAST (5 DAY RANGE) SUGGESTED PLANTING DATES FOR GRAIN SORGHUM IN SOUTH TEXAS

South Texas Regions	Suggested Early Planting Date Limits	Planting Date Preferred Target	Suggested Final Planting Date Limits
Lower Rio Grande Valley	January 21 - January 30	January 31 - February 10	February 15 - February 20
Coastal Bend	February 15 - February 21	February 22 - March 5	March 15 - March 20
Upper Gulf Coast	February 25 - March 4	March 5 - March 15	March 25 - March 30
San Antonio Region[1]	---	---	---
Gonzales to Uvalde	March 5 - March 10	March 10 - March 20	March 20 - March 25

[1]Use of soil temperature and extended 7-10 day weather forecast for this region is strongly encouraged.

TABLE 4. RANGE OF SUGGESTED EARLY (6-10 DAY RANGE), PREFERRED AND LAST (5 DAY RANGE) SUGGESTED PLANTING DATES FOR GRAIN SORGHUM HYBRIDS IN CENTRAL AND NORTH TEXAS

South Texas Regions	Suggested Early Planting Date Limits	Planting Date Preferred Target	Suggested Final Planting Date Limits, Primary Crop[1]
Lower Backlands (Georgetown to Waco)	March 10 - March 15	March 15 - March 25	March 31 - April 5
Central Backlands (Waco to Dallas)	March 15 - March 25	March 26 - April 5	April 15 - April 20
Northern Backlands (Dallas to Red River)	March 25 - April 4	April 5 - April 15	April 21 - April 25

[1]Some double cropping may occur in Central and North Texas. Later plantings can assume sorghum midge risk and possible dry-down issues in the fall if planted mid-June or later.

Late Season Planting

On occasion a late-planted sorghum crop (possibly a double crop) may be considered. There is little concern about being able to mature a late-planted sorghum crop anywhere in Central and South Texas for a July 1-July 15 planting date. However, end-of-the-season factors like midge, drought, tropical storms and poor drying conditions in Central and especially North Texas can greatly reduce the practicality and economic return of a late crop. In South Texas, late-planted grain sorghum may occur when another crop fails or following wheat harvest when soil moisture is in abundance, but it is risky due to insufficient rainfall.

Harvestability is often the key consideration for late season sorghum. Fog, fall rains, high humidity and muddy fields that may not dry for months, frequently interfere with grain sorghum harvest for late-planted sorghum. These issues lead to poor dry down, increased lodging potential, sucker heading, feral hog damage and more. For these reasons, conclude late planting by the following recommendations.

- Plant by July 1 in South Texas. A medium or medium-early maturity hybrid may enable harvest when drying conditions are still favorable.
- For North Texas, late June plantings can mature adequately, but harvest issues are significant. Plantings after June 1, though easily matured, face harvest timing during the wet fall months when fields might never dry sufficiently to achieve harvest.

Seeding Depth

Optimum seeding depth is 1.25-1.75 inches deep. Seeding depths greater than 2 inches may reduce seedling stand and, at the very least, will lengthen the time prior to emergence. A seeding depth of less than 1 inch may result in poor emergence due to drying of the soil surrounding the seed. Seed is typically planted a little deeper in sandy soils more prone to drying out.

Non-Uniform Stands and Replanting

Sorghum has a remarkable ability to compensate for non-uniform stands. Large gaps up to 9 feet in length within a 30-inch row can be compensated for by intact adjacent rows. Studies have shown a sufficient number of 3-6 foot gaps must be present to reduce stands by 30 percent to significantly impact yield. Compensation occurs by increases in the number of heads per plant and the number of seeds per head in neighboring plants both within a non-uniform row and in adjacent rows.

Seeding Rate

Grain sorghum seed can vary widely in seed size, often 12,000-18,000 seeds per pound, with 13,000-16,000 being most common. If 14,500 seeds per pound are assumed but the seed number was actually 16,500, the actual planted seeding rate has been increased 14 percent.

Calculating seed rates can be done in the following ways:

Seeding Rate

$$\frac{12 \text{ in.}}{\text{row spacing (in.)}} \times \frac{43{,}560 \text{ ft}^2}{\text{acre}} \times \frac{\text{seeds}}{\text{foot of row}} = \text{seeds/acre}$$

Seeds (or plants) Per Foot

$$\frac{\text{target seeding rate}}{43{,}560 \text{ ft}^2} \times \frac{\text{row spacing (in.)}}{12 \text{ in.}} = \text{seeds/foot or row}$$

Although planter seeding rate charts should be accurate, growers are encouraged to check actual seed drop. Table 5 lists the number of seeds per foot at various row spacings needed to achieve a specific seeding rate per acre. Keep in mind the seeding rate will need to be adjusted up to take into account seed germination and establishment. Typically under dryland conditions 70 percent of seed planted will result in plants. Under good germination and growing conditions expect 85 percent of seed planted to result in established plants.

Seeding Rate General Guidelines

The principle of 'less is more' has long guided grain sorghum seeding rates, especially for rainfed production when drought conditions are a regular occurrence. Lower seeding rates can produce higher yields when droughty conditions prevail. Lower plant populations are suited to these drought conditions preserving more moisture per individual plant, thus reducing the plant’s stress level. Furthermore, high plant populations for the production environment will enhance the development of charcoal and other stalk rots in drought-stressed plants, leading to lower yield and significant lodging potential.

TABLE 5. SEEDS PER FOOT OF ROW AT VARIOUS ROW SPACINGS AND SEEDING RATES

Planter Row Width (in.)	Target Seeding Rate per Acre for Central and South Texas							
	30,000	40,000	50,000	60,000	70,000	80,000	90,000	100,000
	Seeds per Foot of Row							
40	2.3	3.1	3.8	4.6	5.4	6.1	6.9	7.7
38	2.2	2.9	3.6	4.4	5.1	5.8	6.5	7.3
36	2.1	2.8	3.4	4.1	4.8	5.5	6.2	6.9
30	1.7	2.3	2.9	3.4	4.0	4.6	5.2	5.7
20	1.1	1.5	1.9	2.3	2.7	3.1	3.4	3.8
15	0.9	1.1	1.4	1.7	2.0	2.3	2.6	2.9
10	0.6	0.8	1.0	1.1	1.3	1.5	1.7	1.9

Sorghum plants are very water-efficient and have the ability to compensate considerably in grain yield with respect to growing conditions and planting rates. If a modest plant population is used for an area typically limited by adequate moisture and above average rainfall is received, sorghum plants can tiller adjust their grain numbers and weight considerably to compensate for the improved growing conditions. Depending on soil moisture conditions, recommended seeding rates vary between 30,000-80,000 plants per acre for South Texas. Under limited moisture conditions, studies have shown no advantage in increasing seeding rate over 55,000 seed per acre on 38-inch rows (Table 8). Irrigated sorghum performs better with no more than 80,000 plants per acre (Table 7).

TABLE 6. DRYLAND SORGHUM SEEDING RATE RESULTS FROM FIVE YEARS OF TESTING AT UVALDE (38-INCH ROWS)

Plants per Acre	Estimated Seed per Acre at 75% Establishment	Yield, pound per acre
27,000	36,000	2,360
41,000	55,000	2,750
55,000	73,000	2,640
76,000	101,000	2,570

TABLE 7. SUGGESTED SEEDING RATE TARGETS AND RESULTING PLANT POPULATIONS FOR CENTRAL AND SOUTH TEXAS

Texas Region	Plant Population	Targeted Seeding Rate
Lower Rio Grande Valley and Coastal Bend		
Irrigated (limited)	60,000 - 70,000	70,000 - 80,000
Rainfed	50,000 - 60,000	60,000 - 70,000
Rainfed, Low Stored Soil Moisture	40,000 - 50,000	50,000 - 60,000
Upper Gulf Coast		
Rainfed	70,000 - 80,000	80,000 - 90,000
Rainfed, Low Stored Soil Moisture	60,000 - 70,000	70,000 - 80,000
San Antonio Region		
Irrigated	60,000 - 70,000	70,000 - 80,000
Rainfed	40,000 - 50,000	50,000 - 60,000
Rainfed, Low Stored Soil Moisture	30,000 - 40,000	40,000 - 50,000
Central and North Texas		
Rainfed, Early Plantings	60,000 - 70,000	70,000 - 80,000
Rainfed, Later Plantings and/or Low Stored Soil Moisture	50,000 - 60,000	60,000 - 70,000

Suggested Seeding Rates

Table 9 lists suggested seeding rates for various regions under average conditions. **These rates should be decreased 10-20 percent in those years where soil profile conditions are dry at planting or drier than normal conditions are expected during the growing season.**

The driest region with the lowest average rainfall of the sorghum production area in Central and South Texas is the region west and southwest of San Antonio in Uvalde, Medina, Zavala and Frio counties. Annual rainfall approaches 20 inches and is lower in some years. This calls for the reduced seeding rates more so than other areas as plant population can too easily outstrip available water. The goal for this region is to make a modest and consistent yield in spite of prolonged dry conditions.

Seeding rates should not change when moving from wider row spacing to narrower rows when using a row planter. **If using a drill, consider increasing seeding rate 10-15 percent in order to compensate for diminished seed placement.**

NUTRIENT MANAGEMENT

Grain sorghum is grown over a wide range of growing conditions across Central and South Texas. Thus, nutrient management depends on the specific environment in which the crop is grown. The large fibrous root system of grain sorghum is very efficient at utilizing nutrients from the soil, which gives grain sorghum the ability to extract large amounts of residual nutrients and allows it to respond to nutrient application. Accurate soil testing is necessary for economical nutrient application. However, soil tests are no better than the sample collected in the field. Interpretations of soil tests and resulting fertilization recommendations are made based on many years of research. Fertilizer rates are targeted for optimum yields assuming yield potential is not restricted by other growth-limiting factors.

Nitrogen (N)

Nitrogen is the most frequently lacking nutrient for optimum sorghum production. Universities and laboratories may differ slightly in how much nitrogen is recommended for a particular yield goal. However, all recommended amounts of nitrogen will take into account residual nitrogen from soil test results. In addition, some laboratories consider crop rotation, previous manure application and soil organic matter in their recommendation. A soil test for available nitrogen deeper in the soil profile is recommended where nitrogen or manure applications have been excessive relative to yields. This profile nitrogen soil test is used to potentially reduce the amount of nitrogen applied and thus allowing nitrogen that has been accumulated in the soil to be utilized. Proper soil sampling is necessary to provide accurate test results. Samples should be taken to a depth of at least 2 feet (for profile nitrogen) from randomly selected locations within a management area. The samples should be air dried and sent to a soil testing laboratory. See extension service or laboratory websites for instructions on collecting and preparing soil samples.

The time of year that soil samples are collected can influence how much nitrogen will be recommended. More nitrogen becomes available through mineralization as temperatures increase in the spring. **The best nitrogen recommendations are achieved when soil samples are collected as close to the time of planting as possible.**

Other considerations are crop rotation and soil organic matter content. In addition, nitrogen will be made available from soil organic matter during the growing season. For every percent organic matter present, a nitrogen credit of 20 pounds can be given. If sorghum is following soybeans then 1 pound of nitrogen can be credited for every bushel of soybeans up to a total of 40 pounds.

Nitrogen recommendations will vary slightly based on the different equations used by various commercial and university soil labs. The Texas AgriLife Extension equation is the most simple and conservative and is presented below. See the soil testing websites at other labs for alternative equations.

Texas Equation for Nitrogen (N):
Yield goal in pounds/100 x 2
= amount N to apply as fertilizer.

The amount applied should take into account any credits from soil test results. Using this equation a 4,000 pound yield goal would require 80 pounds of nitrogen fertilizer assuming **no residual nitrogen** is present in the soil.

Table 8 gives the amount of nitrogen to apply for various yield goals assuming 30 pounds of residual nitrogen is present in the soil based on soil test results.

