UNITED SORGHUM CHECKOFF PROGRAM

SOUTHWEST HIGH PLAINS PRODUCTION GUIDE

SORGHUM THE SMART CHOICE

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

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

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

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United Sorghum Checkoff Program

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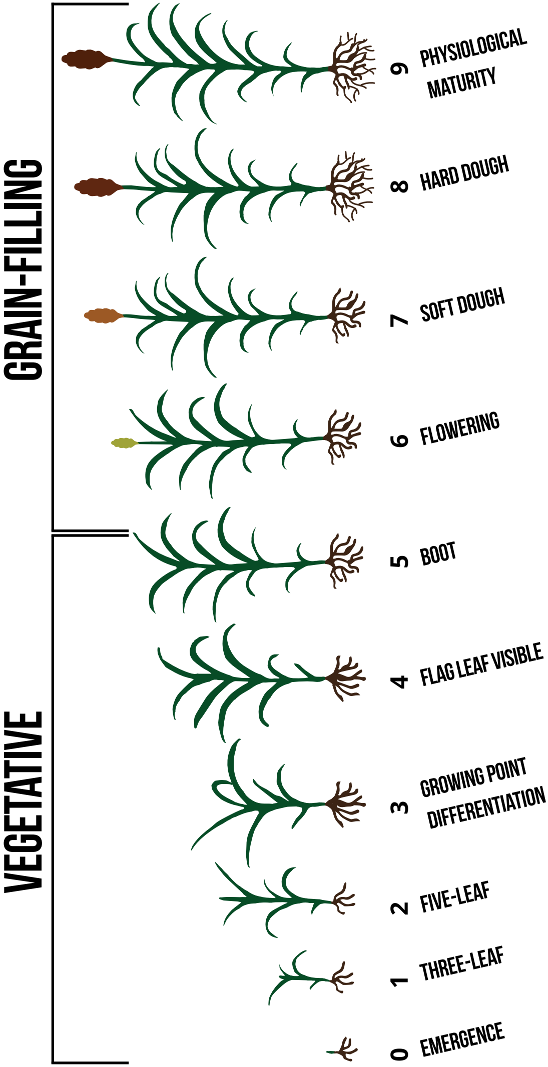
TOPIC	PAGE

GROWTH STAGES

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

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


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

Emergence (Stage 0)

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

Three-Leaf (Stage 1)

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

Five-Leaf (Stage 2)

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

Growing Point Differentiation (GPD)(Stage 3)

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

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

Flag Leaf Visible (Stage 4)

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

Boot (Stage 5)

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

Heading (Not Official Stage)

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

Flowering (Stage 6)

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

Milk (Not Official Stage)

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

Soft Dough (Stage 7)

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

Hard Dough (Stage 8)

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

Physiological Maturity (Stage 9)

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

Determining Leaf Stage

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

APPROXIMATE DAYS TO EACH GROWTH STAGE

Boot		Heading		Flowering		Milk		S. Dough		H. Dough		PM
	3-5 →		5 →		5 →		14 →		10 →		10-14	

GRAIN SORGHUM YIELD COMPONENTS

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

FREEZE DAMAGE & HAIL INJURY

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

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

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

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

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

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

HYBRID SELECTION

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

<u>Maturity</u>

Under optimal growing conditions, a good longer-maturing hybrid will almost always out-yield a good shorter-maturing hybrid. The stalks of full-season hybrids tend to be larger and stand better than those of earlier hybrids. The rule of thumb is to plant the latest-maturing hybrid available within the limitations of projected moisture availability, average length of growing season and crop sequence. Hybrid selection can then be narrowed to the group of hybrids meeting the maturity criteria. Choose a maturity class that will allow the hybrid to reach physiological maturity 7-14 days prior to the average first freeze date for the region. In the Texas and Oklahoma Panhandles, western Kansas and eastern Colorado, the maturity class chosen should be based not only on the length of the growing season but planting date, soil water holding capacity, rainfall amount and distribution. Where water is the limiting factor in yield potential, consider a hybrid's drought tolerance rating, as well as choosing a shorter maturity class. Planting two or three hybrids with slightly different maturities is a good way to protect against short-term, adverse environmental conditions greatly affecting the total yield of a given field.

Seed companies vary in how many days they assign to the various maturity classes. Care should be taken in comparing the maturities of hybrids of different companies. Days to half bloom and physiological maturity will depend greatly on weather since maturation is driven by heat accumulation.

Standability

All sorghum hybrids will lodge under the right conditions. However, genetics do play a significant role in the standability of a hybrid. Standability rating should be a particularly important consideration when planting in environments where drought stress is common late in the season.

Drought Tolerance

The majority of the sorghum acres planted in the Southwest High Plains is planted under dryland and limited irrigated conditions. Due to the region's limited rainfall, hybrids will not be successful without some degree of drought tolerance. Selecting a hybrid based on its drought tolerance rating is particularly important on sandy soils with less water-holding capacity. Some yield potential may be given up with hybrids containing the highest drought tolerance rating, but they may yield more consistently over multiple years.

