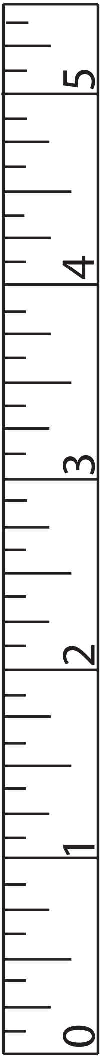
UNITED SORGHUM CHECKOFF PROGRAM

South & Central Texas Production Handbook



Welcome to the United Sorghum Checkoff Program's South Central Texas Production Handbook. 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 the work of the Sorghum Checkoff will only improve that potential over time. As you manage your sorghum, keep these tips in mind:

- Make sure you are using the hybrid that works in your area and planting to get the right "plants per acre" in your field.
- Use an integrated weed management strategy.
- Most importantly, provide the crop with adequate fertilizer.

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. But 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

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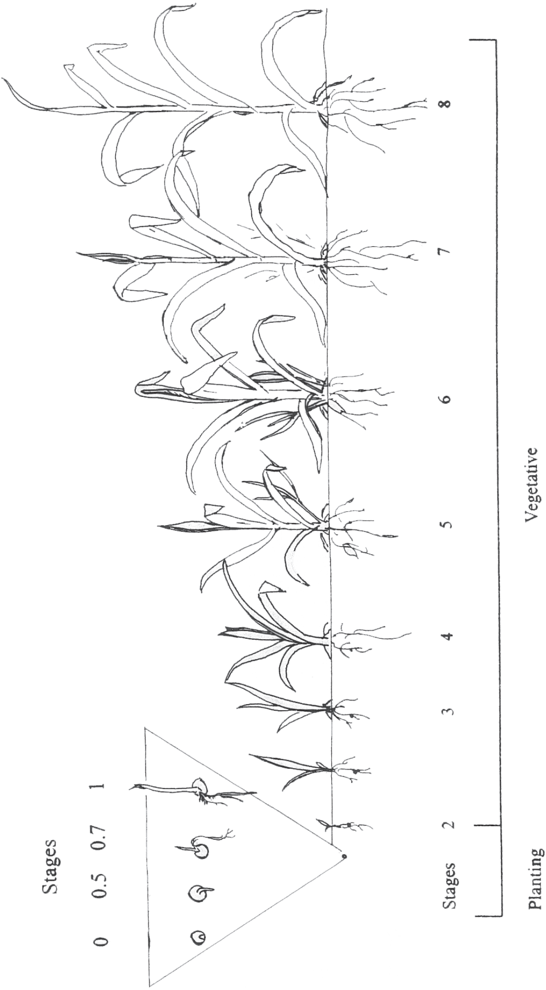
Growth Stages

It is important to understand the various developmental stages of sorghum since this understanding will assist in making irrigation and management decisions. The stages are based on key stages of sorghum growth that are used to describe sorghum from planting to maturity (Figure 1).

Another common scale that is used among sorghum researchers is a more simplified growth scale. GS1 would equate to stages 0-5 in this system. GS2 would represent from stages 5-10, and finally, GS3 would be from stage 10 to 11.5.

Comprehensive grain sorghum growth and development guides are available, such as Kansas State's "How a Sorghum Plant Develops" (http://www.oznet.ksu.edu, currently being revised with your sorghum Checkoff dollars) and Texas AgriLife's "How a Sorghum Plant Grows," (http://agrilifebookstore.org). Both of these guides provide pictures of different growth stages, graphs of cumulative nutrient uptake relative to growth stages (KSU), or approximate heat unit requirements (base temperature 50°F, maximum 100°F) for attaining a particular growth stage (Texas AgriLife). Cool or wet weather early in the season or an early planting date can significantly slow growth early in the season adding a week or even two weeks to the time to half bloom.

Refer to Appendix A.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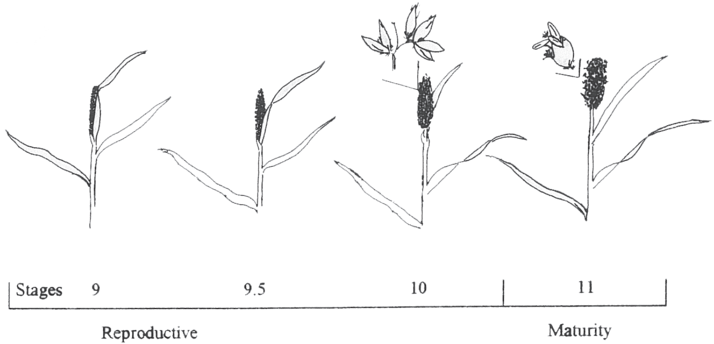

Fig. 1. Stages of sorghum growth: Stage 0: 0.0 planting; 0.1 start of imbibition; 0.5 radicle emergence from seed (caryopsis); 0.7 coleoptile emergence from seed (caryopsis); 0.9 leaf at coleoptile tip; Stage 1: emergence; Stage 2: first leaf visible; Stage 3: third leaf sheath visible; Stage 4: fifth leaf sheath visible; Stage 5: Panicle differentiation and start of tillering; 5.1 main shoot and one tiller; 5.9 main shoot and several tillers; Stage 6: stem elongation (late vegetative stage); Stage 7: flag leaf visible, whorl; Stage 8: booting (end of vegetative stage); Stage 9: panicle just showing, inflorescence emergence; Stage 10: anthesis (50% of panicle flowering); Stage 11: maturity; 11.1 grains at milk stage; 11.2 grains at early dough stage; 11.3 grains at late dough stage; 11.4 grains at physiological maturity (black layer, approximately 30% seed moisture); 11.5 mature grain (seed moisture approximately 15%). (Courtesy K. Cardwell). *For more information see Appendix A, page 163.*

Hybrid Selection

The initial criteria most producers make in choosing a grain sorghum hybrid in Texas is maturity. Once an appropriate maturity range is decided upon, then yield is paramount. Full-season, and even medium-long, maturity hybrids in South and Central Texas (unless irrigated in the Lower Rio Grande or Coastal Bend) can exhaust available moisture before maturity, and thus have reduced yields potential especially in dry years. Any late planted grain sorghum production in the Blacklands faces the task of reaching adequate maturity prior to the onset of cold night-time 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.

Sources for Hybrid Yield Data

The Texas AgriLife Research Crop Testing Program conducts performance tests in South and Central Texas at five to seven sites per year. These regular sites include:

- Weslaco (full and limited irrigation), Lower Rio Grande Valley
- Gregory, San Patricio Co., Coastal Bend
- Danevang, Wharton Co., West Upper Gulf Coast
- Hondo/Castroville, Medina Co.

- Granger, Central Texas Blacklands
- College Station, South Central Texas
- Leonard/Princeton, North Texas Blacklands (between Dallas and the Red River)

In most cases, companies plant the hybrids they think will perform best at each site. These independent tests collect a variety of data including days to half bloom, lodging, test weight and yield. Trial results are published at http://varietytesting.tamu.edu and producers may choose test sites and then review several years of results, looking for hybrids that have good consistent results over years and locations.

Additional on-farm sorghum hybrid testing is also conducted in the Lower Rio Grande, Coastal Bend and Upper Gulf Coast by Corpus Christi Research and Extension Center staff (Dan Fromme) and cooperating county agents (results annually posted at http://coastalbend.tamu.edu, then locate 'Soil and Crop Sciences').

Producers are also encouraged to consult individual companies for their recommendations, as well as plant their own on-farm observation with different hybrids. Company data is not considered independent in the manner that public tests are conducted. However, these tests can still be an excellent source of information particularly when comparing yields among hybrids from the same company.

Additional Hybrid Selection Criteria

In addition to maturity and yield, the following hybrid parameters have a potentially major impact on sorghum performance in Texas.

- **Tillering**—Hybrids express differences in tillering. Early planting and low populations foster increased tillering. Although tillering is one important means by which sorghum hybrids may adapt to their environment, extension cautions producers about high tillering hybrids where drought stress is expected. In contrast, low tillering hybrids reduce the possibility that early favorable conditions lead to increased tillering, only to have drought and heat increase, leaving the plant with too little moisture per head hence reducing actual yield.
- **Lodging**—Standability is important for grain sorghum. Companies rate their own hybrids for lodging resistance, but significant lodging only occasionally shows up in Texas AgriLife hybrid trials and it is often not even reported. 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 storm damage can also make strong standing sorghum hybrids more valuable.
- **Weathering**—This is particularly important for grain sorghum grown along the Texas coast. Hybrids that can better withstand storm damage, do not deteriorate after matu-

rity while they await harvest in the event of extended rain, minimize germination in the head, etc., are a plus. Sources of weathering durability include seed companies, the Texas AgriLife Research Crop Testing Program and producer experience.

Lesser sorghum hybrid considerations include the following:

- **Stay-green**—Ability of grain sorghum hybrids to maintain prolonged leaf and stalk integrity after flowering. This trait can assist grain fill as well, take better advantage of late rains and maintain stalk health later in the season (which may reduce lodging).
- **Greenbug tolerance**—Many hybrids note resistance to Biotype C and E greenbugs, but these biotypes have been gone from Texas for many years. Biotype I is now predominant, but only a few hybrids offer resistance. A small amount of Biotype K is also present. With the advent of numerous insecticide treatments there is little emphasis placed on greenbug resistance.
- **Head exsertion**—Some hybrids have heads that do not emerge as much from the whorl, hence they remain down in the leaves at harvest leading to more trashy harvest. Some hybrids may have modest exertion, but then are poorly exserted during droughty conditions.
- **Grain color and plant color**—Red, bronze, crème, yellow and even white grain hybrids are marketed. Unless you are pursuing a

specialty market (food sorghum, chicken feeding, etc.) where white grain seed coat is desired, then there is little reason to choose a hybrid based on seed coat color, unless you simply have a preference. Yield considerations generally override any considerations of grain or plant color (purple, red, tan).

- **Panicle (head) type**—Loose panicle hybrids (in contrast to tight, compact heads) that are fast growing and dry down rapidly may be preferred in areas with higher humidity and greater panicle feeding pressure from insects.
- **Plant disease resistance**—Though some hybrids may have tolerance of certain diseases, this consideration is largely ignored by producers. If you have a particular disease that has affected your crop in many years, consult your Texas AgriLife Extension plant pathology experts or your seed dealer for possible suggested hybrids that may reduce disease injury potential.
- **Herbicide tolerance**—Although these technologies are now in the testing phase with universities and will not be available until about 2014, two major non-GMO herbicide tolerant lines will likely become important selection criteria once the traits are bred into competitively yielding commercial hybrids. These include ALS-herbicide or sulfonylurea tolerance (metsulfuron, nicosulfuron, rimsulfuron, e.g., Ally) and ACC-ase herbicide tolerance (quizalofop, e.g. Assure II).

Duration of Hybrid Bloom and Physiological Maturity

Hybrid ratings of the same hybrid may vary among companies. Days to half bloom and physiological maturity will depend greatly on weather since maturation is driven by heat accumulation. South Texas Crop Testing results mostly represent planting dates from mid-February at Weslaco to about March 25 at College Station, note individual years with great differences in 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. This is just one example of the complexities of projecting the days to maturity, as planting date and climate affect growth and development.

For North and Central Texas, where rare fields might be planted later in the season into July, a cutoff date should allow the sorghum to reach black layer one to two weeks before your area's average killing frost (or since that data is harder to find, two to three weeks prior to the average first freeze). This allows for sorghum maturation without significant risk to yield or test weight if a frost or freeze occurs up to 10 days earlier than average.

Table 1 provides the approximate range of days to half bloom and physiological maturity for hybrids planted at typical planting dates. As noted above, for the lower Rio Grande Valley north into the Texas Blacklands. This is in contrast to harvest maturity which can be up to several weeks later depending on weather conditions and drying.

Additional Seed Selection Criteria
Seed Treatments:

- Many companies now treat all their seed with Concep III which enables a producer to use s-metolachlor (e.g., Dual Magnum) herbicides, which is the preferred method of grass control in grain sorghum. This usually costs $10-15 per bag, and should not factor in your decision on which hybrid to choose.
- Insecticides and fungicides—Gaucho and Poncho for insects (the latter potentially offers longer-season greenbug control) may cost about $30 per bag, but generics are inexpensive and may enable some greenbug control for cents per acre. Advanced combination of insecticide and fungicide treatments like CruiserMaxx, etc. may double the cost of a bag of seed. Early season control of yellow sugarcane aphids, southern corn rootworm, etc. make seed treatments a nearly essential part of grain sorghum production for many producers in South and Central Texas. Modest seeding rates are usually more than adequate for most production conditions and this can reduce the cost of more expensive grain sorghum seed treatments.

Consult the insect section of this production guide for further comments about the value of seed treatments particularly in South Texas and the lower region of the Texas Blacklands. Numerous seed treatment tests have shown the long-term value of seed insecticide treatments.

Cheap Seed—Because cost of seed, when prorated per acre, is relatively low for grain sorghum, particularly compared to just about all other crops, selecting sorghum seed based on price alone is a poor choice. Low-priced seed probably doesn't represent the best yield potential and proven genetics you would like to have for your farm. Shop hybrid maturity and yield potential, scour the yield trial data, narrow your choices, then find your best price for those hybrids on your short-list, and don't fret paying $2-3 per acre more to plant the hybrid of your choice.

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. South and Central Texas does not face issues of hybrid maturity from late plantings like the Texas high plains or Kansas may. In general, for both South Texas and all of the Texas Blacklands, Texas AgriLife does not recommend either full-season hybrids or early season-hybrids. The former can indeed increase risk of not fully

Table 1. Expected and observed days to sorghum half bloom as well as expected days to physiological maturity for South and Central Texas from Texas AgriLife Research Crop Testing trials.

General company maturity rating (# of leaves)	Production system	Expected mid-range half bloom	Expected physiological maturity†	Common observed range, half bloom (2006-2009)‡
		Days		
Early (~15)	Rainfed	≤60	85-100	
Medium-early	Rainfed	61-65	96-105	67-80
Medium (~17)	Rainfed	66-70	100-110	67-82
Medium-long	Rainfed/ Irrigated	71-75	106-115	67-83
Long (~19)	Rainfed/ Irrigated	≥76	111-125	

†Expected maturity is highly dependent on planting date, early season cool temperatures, cloudy/rainy weather, and heat accumulation.

‡Planting dates for Texas AgriLife Research Crop Testing trials typically beginning mid-February at Weslaco to early April in the north Texas Blacklands.

maturing due to drought. Yield potential of the latter is a significant drop off from even the medium maturity hybrids.

South Texas

Lower Rio Grande Valley and Coastal Bend: Due to less rainfall than other areas we suggest producers target medium and medium-early hybrids. 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) up to I-10**: medium-long and medium. Texas AgriLife recommends, however, that if plantings are later in this region, rather than shorten maturities, producers consider planting crops other than grain sorghum.
- **San Antonio Region**: some irrigated but mostly dryland to west, rainfed to east: 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 hybrid 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.

The Bottom Line of Hybrid Selection

When extension staff surveys the means by which many producers choose their hybrids for planting grain sorghum, for both irrigated and rainfed production, we believe Texas producers could moderately improve their yields by planting hybrids that have a track record of better performance.

Early maturity hybrids are frequently criticized for their lower yield potential. This is a fact of having less time and less capacity to produce high yields. These hybrids may have their place when time is short (oncoming midge potential, hot summer conditions during flowering and grain fill), but for South and Central Texas producers extension recommends never plant a shorter maturity hybrid than medium-early to retain good yield potential. Some producers accept the increased risk of planting a medium-maturity hybrid in exchange for greater yield potential knowing that oncoming sorghum midge potential or summer heat in some years may limit the crop and reduce yields.

Irrigation

South & Central Texas Irrigation Methods

Most of the irrigated sorghum in the region is flood irrigation via canals in the Lower Rio Grande Valley. Producers may not have much control over the timing or the amount of the 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 in a few cases in addition to furrow irrigation.

As with all grain crops, sorghum yield is most directly related to available water during the cropping season—applied irrigation water stored soil water, and in-season precipitation. Each of these sources of water can be managed to optimize the grain yield return per unit of water available. Studies have shown that prior to bloom, grain sorghum can use up to 10 inches of water, and that each subsequent inch of rainfall or irrigation will produce about 350 to 400 lbs. of grain per acre though the efficiency of grain production is less from flood and furrow irrigation (Table 2). Where grain sorghum plant populations are restricted as part of a drought management and risk management strategy, the amount of water required to reach the point of initial grain production can be reduced preserving more moisture for grain formation and yield.

Table 2. Typical comparative expected efficiency for different agricultural irrigation systems under optimal field conditions.

Irrigation Method	Potential Irrigiation Application Efficiency
Surface	
Common flood	50%
Common flood w/land leveling	60%
Row (all furrow)	65%
Alternate furrow	70%
Furrow w/surge levels†	80%
Center pivot	
Low elevation spray app (LESA)	85%
Low elevation precision app (LEPA)	90%
LEPA with drag hoses	92%
Drip	
Above ground	85-90%
Subsurface drip	90-95%

†Surge has been found to increase efficiencies 8 to 28% over non-surge furrow systems in Texas.

Grain Sorghum Water Use Pattern

Sorghum's drought tolerance and water use characteristics make it an excellent crop for a wide range of irrigation scenarios in South Texas. Sorghum can yield reliably under rainfed conditions in many semi-arid environments (15-20 inches annual precipitation) and can be managed to reach significant yield capacity with ample rainfall and/or timely irrigation. Because of sorghum's water use versatility, it fits well into many cropping and irrigation patterns, a valuable trait considering current trends of declining available irrigation resources and pending regulatory water use limitations.

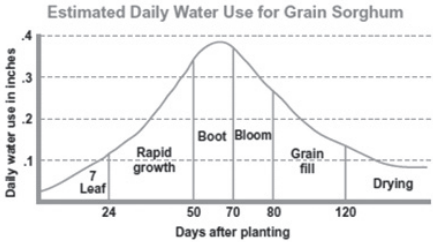

Fig. 2. Daily water needs for sorghum rise sharply at the rapid growth stage, peak during boot stage and decline afterward.

Moisture stress early in the season will limit head size (number of seed per head) and delay maturity whereas if stress occurs later, in the season grain filling is reduced (either seed set or reduction in seed size). Water needs for sorghum vary according to the different plant stages—different amounts are used in the seedling development phase, the rapid growth and development stage, and the bloom to harvest phase (Fig. 2).

Irrigation & Grain Sorghum Growth Stages

Seedling Development

During the seedling stage up to near 28 days of growth, only a small amount of moisture in the soil surface is required to establish the crop. More moisture is lost during this stage through evaporation from the soil surface than through the crop canopy (to reduce soil moisture loss see Saving Rain and Irrigation below). This early-growth stage does not directly affect the number of seeds produced, but it does set the direction of development.

Key 'Hidden' Growth Stage for Sorghum Yield—Irrigation Considerations

As noted earlier in the growth and development section of this guide, for South and Central Texas about 35-40 days after germination, five to seven 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- to 10-day period (at most no more than two weeks if the crop is growing slowly due to cool, wet weather), 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. Once this process is completed, subsequent irrigation cannot increase potential seed number.