Field comparisons of nitrogen sources indicate little agronomic difference between sources when properly applied. For no-till or reduced-till systems that leave almost a 100 percent residue cover, materials containing urea should be injected below the residue to minimize volatilization and immobilization losses. If urea or UAN (urea + ammonium nitrate solution) fertilizer is surface applied and not incorporated by tillage or does not receive one-half inch of

TABLE 8. NITROGEN TO APPLY BASED ON YIELD GOAL AND 30 POUNDS OF SOIL RESIDUAL NITROGEN

Yield Goal (lb/A)	LB N/A
2,500	30
3,500	50
5,000	80
7,500	130
10,000	180

rainfall or irrigation within 24 hours, there is potential for ammonia loss. Enough ammonia loss to reduce crop yields can sometimes occur when urea or UAN is applied to a warm and moist soil or soil heavily covered with crop residue. **Source selection should be based on cost, availability, adaptability to farm operation and dealer services.** Nitrogen utilization is quite rapid after the plants reach the five-leaf stage. By boot stage, 65-70 percent of the total nitrogen has been taken into the plant.

Nitrogen applications should be timed so nitrogen is available when needed for this rapid growth. Pre-plant nitrogen applications can be made in late fall or spring (except on sandy soils) with little concern for leaching loss. On sandy soils, pre-plant nitrogen applications should be delayed until spring or split with a portion applied in the spring and the remainder applied as a side-dress application. If nitrogen is applied side-dress the applications should be made 25-35 days after emergence.

Active optical sensing systems are useful in measuring crop biomass early in the growing season to predict final yield. Coupled with a well fertilized reference strip and an unfertilized check strip to provide an estimate of the soils nitrogen supply to the crop sensors may provide an accurate nitrogen recommendation. The sensor technology seems to work best 35-45 days after planting; however this provides only a narrow window of opportunity to fertilize the crop. Producers using this technology may want to apply a base level of nitrogen on sorghum at planting to ensure optimum yield.

Application of nitrogen through a sprinkler system is an efficient way to apply the nutrient, especially on sandy soils. However, keep in mind the distribution of the fertilizer will only be as good as the distribution of the water. No nitrogen material containing free ammonia should be used when applying through a sprinkler system unless special precautions are taken. A small amount of nitrogen also may be applied in starter fertilizer.

Starter Fertilizer and Salt Injury Potential

Using a starter fertilizer application for sorghum is a sound practice in Central and South Texas and can stimulate early growth. Starter fertilizer research has shown rooting and early growth is promoted by starter fertilizer applications in the 2-inch by 2-inch configuration (2 inches to the side and 2 inches below the seed).

Starter fertilizer can be applied with the seed, pop-up fertilization, but at rates much less than the 2-inch by 2-inch placement. A common concern is potential salt injury and ammonia damage if the rate of pop-up fertilizer is too high.

- Salt injury comes from N, potassium (K), and sulfur (S).
- Pounds per acre of N+K+S applied will determine injury potential, but K and S fertilization is much less common than N as soil K is high in most Texas soils (acid soils the likely exception) and S is sufficient.
- N fertilizers that contain or readily form ammonia, NH_3, can be toxic to seed.
- Phosphorus fertilizer (e.g., triple superphosphate, 0-46-0, etc.) does not cause injury to seedlings, but most P fertilizers contain N (e.g. 11-52-0, 10-34-0).

More salt-forming N and K fertilizers can be applied to loamy and clay soils than to sandy soils or on more narrow rows spacings. Pop-up starter fertilizer rates are much lower than starter fertilizer placed 2 inches from the seed.

Phosphorous (P)
It is difficult to gauge P requirements for grain sorghum without soil test information. Furthermore, once soil test P levels rise above "very low" and "low" P response is inconsistent. When growing conditions are cool or wet early in the season, especially where producers

might be planting early to minimize sorghum midge potential, seedlings may show temporary P-deficiency symptoms. This particular situation lends itself well to either banded or in-furrow applications of P.

Since soil P is relatively immobile, or "fixed" in soils, placement in a concentrated form is particularly important in low to medium testing soils. Research has shown plants obtain a higher proportion of their needed P from soil reserves. Even if banded, only about 30 percent of applied P is used by the crop following fertilization in the current year.

Phosphorus can be applied preplant-broadcast, preplant-knifed or banded at seeding. If a difference among methods is found, broadcast is normally inferior. Starter applications are most efficient when applied on acidic soils low in available P. Starter applications can be placed in direct contact with the seed or placed to the side and below the seed. Keep in mind the potential of crop injury from salt from any N, K or S discussed in the previous section that might be applied with the phosphorous.

Potassium (K)

Soil K levels in Central and South Texas are generally high and, unless soil K levels have been diminished greatly, it is likely only top end grain sorghum yields would consider K additions. Texas AgriLife Extension soil test guidelines project the K requirement at 2 lbs. K_2O/A per hundredweight of yield goal. However, the soil test levels are normally sufficient (if not well in excess) to preclude fertilizing with potassium.

Iron (Fe) and Zinc (Zn)

Two other important nutrients for grain sorghum production in Central and South Texas are iron and zinc. Zinc is not commonly an issue in sorghum, but iron deficiency related to high pH (usually pH $\geq$ 7.8), whether it be alkali spots in South Texas or carbonitic soils in the Blacklands, is a particular concern for sorghum. Soils that produce spotty yet heavy iron deficiency across a field in South Texas should probably never be used for grain sorghum production. It is prohibitively expensive to correct iron deficiency.

TABLE 9. SUGGESTED MAXIMUM FERTILIZER SALT AMOUNTS (LBS. N-K_2O-S/ACRE) FOR SEED ROW FERTILIZER PLACEMENT, ROW SPACING AND SOIL TYPE

Fertilizer Placement	Row Spacing (inches)					
	Loamy-Clay Soil			**Sandy Soil**		
	20	30	40	20	30	40
Pop-Up (with seed)	8-12	5-8	6	8	5	4
2 in. x 2 in.	60	40	30	40	20	15

Many fields, however, simply experience some degree of iron deficiency, the classical condition of interveinal chlorosis where the veins of the younger leaves remain green and the leaves are yellow between the veins. In the worst of cases, the leaves are almost completely bleached out and the plants do not grow. Iron deficiency can be induced temporarily due to water-logged conditions. When modest cases of iron deficiency occur as the root volume expands due to soil drying then iron deficiency usually diminishes.

Iron deficiency is normally expressed on the newest leaves since iron is immobile within the plant. When iron becomes available again, newly emerging leaves will again be dark green. Older chlorotic leaves will not green up unless they receive a direct foliar feed. In contrast, nitrogen is mobile in the plant and will move to the youngest leaves from older plant tissues (which may express N deficiency). There is no striping in nitrogen deficiency symptoms.

Most soil tests will flag iron less than four parts per million (ppm) as deficient. Currently, there are no economical sources of soil-applied iron available. Therefore, the only options for correcting iron deficiencies are to apply foliar iron sprays in-season or to apply manure for long-term correction. If iron chlorosis has been observed during previous years in a field, iron fertilizer materials may be applied preemptively to the foliage through multiple sprayings early in the season. Table 10 gives suggested foliar treatments to correct iron as well as zinc deficiencies.

Zinc Deficiency

If soil test results indicate a possible zinc deficiency (less than 1 ppm Zn), zinc fertilizer may be broadcast and incorporated preplant with other fertilizers or ideally banded near the seed at planting. Chelates are up to five times more effective than inorganic sources, but price will determine which product is a better choice.

Sulfur Deficiency

Sulfur deficiencies typically occur with low organic matter (less than 1.5 percent) in sandy soils. Since sulfur is mobile in the soil, a deep sample (2 feet) should be taken to get a measure of sulfur deeper in the soil profile. Soil testing labs analyze sulfur with a calcium phosphate extract, but the crop response data is variable. Therefore, sulfur-deficient areas should have soil organic matter examined to complement the sulfur analysis. Current sulfur soil tests, when used alone, are poor predictors of sulfur deficiency. Growers with sandy soils with low organic matter and a low sulfate soil test should try sulfur to ascertain the likelihood of a sulfur response.

Foliar Feeding Major and Minor Nutrients

In general foliar feeding is expensive. Texas AgriLife Extension does not recommend producers rely on foliar feeding for nitrogen due to the far higher per unit cost of nitrogen. Foliar feeding of micronutrients is more common, and many products will have a package of micronutrients and simply may be the most convenient means to use if you have a known deficiency with an individual nutrient. Micronutrient deficiencies other than iron are hard to diagnose without experience and/or a tissue test.

TABLE 10. SUGGESTED SOURCES, RATES AND TIMING OF IRON AND ZINC FOLIAR SPRAYS

Product	Product/100 gal. water	Product/acre	Timing
Iron Sulfate (20% Fe)	20 lbs. (2.5% solution)	1 lb., then 2-3 lbs.	• 10-14 days after emergence use 5 gal/acre over crop row • Follow with two applications at 10-14 day intervals of 10-15 gal/acre
Iron Chelate (10% Fe)	4-8 lbs. (0.5-1% solution)	0.25-0.5 lbs.	• 10-14 days after emergence use 5 gal/acre over crop row • Follow with two applications at 10-14 day intervals of 10-15 gal/acre
Zinc Sulfate (30% Zn)	2 lbs. (0.5% solution)	0.2-0.4 lb.	• 10-20 gal/acre in first 30 days
Zinc Chelate (9% Zn)	2 qts. (0.1% solution)	1 pint	• 10-20 gal/acre in first 30 days

WEED CONTROL

Weeds compete with grain sorghum for light, nutrients and soil water thus reducing yield and grain quality. In addition, they harbor insects and diseases that further impact yield and increase costs. Effective sorghum weed control first begins with identifying problem weeds in a given field and developing a control strategy. If there is any doubt about a particular weed, take it to your county agent or extension specialist for identification. Implement control strategies to first control those weeds that most affect yield.

Weed Control Prior to Planting

Weed control in sorghum must begin in the months and days prior to planting. Removal of weeds prior to planting is extremely important in sorghum production due to the limited number of herbicides available for selective post emergence control. Weeds left uncontrolled during any fallow period will use up valuable soil moisture that could otherwise be used by the sorghum crop. Control these weeds either by tillage or with herbicide application. The use of soil residual herbicides like atrazine can be particularly valuable prior to planting, reducing tillage and herbicide applications that might otherwise be necessary to control multiple flushes of weeds. However, make certain any soil residual herbicide used is safe for planting sorghum. A relatively new product, Sharpen, is a PPO inhibitor that has provided excellent control of many broadleaf weeds, including marestail.

Sharpen has mostly post activity and is often tank mixed with glyphosate to control weeds prior to planting. Atrazine plus dicamba can be an excellent treatment for control of kochia when applied in February or March prior to kachia emergence.

Weed Control at Planting and During the Season

The yield loss associated with sorghum typically ranges 30-50 percent but in extreme cases can result in complete crop failure. In Central and South Texas the most common weeds mentioned in surveys include Texas panicum, pigweed (careless weed) species, barnyard grass, smell melon, Johnsongrass, shattercane and morningglory. Studies have shown even one pigweed within 24 inches of a grain sorghum plant can reduce its yield nearly 40 percent. And for each inch per acre of soil moisture used by weeds (not to mention nitrogen) can be worth 300-400 lbs. per acre of grain sorghum yield.

Annual grasses generally do not reduce yield as much as broadleaf weeds but are more difficult to control. Yield loss will be the greatest when weeds emerge with the crop or soon afterward. **The most critical period for weed control is the first four weeks after planting.** If weeds are controlled during this time, and control is maintained through the remainder of the season, little reduction in grain sorghum yield will occur. Yield reduction from weeds that emerge four weeks after planting is usually minimal. However, weed escapes can be a major interference with harvest.

Broadleaf Weed Control

Most weed control strategies should consider the use of atrazine or propazine either applied prior to planting, at planting, prior to crop emergence or soon after crop emergence. These products are relatively inexpensive and will control most broadleaf weeds when properly applied. Restrictions and rates of atrazine use vary considerably depending on soil type and other factors. Closely examine the label for use in any particular field. Generally, atrazine should only be applied prior to sorghum emergence in medium or fine textured soils at reduced rates or crop injury can occur. The safest way to use atrazine is to apply the herbicide soon after the crop has emerged but before it reaches 12 inches in height. To control emerged weeds, atrazine should always be applied with crop oil. The smaller the weeds, the better the control will be. Propazine is very effective on many broadleaf weeds and is safer on the sorghum crop than atrazine. It is also safer to use when sorghum is rotated with cotton.