Insect and Disease Resistance

The Southwest High Plains region is one of the best places in the world for growing sorghum because the dry climate is not conducive for many insects and diseases to flourish like they do in other regions. For this reason, choosing a hybrid based off its insect or disease resistance is not as important as other traits.

The two insects of most concern are greenbug and sugarcane aphid. Of these two, sugarcane aphid can cause the most economic loss. Hybrids with tolerance to the sugarcane aphid should be considered. It is important to note that even though a hybrid is considered to have some tolerance to sugarcane aphid, scouting these hybrids will still be necessary and insecticide should be applied if threshold levels are reached.

Stalk rot diseases can be an issue in the Southwest High Plains leading to lodging prior to harvest. Many companies rate their hybrids on charcoal and fusarium stalk rot. These ratings should be considered when selecting a hybrid, especially under dryland conditions.

Head Exertion

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

Summary

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

- Spend sufficient time searching for improved hybrids.
- Look at hybrids from several companies.
- Look at a broad base of information on hybrids of interest. Avoid reliance on only one source of hybrid-performance information. Use results from company tests, county strip trials and university performance tests to select a small set of

hybrids to try on your farm.

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

TILLAGE SYSTEMS

Grain sorghum needs a warm, moist soil well supplied with air and fine enough to provide good seed-soil contact for rapid germination. A number of different tillage and planting systems can be used to achieve these conditions. These systems may involve primary or secondary tillage or no tillage operations at all prior to planting. Any seedbed preparation should provide a means of profitable crop production while minimizing soil erosion due to wind and water. Conservation tillage systems (e.g. reduced-till, mulch-till, ecofallow, strip-till, ridge-till, zero-till and no-till) provide protection from erosion. These systems also provide the additional benefits of moisture, energy, labor and equipment conservation.

An ideal sorghum production system should include the following at planting:

- Weed-free conditions
- Moisture conservation
- Improve soil tilth preservation
- Wind and water erosion reduction
- Adequate stand establishment

The Southwest High Plains region may respond more to reduced tillage production practices than any other region in the country due to climate. The region's annual precipitation is generally 15-22 inches per year. However, total annual precipitation does not give the complete picture. Rainfall during the growing season varies greatly from year to year. On average, approximately 10 inches of rainfall occurs during the growing season. When a rain event does occur, 60 percent of the time the amount of precipitation is one-fourth inch or less. This rainfall is considered to have very little benefit to the sorghum crop. For dryland sorghum to be successful it is critical that as much precipitation as possible is stored in the soil profile. In addition, runoff from high intensity rainfall events is greatly reduced by maintaining residue on the soil surface. Every time the soil is tilled, some moisture is lost. With newer herbicide chemistry and lower cost of these herbicides, chemical fallow (no-till) has become more common in recent years. Studies at Tribune, Kansas, as well as other locations in the Southwest High Plains have consistently showed the yield advantage of no-till and reduced tillage systems (Table 2).

It is important to note that the full advantage of no-till may not be realized the first few years. This was the case at Goodwell, Oklahoma, (OPREC) where yields were not realized until year six in the no-till system (Figure 1). At Tribune, Kansas, it was year four before no-till yields were higher than reduced tillage (Table 2).

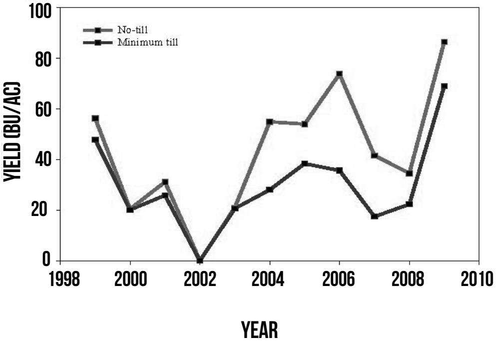
Strip till has been widely adopted for irrigated corn production throughout the Southwest High Plains region. This concept resembles

TABLE 2. GRAIN SORGHUM RESPONSE TO TILLAGE IN A WHEAT-SORGHUM-FALLOW ROTATION, TRIBUNE KAN. 1991-2000

Tillage	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Mean
						bu/ac					
Conventional	23	38	47	20	37	97	71	87	19	13	45
Reduced	39	41	83	38	54	117	94	105	88	37	70
No-till	39	27	68	57	59	119	115	131	99	51	76
L.S.D.$_{0.05}$	18	15	11	9	5	12	33	37	10	6	5

both no-till and minimum till systems and allows anhydrous ammonia (the least expensive nitrogen fertilizer) to be used. Small strips, generally a width of eight inches or less, are tilled and fertilizer applied below where the seed is placed. Strip-till is more like traditional tillage where the residue is removed and the seed is planted into a clean soil surface. However, the residue between the strips remains, similar to no-till. For dryland grain sorghum production, strip-till could be a good intermediate step for a producer that does not want to switch to no-till.