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 0.35 inches per day. This critical water demand requires that as best you can you limit moisture stress during the rapid growth phase so that a robust plant structure and full panicle have been produced. Growers should not wait too long to irrigate, else production will suffer.

Boot to Post-Flowering—Critical Sorghum Growth Stage for High 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 you can irrigate only once then do so about mid or late boot stage (provided you can get to that point without severe moisture stress) for optimum use and timing of limited irrigation. Sprinkler irrigation will spread a similar amount of water over 2-3 weeks beginning in mid-boot. This most critical period for water availability for grain sorghum begins about one week before head emergence or the "boot" stage, and continues through about two weeks past flowering (Fig. 2). 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; seed size will be determined by soil moisture after flowering. Moisture demand drops rapidly after the grain has reached the soft-dough stage. The soft-dough stage has occurred when immature seed squeezed between the thumb-nail and the index finger does not exude "milk" or white juice. The combined drop in moisture demand, natural drought tolerance in sorghum and the extensive root system generally make late irrigations unprofitable.

When can I stop irrigating grain sorghum?
Irrigation cut-out will occur no later than early hard dough stage. The sorghum seed will proceed through grain development from watery-ripe to milky-ripe to mealy-ripe then begins to firm at soft dough on to hard dough. As a rule of thumb if good soil moisture is still available to the plant—at least 2 inches—then terminate irrigation as sorghum moves past soft dough. It is not reliable to base irrigation termination on grain color (see below). A final irrigation may be applied during hard dough only if soil moisture storage is completely depleted or drought conditions are severe enough to hinder stalk quality at harvest.

When examining the head for seed maturation, be sure to check many heads and check the whole head. Some difference in maturity will be observed on each head as seeds at the tip could easily be 7 days older (thus more mature) than seeds at the bottom of the head, and primary tillers may also be several days later than the main head.

Timing the last furrow irrigation—This is more difficult to do because the amount of water might be uncertain and the timing can be unpredictable. Generally, apply the water no later than soft dough, or perhaps slightly earlier.

TIP: As a general rule of thumb for sprinkler irrigation, if you have doubts about irrigating one more time prior to hard dough, then do so, especially when grain prices are high. These late waterings, though they likely may not contribute as much to economic yield, may help maintain stalk health and reduce lodging potential.

Can I use the color of the grain sorghum head to determine irrigation termination?
Not reliably. You still need to hand-check the heads and seeds. Furthermore, turnrow observations of sorghum fields do not tell you how much soil moisture is still available, which could be from none to an amount that is more than twice what you may apply in one irrigation. Head coloration varies depending on hybrid as some 'red' sorghums are not as red as others (and many hybrids have grain color of orange, yellow, crème, and white which never do give the sharp impression of distinct color change). In general when the seed in the head begins to take on an orange or reddish tint, the seed is most likely at the milk stage. As a field turns color so you readily observe it while driving past the field, then the sorghum grain tends to be in the mealy stage to perhaps just entering soft dough. But this is not a reliable means of deciding to irrigate again unless you check for available soil moisture and the stage of seed maturity. In general extension staff note that little to no increase in yield is likely after a general red color appears over the field but an additional late season sprinkler irrigation might help maintain stalk quality for harvest.

Soil Water Availability

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 that 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 of 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 3. Available soil moisture by soil texture class. Soils with higher clay content hold a great amount of total water, but increasingly it is less available to plants.

Soil Texture	Approximate Inches of Available Soil Moisture at Field (Full) Capacity (3' root zone)
Coarse sand	1.5
Fine sand	2.8
Loamy sand	3.5
Sandy loam	4.0
Fine sandy loam	5.3
Silt loam	6.8
Silty clay loam	5.8
Silty clay	5.0
Clay	4.0

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. “Catch it! Keep it! Reap it!" is a popular mantra for describing the need to ensure that rainfall is translated into harvestable grain. Low impact, minimum tillage operations are recommended where feasible to minimize soil water evaporation and surface run-off while maximizing 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, especially in lower rainfall regions, that helps early season plant growth, can buffer drought stresses throughout the season, and saves costs associated with pumping and delivering irrigation water. Ideally, water from soil storage should be exhausted at the end of the season when grain reaches maturity.

In-Season Precipitation

Depending on location and weather patterns, in-season precipitation still may be the main component 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 water capacity should be maintained to provide sufficient room to capture and contain water from small to moderate rainfall events. In addition to increased seasonal water use and reduced pumping costs from holding and utilizing in-season precipitation, run-off and erosion are reduced, leaching effectiveness is increased, and in many cases, nitrogen better supplements the crop.

In regards to irrigation scheduling, in-season precipitation should be evaluated on an “effective rainfall” basis. Research has shown that 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 0.25 inch (unless the soil is already wet), or the peak daily sorghum evapotranspiration. Consideration should be given to forgoing or delaying irrigation only if a rainfall event is larger than the scheduled irrigation depth or exceeds available soil moisture holding capacity. The benefit of in-season precipitation can often be redeemed at the end of growing season by terminating irrigation earlier with sufficient water stored in the soil profile.

Saving Rain and Irrigation Water by Minimizing Soil Evaporation

Producers can take steps to minimize moisture losses from the soil by adopting water-conserving practices, such as:

- Spacing the plants equally in narrow rows. Narrow-row crop production reduces the amount of bare soil, which loses more moisture through evaporation than do shady and mulched soil surfaces. However, if the row spacing is reduced it is likely agronomically sound to NOT increase the per acre seeding rate.

- Leaving crop residues on the soil surface, which can reduce soil evaporation by 1 to 3 inches during the season, as well as other conservation tillage measures.
- Uncontrolled weeds also contribute significantly to loss of soil moisture.
- Proper planting date for rapid canopy establishment.

Evapotranspiration & Grain Sorghum Irrigation

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 measure of crop water use in a production setting as 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 the soil storage. ET values for sorghum can be obtained locally for most Texas agricultural regions through weather station networks such as *http://texaset.tamu.edu*

Keep in mind, however, that full irrigation of sorghum is probably not the goal in most Texas sorghum production rather timely but limited (deficit) irrigation is most likely. Crops other than sorghum are more likely to receive full irrigation, thus understanding the timing of sorghum irrigation related to growth stage importantance.

In South Texas the average peak daily grain sorghum ET is about 0.35 inches. This value will vary depending on seasonal climate or planting date (early versus delayed, which faces higher evaporative conditions). In the Lower Rio Grande Valley or Coastal Bend sorghum water use commences at planting in February or March, and normally peaks in late April and May and continues through harvest. Under fully irrigated conditions, seasonal sorghum ET can reach 28 inches.

Irrigation Scheduling Based on Potential Evapotranspiration (PET)

Researchers have developed the means for sorghum growers to calculate the water requirement for their crop. This method helps predict the amount of water use and the replacement amount of water needed to sustain maximum crop production. This method is predicated on having sufficient irrigation resources to meet the full water requirement of the crop, which is not practical in many, if not most cases as irrigation for sorghum and other crops is at a deficit versus the potential water use in most of Texas. In this event, irrigators may target a set percent of full ET, often 75%, to ensure that water is being provided at key growth stages even if less than what the crop can use.

For further information on how to use PET for irrigating your crop as well as how to adjust for differences in irrigation system efficiency, consult extension's 'Irrigating Sorghum in South and South Central Texas,' L-5434 (2003), which is available through county extension offices or can be downloaded from *http://agrilifebookstore.org*

Grain Sorghum Water/Irrigation Requirements in Relation to Heat Unit Accumulation

When a deficit irrigation strategy is implemented, either due to limited water or as part of a producer's overall agronomic approach, irrigation water should be applied during the priority periods of rapid growth and reproduction. Smaller, timely applications are recommended for sorghum under deficit irrigation to encourage uniform growth conditions. The concept of heat unit accumulation is applied to many crops in Texas, particularly cotton. The same principle, using a base temperature is 50^{o}F (cotton is 60^{o}F), govern grain sorghum growth and development. Heat units can also be used to predict plant water use at different stages of growth.

Irrigation System Efficiency

Irrigation efficiency is defined as the percentage of water delivered to the field that is beneficially utilized by the crop. Factors such as wind, leaching, evaporation and run-off all lead to decreased irrigation efficiency. To determine the depth of

Table 4. Example sorghum evapotranspiration (ET) and approximate irrigation levels (typical rainfall pattern assumed) for medium-early maturity sorghum hybrid growth stages based on heat unit accumulation.

Sorghum Growth Stage	Days after Planting	Approx. Cumulative Heat Units after Planting (Medium-early hybrid)	Example Water ET per Stage (in)†	Suggested Irrigation per Stage (in)
Seeded	0	0	1.1	1
Emerged	8	200	2.2	0
Rapid Growth				
3 Leaf	20	500	0.6	1
4 Leaf	23	575	0.8	0
5 Leaf	27	660	1.6	2
GPD	35	925	3.2	2

Flag	49	1,290	2.7	2
Boot	59	1,550	2.5	2
Reproductive				
Heading	67	1,710	0.9	1
Flower	70	1,850	3.5	2
Soft Dough	85	2,210	2.7	2
Hard Dough	98	2,510	1.8	None
Black Layer	108	2,700	3.9	None
Grain Harvest	136	3,100		None
Total water use through hard dough based on ET			23.6”	

†Water use will depend greatly on climate—hotter conditions will lead to more water evaporation from the soil as well as higher transpirational water use by the plant.

water to be applied during an irrigation event if you are able to irrigate at full ET, irrigation system efficiency should be accounted for by using the following equation:

Target irrigation depth to apply = Irrigation demand / Irrigation system efficiency

This correction factor is necessary when using the crop coefficient (Kc) noted above, which defines water use by sorghum whereas inefficient irrigation requires more water applied.

With rising energy and water costs and declining water levels, wasted or underutilized water has the potential to directly impact sorghum profitability. To maximize the return on water and pumping cost inputs, it is recommended that irrigated producers make use of high efficiency irrigation systems such as subsurface drip irrigation(SDI) and low elevation center pivot sprinklers (LESA and LEPA) wherever feasible (Table 2). To reach sorghum yield potential, an SDI, LESA or LEPA irrigation system should be designed or nozzled at 4 gallons per minute per acre (gpm per acre) or higher. (In contrast maximum corn water needs would likely translate to 5-6 gpm per acres.) At lower system capacities, irrigation should begin earlier in each crop stage to ensure that soil moisture reserves are present to buffer sorghum water needs during the rapid growth and reproductive stages. (Table 4).

Tracking Soil Moisture Levels

You may use soil moisture monitoring devices such as tensiometers, gypsum blocks or even the simple soil probe to determine soil moisture levels and the date to restart irrigations after rains. For more information on these methods, see Texas AgriLife Extension's "Irrigation Monitoring with Soil Water Sensors," B-6194, *http://agrilife-bookstore.org*

Irrigation Costs

In most sorghum regions, the most significant portion of irrigation cost is related to the energy consumed during pumping or delivery (if by canal). Historically, natural gas and electric pumping plants offer the lowest cost per unit of water pumped, typically by a significant margin. Where natural gas pipelines or electrical service 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, and should be avoided except in very specific situations. Regardless of energy source, the following operational practices universally promote lower irrigation water costs:

- Irrigate to crop needs, not irrigation system capacity.
- Regularly maintain and/or replace irrigation motors and pumps—many producers do not realize that pumping plant inefficiency can sig-

Table 5. Depth of irrigation water applied over time at various irrigation system capacities.

Cumulative Inches Applied						
GPM/ Acre	Daily	Weekly	30 Days	45 Days	60 Days	90 Days
2.0	0.11	0.74	3.2	4.8	6.4	9.5
2.5	0.13	0.93	4.0	6.0	8.0	11.9
3.0	0.16	1.11	4.8	7.2	9.5	14.3
3.5	0.19	1.30	5.6	8.4	11.1	16.7
4.0†	0.21	1.48	6.4	9.5	12.7	19.1
4.5	0.24	1.67	7.2	10.7	14.3	21.5
5.0	0.27	1.86	8.0	11.9	15.9	23.9
6.0	0.32	2.23	9.5	14.3	19.1	28.6
7.0	0.37	2.60	11.1	16.7	22.3	33.4
8.0	0.42	2.97	12.7	19.1	25.5	38.2
9.0	0.48	3.34	14.3	21.5	28.6	43.0
10.0	0.53	3.71	15.9	23.9	31.8	47.7

†Approximate minimum irrigation capacity to water grain sorghum at full ET; reduced irrigation capacities can still be managed to produce high yielding sorghum using timely application of irrigation.

nificantly diminish efficiency and increase costs.
- If your irrigation supply company, local water district or extension staff offer irrigation system efficiency testing then take advantage of it.
- 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.

How much does it cost me to pump or deliver 1 inch of irrigation water?

Unfortunately, most producers do not have an approximate answer to this question. When Extension asks this question of producers, too many reply they do not know, and other say they will look at it when they get their next bill. You need to know, not just for sorghum, but for all your crops. This is particularly important when grain prices are low. If grain sorghum is only $5 per hundred weight and you figure your production at 400 lbs. per acre-inch (see above), then the gross return is $20 per acre-inch. But if pumping costs you $11 per acre-inch then you may conclude that this is insufficient return at this lower sorghum price and another crop may provide a better economic opportunity. On the plus side, however, grain sorghum has both lower input costs per unit of return, and better suitability to limited, timely irrigation, so producers should consider this aspect based on net return compared to crops like cotton or corn where production costs are significantly higher.

Failure to consider cost of irrigation or the potential return based on favorable commodity prices can lead to unfortunate unintended consequences:

- Producers select and plant longer-season hybrids and/or higher seeding rates that can outstrip rainfall and irrigation capacity.
- Upon realizing the lack of return in some seasons for sorghum irrigation, producers reduce or even stop irrigation.
- Then the field is left more susceptible to significantly reduced production potential because the hybrid maturity is too long and the seeding rate is much too high.

Tips for Furrow Irrigation

(From 'Irrigating Sorghum in South and South Central Texas,' Charles Stichler)
Furrow irrigation is best timed according to the plant's stage of growth. Furrow irrigation and timing is not as exact as sprinkler irrigation. If furrow irrigation is managed well, most water applications will be about 3 to 4 inches per irrigation. A good guide is to apply irrigations at key growth stages if there is no rain and additional soil moisture is needed:

- If the soil profile is full at planting, the stored soil moisture should supply the water requirements until the first irrigation at the reproductive stage.
- The onset of the reproductive stage is 35 to

40 days after planting. One 4-inch furrow irrigation will last the 25 days until flag leaf.

- At flag leaf or boot stage, two 3-inch irrigations about 2 weeks apart will last until soft dough in the grain fill period.
- The last irrigation will maximize yield, but is generally not economical and does not pay for the water. One 3- or 4 inch-irrigation is needed beginning at soft dough to complete grain fill, which will take approximately another 3 weeks to physiological maturity.

Using this schedule, the appropriate amount of irrigation water will be applied during each growing period if rainfall is not received. If those amounts are totaled for the entire growing period, the amount need by the crop will approximate the following:

6-8 in. rainfall or pre-irrigation
to fill the soil profile if totally dry
+
4 in. 30 days after planting
+
6 in. in two 3-in. irrigations
at flag leaf or boot stage
+
3 in. at soft dough
=
19-21 in. of total water

The 19 to 21 inches of irrigation is the amount of water needed to produce a crop without stress. The total amount needed will vary somewhat depending on weather conditions such as heat, humidity, cloud cover and wind.

Common Mistakes in Grain Sorghum Irrigation and Water Usage

Growers need to avoid these common mistakes affecting water usage in South Texas (Charles Stichler):

- Waiting too long to put on the first irrigation. The head begins to form about 35 days after planting. If the plant is stressed during this period, the number of potential seeds per head will be reduced.
- Irrigating too late. Do not irrigate for yield after the soft dough stage. Also do not irrigate after the plants have reached physiological maturity, which is up to 45 days after flowering or at black layer. After that point, the individual seed's "umbilical cord" is sealed off and stops functioning. It will not gain any more weight after this event, which occurs at about 30% moisture.
- Over-planting. For full irrigated production, do not exceed 70,000 to 80,000 established plants per acre; dryland production should not exceed 50,000 to 60,000 established plants per acre and even this is likely too high when soil moisture is limited and drought occurs. Over-planting reduces head size, increases the chance of charcoal rot and lodging, increases plant competition and increases water use with little increase in yield. Proper irrigation management is critical for profitable yields. If you pay attention to timely

and adequate irrigation, you can keep costs to a minimum while maximizing production.

Summary of "Top Tips" for Grain Sorghum Irrigation

Statewide Texas AgriLife Extension Service and Texas AgriLife Research staff

- Begin the sorghum season with significant water reserves in the soil profile. This is best accomplished by maximizing off-season precipitation capture with minimum tillage and residue management practices. Pre-plant irrigation is not generally recommended for sorghum because of reduced efficiency of the applied water (which makes the water expensive).
- In arid and droughty conditions, low elevation precision application (LEPA) irrigation coupled with furrow diking and drag hoses is an excellent means to conserve water and maximize economic return on grain sorghum.
- Irrigate immediately following planting to improve germination, plant stand and soil-water reserves.
- Critical in-season irrigation periods are near growing point differentiation (if dry), early to mid-boot stage and early in the grain fill stage. Under limited water conditions, any amount of water during these periods will be beneficial.
- Preference should be given to applying water early during critical crop stages, especially in limited water conditions. Stress caused

by lack of water prior to and during the boot stage and grain-fill stages will define lower yield capacity that cannot be overcome with adequate or excess water during subsequent plant growth stages.

- Smaller, timely applications are recommended for sorghum under deficit irrigation to encourage uniform growth conditions. As little as 6 inches of timely irrigation water on sorghum can significantly increase yields and profitability.
- Irrigation termination should occur following the soft dough stage under typical seasonal conditions.
- On an on-going basis, know how much it costs you to pump or deliver 1 acre-inch of irrigation.
- Avoiding excessive plant populations above what is appropriate for the environment and the projected irrigation level ensures better, more efficient use of irrigation.

Planting

Grain sorghum's practical planting date throughout the region is restricted by too early planting with potentially cool air and soil temperatures that can needlessly retard growth versus delayed plantings that risk sorghum midge potential and flowering/maturation under hotter conditions with reduced rainfall in July and August. Guidelines are provided for what we can and cannot expect from sorghum if planted early or planted late.

Traditional and Practical Rules for Early Grain Sorghum Planting

Grain sorghum agronomics may say one thing whereas regional practicalities may say another when it comes to establishing grain sorghum in your field. Grain sorghum seed has temperature requirements for optimum germination, but farmers in South and Central Texas have practical issues of sorghum midge, and especially as you near the coast storm potential that may influence a planting decision that occurs four or more months earlier. This is why the agronomic optimum time for planting grain sorghum may not be the same as the local and regional practical planting window.