Other commonly used herbicides applied prior to sorghum and weed emergence are metolachlor, acetochlor and dimethenamid (Table 11). These are sold under a host of trade names. These herbicides are more specific on which broadleaf weeds they will control and generally do not control the weeds for as long a period of time. **Combining atrazine with any of the three improves overall control of broadleaf weeds.**

Lumax and Lexar are herbicides that contain the HPPD inhibitor mesotrione (Callisto) plus metolaclor

(Dual II magnum) and atrazine. Either product can provide excellent control of many annual grasses and broadleaf weeds including velvetleaf and triazine-resistant pigweed and kochia. Lumax and Lexar should not be used on sandy soils due to excessive risk of crop injury and stand loss.

Herbicides commonly used after crop and weed emergence are listed in Table 12, along with a brief description of their strengths and weaknesses. Check labels for rates, application timing and other restrictions, as herbicides can often be used in combination with each other. Dicamba and 2,4-D have been used for decades for broadleaf weed control. However, these must be applied correctly, or severe crop injury can occur. These should only be applied to sorghum that has not exceeded 8 inches in height. Drop nozzles that keep the herbicides out of the whorl of the sorghum can be used on up to 15-inch sorghum. Care should be taken to minimize drift of dicamba and 2,4D, or damage to other broadleaf crops and ornamentals can occur.

Huskie is a premix of a HPPD herbicide, and Buctril is a contact photosystem II inhibitor. Huskie can be very effective on small broadleaf weeds and gives acceptable control of larger weeds. It will, however, cause some yellowing and burning of the sorghum leaves. Sorghum will grow out of these injury symptoms within a few days. Huskie works best when applied with 0.5-1.0 pound of atrazine. There is a cotton rotation restriction on the label that should be observed.

TABLE 11. POPULAR PRE-EMERGENT HERBICIDES BY ACTIVE INGREDIENT NAME (COMMON TRADE NAMES)

Herbicide	Use
Atrazine (AAtrex, atrazine)	Primarily broadleaf weed control. Long residual.
Propazine (Milo-Pro)	
Metolachlor or S-metolachlor (Dual II Magnum, Cinch, Parallel, Brawl Charger, Medal)	Good annual grass control with some broadleaf activity. Must use Concep III treated sorghum seed.
Dimethenamid (Outlook, Commit, Slider, Sortie)	
Acetochlor (Warrant)	
Atrazine + Metolachlor (Bicep II Magnum, Cinch ATZ, Metal II AT, others)	Broadleaf weed and grass control. Must use Concep III treated sorghum seed.
Saflufenacil + Dimethenamid (Verdict)	
Atrazine + Acetochlor (Degree Xtra, Fultime NXT)	
Atrazine + Metolachlor + Mesotrione (Lumax, Lexar)	Broadleaf weeds including triazine resistant pigweed and kochia in addition to grass control. Must use Concep III treated seed.
Others	See state and local Extension service recommendations for other pre emergent herbicides.

TABLE 12. POPULAR BROADLEAF POST EMERGENT HERBICIDES BY ACTIVE INGREDIENT NAME (COMMON TRADE NAMES)

Herbicide	Use
Atrazine (AAtrex, atrazine)	Effective on most broadleaf weeds and will provide soil residual control. Apply with crop oil.
2,4-D (2,4-D, Unison, Barrage, Saber, Weedar 64, others)	Will control most broadleaf weeds, crop injury can be significant and drift to cotton and soybean fields is a concern.
Dicamba (Banvel, Clarity, Rifle, Vision)	Will control most broadleaf weeds, crop injury can be significant and drift to cotton and soybean fields is a concern but safer than 2,4-D.
Prosulfuron (Peak)	Must be applied to small weeds. Best to use with dicamba, 2,4-D or atrazine.
Fluroxypyr (Starane)	Weak on pigweed. Good on kochia, morning glory, and devils claw.
Carfentrazone (Aim)	Fast burn down. Effective only on small weeds (<2 inches).
Halosulfuron (Permit)	Best product to use for nutsedge (nutgrass) control. Ineffective when used alone on most broadleaf weeds.
Pyrasulfotole + Bromoxynil (Huskie)	Excellent on many broadleaf weeds but will cause temporary injury to sorghum leaves. Often used as a rescue treatment. Works best with the addition of 0.5 to 1.0 lb atrazine.
Others	See state and local extension service recommendations for other post emergent herbicides.

Grass Control

Until recently there have been no effective herbicides in grain sorghum that could be used after crop and grass have emerged. Sorghum hybrids tolerant to ALS herbicides have now been developed. The ALS tolerant trait is called "Inzen." The herbicide labeled for use in Inzen sorghum is Zest, which contains the active ingredient nicosulfuron. **Zest can be applied over the top of Inzen grain sorghum for the control of annual grasses as well as many broadleaf weeds**. Special care should be taken to follow all stewardship guidelines associated with Inzen technology. Check with your seed representative regarding the availability of ALS/Inzen hybrids.

It is very difficult to successfully grow grain sorghum in fields heavily invested with Johnsongrass. If at all possible, Johnsongrass should be sprayed in the fall prior to planting sorghum the following spring. This should be followed by an application of glyphosate just prior to planting.

Sorghum should then be immediately planted with as little disturbance of the treated Johnsongrass as possible. Although this will not provide season long control, it will allow the grain sorghum to grow with very little Johnsongrass competition during the critical four weeks after planting. Grain yield will be considerably better than if no control was attempted.

Other Information

Herbicide labels are constantly updated. Before using any herbicide check the label for use under your specific conditions. Most state extension services provide updated herbicide lists and specific weed control recommendations.

The following reflect research observations, producer experience and potential limitations for atrazine and propazine in grain sorghum weed control. Follow all atrazine and propazine label restrictions and instructions.

- Be careful with both herbicides especially on sandy soils and/or less than 1 percent O.M.
- Both herbicides have similar activity on broadleaves when used pre-emergence, but atrazine has better post-emergence activity.

Atrazine

- Atrazine rates less than or equal to 1 lb. per acre should minimize the potential for sorghum injury and lessen the chance of residual carryover if rotating to cotton.
- For sandy loam, reduce rates to about 0.75 lb. per acre or even slightly less if potential carry over is a concern.
- For sandy soils, early post-emergence may be slightly better than pre-emergence, but weeds must be small.
- Post-emergence application is safer on the sorghum, but may have potential carryover issues to cotton and wheat.

Propazine

- Pre-plant and pre-emergence applications (not labeled post-emergence) are excellent on pigweed and provide additional control of other broadleaf weeds.
- Propazine is considered safer than atrazine on grain sorghum and for rotating to cotton.
- Tank mix with metolachlor, acetolchlor, dimethenamid or glyphosate as appropriate.
- Rates at 0.75-1.0 qts. per acre can be rotated to cotton though rates above 0.75 qt. per acre are not recommended for sandy loam soils.
- The rate 1.2 qts. per acre can be used on heavier soils and irrigated sorghum.
- Propazine has minimal to poor activity on grasses at the labeled rates, hence it is not recommended for grass control.

Planting Sorghum Following Cotton

Check herbicide labels for sorghum planting restrictions following cotton. Products of particular concern are:

- Flexstar, Reflex - Active ingredient is fomesafen
- Envoke - Active ingredient is trifloxysufuron-sodium
- Staple LX, Pyrimax - Active ingredient is pyrithiobax sodium
- Brake FX - Active ingredients are fluometuron + fomesafen
- Sorghum should not be planted if these products were applied to cotton the previous season

Planting Cotton Following Sorghum

Check herbicide labels for cotton planting restrictions following sorghum. Products of particular concern are:

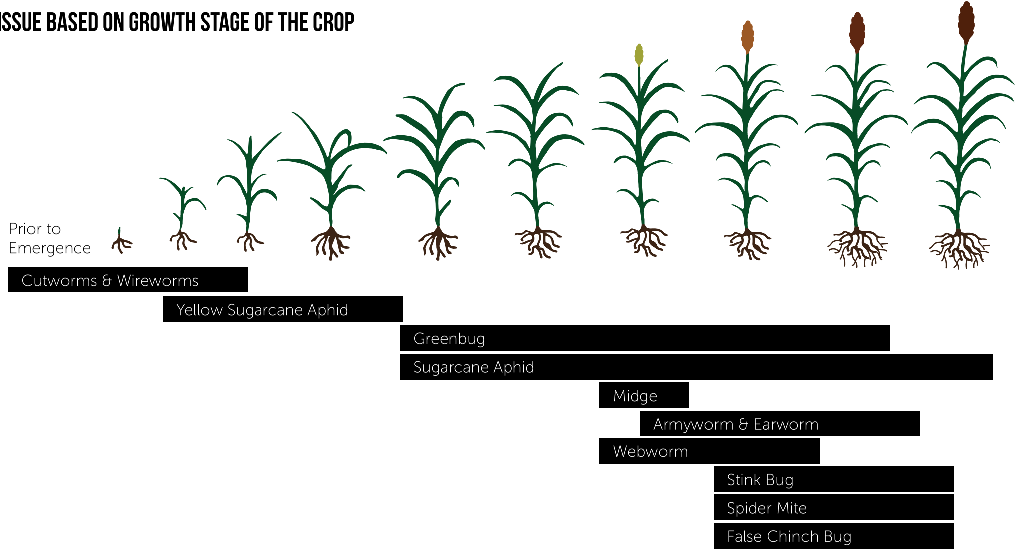
- Peak - Active ingredient is prosulfuron
- Lumax, Lexar - Active ingredients are atrazine, metolachor and mesotrione
- Cotton should not be planted if these products were applied to sorghum the previous season

INSECT MANAGEMENT

A number of insects can attack sorghum during the growing season in Central and South Texas. The most common insects found at planting are cutworm and wireworm. Midseason and late season insects commonly found include sugarcane aphid, greenbug and other aphids, flea beetles, grasshoppers, fall armyworm, corn earworm, and occasionally spider mites. **The extent of damage by insects to grain sorghum is often related to the planting date.** The sugarcane aphid and greenbug are more common in early-planted sorghum while stink bugs, corn earworm, fall armyworm and webworm are more severe in late-planted sorghum. Figure 1 serves as an outline of when the most common insects are an issue in sorghum.

Seed insecticide treatments such as clothianidin (Poncho®), thiamethoxam (Cruiser®) and imidacloprid (Gaucho®) have good efficacy on many below-ground soil pests and early seedling pests of sorghum such as flea beetle, chinch bug, stink bug and aphids. A number of foliar insecticides provide excellent control of sorghum leaf and grain pests. **Visit SorghumCheckoff.com or state extension service websites for specific insecticide information.**

FIGURE 1. OUTLINE OF WHEN THE MOST COMMONLY FOUND INSECTS IN SORGHUM IN CENTRAL AND SOUTH TEXAS ARE AN ISSUE BASED ON GROWTH STAGE OF THE CROP



Sugarcane Aphid

Sugarcane aphid has become the most serious threat to sorghum in Central and South Texas in recent years. Photo 3* shows the four most common aphids found in sorghum.

Sugarcane aphids are gray, tan or pale yellow and are sometimes referred to as the white aphid. With the aid of a magnifying glass, a pair of black cornicles or tailpipes can be seen on the aphid's back end. The tips of feet and antennae are black. Colonies or groups of sugarcane aphids are usually clustered around the midrib of the bottom side of the sorghum leaf. The sugarcane aphid has the ability to multiply very quickly in fields depending on weather conditions and the presence of predatory (beneficial) insects that feed on aphids.

Heavy infestations of the sugarcane aphid can cause leaves to be covered with a sticky, shiny substance called honeydew. This honeydew is made up of plant sugars and water, which are harmless to animals. Black sooty mold will often begin growing on the honeydew of sorghum leaves. This mold blocks sunlight and eventually leads to yellowing and death of leaf tissue. Loss of plant sap from the sugarcane aphid feeding directly impacts yield. In addition, plant stress caused by the sugarcane aphid can lead to uneven and lack of head emergence, poor grain set and may contribute to lodging. Actual yield loss will depend on the sugarcane aphid population level and when the infestation occurs (Table 13).