FIGURE 1. GRAIN SORGHUM YIELDS IN NO-TILL AND MINIMUM-TILL SYSTEMS IN A WHEAT-SORGHUM-FALLOW SYSTEM



PLANTING

Row Spacing

Row spacing also varies throughout the region, but the most common is 30 inches. Historically 30-inch rows have performed better than wider rows except for environments where precipitation is lower than the historical average. Using narrower rows (10, 15 or 20 inches versus 30 inches) can be an advantage in those environments where yields are expected to be greater than 110 bushels or 6,000 pounds. However, the yield advantage of the narrower rows is usually small and not consistent. One advantage to narrow rows is that plants shade the soil quicker, improving weed control and reducing soil erosion. Planting with a row planter verses a drill typically results in better seed placement and uniform emergence. However, advances in new drill technology have narrowed this gap.

Planting Date

There is a wide range in planting dates for grain sorghum. Planting should be timed so flowering avoids the hottest, driest period of summer. Utilizing several planting dates is suggested to spread the risk of one planting date flowering during a stress period. Quick germination and emergence occur when the soil temperature is 70°F. **However, sorghum can be planted once soil temperatures are above 60°F when warm weather is expected for the next few days**. Planting too early results in delayed emergence and reduced stands. Late plantings may not allow the crop enough time to mature before a damaging fall freeze. Use earlier-maturing hybrids if planting is delayed into late June or July.

Seeding Density

Typical dryland seeding rates in the Southwest High Plains are lower than in many other regions because of limited precipitation. Under dryland conditions, the seeding rate should be tied to both planting date and available soil moisture. Use a low seeding rate when soil moisture is limited and a higher seeding rate when soil moisture is plentiful in order to take advantage of higher grain yield potential. In the southern part of the region, lower seeding rates are generally used. A common planting rate is 24,000-30,000 seeds per acre. In western Kansas dryland seeding rates are typically 30,000-40,000 seeds per acre. Expect abundant tillering with lower seeding rates when growing conditions are good early in the season. Although all sorghum hybrids will tiller, some will do so more than others. Contact your seed dealer for information on tillering of selected hybrids.

Seeding rate should ultimately be tied to a predetermined yield goal based off of soil moisture, expected precipitation or irrigation level. Table 3 lists recommended seeding rates based on yield goal. When the seeding rate increases, the percentage of seeds that produce plants decreases. For example, in a trial near Walsh, Colorado, when the seeding rate was 25,400, near 66 percent of seeds produced

TABLE 3. SEEDING RATE BASED ON YIELD GOAL

Seeding Rate per Acre	Yield Goal
30,000	3,000-5,000 lb or 60-90 bu
50,000	5,000-8,000 lb or 90-145 bu
70,000	8,000-10,000 lb or 145-180 bu
90,000	Greater than 10,000 lb or 180 bu

a plant compared to only 49 percent when 63,500 were planted (Figure 2). Therefore, when seeding rates increase, expect a lower percentage of the seed to produce viable plants.

Seeding Depth

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

Non-Uniform Stands and Replanting

Sorghum has a remarkable ability to compensate for non-uniform stands. Large gaps up to 9 feet in length within a 30-inch row can be compensated for by intact adjacent rows. Studies have shown a sufficient number of 3-6 foot gaps must be present to reduce overall stand by at least 30 percent to significantly impact yield.

Compensation occurs by increases in the number of heads per plant and the number of seeds per head in neighboring plants both within a non-uniform row and in adjacent rows.