1. **Agronomic** Target grain sorghum no earlier than a minimum of two weeks after your last average spring freeze (see Tables 7 and 8). Last spring freeze temperatures are an

indirect means of estimating when soil temperatures are likely sufficient to not impede good adequate sorghum stand establishment. Sorghum seedlings can recover from a freeze. However, cold soil temperatures during germination can significantly reduce germination, stand, early season vigor and this can negatively affect a crop well into the growing season.

2. **Agronomic** Delay Rule #1: if the average soil temperature has not reached a five-day average of at least 60°F at two inch depth, although an ideal temperature for quick germination and establishment grain sorghum is near 65°F. The minimum soil temperature at the desired planting depth for germination and emergence of sorghum is about 55°F (expect slow growth).

3. **Practical** The single risk of early seedings and subsequent mediocre stand establishment, especially in coastal Texas, may still be a better bet to minimize the combination of multiple potential risks—sorghum midge, a trend toward hotter temperatures, especially at night, later in the cropping season during flowering and grain fill, and storm damage at the end of the cropping season.

- Prolonged wet periods early in the season during the planting window can be quite risky for grain sorghum, especially along the coast, and in soils that have poor drainage. So in the mind of many producers if you can plant now, when fields are dry, in spite of less than optimum temperature conditions, you may need to plant anyway. What will you do if you have two weeks or more of wet fields that delay sorghum planting? Stay with sorghum? If so, reduce maturity? Or even change crops?

- Long-term weather forecasts: 10-day forecasts have improved their prediction of long-term temperature trends and cold fronts. These may simplify your planting plans. If you are planting early and see no indication of a forthcoming cool down, then you can better plant with confidence, and might even be able to reduce your seeding rate since you can assume a higher percentage of seeds are becoming established plants. On the other hand prediction of coastal climate for rainfall conditions is less precise than for continental climates, so recognizing rainfall trends in the next 10 days is more difficult along the coast.
- Reduced rainfall, beginning in June, for the Coastal Bend to Lower Rio Grande Valley—earlier plantings are more likely receive rainfall during grain fill.
- Cool soil temperatures for grain sorghum versus cotton: Grain sorghum and cotton actually have similar optimum soil temperature requirements, but early season cooling is potentially much more detrimental to cotton stand establishment, especially as some cotton seed has poor cold germination vigor, which can affect the crop well into the cropping season.

4. **Practical** If you plant very early when cool soil temperatures are a risk contact your seed dealer for any hybrids that may have better cool soil germination and vigor.

You can view local soil temperatures at:

- http://cwp.tamu.edu, a weather network for soil temperatures, rainfall and several other useful tools that cover the region from Weslaco north through the Coastal Bend to the Upper Gulf Coast as well additional sites in Uvalde and Williamson Co.
- http://researchfarm.tamu.edu/test.txt, the Texas A&M University research farm in the Brazos Bottoms west of College Station.
- http://www.ars.usda.gov/Research/docs.htm?docid=9697 contains current daily soil temperatures from Temple (six inch depth), but only historical data for soil temps at Riesel.
- The Texas Potential Evapotranspiration Network, http://texaset.tamu.edu, offers comprehensive weather information at numerous South and Central Texas sites, but does not provide soil temperature information.

Have you had trouble with sickly seedlings and poor early season vigor in your sorghum crop? If so, then consider your planting date. Increasing your seeding rate to overcome this may be a practical solution, but this is not good agronomics for your sorghum crop. Normally, a sorghum crop is not worth planting too early unless the risk of an early planting is outweighed by factors at and after flowering and maturity (midge, heat, slow drydown, increased potential storm damage).

Are you frequently dealing with significant sorghum midge damage or possible poor grain fill? Sometimes early planting can't be accomplished due to cool conditions or especially wet fields. If delays in planting are increasing your problems with midge or harvest issues, then consider how you can move plantings forward slightly, or perhaps shorten maturity. (We note, however, that in South and Central Texas there are typically only a few days difference in the half-bloom dates for medium-early, medium and medium-long hybrids.) The Lower Rio Grande Valley, Coastal Bend and Gulf Coast regions have about a two to three week window for planting when considering the average last freeze (which is sporadic in South Texas) and flowering to minimize midge issues (Table 6).

This window is much narrower for the region from Uvalde to Guadalupe County where producers must weigh the risk of either early planting and cool soil temperatures (and a late freeze) versus anticipated midge potential. Tables 6 and 7 suggest a practical justification for planting dates based on the window between early cool conditions and planting to minimize sorghum midge potential. What are actual suggested planting dates for different regions of South & Central Texas? Tables 8 and 9 provide Texas AgriLife suggested planting dates and typical 'plant by' dates based on agronomics,

Table 6. Average last spring freeze, early planting date scenarios, and projected 'safe' planting dates for typical medium-long and medium hybrids in South Texas.

Location	Last average spring freeze†	Earliest suggested planting based on last average spring freeze‡	Approx. 'Plant by' date for medium & medium-long hybrids to minimize sorghum midge§	Target 'Flower by' date to minimize sorghum midge
Weslaco			2/25	5/10
Sinton	2/7	2/21	3/10	5/26
Kingsville	2/10	2/25	3/10	5/26
Beeville	2/14	2/28	3/10	5/26
Victoria	2/9	2/23	3/10	5/26
Bay City	2/11	2/25	3/10	5/26
Wharton	2/19	3/3	3/20	6/5
Seguin	3/6	3/20	3/25	6/10
Uvalde	3/10	3/24	3/25	6/10
(above dates set 75 days before last column)				

Table 7 Notes: †30-year averages from Texas Almanac, 2008-2009.
‡Early planting still requires minimum thresholds for soil temperature. An additional 1-week delay will significantly diminish early season planting concerns but might increase risk from sorghum midge or heat depending on location and year.
§Texas AgriLife Research Crop Testing trials in South Texas have found the most common range of days to half bloom for medium-long and medium grain sorghum hybrids of 71 to 76 days from planting. Half bloom @ 75 days is used as a conservative value in this calculation to determine at what point in a typical year you could expect to plant to minimize significant sorghum midge potential. For 2006-2009, average days to half-bloom was only 2 days shorter for a medium vs. medium-long. Refer to the insect chapter for a chart on estimated flower-by dates for sorghum midge in Texas.

yield potential, crop safety, etc. These are, in fact, mostly similar to the previous tables. Since Texas AgriLife hybrid trial data reports that there are for the most part only small differences in crop development from planting to bloom in South and Central Texas, you may use the same duration for medium-early, medium, and medium-long maturities.

Keep in mind that local experience is worth a lot in terms of optimum planting dates. If you have a planting date that is working for you, or a hybrid that is working for you at the planting dates you use, then be slow to change your planting. Due to the rainfall and soil planting conditions that sorghum producers routinely face at planting time, if the window is open to plant, because field conditions are favorable, then you may choose to err on the side of planting early to ensure that you aren't set back by a prolonged wet spell (although that wet spell does not do your sorghum any good).

Table 7. Average last spring freeze, early planting date scenarios, and projected 'safe' planting dates for medium-long and medium hybrids in Central & North Texas.

Location	Last average spring freeze†	Earliest suggested planting based on last average spring freeze‡	Approx. 'Plant by' date for medium & medium-long hybrids to minimize sorghum midge§	Target 'Flower by' date to minimize sorghum midge
Georgetown	3/5	3/19	4/5	6/20
Cameron	3/7	3/21	4/5	6/20
Waco	3/12	3/26	4/10	6/25
Waxahachie	3/14	3/28	4/15	6/30
McKinney	3/21	4/4	4/15	6/30
Sherman	3/22	4/5	4/15	6/30
(above dates set 75 days before last column)				

†30-year averages from Texas Almanac, 2008-2009.
‡Early planting still requires minimum thresholds for soil temperature. An additional 1-week delay will significantly diminish early season planting concerns but might increase risk from sorghum midge or heat depending on location and year.
§Texas AgriLife Research Crop Testing trials in Central Texas have found the most common range of days to half bloom for medium-long and medium grain sorghum hybrids of 71 to 76 days from planting. Half bloom @ 75 days is used as a conservative value in this calculation to determine at what point in a typical year you could expect to plant to minimize significant sorghum midge potential. For 2006-2009 average days to half-bloom was only 2-3 days shorter for a medium vs. medium-long. Refer to the insect chapter for a chart on estimated flower-by dates for sorghum midge in Texas.

Suggested Final Planting Dates: Late-Season Planting?

In contrast to the above agronomic planting date suggestions, on a rare 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 South and Central Texas for plantings to July 1 and even mid-July to the south; however, end-of-the-season factors like midge, drought, tropical storms and poor drying conditions (and for Central and especially North Texas, muddy fields) can greatly reduce the practicality and economic return of a late crop. Perhaps you have tried it before. Some farmers simply say it does not work well.

South Texas—Late grain sorghum may occur when another crop fails, wheat is harvested, but it is risky due to insufficient rainfall. However, it will make modest yields if rain is sufficient. Do not plant so late that heads will not dry.

Central and North Texas—Where rare later fields may be planted into late June, a cutoff date should allow the sorghum to reach black layer 1-2 weeks before your area's average killing frost (or since that data is harder to find, 2-3 weeks prior to the average first freeze, for example, Sherman, 11/11; McKinney, 11/14; Waxahachie, 11/18). This allows for sorghum maturation without significant risk to yield or test weight if a frost or freeze occurs up to 10 days earlier than average. In practical terms, though you can mature a late

Table 8. Range of suggested early (6 to 10-day range), preferred, and last (5-day range) suggested planting dates for grain sorghum hybrids in South Texas. Agronomically, optimum dates for stand establishment in many years may trail suggested early dates by 1 to 2 weeks. The window between early planting dates (cool conditions) and late planting (potential for sorghum midge, hot weather and drought during flowering & grain fill, and rain & tropical storm damage prior to harvest) is unfortunately sometimes less than one month.

South Texas Regions	Suggested early planting date limits	Planting date preferred target	Suggested final planting date limits
Lower Rio Grande Valley	1/21-1/30	1/31-2/10	2/15-2/20
Costal Bend	2/15-2/21	2/22-3/5	3/15-3/20
Upper Gulf Coast	2/25-3/4	3/5-3/15	3/25-3/30
San Antonio Region†			
(Gonzales to Uvalde)	3/5-3/10	3/10-3/20	3/20-3/25

†Agronomic suggestions crowd the last average freeze date for the Uvalde region (March 10, Table 4-1) yet sorghum midge on the back side pinches preferred planting dates in this region to a narrow range. Use of extended 7-10 day weather forecast for this region is strongly encouraged, more so than other regions.

Table 9. Range of suggested early (6 to 10-day range), preferred and last (5-day range) suggested planting dates for grain sorghum hybrids in Central & North Texas. Agronomically, optimum dates for stand establishment in many years may trail suggested early dates by 1 to 2 weeks. The window between early planting dates (cool conditions and last spring freeze, see Table 4-2) and late planting (potential for sorghum midge, hot weather and drought during flowering & grain fill) is unfortunately sometimes less than one month.

Central & North Texas Regions	Suggested early planting date limits	Planting date preferred target	Suggested final planting date limits, primary crop†
Lower Blacklands—(Georgetown to Waco)	3/10-3/15	3/15-3/25	3/31-4/5
Central Blacklands—(Waco to Dallas area)	3/15-3/25	3/26-4/5	4/15-4/20
Northern Blacklands (Dallas to Red River)	3/25-4/4	4/5-4/15	4/21-25

†Some double cropping may occur in Central & North Texas. Later plantings can assume sorghum midge risk and possible drydown issues in the fall if planted mid-June or later.

sorghum crop, can you harvest it? Harvestability is 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 leading to long harvest delays, increased lodging potential, sucker heading, feral hog damage, etc. For these reasons, concluding late planting 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. Local Texas AgriLife staff in the northern Blacklands suggest that plantings after June 1, though easily matured, face harvest timing during the wet fall months when fields might never dry sufficiently to achieve harvest.

Does planting date affect grain sorghum hybrid growth? Yes. Although some hybrids tiller more than others, the same hybrid planted in any location in Texas over a period of time (six weeks and more) will likely have more tillers early in the season. This is most likely triggered by cool conditions. Tillering, though largely regarded as a common and even essential facet of grain sorghum production, can sometimes diminish a crop because it sets too many tillers early in the season then drought occurs, and then the crop's heads per acre is too high to fill very well and yields can actually be diminished because of tillering.

Grain Sorghum Seeding Rates

Planting: Seeds per Acre versus Pounds per Acre
Texas AgriLife has long recommended that sorghum producers base planting on seeds per acre rather than pounds per acre. Grain sorghum seed can vary widely in seed size, often 12,000 to 18,000 seeds per pound with 13,000 to 16,000 being most common. If you have to use seed number per pound (e.g., you have a plate planter rather than an air-vacuum planter) check the seedtag first or choose about 14,500 or 15,000. If you assume 14,500 seeds per pound but the seed was actually 16,500 then you have effectively increased the seeding rate 14% (germination and emergence will probably be similar).

Calculating seeding rates can be done two ways.

Seeding rate:

$$\frac{43{,}560 \text{ sq. ft.}}{\text{Acre}} \times \frac{12 \text{ inches}}{\text{Row spacing(in.)}} \times \frac{\text{Seeds}}{\text{Foot of Row}} = \text{Seeds/A}$$

For example:

$$\frac{43{,}560 \text{ sq. ft.}}{\text{acre}} \times \frac{12 \text{ in.}}{38 \text{ in.}} \times \frac{3.5 \text{ seeds}}{\text{Foot of row}} = 48{,}145 \text{ seeds/A}$$

Seeds (or plants) per foot:

$$\frac{\text{Target seeding rate}}{43{,}560 \text{ sq. ft. per acre}} \times \frac{\text{Row spacing}}{12 \text{ in.}} = \text{Seeds/foot of row}$$

For example:

$$\frac{55{,}000 \text{ seeds}}{43{,}560 \text{ sq. ft. per acre}} \times \frac{38 \text{ inches}}{12 \text{ in.}} = 4 \text{ seeds/foot of row}$$

TIP: Texas AgriLife found that grain sorghum seeding rate varied by approximately 20% on individual rows of an air-vacuum planter. Even a new planter had significant differences in seed drop that needed correction. Before planting season arrives check your seed drop at both low and high rates to ensure you are planting your target seeding rate. Use Table 10 to help determine an approximate seed drop for each row over a pre-determined length such as 50 feet.

Seeding Rate General Guidelines

Guiding principle-less is more! This principle 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 and you are begging for a rain. Lower plant populations are suited to these drought conditions preserving more moisture per individual plant, thus reducing the plant's stress level. Moisture and yield potential is conserved as less moisture is used to produce unneeded stems and leaves while the crop is better able to wait extra days until that next rain you are hoping for. Furthermore, anywhere in Texas, 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. Reduced seeding rate is perhaps the key for managing grain sorghum production risk anywhere in Texas, unless you have full control of irrigation.

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 soil moisture is limiting, grain yield will be greater if plant population is lower. Furthermore, if soil moisture is favorable due to irrigation or adequate rainfall, there is a level of plant population above which no additional grain yield will be achieved from an increase in plant population. If a modest plant population is used for an area typically limited by adequate moisture and above average rainfall is received, sorghum plants can adjust their grain numbers and weight considerably to compensate for the improved growing conditions.

Depending upon soil moisture conditions, recommended seeding rates vary between 30,000 and 80,000 plants per acre for South Texas. Don't be too quick to assume that your production conditions merit the highest end of this range. Under limited moisture conditions, 2 to 4 plants per foot for 38-inch row spacings will normally use all available soil moisture (Table 12). Irrigated sorghum performs better with no more than 80,000 plants per acre (this would require full irrigation).

Furthermore, Texas AgriLife field tests in the Corpus Christi area examined greatly reduced grain sorghum seeding rates. Yields in the area were maintained by seeding as little as 1/3 of the highest seeding rates that some commercial seed companies recommend, thus reducing

Table 10. Row spacing and seeds per acre and the resulting seeds per foot. For air vacuum planters your planter book lists both the seeds per acre and resulting seeds per foot in combination with the needed planter settings to achieve your targeted seed drop.

Planter Row Width (inches)	Linear Row Feet per acre†	Target Seeding Rate per Acre for South & Central Texas‡							
		30,000	40,000	50,000	60,000	70,000	80,000	90,000	100,000
		Seeds per foot of row							
40	13,068	2.3	3.1	3.8	4.6	5.4	6.1	6.9	7.7
38	13,756	2.2	2.9	3.6	4.4	5.1	5.8	6.5	7.3
36	14,520	2.1	2.8	3.4	4.1	4.8	5.5	6.2	6.9
30	17,424	1.7	2.3	2.9	3.4	4.0	4.6	5.2	5.7
20	26,136	1.1	1.5	1.9	2.3	2.7	3.1	3.4	3.8
15	34,848	0.9	1.1	1.4	1.7	2.0	2.3	2.6	2.9
10	52,272	0.6	0.8	1.0	1.1	1.3	1.5	1.7	1.9

	85%	25,500	34,000	42,500	51,000	59,500	68,000	76,500	85,000
(Common when water and soil temperature are favorable or irrigation is used to establish the crop.)									
	67%	20,000	27,000	33,500	40,000	47,000	53,500	60,500	67,000
(Somewhat less favorable soil, moisture, and environmental conditions including early planting in cooler conditions.)									

†Linear row-feet per acre = 43,560 sq. ft. per acre divided by the row width in feet.
‡Extension encourages producers to think in terms of Seed Drop per acre, not pounds per acre or plants per acre. With air vacuum planters seed size should not affect planting, but note seeds per pound onyour seed bag's analysis tag.

production costs and insulating against potential charcoal and stalk rot development.

TIP: Have you ever had a seed salesman or seed company tell you: "No, that is too high a sorghum seeding rate?" If so, they have your sorghum crop and your best interests in mind. You should consider being their customer a long time. Some seed company websites recommend as much as 10 lbs. per acre for grain sorghum production without saying anything about your rainfall, irrigation level, etc. No sorghum production area in the U.S. requires such an excessive seeding rate! A rate in this range is potentially 150,000 seeds per acre—that almost sounds like a decent hay crop!

Reducing Seeding Rate when Stored Soil Moisture is Low

As noted in other sections, too high seeding rate leads to problems in grain sorghum. The primary concerns are drought and the subsequent potential for charcoal and stalk rots hence lodging. If stored, soil moisture is low or poor (in contrast to planting moisture) and Texas AgriLife recommends that you immediately reduce your seeding rate by at least 10,000 seeds per acre. That would hopefully be more than 10% and as much as a 20% reduction in your seeding rate. This is one way to manage (reduce) risk in your sorghum crop.

As in Table 11, the driest region with the lowest average rainfall of the sorghum production area in South and Central 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 covered in this handbook as plant population can too easily outstrip available water. The goal for this region is to make a crop, not a mistake (too high seeding rate), to provide the producer the best possible chance for a modest yield in spite of prolonged dry conditions. Table 11 below notes a five-year trial in which lower populations were sufficient to meet the yield potential of the conditions.