*Photos are located in Appendix B on page 113.

TABLE 13. YIELD LOSS IF LEFT UNTREATED

Crop Stage at 20% Infestation	Percent Yield Loss with no Treatment
Pre-boot	81-100%
Boot	52-69%
Heading	67%
Soft Dough	21%

Source: Mississippi State University

Fields should be scouted once a week for signs of the aphid. Once they are found, begin scouting at least twice a week. To determine if an insecticide treatment is needed, note the presence and number of aphids on leaves in at least four areas of the field. In each area of the field examined, collect a leaf from the bottom and top of 20 plants and observe the presence and number of aphids.

Entomologists with different state extension services vary slightly on their thresholds for when to apply an insecticide application for sugarcane aphid control. Current Texas AgriLife Extension threshold guidelines for Central and South Texas are state in Table 14. **In general, an insecticide application should be made when 25 percent of the plants are infested with 50 aphids per leaf.** Sivanto Prime and Transform WG have proven to be effective in controlling the aphid. Refer to SorghumCheckoff.com or local extension entomologists for updates on threshold levels as well as other insecticides that may be available.

Best Management Practices for Sugarcane Aphid Control

1. Sugarcane aphids can only survive on sorghum-related species. To help reduce local populations, control Johnsongrass, volunteer sorghum and other sorghum species in and around your fields during spring prior to planting.

2. Consider planting a hybrid with tolerance to the aphid. Tolerance does not mean immunity to the aphid. These hybrids still require monitoring and treating with an insecticide if action thresholds are reached. Be careful in giving up hybrid adaptability, yield potential and other favorable agronomic characteristics. In most cases, these characteristics should not be given up in order to plant a sugarcane aphid tolerant hybrid.

3. Plant seeds treated with an insecticide seed treatment. These seed treatments will protect sorghum from potential early season infestations. Acceptable seed treatments include Cruiser (thiamethoxam), Poncho and Nipsit (clothianidin), and Gaucho (imidaclorprid).

4. Plant early. Sugarcane aphids tend to infest fields later in the growing season. Early planting may avoid infestation.

5. Scout fields early and often using proper procedures to determine the level of aphid infestation. Once sugarcane aphid infestation

occurs in the field, the number of aphids can increase quickly.

6. Apply insecticide as soon as the action threshold is reached. Threshold levels change and vary with individual states. Check with your local experts for current information.

7. Use only recommended insecticides and follow label rates and application instructions. Coverage is critical. Best results are achieved when high volumes of water are used.

8. If aphids are present in the upper canopy or grain panicle in sufficient numbers to produce honeydew, consider applying an insecticide in order to prevent potential issues with harvest. If a harvest-aid product is used, tank mixing with the insecticide has worked well when the sugarcane aphid is present.

9. Avoid use of insecticides, especially pyrethroids, that are harmful to beneficial insects because they may result in sugarcane aphid numbers increasing rapidly.

Basic identification and threshold information is included for some of the other most troublesome insect pests in grain sorghum. Refer to regional extension publications or visit SorghumCheckoff.com for the most up-to-date recommendations.

Greenbug

(Photo 2) The greenbug is a small, light green aphid with a dark stripe down its back, usually found on the underside of leaves. Early-planted sorghum is more likely to be infested by this pest. The greenbug injects a toxic substance in its saliva that causes red spots on leaves where it feeds. The threshold for when to treat for greenbug varies with growth stage. See Table 14 for when to treat sorghum for greenbug.

TABLE 14. ECONOMIC THRESHOLD LEVELS FOR GREENBUG ON SORGHUM AT DIFFERENT PLANT GROWTH STAGES (TEXAS AGRILIFE RECOMMENDATIONS)

Plant Size	When to Treat
Emergence to 6 Inches	20 percent of plants visibly damaged (beginning to yellow), with greenbugs on plants
Larger Plants to Boot	Greenbug colonies causing red spotting or yellowing of leaves and before any entire leaves on 20% of plants are killed
Boot to Heading	At death of one functional leaf on 20 percent of plants
Heading to Hard Dough	When greenbug numbers are sufficient to cause death of two normal-sized leaves on 20 percent of plants

Corn Leaf Aphid

(Photo 2) The corn leaf aphid has a bluish-green body about one-sixteenth inch long with black cornicles (tailpipes), legs and antennae. Corn leaf aphids are usually found in sorghum whorls. Corn leaf aphids can transmit viral diseases from weeds like Johnsongrass, but sorghum can tolerate large numbers of these aphids. Treatment is not usually necessary for the corn leaf aphid. Corn leaf aphid populations early in the year can help attract beneficial insects to combat other pests later in the growing season.

Yellow Sugarcane Aphid

(Photo 2) Adults and nymphs are bright yellow to light green in color and covered with small spines with two double rows of darker spots down the top of the abdomen. **Feeding on sorghum causes reddening and yellowing of leaves and may transmit viral diseases**. Early infestations of yellow sugarcane aphid can quickly reduce stands. Threshold levels on when to treat are based on the size of the sorghum and percent of plant infested. See the Texas AgriLife Extension insecticide guide for specific guidelines on when to treat for yellow sugarcane aphid.

Corn Earworm

(Photo 3) The corn earworm larvae have alternating light and dark stripes down the body. The color varies from green to pink. The head capsule is a creamy yellow. Larvae feed on whorl tissue of young sorghum plants and on developing grain in maturing plants. Full-grown larvae are about 1.5 inches long and feed on grain heads. **In general, treatments should be applied when two or more small larvae or one large (greater than half an inch) larva is found per head.**

Fall Armyworm

(Photo 4) Fall armyworm larvae have a dark head capsule and a prominent inverted Y on the front of the head. Body color is green to brown with brown to black stripes on the sides of the body. Check whorls of young, late-planted sorghum and inside grain heads of more mature plants for fall armyworms. **In general, treat when an average of two or more small larvae or one large (greater than half an inch) larva is found per head.**

Sorghum Webworm

(Photo 5) These are small, greenish, hairy caterpillars with four reddish brown stripes down the back. Full-grown larvae are about half an inch long and are usually associated with sticky webbing in the area of their feeding. Check inside grain heads for worms and on leaves under grain heads for white fecal droppings. Treat when an average of 3-4 or more larvae are found on a grain head.

Stink Bugs

There are several stink bugs that can be an issue in South Texas and the Coastal Bend which may move in relatively large numbers from alternate host plants into sorghum during kernel development. These include rice stink bug, southern green stink bug, conchuela stink bug, brown stink bug, red-shouldered stink bug, leaf-footed bug and false chinch bug. The rice stink bug tends to cause the most problems. The rice stink bug is straw-colored, shield-shaped, and a half inch long. Females lay about 10-47 short, cylindrical, light-green eggs in a cluster of two rows. Rice stink bugs suck juices from developing sorghum kernels and, to a lesser extent, from other grain head parts. Damage depends on the number of bugs per grain head, the duration of infestation, and the stage of kernel development. Damaged kernels rarely develop fully and may be lost during harvest.

Grain head-feeding bugs tend to congregate on sorghum grain heads and sometimes within areas of a field. Using the beat-bucket method, count all bugs including fliers as well as those on leaves. Sample at least 30 plants from a field. Take at least one sample per acre in fields larger than 40 acres. **The economic threshold for stink bugs will vary on grain value and cost of control. In general, 5-10 stink bugs per 10 heads would warrant an insecticide treatment.**

<u>Sorghum Midge</u>

(Photo 6) The sorghum midge is one of the most damaging insects to sorghum. The adult sorghum midge is a small, fragile-looking, orange-red fly with a yellow head, brown antennae and legs, and gray, membranous wings.

The sorghum plant is only susceptible to midge during the flowering stage. A sorghum midge damages sorghum when the larva feeds on a newly fertilized ovary, preventing normal kernel development. Grain loss can be extremely high. Glumes of a sorghum midge-infested spikelet fit tightly together because no kernel develops. Typically, a sorghum grain head infested by sorghum midge has various proportions of normal kernels scattered among non-kernel-bearing spikelets, depending on the degree of damage. Only the portion of the head with yellow anthers is susceptible to midge. This is because when the glume opens and puts the yellow anther out to pollinate, the midge inserts an egg into the open glume. Each female midge lays 30-120 eggs.

Effective control of sorghum midge requires the integration of several practices that reduce sorghum midge abundance and their potential to cause crop damage. The most effective cultural management method for avoiding damage is early, uniform planting of sorghum so flowering occurs before sorghum midges reach damaging levels. Planting hybrids of uniform maturity early enough to avoid late flowering of grain heads is extremely important. This practice allows sorghum to complete flowering before sorghum midge increases to damaging levels. Cultural practices that promote uniform heading and flowering in a field are also important.

To determine if adult sorghum midges are in a sorghum field, check at mid-morning when the temperature warms to approximately 85°F. Sorghum midge adults on flowering sorghum grain heads are most abundant at that time. Because adult sorghum midges live less than one day, each day a new brood of adults emerges. Sampling must be done almost daily during the time sorghum grain heads are flowering. Sorghum midge adults can be seen crawling on or flying around flowering sorghum grain heads.

The most simple and efficient way to detect and count sorghum midges is to inspect carefully and at close range all sides of randomly selected flowering grain heads. Handle grain heads carefully during inspection to avoid disturbing adult sorghum midges. Other sampling methods can be used, such as placing a clear plastic bag or jar over the sorghum grain head to trap adults.

Since they are relatively weak fliers and rely on wind currents to aid their dispersal, adult sorghum midges are usually most abundant along edges of sorghum fields. For this reason, inspect plants along field borders first, particularly those downwind of earlier flowering sorghum or Johnsongrass. If no or few sorghum midges are found on sorghum grain heads along field edges, there should be little need to sample the entire field.

The threshold for midge depends on yield potential and crop value but is generally one midge per head. Fields vulnerable to midge infestation should be scouted daily until flowering is complete. See extension service recommendations for scouting and control options for midge.

Economic Threshold

The economic threshold injury level for sorghum midge can be calculated from the following equation:

$$\text{No. of Sorghum Midges per Flowering Head Needed to Trigger Spray} = \frac{(\text{Cost of control as \$/acre}) \times 33{,}256}{(\text{Value of grain as \$/cwt}) \times (\text{No. flowering heads})}$$

In the equation above, the control cost is the total cost of applying an insecticide for sorghum midge control, and the grain value is the expected price at harvest as dollars per 100 lbs. The value 33,256 is a constant and results from solving the economic injury equation.

Economic injury levels, as determined from the above equation, are shown in Table 15 for a range of typical treatment costs per acre, market values per 100 lbs. of grain, and numbers of flowering heads per acre. Use the equation for estimating injury levels for actual control costs, crop value and number of flowering heads per acre.

Insecticide residues should effectively suppress sorghum midge egg-laying 1-2 days after treatment.

However, if adults are still present 3-5 days after the first application of insecticide, immediately apply a second insecticide treatment. Several insecticide applications at three-day intervals may be justified if yield potential is high and sorghum midges exceed the economic injury level.

TABLE 15. ECONOMIC THRESHOLD LEVELS FOR GREENBUG ON SORGHUM AT DIFFERENT PLANT GROWTH STAGES (TEXAS AGRILIFE RECOMMENDATIONS)

Control Cost $/acre	Crop Value $100/lb.	Flowering Heads = 18,000/acre	Flowering Heads = 45,000/acre	Flowering Heads = 67,500/acre
5	6	1.5	0.62	0.41
5	7	1.3	0.53	0.35
5	8	1.2	0.46	0.31
6	6	1.8	0.74	0.49
6	7	1.6	0.63	0.42
6	8	1.4	0.55	0.37
7	6	2.2	0.86	0.57
7	7	1.8	0.74	0.49
7	8	1.6	0.65	0.43

DISEASES

Diseases of grain sorghum, like those of other crops, vary in severity from year to year and from one locality or field to another, depending upon environment, causal organism(s) and host (plant) resistance.