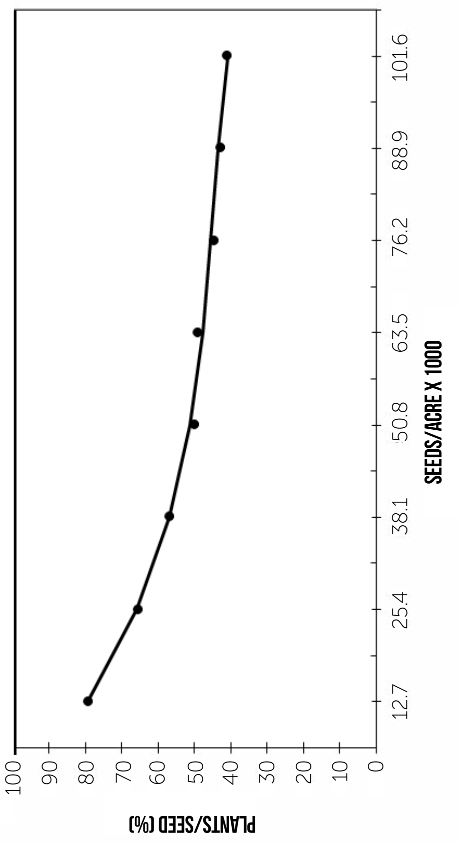


FIGURE 2. PLANT DENSITY TO SEEDING RATE RATIO IN DRYLAND GRAIN SORGHUM IN WALSH, CO

NUTRIENT MANAGEMENT

Grain sorghum is grown over a wide range of growing conditions across the Southwest High Plains region. Thus, nutrient management depends on the specific environment in which the crop is grown. This overall production region is characterized by moisture-limited dryland and high-yielding irrigated grain sorghum. The large fibrous root system of grain sorghum is very efficient at utilizing nutrients from the soil, which gives grain sorghum the ability to extract large amounts of residual nutrients and allows it to respond to nutrient applications. Because the Southwest High Plains commonly incorporates fallow into crop rotation, and because grain sorghum is responsive to residual nutrients, accurate soil testing is necessary for economical nutrient and lime application. However, soil tests are no better than the sample collected in the field. Interpretations of soil tests and resulting fertilization recommendations are made based on many years of research. Fertilizer rates are targeted for optimum yields assuming yield potential is not restricted by other growth-limiting factors.

Nitrogen (N)

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

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

Other considerations are crop rotation and soil organic matter content. Research has shown when sorghum follows a soybean crop, the soil can be credited with an additional 40 pounds of nitrogen. In addition, nitrogen will be made available from soil organic matter during the growing season. For every percent organic matter present, a nitrogen credit of 20 pounds can be given. In many of the soils in the Southwest High Plains the percent of organic matter is less than 1.5 percent and is not considered when determining how much nitrogen to apply.

Nitrogen recommendations will vary slightly based on the different equations used by soil labs from the land grant universities in Texas, Oklahoma, Kansas and Colorado. The Texas equation is the most simple and conservative and is presented below. See the soil testing websites at other universities and labs for alternative equations.

Texas Equation for Nitrogen (N):

Yield goal in pounds/100 x 2
= amount N to apply as fertilizer.

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

Table 4 gives the amount of nitrogen to apply for various yield goals assuming 30 pounds of residual nitrogen is present in the soil based on soil test results.

TABLE 4. NITROGEN TO APPLY BASED ON YIELD GOAL AND 30 POUNDS OF SOIL RESIDUAL NITROGEN.

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

Field comparisons of nitrogen sources indicate little agronomic difference between sources when properly applied. For no-till or reduced-till systems that leave almost 100 percent residue cover, materials containing urea should be injected below the residue to minimize volatilization and immobilization losses. If urea or UAN (urea + ammonium nitrate solution) fertilizer is surface applied and not incorporated by tillage, or does not receive one-half inch of rainfall or irrigation within 24 hours, there is potential for ammonia loss. Enough ammonia loss to reduce crop yields can sometimes occur when urea or UAN is applied to a warm and moist soil or soil heavily covered with crop residue. **Source selection should be based on cost, availability and adaptability to farm operation and dealer services.** Nitrogen application for grain sorghum can be made at various times with equal results on most soils. Nitrogen utilization is quite rapid after the plants reach the five-leaf stage. By boot stage, 65-70 percent of the total nitrogen has been taken into the plant.

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

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

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

Phosphorus (P)

Grain sorghum typically responds to phosphorus when soils test low in available phosphorus. When phosphorus levels are between low and adequate, responses may be erratic or very small. However, phosphorus applications under these conditions are recommended to maintain productive soil fertility and keep the yield potential high.

Phosphorus requirements should be based on a soil test. The sample should be taken to a depth of 6-8 inches and represent a given management area of the field. After a representative sample is collected, it should be submitted to a soil testing laboratory. Laboratories use different procedures and extractants for determining the amount of phosphorus in the sample. The most common procedures are Mehlich-3 and Bray-P1. Results from either procedure can be similarly interpreted. Both are good procedures that may be used in the Southwest High Plains region. Table 5 gives the recommendation of phosphorus needed using the Mahlich-3 or Bray-P1 procedures.

TABLE 5. PHOSPHORUS SUFFICIENCY RECOMMENDATIONS FOR GRAIN SORGHUM

Soil Test P (ppm)	Yield Goal, bu/a - lb K_2O_5/A				
	40	80	120	160	200
0-5	50	55	60	65	70
5-10	35	40	45	45	50
10-15	20	25	25	30	30
15-20	15	15	15	15	15
20+	0	0	0	0	0
Crop Removal	16	32	48	64	80

Grain Sorghum Sufficiency

P Rec= [50 + (0.16 x Yield Goal) + (Bray P x -2.5) + (Yield Goal x Bray P x -0.008)]

If Bray P is greater than 20 ppm, then only a NP or NPKS starter fertilizer is suggested

If Bray P is less than 20 ppm, then the minimum P Recommendation = 15 Lb P2O5/A

Source: "Soil Test Interpretations and Fertilizer Recommendations" Pub. No. MF-2586, Kansas St. Red. and Ext., Manhattan, KS, 66506

Phosphorus can be applied preplant-broadcast, preplant-knifed or banded at seeding. If a difference among methods is found, broadcast is normally inferior. Starter applications are most efficient when applied on acidic soils low in available P. Starter applications can be placed in direct contact with the seed or placed to the side and below the seed. **If placed in contact, the starter material should contain no more than 10 pounds of nitrogen plus potassium per acre on rows spaced 30 inches apart.** The nitrogen and potassium can cause germination damage with their high salt index. No urea or ammonium thiosulfate should be placed in direct seed contact.