Why are some rainfed Texas grain sorghum fields seeded at more than 100,000 seeds per acre? It is the practice in some areas of Texas in the Upper Gulf Coast to use seeding rates that may go up to 120,000 seeds per acre and as high as 140,000 seeds per acre on the best ground where high inputs are used. No Texas AgriLife tests have ever reported significant yield increases from these excess seeding rates. In contrast, the conclusion of numerous Texas AgriLife trials has noted that reduced seeding rates, even lower than those suggested in Table 11, have maintained yield potential on par with higher seeding rates.

Do relatively inexpensive sorghum seed costs affect seeding rate? Yes. Farmers often cite the fact that sorghum seed is inexpensive as a reason why they do not bother with reducing seeding rates. Inexpensive seed costs mean that a producer is not concerned much by using a high

Table 11. Suggested seeding rate targets and resulting plant populations for South & Central Texas. Lower seeding rates are suggested a) when stored soil moisture is low at planting, b) for later plantings when soil temperatures are up (stand establishment will be much improved), and c) if you have a history of drought that may lead to potential lodging from overpopulation. In contrast, early planting subject to cool wet conditions could lead to a stand establishment in the 50-60% range thus the higher end seeding rate is suggested for those conditions.

Texas Region	Targeted Plant Pop.	Targeted Seedling Rate to Achieve Plant Population
Lower Rio Grande Valley & 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	80,000-95,000
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 & North Texas		
Rainfed, particularly early plantings	60,000-70,000	70,000-80,000
Rainfed, with later plantings and/or low stored soil moisture	50,000-60,000	60,000-70,000

Table 12. Dryland sorghum seeding rate results from five years of testing at Uvalde (38" rows) demonstrate the lack of benefit of excessive seeding rates (courtesy Charles Stichler, former Extension agronomist, Uvalde).

Plants per Acre	Estimated Seed per Acre @ 75% Establishment	Yield (lbs ac-1)
27,000	36,000	2,360
41,000	55,000	2,750
55,000	73,000	2,640
76,000	101,000	2,570

seeding rate if planting early in cool conditions so that he will still have an adequate stand. If seed costs were two or three times higher, high seeding rates would be reduced to agronomic rates and producers would likely be more hesitant to plant early in cold conditions.

Planter Row Spacing and Seeding Rate

Depending on the area predominant row spacing is 30 inch, 36 inch, 38 inch or 40 inch rows. A few producers use 15 inch or 20 inch rows on occasion by either drilling or using an interplant 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 to 40 inches can help shade the soil faster and reduce weed growth.

Further research in the Coastal Bend and Uvalde (Table 13) regions has shown that narrower row spacing (for example 19 inch versus 38 inch) has fairly consistently produced slightly higher yields (seeding rate held the same).

One Texas AgriLife test in the Corpus Christi area found that grain sorghum yields increased 10 to 26% 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.

Sorghum plants are more efficient when each plant is given space to intercept sunlight and competition between plants is minimized. In addition, closer spacing (i.e., double row or narrow rows) will promote shading of the soil surface to reduce evaporation losses and provide weed suppression.

Table 13. Irrigated sorghum seeding rate and row spacing from five years of testing at Uvalde demonstrate the potential advantage of narrow row spacing in grain sorghum (Courtesy Charles Stichler, former Extension agronomist, Uvalde).

Plants/A	Estimated Seeds/A at 75% Establishment	Yield(lbs/A -1) Row spacing	
		26”	38”
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

TIP: We recommend you do not increase your target plant population per acre if you move from wider row spacing to narrower rows—let the sorghum plant compensate for you in the field lest you err by raising seeding rate too much. Furthermore, maintaining the same seeding rate guards against the potential effects of over-populating a field.

For narrow row seeding, a planter perhaps with a second set of planter boxes (e.g., Kinze interplant planter) is preferred, but if you use a drill follow these guidelines:

- Consider plugging 1 of 2 or 1 of 3 holes to ensure that you can lower the seeding rate, especially if drilling (calibrate the drill, don't just assume the settings are accurate, especially since seed size varies). The value of good seed placement with a planter under adverse conditions to ensure a stand at low seeding rates may make drilling undesirable.
- If using a drill, increase seeding rate no more than 10% over what you would use with a planter only if you expect reduced stand establishment due to decreased desirability of seed placement with a drill.
- By all means avoid overseeding on narrow rows. If you bump the seeding rate up substantially thinking you might have trouble getting a stand but all the seeds come up due to a good rain you immediately and irreversibly have too many plants per acre in a crop that will have higher susceptibility to drought.

TIP: Where ever you farm in Texas, if you are having doubts about whether you need to increase your seeding rate, don't do it! Apart from a stand failure or major insect damage you will rarely if ever see a South Texas sorghum field that was too thin for its production environment.

CAUTION: Over Seeding Equals Speeding! If you drive too fast at the risk of your safety and well being, the police or highway patrol will stop you and you are cited for 'failure to control speed.' Likewise, in grain sorghum production speeding is akin to 'failure to control seeding rate!,' and the risk is to your sorghum crop's yield potential and your balance sheet's bottom line.

Likewise, in grain sorghum production speeding is akin to 'failure to control seeding rate!,' and the risk is to your sorghum crop's yield potential and your balance sheet's bottom line.

Seeding Rate May be more Important than Hybrid Selection

You can spend a lot of time selecting a good hybrid choice, but you can quickly undo your hybrid's potential by seeding too high. This does not diminish the importance of hybrid selection, but serves as a reminder to ensure seeding rate decisions are given your best effort.

Successfully Seeding Your Selected Grain Sorghum Hybrid

Consider these TIPS to ensure success:

- Ensure that sorghum seed sits on good moisture.
- Typical sorghum seeding depth is near 1.0-1.5 inches, but
- 2.0 inches can lead to emergence problems and a spindly seedling. Sorghum can emerge in a hurry in a couple of days from 1 inch depth if conditions are warm.
- There is no substitute for local producer experience; if you've had trouble getting sorghum to emerge, ask your neighbors for suggestions.
- Particularly in rainfed production, minimize possible soil crusts by dragging dry soil back over the seed row to reduce drying and baking of the soil if hot weather prevails. This will enhance seedling emergence.

Fertilization

Grain sorghum production in Texas ranges from low input rain-fed production to high-input full irrigation. Hence soil nutrient status is highly variable. Crop rotation and the frequent producer practice to fertilize only when a certain crop is in rotation means that residual fertility may be more important. Likewise, tillage and fertilizer placement practices will affect the nutrient use efficiency of grain sorghum.

Soil Testing

Many producers do not realize the extent of research and testing that is behind the process of analyzing soil samples for nutrients and the subsequent recommendations they generate. A realistic goal for many producers is to take a soil sample every three years.

Different Philosophies of Soil Test Recommendations

There are two common approaches to soil fertility recommendations for the same crop and production conditions. Each has its own merits and can be used successfully although these approaches can generate recommendations that seemingly are at odds with each other.

1. Provide what the crop needs for current-year production. Based on your yield goal, your current soil nutrient status and that nutrient's projected availability to your crop, add

the level of nutrients needed to fertilize your crop for this year. This approach in terms of out-of-pocket expenses, costs less and also may reduce potential nutrient losses due to leaching or other means. This is most likely the approach that state labs take.

2. Build-and-maintain soil nutrient status. Most likely this means fertilizing to maintain a higher long-term residual level of nutrients in the soil. Nutrient levels may be in excess of the crop's requirement, but also not at a luxury or wasteful level that squanders money. This approach, provided there are ample nutrients available, may guard against unexpected limitations in nutrient availability or higher crop demand if yields are higher than expected. This philosophy is more likely to be found among private labs.

TIP: If you have a fertilizer dealer, crop consultant or other third party collect and submit soil samples for you, be sure to obtain a sample of the soil test report itself. Understand what the report is saying, and keep it in your records for the farm or field for up to 15 years so that you may track changes in the soil over time (Table 14).

Why are there differences between soil sample report recommendations?

Different methods of soil sample nutrient extraction and analysis

Have you ever submitted samples of the same soil to two different labs? You might have found different recommendations. Although, labs within a given region of the country tend to have uniform testing procedures, this is not always the case. For example, there are different tests for soil P (soil pH may dictate which one should be used). Labs may use a different extractant for the soil, or once they have obtained the extract for nutrient analysis may use a different method of measuring the nutrient in the extract which could be affected by other constituents in the sample. These differences lead to different test values of nutrients measured in your soil.

Different fertilizer recommendations

As noted above there are differences in the philosophy of soil testing. Provided the soil test value for a particular nutrient is the same, then build-and-maintain would likely have a higher fertilizer recommendation. This philosophy may be the normal approach to recommendations by a test lab. Apart from differences in philosophy the calibration curves plotting nutrient requirement for a unit of yield are not necessarily the same. One lab may recommend 2 lbs. of N per hundred weight of sorghum yield goal, whereas another recommends 2.5. Or, a particular lab's recommendations might include additions or deductions to their calculation that are not factored in by a different lab.

TIP: When your soil test lab, fertilizer dealer, crop consultant or other third party provides fertilizer recommendations, do the following:

- Ask about their philosophy of soil test recommendations as noted in Nos.1 and 2 above.
- Furthermore, if you are receiving fertilizer application recommendations without the benefit of soil test results, then ask about the guidelines used in arriving at those recommendations.
- Finally, if you receive recommendations without having even provided a yield goal then you need to question the recommendations closely to ensure that at least a minimum agronomic basis and not a pure sales motive alone is guiding fertilizer plans.

Texas A&M University Soil Testing Lab

The College Station lab provides complete fee-based services for soil, plant tissue and water analyses. Texas AgriLife testing across Texas on grain sorghum (as well as other crops) forms the basis for soil test recommendations for samples. For more information on services, submittal forms (including the Soil Profile N form discussed below) and how to collect and submit representative samples visit http://soiltesting.tamu.edu/. A key soil test procedure that Texas A&M uses, which is now a common standard across many labs, is the Mehlich III extractant. Soil test numbers (but not necessarily the recommendations) using this method compared to other procedures will vary, especially for P. The Mehlich III test is better suited for the varied soil types across Texas. The test has been key to improving P recommendations for the state.

TIP: When choosing a soil test lab, inquire if the lab is accredited by a state agency or certification board, a participant in the North American Proficiency Testing program, or some other testing standard guidelines. This ensures that the lab meets recognized standards and practices that are foundational for providing you with good test values and recommendations.

TIP: If you already use or consider using a soil test lab that is far removed from the region or state where your soil was sampled, call them to ensure they can provide you with results based on suitable test procedures and recommendations for your soil type and your crop (especially if your crop is not grown in that state).

Sorghum Nutrient Requirements
Nitrogen

"You can't get something from nothing for very long"

Occasionally in Texas, particularly where rainfall is lower (especially less than20 inches), farmers may fertilize grain sorghum minimally or not at all, even for nitrogen. To some extent this 'just-get-by' attitude resulted from low grain sorghum prices, but it may also reflect poor attitudes and the lack of success on the part of many producers due to too-high seeding rates and little thought in hybrid selection. Sorghum indeed responds to nitrogen.

Nitrogen(N) is by far the most important nutrient for sorghum to maximize production. For maximum yields relative to the available water, N

Table 14. Approximate nutrient uptake and removal by grain sorghum per acre for major nutrients.

	Nutrient Uptake†			Nutrient Removal‡		
Yield	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Pounds per Acre						
2,000	60	21	55	30	15	8
4,000	120	42	110	60	30	16
6,000	180	63	165	90	45	24
8,000	240	84	220	120	60	32
10,000	300	105	275	150	75	40

†Nutrient uptake at the rate (per cwt.) of 3.0 N, 1.1 P2O5, 2.75 K2O. Nutrient uptake is the total taken up by the crop grain and above ground vegetation. These numbers should be used only as general guideline (Potash & Phosphate Institute). ‡Nutrient removal at the rate (per cwt.) of 1.5 N, 0.75 P2O5, 0.4 K2O

should not be lacking or grain development will be reduced. The long-standing general N nutrient requirement for Texas grain sorghum is:

N requirement:
2 lbs. actual N (soil or fertilizer) per acre per 100 lbs. of yield goal

Thus a 5,000-pound grain yield would need about 100 lbs. of N per acre. In Texas this has often been presented—erroneously—to producers as the amount of N fertilizer to add without acknowledging available soil N. However, the Texas A&M University soil test lab recommends using the above rule but correctly deduct nitrate-N from a soil test in the top 6 inches as noted below.

Texas A&M Recommendation:
(Fertilize 2 lbs. actual N/acre per 100 lbs. of yield goal) - (soil N at 0-6 in.)

Hence for the same yield goal noted above, but with a soil test report showing 9 ppm NO3-N for a 6-inch deep sample (which is about 2 million lbs. of soil), the calculated N fertilizer addition is:

Fertilizer N to add:
(2 lbs. N/acre)X(50 cwts./A yield goal)–(2 X 9 ppm) = 82 lbs. N/acre

This N recommendation, particularly when the soil N is deducted, is more conservative (lower) that what is normally generated in other states such as Kansas or Oklahoma which each use a more complicated formula or include other adjustments, but AgriLife Extension recommends Texas producers maintain the simple rule of thumb above. When soil test information is not available this rule will help producers at a minimum to be in the range of meeting the sorghum's N requirement for good yield.

Soil Profile N Test from Texas A&M—Sampling and Crediting Soil N Below 6 in.

Ideally soil testing for N would use a 24 inches depth sample (in contrast to 6 inches for P, which is largely in the surface, or the standard depth noted above in most soil tests). Research in several areas of Texas across several crops is frequently showing a significant amount of N below the surface 0-6 inches. One way to systematically assess for this potential deeper soil N is the use of the Soil Profile N Test from Texas A&M. In this testing protocol a producer collects and submits a paired soil sample, 0-6 inches for N, P, K, and other nutrients, and preferably a 6-24 inches for nitrate N analysis only. This test potentially captures extra N deeper in the soil. If soil test N is available for depths below 6 inches then credit that 100% N toward your N requirement thus reducing fertilizer N applications and their cost.

(Fertilize 2 lbs. actual N per acre per 100 lbs. of yield goal) - (PROFILE N at 0-24 inches)

The Texas A&M University Soil Testing lab has a special form for these paired samples at http://soiltesting.tamu.edu/files/profilesoil.pdf On the form you record the depth of soil collected below 6 inches. In addition, crop rotations may affect residual N and often credits are assigned to soil N if the previous crop was a legume.

Nitrogen Applications after Sorghum Emergence

Side-dress N applications with knives or coulters should be made about 20-25 days after germination (4 to 5 leaf stage) to ensure good N fertility in advance of initial growing point differentiation (30-35 days after germination) while minimizing any root pruning. Later applications may excessively prune feeder roots and miss the potential benefits to GPD.

Under center pivot irrigation, N fertilizer may be applied several times during the early part of the growing season. Due to the convenience of pivot-applying N especially in the High Plains, up to 20% of N might be held back until after GPD, but Extension recommends that the final N be applied no later than boot stage which is about 60 days after germination for a full-season hybrid and no later than about 50 days for a medium maturity hybrid. About 70% of the needed N for a grain sorghum crop is already in the plant at boot stage.

Because N is relatively mobile in the soil, fertilizer placement is not as critical for N as it is for most other nutrients. Nitrate-nitrogen, NO3-N, the form most available to grain sorghum, will move with water and can be readily brought into contact with crop roots for quick absorption.

Ammonium-nitrogen (NH4, also available to plants) is positively charged and is held by negatively-charged clay and organic matter particles in the soil until converted by soil bacterial action into the nitrate form. The conversion from ammonium to NO3-N in the soil—nitrification—is most likely to occur when fields are arable. When fields are water-logged, nitrate can be converted to nitrogen gas—denitrification—and lost from the soil by volatilization.

Guidelines for Surface Applied N Fertilizer

Ammonium-based fertilizers are more susceptible to volatilization losses when applied to the soil surface if no rain or irrigation occurs. Three key factors reduce the effectiveness of the surface-applied N leading to volatilization losses, particularly when acting together:

- Moist or wet soil
- pH is greater than 7
- Increased temperature, windy conditions

Extension always recommends where possible that producers using broadcast N fertilizer apply to dry soil. Furthermore, applying N prior to a predicted rain or scheduled irrigation is particularly advantageous.

Starter Fertilizer and Salt Injury Potential—Suggestions for Grain Sorghum

Starter fertilizer application for sorghum is a sound practice in Texas. Even if soil tests like phosphorus (P) are in the "medium" range, one of the purposes of "starter" fertilizer for N and P is to "kick-start" or stimulate growth right after emergence. Starter fertilizer research, especially in Kansas has shown that rooting and early growth is promoted by starter fertilizer applications in the 2 inch x 2 inch configuration (from the seed, 2 inches to the side and 2 inches below). Starter fertilizer can be applied with the seed, the so-called "pop-up" fertilization, but at rates much less than the 2 inch x 2 inch placement. A common concern is potential salt injury and ammonia damage if the rate of starter 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, NH3, can be toxic to seed (see below).
- Phosphorus fertilizer (e.g., triple superphosphate, 0-46-0, etc.) does not cause injury to seedlings, but most P fertilizers used in Texas contain N (e.g. 11-52-0, 10-34-0), so follow the below guidelines for N (Table 16).

Table 15. Suggested maximum fertilizer salt amounts (lbs. N-K2O-S/acre) for seed row fertilizer placement, row spacing, and soil type.

	Loamy-Clayey Soil				Sandy Soil			
	--------- Row spacing (inches) -----------							
Fertilizer Placement	15	20	30	40	15	20	30	40
Pop-up (w/ seed)	10-15	8-12	5-8	6	10	8	5	4
2” x 2” pattern	80	60	40	30	40	30	20	15

More salt-forming N and K fertilizers can be applied to loamy and clay based soils than to sandy soils. Narrower row spacings allow more N and K as well. Pop-up starter fertilizer rates are much lower than starter fertilizer 2 inches from the seed. If the total amount of N fertilizer applied to your sorghum is 60 lbs. N and A, and you are on 20-inch rows, than the entire dose could be applied as a 2 in. X 2 in. starter on loamy and clayey soils. However, in most cases, the balance of the N fertilizer will have to be sid-edressed. This can be as 32-0-0 either dribbled or knifed in 6 to 10 inches off the row without the threat of injury, applied through a pivot or using a broadcast spreader.

Some starter N fertilizers have potential for injury from ammonia (NH3) because they either contain NH3 or an N form that quickly converts to NH3 gas. This is primarily a concern with pop-up fertilization. For pop-up applica-tions with the seed producers should avoid urea ammonium nitrate (32-0-0 or 28-0-0), mixtures of 32-0-0 and ammonium thiosulfate (28-0-0-5S), solid urea (46-0-0), mono-ammonium phosphate or MAP (11-52-0) and diammonium phosphate DAP (18-46-0).