The total eradication of disease in sorghum is not economically feasible, so growers must try to minimize losses using an integrated pest management system. Planting resistant hybrids, providing optimum growing conditions, rotating with other crops, burying infested debris, proper seedbed preparation and seed placement, and accurate application of herbicides and insecticides are all practices that can be used to minimize disease losses.

Diseases found in sorghum fields in Central and South Texas are described in Table 16.

TABLE 16. SORGHUM DISEASES

Disease / Cause	Symptoms	Occurrence	Management
Seed Rots and Seedling Blights			
Pythium Blight Fusarium Blight	• Thin uneven stands • Seeds may rot prior to emergence or plants may die back after emergence • Plants may show stunted growth with red to black roots	• Most noticeable following prolonged periods of cool, wet weather just after planting and in poorly drained soil • Fusarium may be a problem in droughty, sandy soils	• All sorghum comes pretreated with fungicides that aid in management • Efficacy of these chemicals is often decreased by long periods of poor germination and early growth conditions
Stalk Rot			
Fusarium Stalk Rot (See KSU bulletin L-741, "Stalk Rots of Corn and Sorghum")	• Premature death of plants • Roots usually show considerable rot • Infected stalk tissue is discolored with salmon to dark red hues often predominating	• Disease is favored by abundant moisture and moderate temperatures following head initiation	• Select hybrids with good standability ratings • Avoid continous cropping, fertilize adequately and avoid leaf loss to insects or foliar disease • Hail tends to intensify stalk rot

Disease / Cause	Symptoms	Occurrence	Management
Charcoal Rot (See extension bulletin L-741)	• Disintegration of the lower stalk with numerous small, black bodies (sclerotia) scattered throughout	• Most apt to occur in light or shallow, drought-stressed soils • Disease may be present only in scattered areas of the field	• Some hybrids are more resistant than others • Reduce plant populations to avoid drought stress • Later-maturing hybrids often escape infection
Foliar Diseases Caused by Fungi[1]			
Sooty Stripe	• Elongated spots that may extend several inches with broad, yellow to orange margins • A sooty-like growth (sclerotia) is generally present on the underside of the lesion	• Oldest leaves usually are attacked first and most extensively • Yield losses of 30 percent or more have been recorded	• Crop rotation • Resistant hybrids are available
Gray Leaf Spot	• Dark purple, rectangular lesions one-fourth inch or longer with a grayish cast during spore production	• Same as northern corn leaf blight • Usually occurs late in growing season as the crop matures • Little, if any, losses occur	• Crop rotation • Resistant hybrids are available

Northern Corn Leaf Blight	• Large (two inches or more) elliptical spots with gray centers and reddish-tan borders • Very similar to sooty stripe but without sclerotia	• Most prevalent during prolonged periods of warm, humid weather	• Crop rotation • Resistant hybrids are available
Rust	• Small brown pustules or blister-like growths on the upper and lower leaf surfaces starting on the lowest leaf	• Usually appears late in the growing season (late August or early September) • Favored by warm, moist weather • Significant losses are rare	• Resistant hybrids are available
Anthracnose	• Small, circular to elliptical spots one-eighth to one-fourth inch in diameter • Depending on the hybrid, lesions may be tan, orange, red or blackish-purple	• Most prevalent in areas where periods of high humidity alternate with relatively dry periods	• Crop rotation • Resistant hybrids are available

Disease / Cause	Symptoms	Occurrence	Management
Zonate Leaf Spot	• Circular, reddish-purple bands alternating with tan or straw colored areas which give a concentric zonate or bull's-eye appearance • Lesion diameter may extend several inches	• Most severe during prolonged periods of high humidity	• Crop rotation • Resistant hybrids are available
Foliar Diseases Caused by Bacteria			
Bacteria Stripe	• Long, narrow, reddish or tan stripes depending on hybrids • Lesions usually confined between veins • Shiny, crusty spots from exudates generally found on underside of leaves	• Most common bacterial disease • Prevalent during cool, humid weather	• Crop rotation

Bacterial Streak	• Narrow, water-soaked, translucent streaks about 1-8 inches wide by 1-6 inches in length • Lesions turn red	• Very common during warm, humid weather	• Crop rotation
Virus Diseases			
Small Seed Primarily MDMV	• Red to black lesions develop on panicle branches • As seed shrinks it becomes dull in color	• Observed when the crop matures during soft dough • Most common during cool, wet weather	• Most current hybrids are resistant to the more severe necrotic symptoms
Maize Dwarf Mosaic Virus (MDMV-A) Sugarcane Mosaic Virus (MDMV-B)	• Mosaic patterns (alternating light and dark green areas) on whorl leaves • Cool nights (below 60° F for Strain A, below 70° F for Strain B) may cause red and necrotic areas resembling a blight • Flowering may be delayed and seed may be underdeveloped	• Virus is carried by insects, mostly greenbug and corn leaf aphid • Both overwinter in Johnson grass	• Most current hybrids are resistant to the more severe necrotic symptoms

Other Sorghum Diseases			
Sorghum Downy Mildew	• Vivid green and white stripes on leaves in late spring or early summer • Leaves shredded by wind until only leaf veins are left • Heads partially or completely sterile	• Most common in eastern and southern production areas of the Central Great Plains • Infections generally take place under saturated soil conditions within the first few weeks of emergence	• Crop rotation • Resistant hybrids are available to pathotype 1
Sorghum Ergot	• Exudation of sweet, sticky "honeydew" from infected flowers occurs • Honeydew drips onto leaves or produces a white, powdery mass during moist conditions • Ovary may be converted to a white fungal mass visible between the glumes	• Occurs only sporadically in the Central Great Plains • The fungus only infects through unfertilized ovaries • It usually only occurs late in the season when colder temperatures affect pollination of late-planted sorghum or late developing tillers	• Occurs only sporadically in the Central Great Plains • The fungus only infects through unfertilized ovaries • It usually only occurs late in the season when colder temperatures affect pollination of late-planted sorghum or late developing tillers

Heat Smut	• A portion or all of the head is replaced by smut galls	• Plants are infected at seedling stage, but symptoms are not apparent until boot or heading stage • More severe in south-central and southwest areas of the Central Great Plains	• Chemical controls are not effective • Utilize resistant hybrids

[1]There are many foliar diseases caused by fungi that can occur on sorghum including sooty stripe, rust and northern corn leaf blight. Sooty stripe and rust can cause economic losses to occur in some years and on some hybrids. Management of these diseases should primarily rely on selecting resistant hybrids and cultural practices such as crop rotation and the removal of residue where soil erosion is not a problem. Fungicides should be considered under high-yielding environments.

IRRIGATION

Most of the irrigated sorghum in the Rio Grande Valley is irrigated via canals. Producers may not have much control over the timing or the amount of irrigation water, thus making its efficiency lower. Scattered irrigation in the Coastal Bend, Uvalde region and river bottoms up through Central Texas, may use pivot irrigation, or in a few cases furrow irrigation. Irrigation systems vary greatly in their ability to efficiently deliver water to the soil profile (Table 17).

Water Use Requirements

Identifying the amount of water to be applied to a crop is one of the most important management contributions that a sorghum producer can make. Evapotranspiration (ET) is the preferred method for measuring and estimating the total crop water use and the irrigation demand of a crop. ET is a comprehensive measurement of crop water use in a production setting. It measures water evaporated from the soil and plant surface in addition to water transpired through the plant's leaves during photosynthesis. Irrigation demand is the difference between the ET value and the water available from precipitation and/or soil storage.

Under fully irrigated conditions, seasonal sorghum ET will range 22-27 inches. Actual amount of water required by the crop in any given year will depend on climatic conditions and the amount of water stored in the soil profile. Typical irrigation requirements to fully meet the need of the crop will range 10-18 inches in most years.

TABLE 17. EFFICIENCIES FOR AGRICULTURAL IRRIGATION SYSTEMS UNDER OPTIMAL FIELD CONDITIONS

Irrigation System	Potential Application Eff.
Surface	50-80%
Common Flood	50%
Land Leveled	60%
Row	65%
Alternate Furrow	70%
Surge[1]	80%
Center Pivot	70-92%
LESA	85%
LEPA	90%
Drag Hoses	92%
Drip	90-95%
Above Ground	92%
Subsurface (SDI)	95%

[1]Surge has been found to increase efficiencies 8-28 percent over non-surge furrow systems in Texas.

Water use rates for the various sorghum growth stages are shown in Figure 2. Average peak water use rates are about 0.3 inch per day, although occasionally a single-day peak use might approach 0.45 inch per day.

Grain sorghum develops an extensive root system, which can extend to 6 feet in a friable soil. Irrigation scheduling usually accounts for only the upper three feet of the root zone since most of the water extraction will occur in this region. About 75 percent

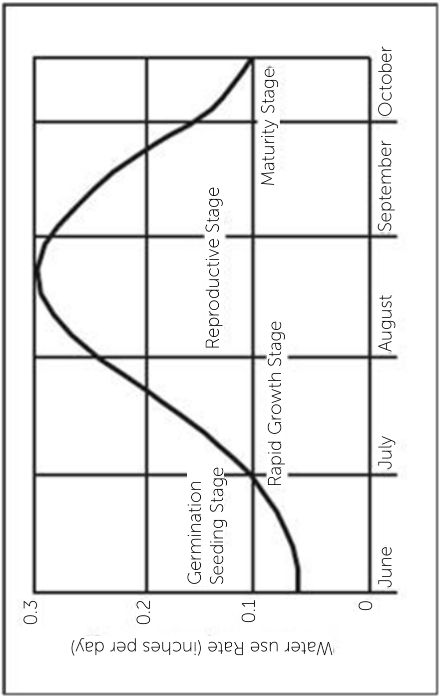


FIGURE 2. CHARACTERISTIC WATER USE PATTERN OF GRAIN SORGHUM

of water use will occur in the upper half of the root zone. Under stress conditions, when the upper zone becomes water-limited, the crop will use water from significant soil depth.

In addition to being able to extract water from a great depth within the root zone, grain sorghum is able to extract soil water at a lower percentage of available soil water without yield loss when water is limited in the upper root zone. **The general irrigation-management recommendation is to maintain soil water at or greater than 50 percent available water. For grain sorghum, however, the soil water can be depleted to an average of 30-40 percent available water before grain yields are severely reduced.**

Grain sorghum is a crop that lends itself to a limited irrigation-scheduling program. For high water-holding capacity soils, like medium-textured silt loams or heavier clay loams, limited water applications during the growing season of about half the full irrigation requirement for well-watered conditions (5-9 inches) will often produce 80-90 percent of the full yield potential under most circumstances.

Irrigation timing is critical to maximize water use efficiency under limited irrigation. **Although pre-plant irrigation can be effective on deep soils, it is not recommended if any in-season irrigation is planned.** In most years, sufficient rainfall is available to recharge the upper root zone, making preplant irrigation an inefficient water use practice. Key water use periods occur 35 days after emergence during the formation of the seed head, during the flag leaf-boot stage, and during early grain fill. Table 18 gives an outline of sorghum development and when irrigation might be applied for a fully irrigated crop.

Early Season Water Requirement

During the seedling stage only a modest amount of water in the upper soil profile is required to establish the crop. More moisture is lost during this stage through evaporation from the soil surface than through the crop canopy. This early growth stage does not directly affect the number of seeds produced but is important in initial plant establishment.

About 35-40 days after germination 5-7 true leaves are visible, and the plant begins rapid growth. A key growth stage in grain sorghum is the initiation of growing point differentiation (GPD), which in South Texas is normally around 35 days after germination (perhaps 40-45 days if planted early and growth is slow). At this point over a 7-10 day period, the maximum number of spikelets and seeds per spikelet is determined. This sets the maximum yield potential for the crop, and what happens later in the season (rainfall, heat, irrigation, further fertilizer, insect activity) will determine what level of yield potential is realized. Irrigation in advance of this growing point differentiation can enhance potential seed number.