Potassium (K)

Potassium deficiencies are also best determined through soil testing. Typically, the areas of the Southwest High Plains (western Kansas, eastern Colorado, Oklahoma Panhandle and Texas Panhandle) are relatively high in potassium and no additional potassium is needed. Deficiencies are most likely to be found in soils with shallow rooting depths and on sandy soil.

Potassium should be applied preplant-broadcast, preplant-knifed or banded at seeding. Broadcast applications should be thoroughly incorporated to get the potassium in the root zone. The most common potassium source is muriate of potash (potassium chloride); however, potassium sulfate, potassium nitrate, potassium-magnesium sulfate and mixed fertilizers are good potassium sources. Potassium recommendations based on soil test results are listed in Table 6.

TABLE 6. POTASSIUM RECOMMENDATIONS FOR GRAIN SORGHUM

Soil Test K	Yield Goal (bu/A)				
(ppm)	40	80	120	160	200
0-40	75	80	85	90	95
40-80	45	50	55	60	60
80-120	20	20	25	25	25
120-130	15	15	15	15	15
130+	0	0	0	0	0
Crop Removal	10	21	31	42	52

Liming

As with other crops, pH affects the availability of soil nutrients. Typically, the Southwest High Plains region has more high pH problems than low pH problems, but there are a few problematic low pH areas in the region. Although grain sorghum is not very responsive to lime, it is very important to maintain adequate pH for other crops in rotation. **Lime is recommended when the soil pH is less than 5.5.** Soil samples for lime application should be taken to a depth of six inches over a representative area. It is important to note that soil pH is an indicator that lime is needed, but the buffer pH is used to determine how much lime to apply.

Secondary and Micronutrients

Grain sorghum will respond to zinc fertilization in some situations, which can be reliably predicted with a soil test. The areas most likely affected by zinc deficiency include highly productive fields where the topsoil has been removed or eroded and has low organic matter and high pH. Zinc soil samples are taken to a depth of six inches and are commonly analyzed with a DTPA (diethylenetriaminepentacetic acid) extractant. Zinc recommendations can be calculated with the following equation:

EQUATION:

Zinc Required (lb/A) = 11.5 - (11.25 x ppm DTPA Zn)

If the soil analysis shows zinc concentration is greater than one part per million, no zinc is needed. Zinc is typically applied with phosphorus and potassium at or before planting. The most effective application of zinc is to band it very close to the seed. The sources of zinc are organic chelates and inorganic sources. The chelates are about 3-5 times more effective per pound than the inorganic sources. **Zinc deficiency symptoms are similar in appearance to iron (Fe) deficiency which is illustrated in Photo 1***. Note the stunted plant with yellowing at the whorl and interveinal striping. Shortened internodes are also characteristic of zinc deficiency.

Similar to zinc, **iron deficiencies** are common on leveled or eroded soils where the topsoil has been removed and organic matter is low. In these situations, highly calcareous soils are exposed, which have a very high pH. Iron soil analysis is identical to zinc, except the calibration data for iron application based on DTPA extractable iron is poor. This analysis does not work well on acidic soils and has limited use on calcareous soils. Often, the easiest way to diagnose problem areas is to note the yellow to white leaf color that first appears on the younger leaves that will continue to an interveinal chlorosis (Photo 1). Currently, there are no economical sources of soil-applied iron available. Therefore, the only options to correct iron deficiencies are to apply foliar iron sprays or to apply manure.

*Photos are located in Appendix B on page 106.

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

WEED CONTROL

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

<u>Weed Control Prior to Planting</u>

Weed control in sorghum must begin in the months and days prior to planting. Weeds left uncontrolled during a fallow period will use up valuable soil moisture that could otherwise be used by the sorghum crop. These weeds can be controlled by tillage or with herbicide application. The use of soil residual herbicides like atrazine can be particularly valuable prior to planting. They reduce tillage and herbicide applications that might otherwise be necessary to control multiple flushes of weeds. However, make certain any soil residual herbicide used is safe for planting sorghum. A relatively new product, Sharpen, is a PPO inhibitor that has provided excellent control of many broadleaf weeds, including marestail. Sharpen has mostly post activity and is often tank mixed with glyphosate to control weeds prior to planting. Atrazine plus dicamba can be an excellent treatment for control of kochia when applied in February or March prior to kochia emergence.

Weed Control at Planting and During the Season

The yield loss associated with sorghum due to weed competition can typically range between 30-50 percent, but complete crop failure can result in extreme cases. In the southern Southwest High Plains, pigweed species and kochia are cited most often as the weeds that infest the largest number of sorghum acres. Studies have shown that even one pigweed within 24 inches of a grain sorghum plant can reduce yield nearly 40 percent.