For sample calculations as well as additional row spacings consult "Starter and In-Furrow Fertilizer & Salt Injury Potential," (Bronson) at http://lub-bock.tamu.edu/sorghum

Phosphorus (P2O5)

It is difficult to gauge needed P requirements for grain sorghum or any crop without soil test information for P in the 0-6 inch depth. Table 17 notes soil test P levels and their relative designa-tion such as very low, low and moderate (20-50 ppm, a very wide range). Soil test P levels above 50 ppm are high. Using the Mehlich III soil test method, the crop response in most of Texas to fertilizer P is inconsistent between 30 to 40 ppm (the transition zone of soil P response), and measurable yield differences are not demonstrated above 40 ppm soil P.

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, as well as P nutrition in general, lends itself well to either banded or in-furrow application of P. Fertilizer P itself is not salt forming or toxic to plants at higher levels of P. See comments above on allowable banded and pop-up P fertilizer rates when N is a component of the P fertilizer.

Since soil P is relatively immobile or "fixed" in most Texas soils, placement in a concentrated form is particularly important in low to medium testing soils. Research has shown that plants obtain a higher proportion of their needed P from soil reserves. Only about 30% of applied P is used by the crop following fertilization in the current year, even though it may have been banded.

Texas AgriLife does not offer a general rule of thumb for P2O5 needs for grain sorghum like we do for nitrogen. However, when soil test P levels are very low, tables from several states' extension soil test guidelines cite a P2O5 requirement for fertilizer that is approximately 50% N (and 40%

for low soil test P, 25% for moderate soil test P). This would reflect the fact that much P comes from residual sources.

TIP: If you do not know your soil P status, are without a soil test, but are willing to band P then consider a P_2O_5 rate that is about one-fourth to one-third of the N rate. Increase the target rate of P if you believe your residual soil P is low.

TIP: Fertilizer P applied in a band is more efficient than broadcast P. As a general rule of thumb producers may be able to reduce P applications by as much as 20% if fertilizer is applied in a band due to relative increased availability of P.

Potassium (K_2O, or Potash)

Soil K levels in South and West Texas are generally high and unless soil K levels have been diminished greatly, it is likely that only top end grain sorghum yields would consider K additions. Texas A&M University soil test guidelines project the K requirement at 2 lbs. K_2O/A per hundred weight, however, the soil test levels are normally sufficient (if not well in excess) to preclude fertilizing with potassium. Exceptions to this rule in most Texas sorghum production soils include sandy soils with low organic matter in the eastern third of the state, however, the acreage involved with this condition will be small.

Table 16. Phosphorus recommendations for grain sorghum in Texas.

Soil test Mehlich III	Yield Goal, bu/A (lbs./A)†				
	40 (2,240)	80 (4,480)	120 (6,720)	160 (8,960)	200 (11,200)
(ppm)	---------------- Lbs. recommended P2O5/A* ----------------				
0-5 (Very low)	35-40	65-70	80	80	80
5-10 (Very low)	30-35	60-65	80	80	80
10-15 (Low)	25-30	50-60	80	80	80
15-20 (Low)	20-25	45-50	70-80	80	80
20-25 (Moderate)	15-20	35-45	60-70	80	80
25-30 (Moderate)	15-20	30-35	45-60	60-80	80
30-35 (Moderate-High)‡	---	20-30	35-45	45-60	60
35-40 (Moderate-High)‡	---	---	20-35	30-45	50
40-45 (Moderate-High)§	---	---	---	15-30	30

*Table 16 P2O5 levels reflect Texas A&M Soil Test lab grain recommendations, however, regional Texas AgriLife soil research results in both West and South Texas suggests published recommendations may be slightly higher than needed, perhaps by 5-10 lbs. per acre for these regions. †P2O5 rates are capped at 80 lbs. In severely depleted P soils, yield could potentially respond at higher rates of P. Visit with your Extension agronomist about severely depleted soil P conditions where a high yield goal is desired. ‡West and South Texas soil research suggests that 30-40 ppm soil test P is a "transition level" at which yield responses to additional fertilizer P are inconsistent. §West and South Texas soil research suggests P fertilizer additions at this level of soil test P do not demonstrate measurable yield differences.

clude fertilizing with potassium. Exceptions to this rule in most Texas sorghum production soils include sandy soils with low organic matter in the eastern third of the state, however, the acreage involved with this condition will be small.

Iron (Fe) and Zinc (Zn)

Two other important nutrients for grain sorghum production in South, Central, and West Texas are iron(Fe) and zinc(Zn). Zn is not commonly an issue in sorghum (it is for corn), but iron deficiency related to high pH (usually pH ≥ 7.8), whether it be alkali spots in South Texas, carbonitic soils in the Blacklands or caliche soils in West Texas is a particular concern for sorghum. Soils that produce spotty yet heavy Fe deficiency across the field in South Texas or have more uniform chalky soils in the High Plains should probably never be used for grain sorghum production. It is prohibitively expensive to correct Fe deficiency. 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. Fe deficiency compared to N deficiency. Fe deficiency is normally expressed mostly on newest leaves, and Fe is immobile within the plant. When Fe 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, N 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 N deficiency symptoms.

Most soil tests will flag Fe less than 4 ppm as deficient. Currently, there are no economical sources of soil-applied Fe available. Therefore, the only options for correcting Fe deficiencies are to apply foliar Fe sprays in-season or to apply manure for long-term correction. If Fe chlorosis has been observed during previous years in a field, Fe fertilizer materials may be applied preemptively to the foliage through multiple sprayings early in the season. Table 17 gives suggested foliar treatments to correct iron as well as Zn deficiencies.

For further information about Fe consult 'Correcting Iron Deficiencies in Grain Sorghum' L-5155, from Texas AgriLife Extension (http://agrilifebookstore.org or contact your local county extension office).

Zn: Where soil P is 'very high' or 'high' and Zn levels are low then further P application may induce Zn deficiency particularly when soil pH is high. If soil test results indicate a possible Zn defi¬ciency (less than one ppm Zn), Zn 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.

Other Nutrients in Texas Sorghum

Unless you have had a particular problem in the past with sulfur, calcium, manganese, etc., there is no fertility correction likely needed. Noting other nutrients and their levels in soil test reports is probably sufficient for keeping an eye on possible imbalances.

Foliar Feeding Major and Minor Nutrients

In general foliar feeding is expensive. Extension does not recommend that producers rely on foliar feeding for N due to the far higher per unit cost of N. A possible exception in Central and South Texas would be if a planned sidedress application of N could not be performed due to continued wet fields. 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. Otherwise, significant amounts of micronutrient sprays are used that probably provide little if any benefit (‘feel good’ or ‘catch all’ treatments). Micronutrient deficiencies other than iron are hard to diagnose without experience and/or a tissue test. Non-chelated sources if available and applied with a good sticking agent can be quite effective and perhaps a better buy.

Table 17. Suggested sources, rates, and timing of iron or zinc foliar sprays.

Deficiency	Product †	Product/100 gal water	Product/A	Timing
Iron	Iron sulfate (20% Fe)	20 lbs (2.5% solution)	1 lb. then 2-3 lbs.	10-14 days after emergence - 5 gal/A over crop row. Follow with 2 apps. @ 10-14 day interval @ 10-15 gal/A
	Iron chelate ‡ (10% Fe)	4-8 lbs. (0.5-1%)	0.25-0.5 lbs.	Same as above
Zinc	Zinc sulfate (30% Zn)	2 lbs. (0.5%)	0.2-0.4 lbs.	10-20 gal/A in first 30 days
	Zinc chelate (9% Zn)	2 qts. (0.1%)	1 pint	10-20 gal/A in first 30 days

†Include a surfactant or other wetting agent. Product composition may vary. Select similar products or adjust mixing ratios to achieve comparable rates of nutrient applications.
‡ Iron chelates range in concentration and chelate strength; consult label directions for actual recommendations as well as the cost compared to iron sulfate applications.
Source: Updated information based on research results and recommendations through the Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory.

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 in sorghum must begin in the months and days prior to planting. Eradication of weeds prior to planting is extremely important in sorghum production due to the limited number of herbicides available for selective post emergence control. This is especially true for weeds such as Johnsongrass and perennial sharppod morningglory. 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 that any soil residual herbicide used is safe for planting sorghum.

The yield loss associated with sorghum due to weed competition is greater than that of most grain crops. Typical losses range from 30 to 50% but in extreme cases can result in complete crop failure. Depending on your region of South or Central Texas the most common weeds and weed problems include Texas panicum, pigweed (carelessweed) species, barnyard grass, smell melon, johnsongrass, shattercane and morning glory. Any of these can be the source of angst among producers is needed to avoid yield losses, but control as best we can, it can be achieved. Studies have shown that even one pigweed within 24 inches of grain sorghum across a field can reduce yield nearly 40%. 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 afterwards. The most critical period for weed control is the first 4 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. Large pigweed plants and morning glory vines can slow up harvest and damage machinery.

Therefore, it is important to keep weeds such as these managed during the growing season and not let them become uncontrollable.

Broadleaf Weed Control

Most weed control strategies should consider the use of atrazine (and perhaps propazine if rotating to cotton) either applied prior to planting, at planting, prior to crop emergence or applied soon after crop emergence. Atrazine is relatively inexpensive and will control most broadleaf weeds. Restrictions and rates of atrazine use vary considerably depending on state and local requirements. 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. If atrazine cannot be used or is ineffective on the weeds present, then other herbicides should then be considered.

Pigweed and common waterhemp MUST be controlled with preemergence herbicides or properly timed applications of 2,4-D or dicamba when the weeds are small (2-4 inches). If you miss them, there are few selective herbicide options left that will provide control of these species when they get large.

Other commonly used herbicides applied prior to sorghum and weed emergence are propazine, metolachlor, alachlor and dimethenamid (Table 18). These are sold under a host of trade names. Propazine is very effective on many broadleaf weeds and is safer on the sorghum crop than atrazine. The other three herbicides are more specific on which broadleaf weeds they will control and generally do not control the weeds for as long. Combining atrazine with any of the three improves overall control of broadleaf weeds.

Herbicide labels are constantly being updated. Before using any herbicide check the label for specific use under your conditions. Most state extension services provide updated herbicide lists and specific weed control recommendations. For a current summary of herbicides labeled for grain sorghum in Texas consult Brent Bean's "Quick Guide for Weed Control in Texas High Plains Grain Sorghum,"http://amarillo.tamu.edu/programs/agrilife_programs/agronomy/agronomy_sorghum.php then click on the appropriate link, or contact your local extension office.

Herbicides commonly used after crop and weed emergence are listed in Table 19 along with a brief description of their strengths and weaknesses. Check label for rates, application timing and other restrictions. All of these can be used in combination with each other. 2,4-D and dicamba 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 up to 15 inch sorghum. Care should be taken to minimize drift of 2,4-D and dicamba or damage to other broadleaf crops and ornamentals can occur.

Table 18. Popular pre-emergent herbicides by active ingredient name (common trade names).

Atrazine (AAtrex, atrazine)	Primarily broadleaf weed control. Long residual.
Propazine (Milo-Pro)	Good annual grass control with some broadleaf activity. Must use Concep III treated sorghum seed.
Metolachlor (Dual II Magnum, Cinch, Parallel, Me-Too-lachlor)	
Dimethenamid (Outlook)	
Alachlor (Micro-Tech)	
Atrazine + Metolachlor (Bicep II Magnum, Cinch ATZ)	Broadleaf weed and grass control. Must use Concep III treated sorghum seed.
Atrazine + dimethenamid (Guardsman Max. G-Max Lite)	
Atrazine + alachlor (Bullet, Lariat)	
Others	See state and local Extension service recommendations for other pre emergent herbicides.

Table 19. Popular broadleaf post emergent herbicides by active ingredient name (common trade names).

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, others)	Will control most broadleaf weeds, crop injury can be significant and drift to cotton fields is a concern.
Dicamba (Banvel, Clarity, Vision)	Will control most broadleaf weeds, crop injury can be significant and drift to cotton 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, morningglory, and devilsclaw.
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.
Others	See state and local Extension service recommendations for other post emergent herbicides.

Grass Control

There are no effective herbicides that can be used after the crop and grass has emerged in grain sorghum. Either metolachlor (Dual, Cinch, Parallel, Me-Too-lachlor), alachlor (Micro-Tech) or dimethenamid (Outlook) must be applied prior to crop and weed emergence. The sorghum seed must be treated with a herbicide seed safener (Concep III) or crop injury will occur. The effectiveness of control of annual grasses will depend on the specific grass species as well as other factors. However, these are the best products currently available for annual grass control. These three products are often sold in combination with atrazine and this combination is your best hope for control on Texas panicum. All herbicides applied pre-emergence require a minimum of 0.5 inches of rain or irrigation to move them into the soil. An alternative to rain or irrigation is to incorporate the herbicides with a rolling cultivator prior to grass emergence. However, care must be taken to avoid damaging the sorghum.

Perennial Weeds

Johnsongrass is the main perennial weed that causes the most problem having the potential to completely eliminate any significant grain sorghum yield. Bindweed is also a major problem in some Texas sorghum areas. Prevention is the best method of control with these weeds. Once Johnsongrass or other local perennial weeds are found producers should do everything possible to prevent their spread. Do not run tillage equipment through isolated spots of these weeds (especially bindweed) as this will tend to spread them to other parts of the field. Diligent spot treating with glyphosate (Roundup) for Johnsongrass and dicamba, 2,4-D, glyphosate and even some soil sterilants for bindweed will be required to eradicate these two weeds. For Johnsongrass that is already widespread, the best control method is to allow the Johnsongrass to emerge prior to sorghum planting. Once the Johnsongrass has about 6 inches of growth treat it with glyphosate. 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 4 weeks after planting. Grain yield will be considerably better than if no control was attempted.

Where severe infestations of Johnsongrass or other weeds are present, applications of Roundup through hooded or shielded sprayers may be warranted. Roundup may be applied through these devices after the sorghum is 12 inches tall. Extreme care should be taken to avoid herbicide contact with the sorghum plants. Refer to your specific glyphosate (Roundup) label for further instructions and precautions regarding this use.

The glyphosate treatment procedure outlined above can also be effective on bindweed. In addition, early in-season treatment of 2,4-D or dicamba should be considered. Another herbicide, quinclorac (Paramount), can be used alone or in combination with 2,4-D or dicamba. Quinclorac is safe on sorghum and can be very effective.

New Advances

Some very promising new herbicides for both broadleaf and grass control will soon be on the market. Continue to check with herbicide dealers and the extension service for information about new products. New grain sorghum hybrids will be available in the next five years that are tolerant to two classes of herbicides giving producers many more herbicide options. For the first time producers will be able to control Johnsongrass as well as annual grasses (including shattercane) with herbicides applied after the sorghum and grass has emerged.

Herbicides, Grain Sorghum and Crop Rotation Restrictions

Cotton Herbicides and Rotation to Grain Sorghum

Staple—NEVER plant grain sorghum in a cotton hailout or replant situation after Staple has been applied (label says do not plant in the year following an application). Even banded applications present a major concern. Though high irrigation or rainfall may diminish Staple residues, significant sorghum injury can still be expected the year after Staple was applied. Don't try to "get by" if Staple was applied, as it is highly risky. Furthermore, grain sorghum is not labeled for Staple the following year after application.

Trifluralin/Prowl—Growers are familiar with the risk associated with cotton failure and subsequent attempts to plant back to grain sorghum. Because trifluralin and similar herbicides do not move much in the soil, in contrast to Staple which is much more soluble and harder to predict where it could be. Buster planting can usually move the treated soil away from the sorghum with success.

Know, however, that the Treflan label states "In portions of Texas receiving less than 20 inches of rainfall or irrigation to produce a crop, unless crop injury is acceptable, do not plant sorghum (milo) for 18 months after an application of Treflan 4EC. In sorghum, cool, wet weather conditions during early growth stages may increase the possibility of crop injury. In areas that receive more than 20 inches of rainfall and irrigation, sorghum planting 12 months after spring application or 14 months after fall application is permitted." Prowl H2O restriction is 10 to 12 months for spring and fall applications.

Valor—In a cotton crop failure situation do not plant grain sorghum for one month.

Other cotton pre-emerge herbicides—Should be OK the next year. For example, the rotation restriction for diuron and Layby Pro is 8 months. Table 20 outlines some additional rotation restrictions.

Table 20. Additional major crop herbicides and rotation restrictions to grain sorghum (incomplete list).

Wheat & Small Grains	Corn	Peanut or Soybean
Amber 75 DF {triasulfuron}, 14	Nicosulfuron (Accent &	
Stinger {clopyralid}, 10.5	Steadfast), 10 or 18	Cadre, 18
Maverick Pro {sulfosulfuron}, 22	Pursuit (Clearfield), 18	Pursuit, 18
Beyond (imazamox) (Clearfield), 9	Corvus, 9 or 17	Raptor, 9
Ally XP {metsulfuron methyl}, 10		
Glean {chlorsulfuron}, 14-25		
Finesse (Glean + Ally) {chlorsulfuron + metsulfuron methyl}, 14-26		
Olympus {propoxycarbazone-sodium}, 12		
Olympus Flex, 9		
Rave 59 WDG {triasulfuron + dicamba}, 14		

Grain Sorghum Herbicides & Rotation to Cotton

Peak (prosulfuron)—22 month restriction

Atrazine and the many products that contain atrazine—the main labels for atrazine products state:

- If applied after June 10, do not rotate with crops other than corn or sorghum the next year, or injury may occur.
- In the High Plains and Intermountain areas of the West where rainfall is sparse and erratic or where irrigation is required, use only when corn or sorghum is to follow.
- Cotton can be planted the following year, but as noted elsewhere there are specific restrictions on use rates and soil types for use in sorghum which may affect rotational cotton.

Propazine—Currently propazine is used sparingly in Central Texas, most likely on sandy soils often in Central Texas river bottom ground. Ironically, the label states that cotton must be planted at least 12 months after a broadcast application of 1.2 quarts per acre (the full rate) in West Texas, which would be medium and fine-textured soils. In contrast for other Texas sorghum regions the label states cotton, only after 18 months, even though propazine is rated as less risky to cotton than atrazine. This clearly tips the scales to atrazine since it is labeled for 12-month rotation to cotton in all of Texas not to mention atrazine costs much less. Nevertheless, because there is limited propazine use, details about its use and comparison to atrazine are noted in Table 21.

Table 21. Comparative details of propazine vs. atrazine for Texas sorghum-cotton rotations.

Parameter	Propazine	Atrazine, 24(c) label
Cost	~2X of atrazine	
Soil pH	No restriction	<8.5, no caliche, cuts, etc.
Organic matter	No restriction	Minimum, 1.0%
Soil texture exclusions	Loamy sand, sand (incorporate shallow on sandy loam soils)	Sandy loam, loamy sand, sand
Application timing	Not labeled for post-emerge	Pre-plant, pre-emerge, post-emerge?
Rotation to cotton	None	Yes, depending on application timing, rain + irrigation
Tank mixes	Many (see label)	Many (see full label)
Minimum carrier volume:		
aerial	3 gal/A	Not listed on 24(c)
ground	10 gal/A	10 gal/A
Additional info.	50 mesh screens min. 30-40 psi agitate well	50 mesh screens 35-40 psi agitate well

Texas AgriLife Weed Scientist Comments on Propazine vs. Atrazine

Wayne Keeling, Research weed scientist, Lubbock, (806) 746-6101, wkeeling@ag.tamu.edu

The following reflect research observations, an analysis of producer experience, and potential limitations for propazine in grain sorghum weed control.