TABLE 18. SORGHUM WATER USE (ET) AND IRRIGATION TIMING ALONG WITH CROP GROWTH STAGES

Crop Stage	Days After Planting	Heat Units After Planting	ET per Stage (in.)	Irrigation per Stage (in.)
Seeded	0	0	1.1	1.0
Emerged	8	200	2.2	0.0
Rapid Growth Stage				
3 Leaf	20	500	0.6	1.0
4 Leaf	23	575	0.8	0.0
5-Leaf	27	660	1.6	2.0
GPD	35	925	3.3	3.0
Flag	49	1290	2.8	2.0
Boot	59	1550	1.8	1.0
Reproductive Stage				
Heading	67	1710	1.4	1.0
Flower	70	1850	3.5	2.0
Soft Dough	85	2210	2.7	2.0
Hard Dough	98	2510	1.8	-
Black Layer	108	2700	3.9	-
Grain Harvest	136	3100	-	-

Reproductive Stage to Boot

Once the rapid growth stage begins, nearly half of the total seasonal water will be used during this stage prior to heading. Near the end of this period, daily water use will be near maximum, potentially averaging about 0.3 inch per day.

Boot to Post-Flowering: Critical Sorghum Growth Stage for Water Use

Sorghum reaches its maximum daily water use requirement during heading and early grain fill. When furrow irrigation is used, a long standing rule of thumb suggests if only one irrigation can be made it should be applied at about mid or late boot stage for optimum water use efficiency. Sprinkler irrigation will spread a similar amount of water over 2-3 weeks beginning mid boot. **The most critical period for water availability for grain sorghum begins about one week before head emergence, the boot stage, and continues through about two weeks past flowering.** Sorghum plants require good soil moisture during this period for maximum yields. Adequate soil moisture prior to the boot stage will assure the highest potential seed set. The actual seed number will depend on the availability of soil moisture at flowering, and seed weight will be determined by soil moisture after flowering. Water demand begins to drop after the grain has reached the soft dough stage. The soft dough stage has occurred when immature seed squeezed between the thumbnail and the index finger does not exude "milk" or white juice.

Termination of Irrigation

Under a full irrigation system, irrigation termination can be considered once the sorghum grain has reached the hard dough stage or when the grain color has changed throughout most of the sorghum head. At this time the decision to terminate irrigation should be made based on stored soil moisture and anticipated rainfall. **Grain sorghum can still use over 5 inches of water from late soft dough to harvest.** During this time, available plant soil moisture can also be important in maintaining stalk strength in high-yielding environments. As long as the plant remains green, some water is required to maintain stalk integrity. Lack of adequate soil moisture to maintain the stalk can lead to an increase in lodging.

Soil Water

In addition to providing necessary structure and nutrients to crops, soil serves as a holding reserve for water. Each soil has a certain holding capacity for plant available water (PAW), or water a plant can successfully extract from the soil. Coarse soils with rapid infiltration rates hold a minimal amount of water within the plant root zone, but nearly all the water is available for plant use. Conversely, fine textured soils hold a significant amount of water within the root zone, but a lesser percentage of the stored water is available for plant use (Table 19).

Soil moisture is generally considered most valuable to a sorghum crop when it has been captured prior to planting. **Field preparation following the crop previous to sorghum is vitally important in capturing off-season precipitation in preparation for the coming sorghum crop.** Low impact, minimum tillage operations are recommended where feasible to minimize soil water evaporation and surface run-off as well as maximize soil water infiltration and sub-surface organic matter to assist in water holding capacity.

Capturing off-season precipitation through soil storage is a recommended agronomic strategy that can lead to early season plant growth, can buffer drought stresses throughout the season, and can save costs associated with pumping and delivering irrigation water. Ideally, water from soil storage should be exhausted at the end of the growing season.

<u>In-Season Precipitation</u>

Depending on location and weather patterns, in-season precipitation is typically a part of the water budget of irrigated sorghum, despite seasonal variations in quantity and timing. Although difficult to manage, the return on in-season precipitation can be optimized. In areas where in-season precipitation is probable, a portion of soil

TABLE 19. AVAILABLE SOIL MOISTURE BY SOIL TEXTURE CLASS

Soil Texture	Inches of Water (3 foot root zone)
Course Sand	1.50
Fine Sand	2.75
Loamy Sand	3.50
Sandy Loam	4.00
Fine Sandy Loam	5.25
Silt Loam	6.75
Silty Clay Loam	5.75
Silty Clay	5.00
Clay	4.00

water capacity should be maintained to provide sufficient room to capture and contain water from small to moderate rainfall events.

In regard to irrigation scheduling, in-season precipitation should be evaluated on an effective rainfall basis. Research has shown only a portion of the water received during a precipitation event will actually become useful to the sorghum crop. To avoid overestimating water received from precipitation, a producer should only credit precipitation events greater than 0.30 inch, or the peak daily sorghum ET.

Irrigation Costs

In most sorghum regions, the most significant portion of irrigation cost is related to the energy consumed during pumping. Historically, natural gas and electric engines or pumps offer the lowest cost per unit of water applied, typically by a significant margin. Where natural gas pipelines or electrical services are not available, diesel is the lowest cost pumping option. Although gasoline and propane engines offer the same thermal efficiency as the natural gas engines, they are traditionally more expensive to operate due to the higher cost of fuel on an energy basis (BTU). They should be avoided except for in very specific situations. Regardless of energy source, the following operational practices universally promote lower irrigation water costs:

- Irrigate to the crop needs, not irrigation system capacity
- Regularly maintain and/or replace irrigation motors and pumps
- Properly size irrigation motors and pumps
- Use properly sized pipelines with smooth transition fittings
- Operate at lower pressures
- Make use of continuous acting air relief valves to eliminate false head and pressure surges
- Utilize flow meters and pressure gauges to monitor irrigation system conditions

PRE-HARVEST

In Central and South Texas, grain sorghum producers may consider harvest aids, particularly glyphosate, to manage sorghum dry-down and harvest for several reasons. Harvest aids can:

- Provide for easier threshing by making fields more uniform for harvest. Dry out the late-emerging, non-productive sucker-head tillers that otherwise could delay harvest several weeks.
- Reduce differences in harvest maturity across a field due to different soil types.
- Kill grain sorghum, which can act as a biennial plant in the Gulf Coast and Rio Grande Valley unless a freeze occurs or tillage is used. This will hasten decay of the crown which could interfere with next year's planting.
- Allow for timely harvest to avoid potential Gulf storm damage.
- Hasten harvest to meet a delivery/ pricing deadline.
- Enact late-season weed control in the field (especially perennials including Johnsongrass) and/or reduce the presence of moist weedy material in the grain.

When conditions are hot and dry harvest aids have less to offer and may be of questionable economic benefit. One caveat of applying harvest aids, however, is the significant presence of stalk or charcoal rot can make fields especially prone to lodging if a harvest aid is used and prompt harvest does not occur. Furthermore, because of tropical storm wind and rain damage in coastal areas, if glyphosate is sprayed (and plants are killed) then harvest must occur before stormy weather, whether the stalks have charcoal rot or not.

Currently, sodium chlorate (which requires hot, dry weather to perform the best) and glyphosate are labeled for application in grain sorghum. Glyphosate is a preferred option among many producers as additional late-season weed control benefits may be achieved, particularly in fields with significant Johnsongrass. Both chemicals state applications should be made once the field is generally mature (black layer) and seed moisture is below 30 percent.

HARVESTING

Sorghum stalks are generally much wetter than corn stalks at harvest, and they may be sticky from sugars. Stalk material mixed in with grain can cause problems with drying and storing. **To avoid problems with green stalks, harvest as little of the stems and leaves as possible.**

Grain sorghum demands the best combine operators. Most crops have a specific problem (such as header loss in soybeans), but grain sorghum can have difficulties at nearly every point in the combining process. These problems are compounded by the fact grain sorghum often ripens unevenly. In good-standing grain sorghum, losses can usually be kept to 5 percent of the yield, but only careful adjustment and operation of the combine makes that possible. Additional time and effort will be required, but expenses are already in the crop, and every extra bushel saved is clear profit.

<u>Five Types of Harvest Loss</u>
Preharvest loss is typically weather related and can be minimized by timely harvesting. Crops left in the field too long can be damaged by birds or field shatter. Severe weather before or during harvest can cause lodging, which makes the crop difficult to harvest.

Combine size, crop acreage and available workdays dictate timeliness. Combines should be large enough to harvest the crop in acceptable time. If this is not economically feasible, custom harvesting is an option. Another option is harvesting earlier, but this must be balanced against greater drying costs. Generally, grain sorghum can be combined whenever the moisture content is less than 30 percent.

Header loss includes shattered kernels, dropped heads and uncut heads. If a conventional reel is used, the speed of the reel bats should be slightly faster than ground speed. Operating the reel too fast will increase shatter losses while operating too slow will cause dropped heads. Several attachments are available to improve gathering efficiency. Flexible guard extensions on grain platforms substantially reduce gathering losses in standing crop conditions. Row attachments on grain platforms, or using a row-crop head, reduces losses in both standing and lodged conditions.

Cylinder loss, or unthreshed grain, can be a major problem with grain sorghum. It is often necessary to compromise between adequate threshing and excessive kernel cracking. **Cracking can be caused by either too little clearance or too fast cylinder speed, but speed is usually the cause.** Severe threshing action can pulverize the stalks and overload the cleaning shoe and walker. It is often necessary to leave up to 2 percent of the grain in the head to achieve the best overall harvesting results.

In high-moisture grain sorghum, cylinder speed and concave-clearance adjustments are critical. As the head passes through the cylinder area, rolling it (rather than a shearing) provides maximum threshing with minimum kernel and stalk damage. The cylinder-concave clearance should be set so the stalks are not crushed, and cylinder speed should be increased until thorough threshing occurs. This often requires wider cylinder-concave clearance than harvesting sorghum at lower moisture contents.

Shoe loss is grain carried or blown across the shoe. Kansas State University research indicates it may be the most serious and most overlooked source of harvesting loss in grain sorghum. In most modern combines, the shoe (and not the cylinder) is the first component of the combine to overload in grain sorghum. If the combine operator pushes the machine as fast as the cylinder can go, the shoe is usually losing large quantities of grain. In one series of tests, a 33-percent increase in ground speed caused shoe loss to increase by more than 4 percent of the total yield. Shoe losses also are increased when operating on hillsides. The amount of air blown on the shoe is important, as is the opening of the louvers. Closing the chaffer louvers will increase the air velocity through the opening; air opening (or fan speed) should be reduced as the louver opening is closed.

Walker loss can be caused by excessive speed also, but in most combines the walkers overload after the shoe; therefore, walker overloading is of secondary importance when combining grain sorghum.

<u>How to Measure Combine Loss</u>

Ground counts are tedious work, especially in grain sorghum. Nevertheless, they offer a reasonably accurate idea of how much grain is being lost. **As a rule of thumb, 17-20 kernels per square foot are equivalent to 1 bushel per acre.**

To accelerate ground counts, a 1-square-foot frame may be constructed from heavy wire. It is best to take at least three ground counts at each location (Figure 3). When making ground counts for kernels, look for lost heads. **One 10-inch head in a 10-foot-by-10-foot area is approximately one bushel per acre.**

Total loss can be checked behind the combine. Make ground counts on 1-square-foot areas in three locations uniformly spaced across the header width, with one count being made in the discharge area of the combine. Average the counts and divide by 20 to get bushels per acre. If the result is 5 percent or less of the total yield, losses are within reasonable limits.

If the total loss was more than 5 percent, the next step is to determine the preharvest loss. Check this in front of the combine in the standing sorghum. Take three counts on 1-square-foot areas, then average them and divide by 20. Subtract the preharvest loss from the total loss to determine the net machine loss. If the net machine loss is more than 5 percent, determine where the loss is occurring.

Header loss can be determined by backing the combine a few feet and taking ground counts between the header and the uncut sorghum. The difference between the header count and preharvest count is the net header loss.