Kochia can be even more competitive than pigweed using one inch of soil moisture by the time it reaches six inches in height. One inch of soil moisture can be worth nine bushels 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 after. **The most critical period for weed control is the first four weeks after planting.** If weeds are controlled during this time and control is maintained through the remainder of the season, little reduction in grain sorghum yield will occur. Yield reduction from weeds that emerge four weeks after planting is usually minimal.

Broadleaf Weed Control

Most weed control strategies should consider the use of atrazine either applied prior to planting, at planting, prior to crop emergence, or soon after crop emergence. Atrazine is relatively inexpensive and will control most broadleaf weeds when properly applied. 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, other herbicides should be considered.

Other commonly used herbicides applied prior to sorghum and weed emergence are propazine, metolachlor, acetochlor and dimethenamid (Table 7). 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. It also is safer to use when sorghum is rotated with cotton. The other three herbicides are more specific on which broadleaf weeds they will control and generally do not control the weeds for as long a period of time. Combining atrazine with any of the three improves overall control of broadleaf weeds.

Lumax and Lexar are herbicides that contain the HPPD inhibitor mesotrione (Callisto) plus metolaclor (Dual II magnum) and atrazine. Either product can provide excellent control of many annual grasses and broadleaf weeds including velvetleaf, triazine-resistant pigweed and kochia. Lumax and Lexar should not be used on sandy soils because of excessive risk of crop injury and stand loss.

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

Huskie is a premix of a HPPD herbicide and Buctril a contact photosystem II inhibitor. Huskie can be very effective on small broadleaf weeds and gives acceptable control of larger weeds. It will, however, cause some yellowing and burning of the sorghum leaves. Sorghum will grow out of

TABLE 7. POPULAR PRE-EMERGENT HERBICIDES BY ACTIVE INGREDIENT NAME (COMMON TRADE NAMES)

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

these injury symptoms within a few days. Huskie works best when applied with 0.5-1.0 lb of atrazine. There is a cotton rotation restriction on the label that should be observed.

Grass Control

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

Perennial Weeds

Johnsongrass and bindweed are the two perennial weeds that cause the most problems in sorghum. Both weeds have the potential to completely eliminate any significant grain sorghum yield. Prevention is the best method of control with these weeds. As soon as either weed is detected, producers should do everything possible to prevent their spread. Do not run tillage equipment through isolated spots of weeds, as this tends to spread the weeds to other parts of the field.

To eradicate Johnsongrass, diligently spot treat with glyphosate (Roundup) or ACCase herbicides

TABLE 8. POPULAR BROADLEAF POST EMERGENT HERBICIDES BY ACTIVE INGREDIENT NAME (COMMON TRADE NAMES)

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

such as Select, Fusilade, Assure II or Poast. 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 approximately six inches of growth, treat 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 four weeks after planting. Grain yield will be considerably better than if no control was attempted.

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 for bindweed control. Another herbicide, quinclorac (Facet, Quinstar and others), can be used alone or in combination with 2,4-D or dicamba. Quinclorac is safe on sorghum and can be very effective.

Other Information

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

INSECT MANAGEMENT

A number of insects can attack sorghum during the growing season in the Southwest High Plains. The most common insects found at planting are cutworm and wireworm. Midseason and late season insects commonly found include sugarcane aphid, greenbug and other aphids, flea beetles, grasshoppers, fall armyworm, corn earworm, sorghum webworm and occasionally spider mites. **The extent of damage by insects to grain sorghum is often related to the planting date.** The sugarcane aphid and greenbug are more common in early-planted sorghum, while corn earworm, fall armyworm and sorghum webworm are more severe in late-planted sorghum. Figure 3 serves as an outline of when the most common insects are an issue in sorghum.