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

Atrazine

- Atrazine rates are greater than or equal to 1 lb. per acre should be OK to minimize sorghum injury potential and rotating back to cotton.
- For sandy loam soils reduce rates to about 0.75 lb./A or even slightly less if you expect potential carryover.
- Watch for atrazine in metolachlor/alachlor mixed herbicides like Bicep II (Lite) Magnum, Cinch II (Lite), Bullet, Lariat.
- For sandy soils, early POST may be slightly better than PRE, but weeds must be small.
- POST safer but still potential carryover issues
- Atrazine on sandy soils does present risks, however, due to possible injury to current-year sorghum and cotton or wheat in rotation.

Propazine

- Preplant and pre-emerge applications (not labeled post-emerge), excellent on pigweed, with some help on troublesome broadleaf weeds.
- Propazine must be pre-emerge to any weed;

application to young sorghum probably not injurious.

- Propazine is safer than atrazine on grain sorghum and for rotating to cotton.
- Rotation flexibility for wheat (120 days) or cotton.
- Tank mix with metolachlor, alachlor, dimethenamid, glyphosate
- 0.75-1.0 qts. per acre (the quart rate) can be rotated to cotton though rates above 0.75 qt. per acre are not for sandy loam soils.
- 1.2 qts. per acre (maximum rate) probably no problem on heavier soils and irrigated sorghum.
- Has minimal to poor activity on grasses at the labeled rates hence not recommended for grass control.
- Mixing with s-metolachlor (Dual, etc.) a good idea, especially for irrigated sorghum, heavy pigweed pressure, and a wet year.
- 0.75-1.2 qts. per acre rates insufficient to control pigweed season-long under challenging conditions, but the addition of Dual could help.
- Dryland—propazine alone probably OK. June sorghum—propazine out in late April-early May would help clean beds, reduce tillage.
- But label suggests applying no more than 28 days before planting.

Additional Considerations for Effective Weed Control in Sorghum

CAUTION: We reiterate that the misapplication of several herbicides whether early, mid or late-season can cause significant injury on grain sorghum. These herbicides include:

- 2,4-D, which is 'hidden' in many herbicides as a second active ingredient (a phenoxy growth regulator herbicide that can cause injury the growing point, cause lodging, etc.).
- Dicamba (Banvel, Clarity, etc.), which is also a co-active ingredient in many herbicides (greatest danger is 'blasting' which leads to flower sterility and a partial to fully blank head).
- Paraquat dichloride (Cyclone Max, Gramoxone Inteon, etc.) for burn down.
- Glyphosate, injury from translocation and reduced growth to plant death.

The potential problems with these chemicals are twofold: 1) chemical applications place too much of the herbicides on the plant or in the whorl, causing injury; 2) errors with both hooded sprayers and mis-directed drop nozzles, which may be due to defective equipment, ground speed too fast, drift within the row and operator error. None of these potential errors are without a solution; attention to detail can solve many of the concerns.

TIP: If you are frequently relying on 2,4-D, dicamba, paraquat or glyphosate mid-season to deal with weed problems, then we need to back up and re-evaluate our comprehensive weed control program to prepare for and attack potential weed issues earlier in the season.

CAUTION: Sprayer equipment, applicators—even labels!—are not perfect. We may be inclined to push the limit on:

1. Herbicide rate (a little more per acre, especially on that sandy soil),
2. Timing (a few days or a week later will not hurt—this leads to increased crop injury OR weeds that germinate or grow larger and become harder to control),
3. Permitting too much herbicide or crop contact.
4. If using 2,4-D in your sprayer equipment, due to the sensitivity of cotton to 2,4-D a separate spray system (not just the tank) is strongly recommended.

The result is too often disappointment, and the outcome when it proves to have been a mistake can not be undone.

Glyphosate Drift from Cotton to Grain Sorghum

Grain sorghum can tolerate low levels of glyphosate drift without long-term impacts but is susceptible to injury. A friendly reminder, however, to neighbors and local aerial applicators might increase awareness of the potential issue.

Your Weed Control Team—Improving Your Employees' Partnership

BENEFIT: The manner in which you train, supervise and verify your employees understanding and their herbicide application methods can pay large dividends. Consider these suggestions:

- Pay to have your permanent employees and/or sprayer operators study and train for their own pesticide applicator's license.

- Then have them take the test.
- When they pass it give them a bonus ($250), which lets them know you value their new skills.

How you verify your staff's mixing and spraying of herbicides can reduce the possibility of a mistake leading to crop injury or worse. Consider these suggestions:

- Confirm and cross-check which chemicals are being used
- Ask questions to double check. There is an effective way to do this:
- What is the potential problem with the following questions?— 'Did you add the four 2.5 gallons jugs of atrazine?' or 'Did you spray 0.75 quarts of propazine per acre at 6 mph?' The problem?—these questions are too easy to answer 'Yes' to. But what if your employee is unsure, or worse, does not know? He does not know and you still do not know.
- Instead ask 'How much atrazine did you add?' and 'Let's double check—What chemical and application rate did you use and what ground speed did you drive?' Your staff can no longer answer 'Yes', rather they have to provide you the information. If they do not know then you DO know there is a problem and resolve it.
- Ride the rig with your staff a couple of rounds even if they have done it for you a lot. There are things you simply see as an experienced operator that can ensure proper

application or recognize something that is not right.

- Communicate how important it is to fix plugged nozzles and other equipment issues right away.
- Teach your staff to CALL YOU before continuing if ground is too rough to maintain speed, hoods are hitting the ground, herbicide is drifting, etc.

Any of these points could reduce the possibility that even just one time you might have a mistake that costs you $5,000, $10,000 or more. The training is worth it as a personal safety issue, but it can also pay off in the mistakes that never happened.

Where Can Producers Go Online to Identify Weeds?

The Texas Weed Information Group (TWIG) maintains a website at http://twig.tamu.edu. This website, however, works best if you already know the name of the weed then you can find pictures, etc. Additional weed ID links are provided that may help you initially identify the weed by name based on its appearance. To visually identify unknown weeds when you do not know the weed name, many Texas AgriLife workers prefer the book Weeds of the West (Western Society of Weed Scienc, 2006, http://www.wsweedscience.org) in contrast to attempting to guess at which pictures to open online when weeds are listed alphabetically and you do not know the weed's name.

Where Do the Weed Scientists Go for Quick Label Information?

- Chemical Data Management Systems, http://www.cdms.net (click on 'Services,' then Labels/MSDS, then type in chemical brand name).
- Greenbook, http://www.greenbook.net, may need to register for use. Allows searches by product or active ingredient. Often database is incomplete as a major chemical label is not found.

Chemical and Worker Safety

Safety with herbicide, fungicide and other chemical applications is paramount. For emergency medical treatment information by phone call 1-800-424-9300 (CHEMTREC) as well as your local 9-1-1. If you have an accident and must require examination and possible treatment take the chemical label with you.

Keys and Concerns for Weed Control in Texas Grain Sorghum

The following weed scientists offer these suggestions regarding weed control tips, concerns and common mistakes in Texas grain sorghum:

Brent Bean, extension agronomist, Amarillo, (806) 677-5600, bbean@ag.tamu.edu; Paul Baumann, extension weed scientist, College Station, (979) 845-4880, pbaumann@ag.tamu.edu; Wayne Keeling, research agronomist, Lubbock, (806) 746-6101, wkeeling@ag.tamu.edu; Todd Baughman, extension agronomist, Vernon, (940) 552-9941, tbaughma@ag.tamu.edu

1. Palmer amaranth and pigweed control—it is a necessity for profitable yields.
2. Mistake: dicamba—applied too late leads to crop injury (as well as reduced weed control effectiveness on larger weeds).
3. Applying 2,4-D or dicamba past the early season labeled stage. Once the growing point is above ground, sorghum injury is more likely. Reduced yield may or may not occur. Potential injury dependent on hybrid. Sometimes injury, including reduced yield, will occur even if these products are applied according to the label.
4. Expecting 100% control of large broadleaf weeds with post emergence herbicides. The smaller the weed the better the control.
5. Expecting atrazine or propazine to control grass. If you get any significant control of grass with these products, consider yourself fortunate.
6. Thinking you have atrazine or propazine tolerant weeds. Most of the time herbicide failures with these two products are a result of either poor application timing, or an environmental issue. For example, if weeds germinate and emerge prior to rainfall or irrigation to incorporate the herbicide, weed control failure will occur.
7. Mistake—Unwillingness to run hooded sprayer: this tool indeed is an effective option to protect grain sorghum but still get many weeds knocked back.
8. Mistake– no pre-emerge herbicide is used, and it gets weedy, then what do you do?

Most Common Weed Issues—South and Central Texas

1. Texas panicum (colorado grass)
2. Pigweed (carelessweed) species (including Palmer amaranth, common waterhemp).
3. Barnyard grass
4. Johnsongrass
5. Shattercane
6. Smell melon
7. Morning glory (sharppod)
8. Parthenian ragweed
9. Wooly croton
10. Sunflower
11. Henbit (in winter fallow)
12. Broadleaf signalgrass

In addition to the extension and research weed staff noted in this guide, South and Central Texas producers may also draw on the expertise other Texas AgriLife herbicide and weed staff:

James Grichar, research weed scientist, Beeville, (361) 293-6326, wgrichar@ag.tamu.edu
Mike Chandler, research weed scientist, College Station, (979) 845-8736, jm-chandler@tamu.edu

Insect Management

Methods of Preventing Insect Pest Infestations

Managing insect and mite pests of sorghum involves actions that prevent pests from increasing to high enough numbers to cause economic damage (Table 22). These practices help avoid pests, reduce their abundance, slow their rate of increase, lengthen the time it takes them to reach damaging levels, and/or increase the plant's tolerance to the insect pest.

These actions include:

- Crop rotation
- Destroying the previous crop (helpful in reducing southern corn rootworm, sorghum midge, etc.), volunteer, and alternate plant hosts (e.g., Johnsongrass)
- Hybrid selection, seedbed preparation, and seed treatment
- Planting time
- Fertilizer and irrigation
- Biological management methods, including protecting beneficials

Sampling and Determining Economic Injury Levels

Because sorghum insect pest levels can change quickly, it is beneficial to scout insects once a week, unless otherwise noted. The major exception is sorghum midge, which may require scouting daily during flowering so as not to miss a sudden increase in their number in the field.

The full Texas AgriLife Extension sorghum insect guide contains further details on scouting and sampling techniques (Figure 3).

Economic injury levels will vary based on the projected or contracted price of the grain as well as insecticide and application costs. Economic injury levels, however, should be regarded as in making decisions about pest insect control.

Seed Treatments

Seed treated with Gaucho® (imidacloprid), Poncho® (clothianidin), or Cruiser® (thiamethoxam) can be purchased to manage southern corn rootworm, greenbug, yellow sugarcane aphid, chinch bug, stink bug, wireworms, false wireworms, and grubs. Recently Extension has suggested the efficacy of these treatments may extend to about 45 days from planting. Texas AgriLife trials with many of these seed treatment products has produced varied results in part depending greatly on the insect and a particular region in Texas.

Bottom Line: Consult your local IPM agents of regional Extension staff for trial results and observations in your area. Many of these insecticide active ingredients are now often packaged with seed fungicides as well (e.g., CruiserMaxx). See the hybrid selection section for comments about price considerations when purchased on your planting seed.

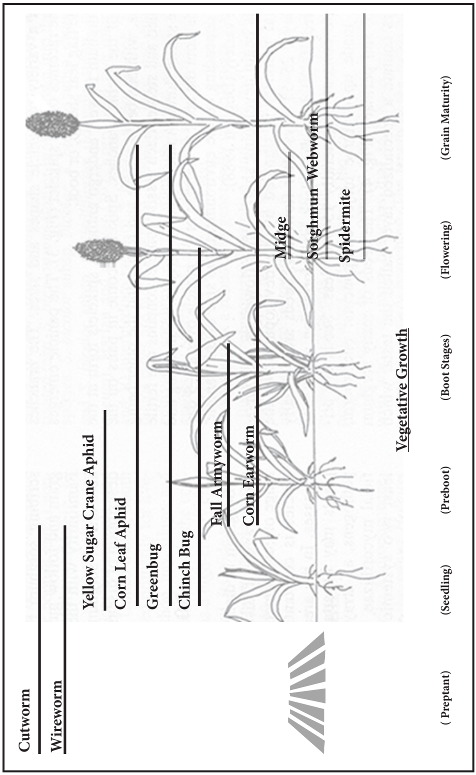

Fig. 3. Consists of data compiled by the University of Arkansas Extension Service which outlines the time-frame (shown in darkened line) when common insect pests are more likely to occur during the sorghum growing season.

Table 22. According to AgriLife Extension entomologists, the pests that can potentially cause the most serious economic damage in Texas grain sorghum are:

Major Pests	High Plains Rolling Plains Concho Valley	Central Texas Coastal Bend South Texas
Southern corn rootworm	No	Yes
Greenbugs	Yes	Yes
Yellow sugarcane aphid	Yes	Yes
Corn leaf aphid	Minor	Common, not severe
Spider mites	Yes	
Sorghum head-worms— corn earworm and fall army worm	Yes	Yes
Rice stink bug	No	Yes
Sorghum midge	Yes	Yes

Major Soil Insect Pests of Texas Grain Sorghum

Wireworms and False Wireworms
Description: True and false wireworms are immature stages of click and darkling beetles. Wireworms generally are shiny, slender, cylindrical, and hard-bodied. Color ranges from yellow to brown.

Time of attack: Primarily planting to a few days after germination.

Damage: Wireworms feed on planted sorghum seed, preventing germination. To a lesser degree, they feed on seedling plant roots.

Sampling: Two to three weeks before planting. Sift soil for wireworms or set up bait stations for examination before planting.

Economic threshold: One wireworm larva per square foot (4 inches deep) or two or more larvae per bait trap.

Major suggested insecticides: Seed treatments- imidacloprid, clothianidin, thiamethoxam; at planting - terbufos.

Southern Corn Rootworm
Description: Southern corn rootworm is the larval stage of the spotted cucumber beetle. Rootworms are small, brown-headed and creamy white with wrinkled skin.

Time of attack: Planting to mid-vegetative stage prior to boot.

Damage: Larvae burrow into germinating seeds, roots and crowns of sorghum plants. Symptoms of rootworm damage include reduced stands, lower plant vigor, and the occurrence of "dead heart" in young plants. Plants may be more susceptible to lodging later in the season. Damage by southern corn rootworm is most likely to occur in the Texas Coastal Bend area.

Major suggested insecticides: Seed treatment—clothianidin, thiamethoxam; at planting—chlorpyrifos, terbufos.

Yellow Sugarcane Aphid (Photo 3)*

Description: Usually lemon-yellow, but under some conditions are pale green. They are covered with small spines and have two double rows of dark spots on the back. Both winged and wingless forms live in the colony. They often feed on nearby Johnsongrass or dallisgrass.

Time of attack: Seedlings and older plants to near whorl stage in Southern Texas. Yellow sugarcane aphid tends to be a later season pest on the High Plains; high numbers on seedling and whorl stage plants are seldom observed.

Damage: Yellow sugarcane aphids feed on sorghum and inject toxin into leaves of seedlings and older plants. Aphids feeding on seedling plants turn the leaves purple and stunt growth. On more mature plants, leaves turn yellow. By the time discoloration symptoms are visible, plants have been injured significantly. Damage often leads to delayed maturity and plant lodging that may be worsened by associated stalk rots.

Sampling: Determine presence soon after sorghum plants emerge. Purple-colored seedling plants are an indication of infestation. Scout sorghum by inspecting plants beginning the first week of plant emergence, then twice weekly until plants have at least five true leaves. As plants grow larger, they become more tolerant of aphid feeding. Very small seedling sorghum plants (one to three true leaves) often are significantly damaged after being infested for a week or less. Discoloration symptoms may be useful in assessing yield losses, and may be used in a decision to replant.

Economic threshold: See Texas AgriLife sorghum insect guide for tables. Decision is based on the percentage of yellow sugarcane aphid-infested plants at 1, 2, or 3 true-leaf stage. There are no established thresholds for later infestations.

Major suggested insecticides: Seed treatment—clothianidin, imidacloprid, thiamethoxam; foliar—dimethoate.

Corn Leaf Aphid (Photo 2)*
Description: This dark bluish-green aphid is oval-shaped, with black legs, cornicles and antennae.

There are winged and wingless forms. Corn leaf aphids are found most frequently deep in the whorl of the middle leaf of pre-boot sorghum, but also found on the undersides of leaves, on stems or in grain heads.

Time of attack: Most likely active from pre-boot sorghum to head exsertion.

Damage: This insect rarely causes economic loss to sorghum and in fact may be considered helpful as they attract beneficial arthropods to grain sorghum, many of which feed on greenbugs and yellow sugarcane aphids. Corn leaf aphids often infest the whorl and undersides of sorghum leaves in great numbers. When feeding, corn leaf aphids suck plant juices but do not inject toxin as do greenbugs and yellow sugarcane aphids. These aphids are common, but their presence does not necessarily mean significant damage is expected. The most apparent feeding damage is yellow mottling of leaves that unfold from the whorl.

Economic threshold: None. Often present, but rarely a pest.

Major suggested insecticides: Rarely justified. Seed treatment—imidacloprid, thiamethoxam; at planting—phorate, terbufos; post-emerge/foliar rescue, several products.

Greenbug (Photo 1)*
Description: Adult greenbugs are light green, approximately 1/16 inch long, with a character-

istic darker green stripe down the back. Usually, the tips of the cornicles and leg segments farthest from the body are black. Winged and wingless forms may be present in the same colony. Females produce living young (nymphs) without mating. Under optimum conditions, the life cycle is completed in seven days. Each female produces about 80 offspring during a 25-day period.

Time of attack: Greenbugs are active throughout the life of the plant. The greenbug may be a pest during the seedling, the boot, and the heading stages.

Damage: The greenbug is an aphid that sucks plant juices and injects toxin into sorghum plants. Greenbugs usually feed in colonies on the undersides of leaves and produce honeydew. Infestations may be detected by the appearance of reddish leaf spots caused by the toxin greenbugs inject into the plant. The reddened areas enlarge as the number of greenbugs and injury increase. Damaged leaves begin to die, turning yellow then brown. Damage at the seedling stage may result in stand loss. Larger sorghum plants tolerate more greenbugs. Yield reductions during boot, flowering and grain-development stages depend on greenbug numbers, length of time greenbugs have infested the plants, and general plant health

Sampling: Scout seedling sorghum, examining the entire plant and the soil around the base of the plant. Note the presence or absence of greenbugs and any damage to plants (yellowing, death of tissue). Usually only the undersides of lower leaves need to be examined, although in some cases greenbug colonies may be found first on the undersides of upper leaves. Greenbugs in a field can increase 20-fold per week, but the seasonal average is a five- to six-fold increase each week. Examine a minimum of 40 randomly selected plants per field each week. Greenbugs are seldomly distributed evenly in a field, so examine plants from all parts of the field; avoid examining only field borders. In fields larger than 80 acres, or if making a control decision is difficult, examine more than 40 plants.