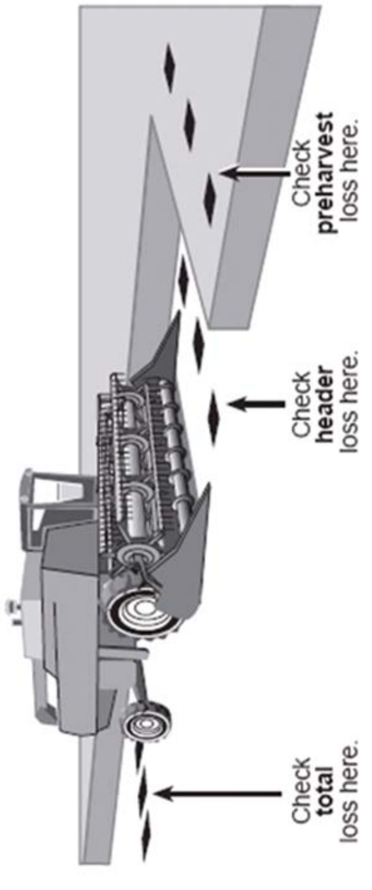
Cylinder and separation loss can be determined by subtracting the header loss from the total machine loss. It is sometimes difficult to determine if the loss is being carried over the walkers or blown across the shoe. Provided the combine does not use a straw chopper, the loss can often be pinpointed by observing the shoe while the combine is operating.

Combine loss monitors can indicate changing harvest conditions. They should be set to indicate a representative loss. If time is not spent setting the monitor, the reading is of little value.

Drying and Storing Grain Sorghum

Grain quality at harvest is influenced by grain variety, weather and combine adjustment.

FIGURE 3. DETERMINING HARVEST LOSSES



Minimizing grain damage in order to maintain quality requires good handling, drying and cooling equipment, and conscientious stored-grain management.

Handling

Grain sorghum may need to be cleaned before being stored in a grain bin, depending on the amount of trash that accompanies the grain. The trash can be reduced by harvesting after a killing frost or after using a desiccant. Excessive trash in the bin can accumulate and become hot spots during drying or can even catch on fire.

Drying

Harvest grain sorghum at 18-22 percent moisture if a suitable heated-air system is available for drying the crop. Harvesting above 22 percent moisture will result in more trash material in the grain.

Producers should be extremely cautious in holding high-moisture grain sorghum prior to drying. High-moisture grain sorghum packs much tighter than high-moisture corn. This inhibits air circulation within the grain and can result in heating, molding and sprouting problems. Never hold wet sorghum longer than 2-4 hours unless aeration is provided.

Grain sorghum is much harder to dry than corn because the seed is small and round, and it is harder to force air through it. Actual drying capacity will be about two-thirds to threefourths as fast as corn for the same grain depth and air temperature.

Continuous flow or batch dryers are the preferred methods for drying grain sorghum. If it must be dried in a bin, the bin should be used as a batch-in bin dryer, limiting the drying depth of each batch to 4 feet. After drying, cool the grain and move it to another storage bin before the next day's harvest. A 3-foot depth of sorghum is equivalent in resistance to a 4-foot depth of corn at an airflow rate of 10 cfm (moving capacity of a fan). An individual seed of grain sorghum will dry faster than an individual seed of corn, but greater flow resistance from a bin of sorghum will reduce the airflow. As a result, drying time for grain sorghum is longer than for corn. Cooling time is also longer.

Optimum drying temperature depends on the type of dryer, airflow rate, end use (feed, market, seed), and initial and final moisture contents. Maximum temperature for drying grain sorghum for use as seed should not exceed 110°F. Dry for milling below 140°F in high airflow batch and continuous flow dryers and 120°F in bin dryers. If used for feed, drying temperatures can be up to 180°F. Always cool grain to within 5-10 degrees of the average outside air temperature after drying. Natural, unheated air may be used when the relative humidity is 55 percent or less and the grain moisture is 15 percent or less.
Natural, unheated air drying can be used to

dry grain sorghum if the moisture content is 16 percent or below and the drying depth is less than 10 feet. Drying fans must be capable of delivering at least 1-2 cfm/bushel. Because the drying process is slow, it is important to start the fans immediately after the floor is covered.

Storage Moisture Content

The final storage moisture for grain sorghum depends on the expected length of the storage period and whether the grain sorghum is to be fed out to the bin continuously or is allowed to remain undisturbed in the bin until it is sold.

- To sell at harvest: 14 percent moisture
- Short term storage (less than six months): 13 percent moisture
- Long term storage (six months or longer): 11-12 percent moisture

Storing Grain Sorghum

Aeration is one of the most important management tools available to producers for maintaining grain quality in sorghum storage. Aeration extends the storage life of grain by removing odors, preventing moisture accumulation and controlling conditions conducive to mold growth and insect activity.

Grain should be aerated after it is dried and in the fall, winter and spring. Begin aeration when the average outdoor temperature is 10-15°F lower than the grain temperature. Average outside temperature can be taken as the average of the high and low temperatures over a 3-5 day period. Check grain temperatures at various locations in the bin with a probe and thermometer.

Inspect all grain in storage at least once a week. Check for indications of moisture such as crusting or condensation on the bin roof. Check and record the temperature at several points in the stored grain. Any increase in temperature indicates a problem unless outside temperatures are warmer than the grain. Probe the grain to check for insects or other problems. If problems are noticed, run the aeration fans.

Grain Quality

Sorghum grain is placed into U.S. Grade Numbers 1, 2, 3, 4 or is classified as Sample Grade, and U.S. No. 1 is the highest quality (Table 20). Value of grain sorghum follows this grading system. Proper harvesting, drying and storage practices are important to achieving the higher grades.

TABLE 20. SORGHUM GRADES AND GRADE REQUIREMENTS, FROM THE UNITED STATES STANDARDS FOR SORGHUM

Grading Factors	**Grades U.S. No.**[1]			
	1	2	3	4
Minimum Pound Limits				
Tested Weight per Bushel	57.0	55.0	53.0	51.0
Maximum Percent Limits				
Damaged Kernels:				
Heat (part of total)	0.2	0.5	1.0	3.0
Total	2.0	5.0	10.0	15.0
Broken Kernels and Foreign Material:				
Heat (part of total)	1.0	2.0	3.0	4.0
Total	3.0	6.0	8.0	10.0

Maximum Count Limits (Other Material)				
Animal Filth	9	9	9	9
Castor Beans	1	1	1	1
Crotalaria Seeds	2	2	2	2
Glass	1	1	1	1
Stones[2]	7	7	7	7
Unknown Foreign Substance	3	3	3	3
Cockleburs	7	7	7	7
Total[3]	10	10	10	10

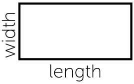
[1] Sorghum which is distinctly discolored shall not grade higher than U.S. No. 3.
[2] Aggregate weight of stones must also exceed 0.2 percent of the sample weight.
[3] Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones, unknown foreign substances or cockleburs.

U.S. Sample Grade sorghum:
(a) Does not meet the requirements for U.S. No. 1, 2, 3 or 4; or
(b) Has a musty, sour or commercially objectionable foreign odor (except smut order); or
(c) Is badly weathered, heating or distinctly low quality.

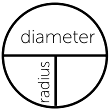
Sorghum Facts

- Sorghum is the fifth most important cereal crop in the world.
- It is used in a wide range of applications such as ethanol production, animal feed, pet food, food products, building material, brooms and other industrial uses.
- Sorghum originated in northeast Africa and spread to Asia, Europe and the Western Hemisphere.
- In the United States, sorghum is the second most important feed grain for biofuel production and is known for its excellent drought tolerance and superior adaptability to different environments.
- The first written record of sorghum in the U.S. traces to a letter that Benjamin Franklin wrote in 1757.

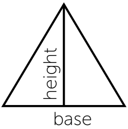
CALCULATIONS & CONVERSIONS



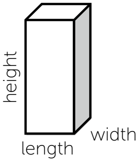
Area of a rectangle or square = length x width



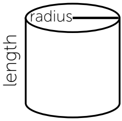
Area of a circle = 3.1416 x radius squared; or 0.7854 x diameter squared
Circumference of a circle = 3.1416 x diameter; or 6.2832 x radius



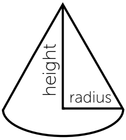
Area of triangle = base x height ÷ 2



Volume of rectangle box or cube = length x width x height

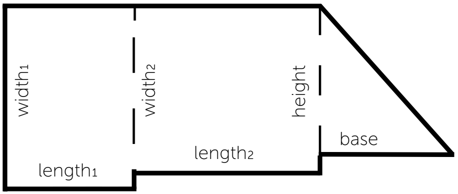


Volume of a cylinder = 3.1416 x radius squared x length



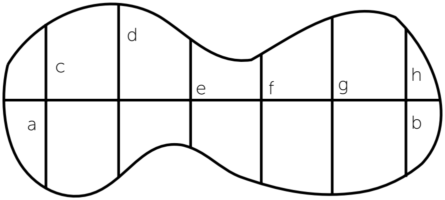
Volume of cone = 1.0472 x radius squared x height

Reduce irregularly shaped areas to a combination of rectangles, circles and triangles. Calculate the area of each and add them together to get the total area.



Example: If b = 25′, h = 25′, L_1 = 30′, W_1 = 42′, L_2 = 33′, W_2 = 31′, then the equation is:
Area = ((b x h) ÷2) + (L_1 x W_1) +(L_2 x W_2)
= ((25 x 25) ÷2) + (30 x 42) + (31 x 33)
= 2595 sq. ft.

Another way is to draw a line down the middle of the property for length. Measure from side to side at several points along this line. Use the average of these values as the width. Calculate the area as a rectangle.



Example: If ab = 45′, c = 19′, d = 22′, e = 15′, f = 17′, g = 21′, h = 22′, then the equation is:
Area = (ab) x (c + d + e + f + g + h) ÷ 6
= (45) x (19 + 22 + 15 + 17 + 21 + 22) ÷ 6
= 870 sq. ft.

Conversion Factors

Acres (A)	x0.405	Hectares
Acres	x43,560	Square feet
Acres	x4047	Square Meters
Acres	x160	Square rods
Acres	x4840	Square yards
Bushels (bu)	x2150.42	Cubic inches
Bushels	x1.24	Cubic feet
Bushels	x35.24	Liters
Bushels	x4	Pecks
Bushels	x64	Pints
Bushels	x32	Quarts
Bushel Sorghum		56 pounds
$CaCO_3$	x0.40	Calcium
$CaCO_3$	x0.84	$MgCO_3$
Calcium (ca)	x2.50	$CaCO_3$
Centimeters (cm)	x0.3937	Inches
Centimeters	x0.01	Meters
Cord (4'x4'x8')	x8	Cord feet
Cord foot (4'x4'1')	x16	Cubic feet
Cubic centimeter (cm^3)	x0.061	Cubic inch
Cubic feet (ft^3)	x1728	Cubic inches
Cubic feet	x0.03704	Cubic yards
Cubic feet	x7.4805	Gallons
Cubic feet	x59.84	Pints (liq.)
Cubic feet	x29.92	Quarts (liq.)
Cubic feet	x25.71	Quarts (dry)
Cubic feet	x0.084	Bushels
Cubic feet	x28.32	Liters
Cubic inches (in^3)	x16.39	Cubic cms
Cubic meters (m^3)	x1,000,000	Cubic cms
Cubic meters	x35.31	Cubic feet
Cubic meters	x61,023	Cubic inches
Cubic meters	x1.308	Cubic yards
Cubic meters	x264.2	Gallons
Cubic meters	x2113	Pints (liq.)
Cubic meters	x1057	Quarts (liq.)
Cubic yards (yd^3)	x27	Cubic feet
Cubic yards	x46,656	Cubic inches
Cubic yards	x0.7646	Cubic meters
Cubic yards	x21.71	Bushels
Cubic yards	x202	Gallons
Cubic yards	x1616	Pints (liq.)
Cubic yards	x807.9	Quarts (liq.)