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

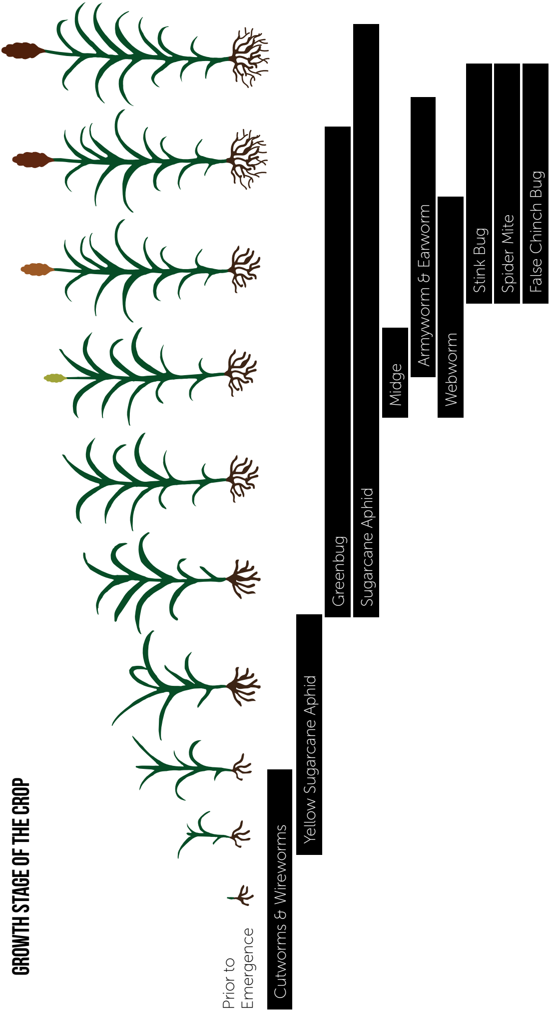


FIGURE 3. OUTLINE OF WHEN THE MOST COMMONLY FOUND INSECTS IN SORGHUM IN THE SOUTHWEST HIGH PLAINS ARE AN ISSUE BASED ON GROWTH STAGE OF THE CROP

Sugarcane Aphid

Sugarcane aphid has become the most serious threat to sorghum in the Southwest High Plains in recent years. Photo 3 shows the four most common aphids found in sorghum.

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

Heavy infestations of the sugarcane aphid can cause leaves to be covered with a sticky, shiny substance called honeydew. This honeydew is made up of plant sugars and water, which are harmless to animals. Black, sooty mold will often begin growing on the honeydew of sorghum leaves. This mold blocks sunlight and eventually leads to yellowing and death of leaf tissue. Loss of plant sap from the sugarcane aphid feeding directly impacts yield. In addition, plant stress caused by the sugarcane aphid can lead to uneven and lack of head emergence, poor grain set, and may contribute to lodging. Actual yield loss will depend on the sugarcane aphid population level and when the infestation occurs (Table 9).

TABLE 9. YIELD LOSS IF LEFT UNTREATED

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

Source: Mississippi State University

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

Entomologists with different state extension services vary slightly on their thresholds for when to apply an insecticide application for sugarcane aphid control. Current Texas AgriLife Extension threshold guidelines for the Southwest High Plains are stated in Table 10. **In general, an insecticide application should be made when 25 percent of the plants are infested with 50 aphids per leaf.** Sivanto Prime and Transform WG have proven to be effective in controlling the aphid. Refer to SorghumCheckoff.com or local extension entomologists for updates on threshold levels as well as other available insecticides.

Best Management Practices for Sugarcane Aphid Control

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

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

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

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

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

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

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

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

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

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

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

<u>Greenbug</u>

(Photo 2) The greenbug is a small, light green aphid with a dark stripe down its back, usually found on the underside of leaves. Early-planted sorghum is more likely to be infested by this pest. The greenbug injects a toxic substance in its saliva that causes red spots on leaves where it feeds. The threshold for when to treat for greenbug varies with growth stage. See Table 10 for when to treat sorghum for greenbug.

Table 10. Economic threshold levels for greenbug on sorghum at different plant growth stages (Texas AgriLife recommendations)

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

Corn Leaf Aphid

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

Yellow Sugarcane Aphid

(Photo 2) Adults and nymphs are bright yellow to light green in color and covered with small spines with two double rows of darker spots down the top of the abdomen. **Feeding on sorghum causes reddening and yellowing of leaves and may transmit viral diseases**. Early infestations of yellow sugarcane aphid can quickly reduce stands, but in recent years this aphid tends to be more of an issue in the Southwest High Plains in the mid to late season. The yellow sugarcane aphid feeds on the underside of sorghum leaves and can reach numbers large enough to require treatment. Threshold levels on when to treat are based on the size of the sorghum and percent of plants infested. See the TexasAgrilfe Extension insecticide guide for specific guidelines on when to treat for yellow sugarcane aphid.

Corn Earworm

(Photo 3) The corn earworm larva has alternating light and dark strips down its body. The color varies from green to pink. The head capsule is a creamy yellow. Larvae feed on whorl tissue of young sorghum plants and on developing grain in maturing plants. Full-grown larvae are about 1½ inches long and feed on grain heads. **In general, treatments should be applied when two or more small larvae or one large (greater than half an inch) larva is found per head.**

Fall Armyworm

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

Sorghum Webworm

(Photo 5) These are small, greenish, hairy caterpillars with four reddish brown stripes down the back. Full-grown larvae are about half an inch long and are usually associated with sticky webbing in the area of their feeding. Check inside grain heads for worms and on leaves under grain heads for white fecal droppings. Treat when an average of 3-4 or more larvae are found on a grain head. These are not as common in the Southwest High Plains as fall armyworms or corn earworms.

Sorghum Midge

(Photo 6) The sorghum midge is one of the most damaging insects to sorghum. The adult sorghum midge is a small, fragile-looking, orange-red fly with a yellow head, brown antennae and legs, and gray, membranous wings. **Fortunately, it is not a major pest in the Southwest High Plains. It is usually only an issue in late planted sorghum.**

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

Effective control of sorghum midge requires the integration of several practices that reduce sorghum midge abundance and their potential to cause crop damage. The most effective cultural management method for avoiding damage is early, uniform planting of sorghum 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.