Economic threshold: When deciding whether to control greenbugs, consider the amount of leaf damage, number of greenbugs per plant, percentage of parasitized greenbugs (mummies), numbers of greenbug predators (lady beetles) per plant, moisture conditions, plant size, stage of plant growth and overall condition of the crop. It is important to know from week to week whether greenbug numbers are increasing or decreasing. Insecticide treatment is not justified if the recommended treatment level (based on leaf damage) has been reached but greenbug numbers have declined substantially from previous observations (Table 23).

Major suggested insecticides: Seed treatment—clothianidin, imidacloprid, thiamethoxam; at planting—aldicarb, chlorpyrifos, phorate, terbufos; post-emerge—chlorpyrifos, dimethoate, malathion, phorate.

Table 23. Economic threshold levels for greenbug on sorghum at different plant growth stages.

Plant size	When to treat
Emergence to about 6 inches	20% of plants visibly damaged (beginning to yellow), with greenbugs on plants
Larger plant 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% of plants
Heading to	When greenbug numbers are sufficient to cause
Hard dough	death of two normal-sized leaves on 20% of plants

Whorlworms and Headworms—Corn Earworm and Fall Armyworm (Photo 4 and 5)*
<u>Description:</u> Corn earworm and fall armyworm comprise the sorghum headworm complex. They infest the whorls and grain heads of sorghum plants. Larvae hatching from eggs laid on sorghum leaves before grain heads are available migrate to and feed on tender, folded leaves in the whorl.

Newly hatched corn earworm larvae are pale in color and only 1/16 inch long. They grow rapidly and become variously colored, ranging from pink, green or yellow to almost black. Many are conspicuously striped. Down the side is a pale stripe edged above with a dark stripe. Down the middle of the back is a dark stripe divided by a narrow white line that makes the dark stripe appear doubled. Corn earworm larvae have small hairs (microspines) over much of the body. Fall armyworms and true armyworms do not, so the presence of microspines is one way to differentiate between corn earworm and fall armyworm or true armyworm. Fully grown larvae are robust and 1.5 to 2 inches long.

Young fall armyworm larvae are greenish and have black heads. Mature larvae vary from greenish to grayish brown and have a light-colored, inverted, Y-shaped suture on the front of the head and dorsal lines lengthwise on the body. An important management tactic is to use sorghum hybrids with loose (open) grain heads.

Time of attack: Whorl stage and then again from flowering into kernel development as late as hard dough. Infestations occur less often in early- than late-planted sorghum.

Damage: Whorl—Damaged leaves unfolding from the whorl are ragged with "shot holes." Although this may look dramatic, leaf damage usually does not reduce yields greatly. The fall armyworm is more likely to cause significant damage since many more are often found on individual plants. Heads—corn earworm and fall armyworm larvae feed on developing grain. Small larvae feed on flowering parts of the grain head at first, then hollow out kernels. Larger larvae consume more kernels and cause the most damage. The last two larval stages cause about 80% of the damage.

Sampling: Whorl stage—Pull the whorl leaf from the plant and unfold it. Frass, or larval excrement, is present where larvae feed within the whorl. Heads—Begin sampling for head-worms soon after the field finishes flowering and continue at five-day intervals until the hard dough stage. Scouting should also determine the percentage of corn earworm larvae separately from the percentage of fall armyworm larvae. Fall armyworms are often more difficult to kill with pyrethroid insecticides, and a treatable population that is mostly fall armyworm might require a different insecticide than one which is predominately corn earworm. This may be especially important if control is to be directed at a popula tion that is composed of larger larvae.

Economic threshold: Whorl—Larvae within the whorl are somewhat protected from insecticide. Control of larvae during the whorl stage is seldom economically justified, but insecticide application may be necessary if larval feeding reduces leaf area by more than 30% or is damaging the developing grain head or growing point within the whorl. It is very difficult to achieve good control of caterpillars in whorl stage sorghum because the larvae are sheltered from the insecticide while in the whorl. If control is needed, chemigation will provide better results than ground application, which in turn will provide better results than aerial application.

Head—Determining the threshold will depend on the number of larvae per head and the size of the larvae. Consult the Texas AgriLife grain sorghum pest guide for instructions, calculations, and tables to help determine spray thresholds.

Major suggested insecticides: Carbaryl, cyfluthrin, cyhalothrin, esfenvalerate, methomyl, zeta-cypermethrin. (Note: It is more difficult to kill fall armyworms with the pyrethroid class of insecticides.)

Banks Grass Mite

Description: Large numbers of Banks grass sometime occur on sorghum, especially in more arid areas of Texas. After feeding, these very small mites turn deep green, except for the mouthparts and first two pairs of legs that remain light salmon colored. Eggs, laid in webbing on the undersides of sorghum leaves, are pearly white, spherical, one-fourth the size of the adults, and hatch in three to four days. The life cycle requires about 11 days under favorable conditions.

Hot, dry weather may lead to a rapid increase in mites. Also, mites in sorghum may respond as induced (secondary) pests after an insecticide application for a key insect pest such as greenbug. A rapid increase in spider mites after insecticide application may be due to tolerance of mites to some insecticides, the destruction of beneficial insects, and the dispersal of mites from colonies. Spider mites increase more rapidly on moisture stressed plants. Irrigation reduces the potential of mite population reaching damaging levels, but once mites are present, resuming irrigation will not diminish the injury potential from the mites.

Time of attack: Present at low to moderate levels, but worst potential damage occurs after heading to early grain fill.

Damage: Spider mites suck juices from the undersides of sorghum leaves, initially along the midribs of the lower leaves. Infested areas become pale yellow and reddish on the top surface, and the leaf may turn brown. As spider mites increase on lower leaves, infestation spreads upward through the plant. The undersides of heavily infested leaves may have a dense deposit of fine webbing. Increases in spider mite abundance generally occur after sorghum grain heads emerge. Large numbers of spider mites occurring early in kernel development can reduce the ability of sorghum plants to make and fill grain. After kernels reach hard dough, grain is not affected.

Sampling: Inspect the undersides of lower leaves carefully. Mites occur in colonies, first along midribs of leaves. Later, they spread away from the midrib and up the plant to higher leaves. Webbing indicates the presence of mites. Mite infestations commonly begin along field borders and may spread quickly throughout a field.

Economic threshold: Miticides produce varying degrees of success. Historically, insecticidal control of mites in sorghum has been erratic. Thorough leaf coverage is essential, especially since the mites live on the lower sides of the leaves. Ground application equipment with high gallons of water per acre is preferred. Insecticide application may be justified when 30% of the leaf area of most sorghum plants in a field shows some damage symptoms from mite feeding.

Major suggested insecticides: Dimethoate, phorate, propargite.

Sorghum Midge (Photo 6)*
Description: The sorghum midge is one of the most damaging insects to sorghum in Texas, especially in the southern half of the state. The adult sorghum midge is a small, fragile-looking, orange-red fly with a yellow head, brown antennae and legs and gray, membranous wings. During the single day of adult life, each female lays about 50 yellowish white eggs in flowering spikelets of sorghum. Eggs hatch in two to three days. Larvae are colorless at first, but when fully grown, are dark orange. Larvae complete development in nine to 11 days and pupate between the spikelet glumes. Shortly before adult emergence, the pupa works its way toward the upper tip of the spikelet. After the adult emerges, the clear or white pupal skin remains at the tip of the spikelet.

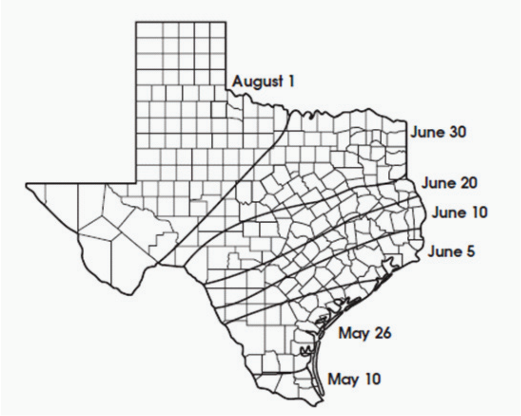

Figure 4. Estimated latest sorghum flowering dates most likely to escape significant damage by sorghum midge.

The simplest and most 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.

Because they are relatively weak fliers and rely on wind currents to aid their dispersal, adult sorghum midges usually are 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 few sorghum midges are found on sorghum grain heads along field edges, there should be little need to sample the entire field.

A generation is completed in 14 to 16 days under favorable conditions. Sorghum midge numbers increase rapidly because of multiple generations during a season and when sorghum flowering times are extended by a range of planting dates or sorghum maturities.

Sorghum midges overwinter as larvae in cocoons in spikelets of sorghum or Johnsongrass. When sorghum is shredded, spikelets containing larvae fall to the ground and are disked into the soil. Sorghum midges emerging in spring do so before flowering sorghum is available, and these adults infest Johnsongrass. Sorghum midges developing in Johnsongrass disperse to fields of sorghum when it flowers.

Time of Attack: Early-season infestations in sorghum are usually below damaging levels. As the season progresses, sorghum midge abundance increases, especially when flowering sorghum is available in the area. Numbers often drop late in the season.

Damage: 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.

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 in an area 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 in deciding treatment methods and in achieving acceptable levels of insecticidal control. To reduce sorghum midge abundance, use cultivation and/or herbicides to eliminate Johnsongrass inside and outside the field. Where practical, disk and deep plow the previous year's sorghum crop to destroy overwintering sorghum midges.

<u>Multiple insecticide applications</u> are used to kill adults before they lay eggs (Table 25). Sorghum planted and flowering late is especially vulnerable to sorghum midge. To determine whether insecticides are needed, evaluate crop development, yield potential and sorghum midge abundance daily during sorghum flowering. Because sorghum midges lay eggs in flowering sorghum grain heads (yellow anthers exposed on individual spikelets), they can cause damage until the entire grain head or field of sorghum has

flowered. The period of susceptibility to sorghum midge may last from seven to nine days (individual grain head) to two to three weeks (individual field), depending on the uniformity of flowering.

Sampling: 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 are most abundant then on flowering sorghum grain heads. 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 about flowering sorghum grain heads.

However, if you find more than one sorghum midge per flowering grain head in border areas of a sorghum field, inspect the rest of the field. Sample at least 20 flowering grain heads for every 20 acres in a field. Flowering heads are those with yellow blooms. Record the number of sorghum midges for each flowering head sampled and then calculate the average number of midges per flowering head. Almost all of the sorghum midges seen on flowering sorghum heads are female.

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

$$\text{Number of sorghum midges per flowering head needed to trigger spray} = \frac{(\text{Cost of control as \$ per acre}) \times 33{,}256}{(\text{Value of grain as \$ per cwt}) \times (\text{Number of flowering heads})}$$

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. The number of flowering heads per acre is determined as described above.

Economic injury levels, as determined from the above equation, are shown in Table 24 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 your actual control costs, crop value and number of flowering heads per acre. Insecticide residues should effectively suppress sorghum midge egg laying one to two days after treatment. However, if adults still are present three to five 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 24. Estimated economic injury levels for sorghum midge for a range of factors. (This table is only a guide. Use the equation in the text to estimate the economic injury level in your field.)

Economic injury level-mean no. of midges/flowering heads				
Control cost $/acre	**Crop value $100/lbs.**	**Flowering heads =18,000/a**	**Flowering heads =45,000/a**	**Flowering head = 67,500/a**
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

Rice Stink Bug and Related Insects

Rice stink bug is a pest of grain sorghum in South Texas and the Coastal Bend. It is one of several species of true bugs, primarily stink bugs, which may move in relatively large numbers from alternate host plants into sorghum during kernel development. Bugs infesting sorghum in Texas 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.

Description: The rice stink bug is straw-colored, shield-shaped, and a half inch long. Females lay about 10 to 47 short, cylindrical, light-green eggs in a cluster of two rows.

Table 25. Suggested insecticides for controlling sorghum midge.

Insecticide	Application rate	Harvest	Graze
Chlorpyrifos **(Lorsban 4E)**	8 oz	30	30
Cyfluthrin **(Baythroid® 2E)**	1.0-1.3 oz	See Remarks	14
Cyhalothrin **(Karate® 1E)** **(Warrior 1E)**	1.92-2.56 oz	See remarks	
Esfenvalerate **(Asana® XL)**	2.9-5.8 oz	21	–
Malathion **(Fyfanon® ULV)**	8-12 oz	7	7
Methomyl **(Lannate®)** **(2.4LV)** **(90WSP)**	12-24 oz 4-8 oz	14 14	14 14
Zeta-cyperme-thrin **(Mustang Max®)**	1.28-4.0 oz	14	45

Remarks: *Cyfluthrin. If one or two applications are made, green forage may be fed or grazed on the day of treatment. If three applications are made, allow at least 14 days between last application and grazing. Cyhalothrin. Do not graze livestock in treated area or harvest for fodder, silage or hay.*

Time of attack: During sorghum kernel development.

Damage: 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.

Sampling: 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.

Economic threshold: Determine the average number of bugs per sorghum head. Then multiply the average number of bugs per head by the plant density per acre to calculate the number of bugs per acre.

Major suggested insecticides: Carbaryl, cyfluthrin, cyhalothrin.

Tips and Concerns for Insects in Grain Sorghum Insects

West Texas

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- Spending the money trying to control worms in the whorl—the insecticide does not get to the insects.

- Though midge in the South Plains is sporadic on late-blooming grain sorghum, failure to check for this insect is a major mistake. Once midge comes it is a potentially huge threat. Prior to your own late sorghum reaching bloom (around Aug. 1 and later in the High Plains) inquire with extension, local crop scouts, chemical dealers if there are reports of midge in the region.
- Failure to adjust to new lower, more accurate thresholds for treating headworms.
- Using or mis-timing pyrethroids in seed and grain production, thus triggering a mite problem.

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- Not utilizing a seed treatment insecticide to control for yellow sugarcane aphid.
- Attempting to treat larvae in whorl stage.
- Triggering secondary pests like mites after a pyrethroid application.
- Blaming lodging problems on insects when it could have very well been water management or the lack thereof.
- Not scouting correctly if at all for midge.

Central & South Texas

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- Failure to use a systematic insecticide seed treatment or in-furrow insecticide.
- Lack of timely scouting for yellow sugarcane aphid.

- Planting sorghum late resulting in high sorghum midge numbers and failure to adequately scout and treat for the midge.
- Use of the incorrect insecticide for rice stink bug.
- Failure to scout properly for rice stink bug and headworms.

Policy Statement for Making Pest Management and Insecticide Suggestions

Labels list product uses for grain sorghum grown for grain. When using products it is impossible to eliminate all risks and conditions or circumstances that are unforeseen or unexpected that could result in less than satisfactory results. Such responsibility shall be assumed by the user of this publication. Pesticides must be labeled for use by the Environmental Protection Agency. The status of pesticide label clearances is subject to change and may be changed since this guide was printed. The USER is always responsible for the effects of pesticide residues on his livestock and crops as well as problems that could arise from drift or movement of the pesticide. Always read and follow carefully the instructions on the container label. Pay particular attention to those practices that ensure worker safety. For information about the registration status of a product and product use, contact a local chemical company representative, a dealer representative, and/or your county extension staff.

The primary Texas AgriLife Extension Service resource for grain sorghum insects was updated in 2007 for insects, new treatment thresholds, and labeled insecticides. "Managing Insect and Mites Pests of Texas Sorghum" B-1220 and "Field Guide to Pests & Beneficials in Texas Grain Sorghum," B-6094 is available at *http://agrilifebookstore.org or through your local county Extension office.*

Texas AgriLife Extension Entomology Staff

Texas AgriLife has Extension entomologists with responsibility in grain sorghum located in Lubbock, Amarillo, San Angelo, Ft. Stockton, Stephenville, Dallas, Corpus Christi, Uvalde, and Weslaco. In addition, most of the sorghum acreage in the South Plains and Concho Valley as well as key production areas in Central Texas, the Coastal Bend, and the Rio Grande Valley are covered by county-based integrated pest management (IPM) extension agents.

Identifying Insects

Contact your local county office or your nearest Texas AgriLife Research & Extension Center for assistance. If the insect still can't be identified then county or regional extension staff can send a digital image or actual specimen to the Texas A&M University Department of Entomology for identification (instructions and submittal form at http://insects.tamu.edu/insectquestions/index.cfm; we recommend further ID be conducted through extension staff rather than submitting directly yourself).

Diseases

Disease:	Stalk Rot
Cause:	Macrophomina phaseolina (Charcoal Rot), Colletotrichum graminicola (Stalk Red Rot/Anthracnose)
Symptoms:	Stalk is spongy, and internal tissue (pith) shredded and often discolored. Plants sometimes turn grayish-green after jointing.
Key Features of Disease Cycle:	Fungi survive on crop residue. High plant population, high nitrogen and low potash can aggravate the diseases. Charcoal Rot is prevalent in hot, dry weather. Stalk Red Rot is prevalent during warm weather with alternating wet and dry periods.
Management:	Use hybrids resistant to Stalk Red Rot and tolerant to Charcoal Rot. Avoid excessive plant populations. Maintain proper soil fertility. Rotate away from sorghum for two or more years following a severe outbreak of either disease. Avoid soybeans and corn for two or more years following severe outbreaks of Charcoal Rot. Azoxystrobin is labeled for management of C. graminicola and Charcoal Rot.

Disease:	Head smut
Cause:	Sporisorium reilianum (syns. Sphacelotheca reiliana)
Symptoms:	At heading, large galls occur in place of the head. Head turns into mass of dark brown, powdery spores.
Key Features of Disease Cycle:	Infection occurs in seedlings from spores in the soil.
Management:	Use resistant hybrids.

Disease:	Leaf spots & blights
Cause:	Setosphaeria, Collectotrichum, Cercospora, Gleocercospera, Ascophyta
Symptoms:	Older leaves are infected first with round, oval, or rectangular leaf spots. Spots are tan, yellow, reddish or purple and sometimes have a darker margin.
Key Features of Disease Cycle:	These fungi survive in crop residue and spores are spread by air currents or by splashing rain. Normally, these diseases do not hurt yields. If the upper leaves become infected, then severe yield losses can occur.
Management:	Use resistant hybrids, especially for no-tillage. Rotate away from sorghum or corn for 1 to 2 years. Control weeds that may be a source of the inoculum. Azoxystrobin is labeled as a foliar spray for Cercospora (Gray leaf spot) control in sorghum.