Cup	x8	Fluid ounces
Cup	x236.5	Milliliters
Cup	x0.5	Pint
Cup	x0.25	Quart
Cup	x16	Tablespoons
Cup	x48	Teaspoons
ºCelsius (ºC)	(+17.98)x1.8	Fahrenheit
ºFahrenheit (ºF)	(-32)x0.5555	Celsius
Fathom	x6	Feet
Feet (ft)	x30.48	Centimeters
Feet	x12	Inches
Feet	x0.3048	Meters
Feet	x0.33333	Yards
Feet/minute	x0.01667	Feet/second
Feet/minute	x0.01136	Miles/hour
Fluid ounce	x1.805	Cubic inches
Fluid ounce	x2	Tablespoons
Fluid ounce	x6	Teaspoons
Fluid ounce	x29.57	Milliliters
Furlong	x40	Rods
Gallons (gal)	x269	Cubic in. (dry)
Gallons	x231	Cubic in. (liq.)
Gallons	x3785	Cubic cms
Gallons	x0.1337	Cubic feet
Gallons	x231	Cubic inches
Gallons	x3.785	Liters
Gallons	x128	Ounces (liq.)
Gallons	x8	Pints (liq.)
Gallons	x4	Quarts (liq.)
Gallons of Water	x8.3453	Pounds of Wa
Grains	x0.0648	Grams
Grams (g)	x15.43	Grains
Grams	x0.001	Kilograms
Grams	x1000	Milligrams
Grams	x0.0353	Ounces
Grams/liter	x1000	Parts/million
Hectares (ha)	x2.471	Acres
Hundred wt (cwt)	x100	Pounds
Inches (in)	x2.54	Centimenters
Inches	x0.08333	Feet
Inches	x0.02778	Yards
K_2O	x0.83	Potassium (K)
Kilogram (kg)	x1000	Grams (g)
Kilogram	x2.205	Pounds

Kilograms/hectare	x0.8929	Pounds/acre
Kilometers (K)	x3281	Feet
Kilometers	x1000	Meters
Kilometers	x0.6214	Miles
Kilometers	x1094	Yards
Knot	x6086	Feet
Liters (l)	x1000	Milliliters
Liters	x1000	Cubic cms
Liters	x0.0353	Cubic Feet
Liters	x61.02	Cubic inches
Liters	x0.001	Cubic meters
Liters	x0.2642	Gallons
Liters	x2.113	Pints (liq.)
Liters	x1.057	Quarts (liq.)
Liters	x0.908	U.S. dry quart
Magnesium (mg)	x3.48	$MgCO^3$
Meters (m)	x100	Centimeters
Meters	x3.281	Feet
Meters	x39.37	Inches
Meters	x0.001	Kilometers
Meters	x1000	Millimeters
Meters	x1.094	Yards
$MgCO^3$	x0.29	Magnesium (Mg)
$MgCO^3$	x1.18	$CaCO^3$
Miles	x5280	Feet
Miles	x1.69093	Kilometers
Miles	x320	Rods
Miles	x1760	Yards
Miles/hour	x88	Feet/minute
Miles/hour	x1.467	Feet/second
Miles/minute	x88	Feet/second
Miles/minute	x60	Miles/hour
Milliliter (ml)	x0.034	Fluid ounces
Ounces (dry)	x437.5	Grains
Ounces (dry)	x28.3495	Grams
Ounces (dry)	x0.0625	Pounds
Ounces (liq.)	x1.805	Cubic inches
Ounces (liq.)	x0.0078125	Gallons
Ounces (liq.)	x29.573	Cubic cms
Ounces (liq.)	x0.0625	Pints (liq.)
Ounces (liq.)	x0.03125	Quarts (liq.)
Ounces (oz.)	x16	Drams
P_2O_5	x0.44	Phosphorus (P)
Parts per million (ppm)	x0.0584	Grains/gallon

Parts per million	x0.001	Grams/liter
Parts per million	x0.0001	Percent
Parts per million	x1	Milligram/kg
Parts per million	x1	Milligram/liter
Pecks	x0.25	Bushels
Pecks	x537.605	Cubic inches
Pecks	x16	Pints (dry)
Pecks	x8	Quarts (dry)
Phosphorus (P)	x2.29	P_2O_5
Pints (p)	x28.875	Cubic inches
Pints	x2	Cups
Pints	x0.125	Gallon
Pints	x473	Milliliters
Pints	x32	Tablespoons
Pints (dry)	x0.015625	Bushels
Pints (dry)	x33.6003	Cubic inches
Pints (dry)	x0.0625	Pecks
Pints (dry)	x0.5	Quarts (dry)
Pints (liq.)	x28.875	Cubic inches
Pints (liq.)	x0.125	Gallons
Pints (liq.)	x0.4732	Liters
Pints (liq.)	x16	Ounces (liq.)
Pints (liq.)	x0.5	Quarts (liq.)
Potash (K_2O)	x0.83	Potassium (K)
Potassium (K)	x1.20	Potash (K_2O)
Pounds (lb)	x7000	Grains
Pounds	x453.5924	Grams
Pounds	x16	Ounces
Pounds	x0.0005	Tons
Pounds	x0.45369	Kilograms (kg)
Pounds of water	x0.01602	Cubic feet
Pounds of water	x27.68	Cubic inches
Pounds of water	x0.1198	Gallons
Pounds/acre	x1.12	Kilograms/ha
Quarts (qt)	x946	Milliliters
Quarts (dry)	x0.03125	Bushels
Quarts (dry)	x67.20	Cubic inches
Quarts (dry)	x0.125	Pecks
Quarts (dry)	x2	Pints (dry)
Quarts (liq.)	x57.75	Cubic inches
Quarts (liq.)	x0.25	Gallons
Quarts (liq.)	x0.9463	Liters
Quarts (liq.)	x32	Ounces (liq.)
Quarts (liq.)	x2	Pints (liq.)

Rods	x16.5	Feet
Square feet (ft^2)	x0.000247	Acres
Square feet	x144	Square inches
Square feet	x0.11111	Square yards
Square inches (in^2)	x0.00694	Square feet
Square meters (m^2)	x0.0001	Hectares (ha)
Square miles (mi^2)	x640	Acres
Square miles	x28,878,400	Square feet
Square miles	x3,097,600	Square yards
Square yards (yd^2)	x0.0002066	Acres
Square yards	x9	Square feet
Square yards	x1296	Square inches
Tablespoons (Tbsp)	x15	Milliliters
Tablespoons	x3	Teaspoons
Tablespoons	x0.5	Fluid ounces
Teaspoons (tsp)	x0.17	Fluid ounces
Teaspoons	x0.333	Tablespoons
Teaspoons	x5	Milliliters
Ton	x907.1849	Kilograms
Ton	x32,000	Ounces
Ton (long)	x2240	Pounds
Ton (short)	x2000	Pounds
U.S. bushel	x0.3524	Hectoliters
U.S. dry quart	x1.101	Liters
U.S. gallon	x3.785	Liters
Yards (yd)	x3	Feet
Yards	x36	Inches
Yards	x0.9144	Meters
Yards	x0.000568	Miles

APPENDICES

a. The Sorghum Plant

Sorghum grain is found on the panicle, commonly referred to as the head. The panicle consists of a central axis with whorls of main branches, each of which contains secondary and at times, tertiary branching. The length of the branches allows for a wide range of shapes and sizes in sorghum and for sorghums with very open panicles or sorghums with very compact panicles. The branches carry the racemes of the spikelets where the grain is found (see Figure 4). The panicle emerges at boot from the flag leaf sheath.

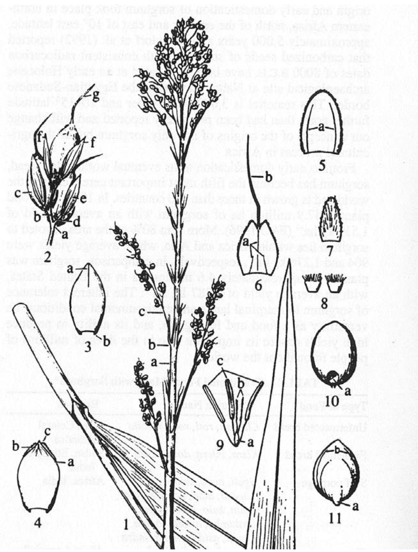


Figure 4. The panicle of Sorghum bicolor subsp. bicolor which consists of the inflorescence and spikelets. 1. Part of panicle: a = internode of rachis; b = node with branches; c = branch with several racemes. 2. Raceme: a = node; b = internode; c = sessile spikelet; d = pedicel; e = pedicelled spikelet; f = terminal pedicelled spikelets; g = awn. 3. Upper glume: a = keel; b = incurved margin. 4. Lower glume: a = keel; b = keel wing; c = minute tooth terminating keel. 5 Lower lemma: a = nerves. 6. Upper lemma: a = nerves; b = awn. 7. Palea. 8. Lodicules. 9. Flower: a = ovary; b = stigma; c = anthers. 10. Grain: a = hilum. 11. Grain: a = embryon-mark; b = lateral lines. (Drawing by G. Atkinson. Reprinted, with permission, from J. D. Snowden, 1936, The Cultivated Races of sorghum, Adlard and Son, London. Copyright Bentham - Moxon Trust - Royal Botanical Gardens, Kew, England).

Seeds begin developing shortly after flowering and reach physiological maturity when the black layer is formed between the germ and the endosperm, some 25-40 days after the black layer is formed when moisture content is generally 15 percent or less. Black layer can be seen at the base of the grain where it attaches to the rachis branch and indicates the grain is physiologically mature.

Seeds are made up of three major components: the endosperm, embryo and pericarp (Figure 5). All sorghums contain a testa, which separates the pericarp from the endosperm. If the testa is pigmented, sorghum will contain tannins. If not, the grain is free of tannins. None of the commercial U.S. grain sorghums have a pigmented testa and are all said to be free of tannins.

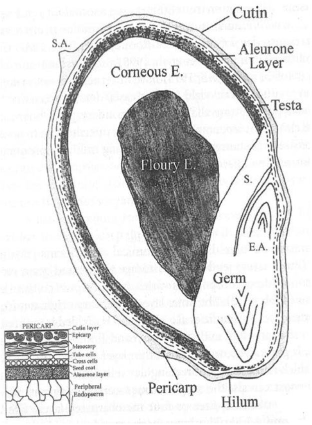


Figure 5. Sorghum grain, showing the pericarp (cutin, epicarp, mesocarp, cross cells, tube cells, testa, pedicel, and stylar area (SA)), endosperm (aleurone layer, corneous and floury), and the germ (scutellum (S) and embryonic axis (EA)). Adapted from L. W. Rooney and Miller, 1982.

b. Photos

Photo 1. Iron Deficiency

Courtesy of International Plant Nutrition Institute

Photo 2. Corn Leaf Aphid, Yellow Sugarcane Aphid, Sugarcane Aphid, Greenbug Aphid

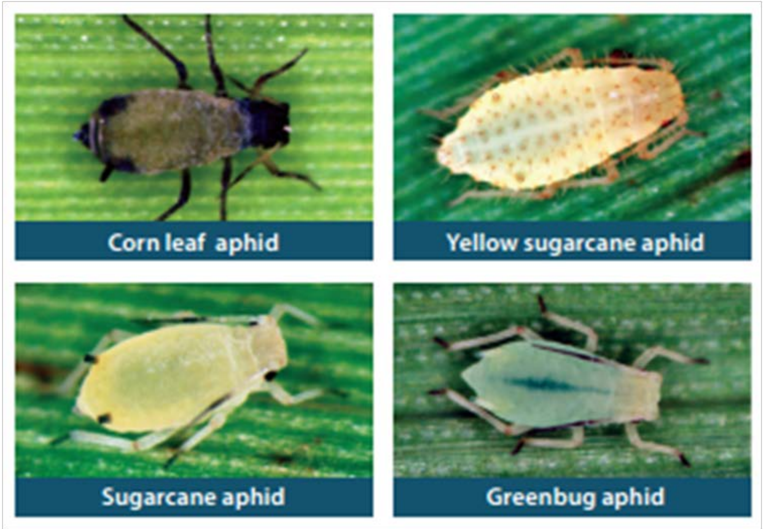


Photo 3. Corn Earworm**

Photo 4. Fall Armyworm*

***Used with permission of USDA-ARS*

Photo 5. Sorghum Webworm*

Photo 6. Sorghum Midge*

Used with permission of Dr. Pendelton, West Texas A&M University

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SORGHUM THE SMART CHOICE

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