Disease:	Maize Dwarf Mosaic
Cause:	Maize Dwarf Mosaic Virus
Symptoms:	Irregular, light and dark green mosaic patterns on the leaves, especially the younger leaves. Tan stripes with red borders between the veins ("red-leaf") occurs under cool conditions.
Key Features of Disease Cycle:	The virus lives in johnsongrass rhizomes and other perennial grasses. The virus is transmitted by certain aphids. Late-planted sorghum is at greater risk.
Management:	Use tolerant hybrids and eradicate johnsongrass and other perennial grassy weeds.

Disease:	Root Rot
Cause:	Periconia, Pythium, Rhizoctonia, Fusarium
Symptoms:	Stunting, sometimes leaf yellowing and/or wilting. Rotted roots are pink, reddish brown, or black.
Key Features of Disease Cycle:	Common fungi in soil, but not damaging unless plant is stressed. Common stresses include cool soils, poor drainage, or inadequate fertility. Vigorously growing plants are able to replace damaged roots with new roots.
Management:	Use adapted hybrids. Plant in warm (above 65°F) moist soils at the proper depth and seeding rate. Place herbicide, fertilizer, insecticide and seed properly to avoid stress or injury to seedling. Azoxystrobin is labeled for in-furrow use for Rhizoctonia and Pythium diseases.

Disease:	**Bacterial Stripe**
Cause:	Burkholderia andropogonis (syns. Pseudomonas andropogonis)
Symptoms:	Long, narrow brick-red to purplish-red stripes, becoming tan when dry. Lesions are bound by secondary veins.
Key Features of Disease Cycle:	Bacteria survive in infected seed and in undecomposed sorghum residue. Warm, humid weather favors infection. Generally does little damage.
Management:	Use clean seed. Rotate away from grain sorghum for two years. Control weeds, especially shattercane (Sorghum bicolor). Use resistant hybrids, especially for reduced tillage and no-tillage fields.

Disease:	**Fusarium head blight**
Cause:	Fusarium moniliforme
Symptoms:	The head becomes infected first while stalk tissue at and immediately below the head become infected later. Cream to pink fungal growth can occur on grain.
Key Features of Disease Cycle:	The fungus can occur in seed or crop residue. Spores are spread by air. Warm moist conditions provide a favorable environment for disease development.
Management:	Timely harvest of grain at proper moisture. Hybrids with pigmented seed coats are more tolerant grain mold. Hybrid with dense, compact heads could be more damaged.

Disease:	Sorghum Downy Mildew
Symptoms:	Yellow-green stripes in leaves. "Downy" growth from fungal spores may occur on underside of leaf. Leaves become shredded as season progresses. Heads are partially or completely sterile.
Key Features of Disease Cycle:	The fungus survives in the soil for many years. Spores germinate and infect roots, and colonize plants internally. Infected plants produce spores carried by the air to other plants. Also infects corn and shattercane.
Management:	Use resistant hybrids. Use seed treated with metalaxyl. Control shattercane to reduce inoculum. Long-term rotation to soybeans, wheat or forages reduces inoculum in the soil. Avoid corn-sorghum rotation where the disease occurs.

Harvesting

In South Texas, grain sorghum producers may consider harvest aids, particularly glyphosate, to manage sorghum drydown and harvest for several reasons. These include:

- Provide for easier threshing, by making fields more uniform for harvest, especially if any of the following factors are a concern:
- 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 that has different soil types or is affected by iron chlorosis (which delays maturity).
- 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.
- Minimize potential Gulf storm damage, especially if harvest stretches into August.
- Hasten harvest to meet a delivery/pricing deadline.
- Enact late-season weed control in the field (especially perennials including Johnson-grass) and/or reduce the presence of moist weedy material in the grain.

When conditions are hot and dry and there is no substantial differential in head maturity (primary head versus tillers, and few if any sucker heads), then harvest aids have less to offer and may be of questionable economic benefit. One caveat of applying harvest aids, however, is that 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. Paraquat is not labeled for use in sorghum drydown. Glyphosate is a preferred option among many producers as additional late-season weed control benefits may be achieved, particularly in fields that have significant Johnsongrass. Both chemicals generally state that applications should be made once the field is generally mature (black layer) and seed moisture is below 30%.

For further sorghum harvest aid information in Texas consult Texas AgriLife Extension's "Harvest Aids in Sorghum," L-5435 (http://agrilifebookstore.org, or your county extension office).

Harvesting and Drying

Grain sorghum can be harvested once seed moisture drops below 20%; however, in many areas of Texas few elevators have significant capacity to dry grain. Thus grain needs to be delivered at 14% moisture or less. When drying conditions are favorable (temperatures greater than 75⁰F, breezy, low humidity) grain may lose 1% moisture per day. Your combine operator's manual and harvesting experience will take care of producing clean grain for delivery. The standard test weight for grain sorghum is 56 lbs. per bushel. Nevertheless, there are a couple of key points that guide grain sorghum harvest:

- Timely harvest—Availability of combines: In some Texas regions sorghum producers may not own their own combine. So make harvest arrangements with neighbors or custom cutters well before crop maturity. If it appears that your custom harvester will experience a major delay move quickly to find an alternative.
- Timely harvest—Lodging and standability: The longer grain sorghum stands in the field, the more lodging potential increases. This is most likely when grain sorghum has smaller stalks, or in particular has been stressed by drought which leads to weakening of the stalk as more carbohydrates, sugars, etc. are moved out of the stalk to make grain, and drought-induced stalk or charcoal rots weaken the stalk. Some hybrids may be more prone to lodging as well.

- Timely harvest—Pricing based on delivery or market conditions which may require closer attention to timely combining and the possible use of harvest aids to hasten drydown if the lost pricing potential is somewhat more than the cost of harvest aids.
- Low test weight grain—Severely drought stressed sorghum (or late maturing in the fall) may not achieve maturity leading to low test weights, which may be significantly discounted below 55 lbs. per bushel. (See Table 26 for grading standards).When setting the combine ensure that much of this light low test grain is blown out the back with the trash. Some buyers may refuse to accept grain below 51 lbs. per bushels. Grain that has a test weight in the 40s can be used for cattle feed as the pound-per-pound feed value is about the same as mature grain. Cattle feeders, however, must still grind the grain and will have to set the hammer mill closer hence the grain will be heavily discounted, perhaps 50%.

Simple Yield Estimator

For your row spacing use the Appendix table for footage to equal 1/1000th acre. Cut all heads from this length of row right below the bottom spikelet, weigh, and multiply by 0.70 (slightly less if the grain has dockage moisture in it). Repeat in other locations in the field then average the estimated yields.

Economic Loss from Selling Low Moisture Grain Due to Excessive Harvest Delay

Producers understand the need for timely harvest to minimize potential lodging and the reduction in yield. A hidden loss of gross income, however, comes from delaying harvest well beyond when sorghum can be cut and sold at 14% moisture. How can this happen? Your pay weight is not adjusted up for low moisture, so you don't get to sell water, i.e. any moisture in the seed up to 14% adds to your pay weight.

Example: For grain sorghum at $6.00 per hundred weights. the net effect of each 1% moisture content below the standard 14% reduces your effective yield. In this example, the reduction in pounds of grain to sell translates to a $0.07 per hundred weight penalty per each -1% of moisture of drier grain. For grain at 10% moisture, the reduction in sale pounds is equivalent to receiving $5.72 per hundred weights. Thus for a 5,000 lbs. per acre dryland crop at 14% moisture, the reduction in income is $14.00 per acre if the same grain is sold at 10% moisture. If a producer has 600 acres of this crop then the lost income potential relative to harvesting and selling at 14% moisture is over $8,000. That is sufficient to justify paying a little more for earlier harvest if you can to avoid dry grain in addition to reduced potential lodging losses or storm damage.

If Sorghum Fails, Grazing and Nitrate/ Prussic Acid Issues

When grain sorghum fails due to drought, grazing and baling are options to recapture some value from the crop. Nitrate accumulation in sorghum crops tend to occur only when drought stresses the crop to the point that little growth is occurring, particularly when significant N fertilizer has been applied. Even thought the sorghum is not growing, nitrate accumulation is still occurring in the plants.

Because sorghum in South and Central Texas is almost all planted early and matures long before frost, prussic acid normally would only be a possible issue for grain sorghum for a very late maturing crop that clearly is not going to reach sufficient grain yield for harvest. Prussic acid, however, can occur in the summer on a drought stressed crop that is not growing but then receives rain. The flush of new growth can be hot with prussic acid, especially for new tillers around the base of the plant. In this case (or for a killing frost) the crop should be left ungrazed for a minimum of one week before grazing, or if is swathed for hay, the prussic acid will dissipate in the time it takes to properly cure the hay for baling. For further information consult "Nitrates and Prussic Acid in Forages, E-543 (http://agrilifebookstore.org, or your county extension office).

After Harvest

Managing Grain Sorghum Stubble

What to do with sorghum stubble? A few producers may bale the hay and sell it for extra cash. Keep in mind, however, that the sorghum has value in terms of soil tilth, erosion control, the protection of future cotton seedlings, and the fertilizer replacement cost of the nutrients that leave the field in the hay.

The Lost Value of Nutrients when Sorghum Stubble is Baled

For each ton of stubble removed from a field you are also selling N and other nutrients in the forage, which has a replacement cost when you purchase fertilizer. N content of grain sorghum stubble is about 0.4-0.6% (or about 2.5-3.5% crude protein), so a ton of baled stubble removes about 8-12 lbs of N. At a fertilizer replacement cost of $0.50 per lb. of N, then each ton contains $4-6 worth of N, and about half that value of P, K and other nutrients. This must be factored in to the price of the hay. If a hay harvester offers to buy your standing grain sorghum stubble 'as is' in the field, and he cuts, bales, etc., this is still not 'free money' because of the nutrient losses let alone the intangible value of the stubble for soil and erosion protection.

Grain Sorghum Stubble & Conservation Tillage

If you are committed to conservation tillage, strip tillage or no-till then the opportunity to manage the stubble to optimize erosion protection, increase water infiltration, protect seedling cotton, etc. should be carefully considered. More producers are now inclined to leave at least some of the stubble on the surface, and if no-till works in your production region then even more stubble covers the soil. Depending on your soil type and local rainfall pattern, however, the massive amount of stubble that grain sorghum can leave on the surface, especially since it does not deteriorate as fast as corn stubble, may be detrimental to warming soils for early planting in the spring or drying out sufficiently to plant the next crop.

Producers are encouraged to experiment with tillage options that grain sorghum rotation affords, especially in retaining much or most of the stubble above the surface. Stubble can reduce the amount of light and wind at the soil surface which leads to moisture loss. Keep in mind that achieving the benefits of the ultimate conservation tillage program—no-till—requires patience in both learning how to make the system work AND having the patience to wait for soils to develop aggregation and other properties that will eventually meaningfully and profitably change the way you farm. For further information on the possible role of grain sorghum in conservation tillage on your farm consult Texas AgriLife Extension's "Best Management Practices for Conservation/Reduced Tillage", B-6189 (Charles Stichler et al., 2006) (http://agrilifebookstore.org, or your county extension office).

There are two main philosophies in handling sorghum residue, and both are successful depending on the system adopted, and each minimizes the potential for intact crowns remaining until spring planting thus being difficult to remove with residue managers. These are highlighted in "Reduced/Conservation Tillage in South and Central Texas," L-5436 (Charles Stichler and Steve Livingston, 2003) (http://agrilifebookstore.org, or your county extension office. Furthermore, each method reduces the potential survival of cotton root rot on live sorghum roots.

- In regions around and north of highway U.S. 90, sorghum is best killed with glyphosate preharvest, which allows the decay process to begin sooner. Unlike the root crown on corn that easily decays, the perennial root crown on sorghum keeps growing. Spraying pre-harvest also kills any Johnsongrass or broadleaf weeds prior to harvest, allows the combines to run faster and thresh the grain cleaner and dries out any late blooming heads or green spots in the field. In dryer regions—less than 25 inches of annual rainfall—sorghum and cotton residue decompose very slowly. Most producers in this rainfall region prefer to flail shred to get the residue on the soil, where it will cover and form a mulch.
- In South Texas and the Gulf Coast, where harvest is early, wait until the ratoon and germinating sorghum seed grows to a height of 8-12 inches and spray the field with

glyphosate. By doing this, the residue cannot float from flooding rains, the seed is not buried with a disc and the sorghum root mass decays "in place," adding to the soil structure without exposing organic matter residues to oxygen and biocombustion.

Could I increase my soil organic matter by plowing sorghum stubble in? Probably not. Over time sorghum maintains and increases soil organic matter much more from the roots, but in dryer soils like the Uvalde region or in West Texas soils (which are often quite sandy), there is little stability for organic matter due to heat and lack of moisture. Any tillage operation compounds this as it destabilizes the organic matter you have.

Table 26. Sorghum Grades and Grade Requirements, from the United States Standards for Sorghum, effective June 2008

Grading Factors	Grades U.S. Nos. [1]			
	1	2	3	4
Minimum pound limits of				
Test weight per bushel	57.0	55.0	53.0	51.0
Maximum percent limits of				
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:				
Foreign material (part of total)	1.0	2.0	3.0	4.0
Total	3.0	6.0	8.0	10.0
Maximum count limits of				
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

U.S. Samples grade is sorghum that:
(a) Does not meet the requirements for U.S. Nos. 1, 2, 3, 4; or
(b) has musty, sour or commercially objectionable foreign odor (except smut odor); or
(c) Is badly weathered, heating or distinctly low in quality

[1]Sorghum which is distinctly discolored shall 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 cockleyburs.

Budget & Custom Rates

Crop Budgets for Your Sorghum Crop

Texas AgriLife Extension Service agricultural economics staff have prepared templates for an extensive list of crops including grain sorghum. Specific budgets are available for the above districts at http://agecoext.tamu.edu, then click on "Crop and Livestock Budgets" and select 'District' or 'Commodity' to access the information for your region.

Custom Farming Rates for Texas

In addition, extension compiles custom rates for a variety of field and transportation operations which are summarized by USDA at the above website, then click on "Custom Rates Statistics." Finally, in each extension district above or through your county office, inquire about any comparative crop budgeting tools for your area.

References

1. FAO. 2007. Global Production of Grain sorghum. Online. *http://www.fao.org/docrep/T0818E/T0818E03.htm#Chapter%202%20-%20Production%20and%utilization*

2. U.S. Grains Council. 2008. Sorghum. Online. *http://www.grains.org/sorghum*

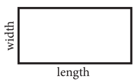
3. National Grain Sorghum Producers Association. Online. *http://www.sorghumgrowers.com/sorghum%20101.html*

4. Kansas Grain Sorghum Producers Association. 2008. Kansas Ethanol Production. Online. *http://www.ksgrains.com/ethanol/kseth.html*

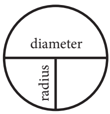
5. U.S. EPA. 2009. Crop Production. Online. *http://www.epa.gov/oecaagct/ag101/printcrop.html*

6. Figure 2. Pocket Guide to Crop Development: Illustrated Growth Timelines for Corn, Sorghum, Soybean, and Wheat. 2003. University of Illinois Extension Publication #C1389.

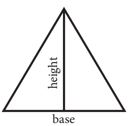
Calculations & Conversions



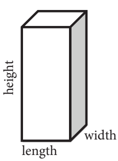
Area of a rectangle or square = length x width



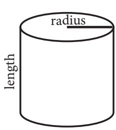
Area of a circle = 3.1416 x radius squared; or 0.7854 x diameter squared
Circumference of a circle = 3.1416 x diameter; or 6.2832 x radius



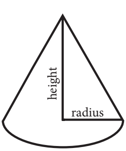
Area of triangle = base x height ÷ 2



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

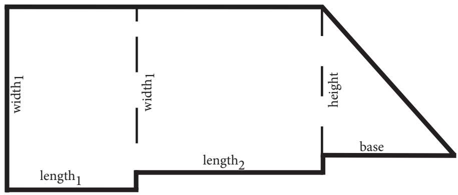


Volume of a cylinder = 3.1416 x radius squared x length



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.



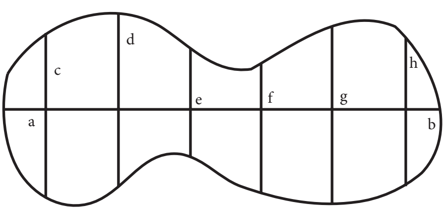
Example: If b = 25', h = 25', L_1 = 30', W_1 = 42', L_2 = 33', W_2 = 31', then the equation is:

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
Cubit 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 1). The panicle emerges at boot from the flag leaf sheath.

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 flowering. Seeds are normally harvested 10-20 days after black layer 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 that the grain is physiologically mature. Seeds are made up of three major components, the endosperm, embryo, and pericarp (Figure 4). 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 all are said to be free of tannins.

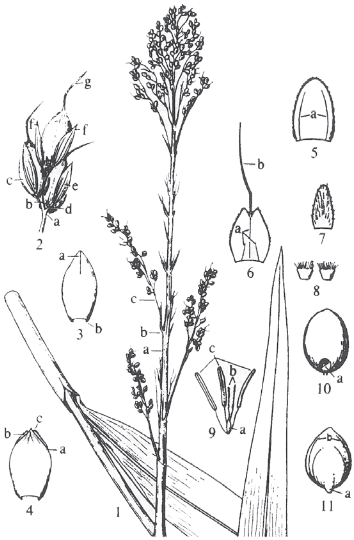


Fig. 5. The panicle of *Sorghum bicolor* subsp. *bicolor* which consists of the inflorescence and spikelets. 1. Part of panicle: a = internode of rachis; b = node with branches; c = branch with several racemes. 2. Raceme: a = node; b = internode; c = sessile spikelet; d = pedicel; e = pedicelled spikelet; 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.

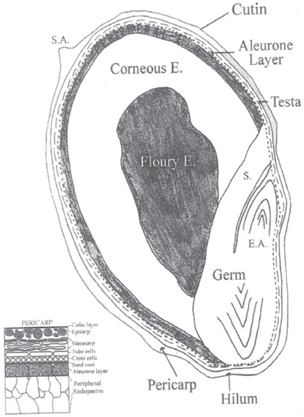


Fig. 6. Sorghum grain, showing the pericarp (cutin, epicarp, mesocarp, cross cells, tube cells, testa, pedicel, and stylar area (SA)), endosperm (aleurone layer, corneous and floury), and the germ (scutellum (S) and embryonic axis (EA). Adapted from L. W. Rooney and Miller, 1982).

b. Photos

Photo 1. Greenbug

Photo 2. Corn Leaf Aphid

*Photo 3. Yellow Sugarcane Aphid**

*Photo 4. Corn Earworm***

*Photo 5. Fall Armyworm**

*Photo 6. Sorghum Midge**

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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.

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United Sorghum Checkoff Program

SORGHUM CHECKOFF℠

DISCLAIMER

Some of the information presented in this handbook is specific to Illinois, Kentucky, Tennessee, and Missouri. Producers in all states should check with their own Cooperative Extension Service or county agents for state-specific information. Reference to products in this publication is not intended to be an endorsement of a particular product to the exclusion of others which may have similar uses. Any person using products listed in this handbook assumes full responsibility for their use in accordance with current label or information directions of the manufacturer.