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

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

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

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

DISEASES

Although sorghum is susceptible to many diseases, there are only a few which cause or have the immediate potential to cause economic losses in the Southwest High Plains on a regular basis. Sorghum is also susceptible to many physiological leaf spots. These can be easily confused with a number of commonly occurring foliar diseases so caution should be taken in making a diagnosis. University plant disease diagnostic laboratories are available to assist in making positive disease identifications.

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

The most common diseases in the Southwest High Plains are stalk rots, primarily fusarium stalk rot and charcoal rot. Seedling blights can also occasionally be an issue. **Although foliar diseases are often present in low levels, they seldom cause a reduction in yield.**

Diseases found in sorghum fields in the Southwest High Plains are described in Table 11.

TABLE 11. SORGHUM DISEASES

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

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

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

Zonate Leaf Spot	• Circular, reddish-purple bands alternating with tan or straw colored areas which give a concentric zonate or bull's-eye appearance • Lesion diameter may extend several inches	• Most severe during prolonged periods of high humidity	• Crop rotation • Resistant hybrids are available
Foliar Diseases Caused by Bacteria[2]			
Bacteria Stripe	• Long, narrow, reddish or tan stripes depending on hybrids • Lesions usually confined between veins • Shiny, crusty spots from exudates generally found on underside of leaves	• Most common bacterial disease • Prevalent during cool, humid weather	• Crop rotation

Disease / Cause	Symptoms	Occurrence	Management
Bacterial Streak	• Narrow, water-soaked, translucent streaks about 1-8 inches wide by 1-6 inches in length • Lesions turn red	• Very common during warm, humid weather	• Crop rotation
Virus Diseases			
Maize Dwarf Mosaic Virus (MDMV-A) Sugarcane Mosaic Virus (MDMV-B)	• Mosaic patterns (alternating light and dark green areas) on whorl leaves • Cool nights (below 60° F for Strain A, below 70° F for Strain B) may cause red and necrotic areas resembling a blight • Flowering may be delayed and seed may be underdeveloped	• Virus is carried by insects, mostly greenbug and corn leaf aphid • MDMV overwinters in Johnson grass	• Most current hybrids are resistant to the more severe necrotic symptoms
Other Sorghum Diseases[3]			
Crazy Top Downy Mildew	• Light colored leaves become stiff, rubbery and twisted • If heads appear, glumes are often proliferated to give "crazy top" symptom	• Most severe when flooding occurs on seedbeds or young seedlings, especially in poorly drained or clay soils	• Avoid areas where the disease is a recurring problem

Sorghum Downy Mildew	• Vivid green and white stripes on leaves in late spring or early summer • Leaves shredded by wind until only leaf veins are left • Heads partially or completely sterile	• Most common in eastern and southern production areas of the Central Great Plains • Infections generally take place under saturated soil conditions within the first few weeks of emergence	• Crop rotation • Resistant hybrids are available to pathotype 1
Heat Smut	• A portion or all of the head is replaced by smut galls	• Plants are infected at seedling stage, but symptoms are not apparent until boot or heading stage • More severe in south-central and southwest areas of the Central Great Plains	• Chemical controls are not effective • Utilize resistant hybrids

Disease / Cause	Symptoms	Occurrence	Management
Sorghum Ergot	• Exudation of sweet, sticky "honeydew" from infected flowers occurs • Honeydew drips onto leaves or produces a white, powdery mass during moist conditions • Ovary may be converted to a white fungal mass visible between the glumes	• Occurs only sporadically in the Central Great Plains • The fungus only infects through unfertilized ovaries • It usually only occurs late in the season when colder temperatures affect pollination of late-planted sorghum or late developing tillers	• Fungicide application at pollination can be made but are usually only economical in hybrid seed production fields • Harvesting right after a rain which temporarily washed off the honeydew may prevent the clogging of harvesting equipment

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

[2]Bacterial leaf diseases have not been shown to cause yield losses under Southwest High Plains conditions, but they are generally present in some fields every year, particularly under wet, humid conditions.

[3]In the Southwest High Plains, only seedling blights, stalk rots and sooty stripe are likely to cause economic yield losses on a regular basis. Crazy top downy mildew and sorghum downy mildew occasionally cause significant yield loss in individual fields or small areas of a field in years with excessive moisture early in the season, but they are not a widespread problem. Sorghum ergot infection is rare, but when it does occur it can cause significant harvesting problems because the sticky honeydew can bind up combines, forage cutters and augers.

IRRIGATION

Sorghum's water use characteristics make it an excellent crop for a wide range of irrigation scenarios in the Southwest High Plains. Sorghum has shown to yield reliably under dryland conditions in many semi-arid environments but can also be managed to reach significant yield capacity under limited or full irrigation. Due to sorghum's water use versatility, it can fit very well into many crop and irrigation patterns, a valuable trait considering current trends of declining groundwater and pending water use limitations.

As with all grain crops, sorghum yield is most directly related to available water during the cropping season. The total available moisture (TAM) a sorghum crop uses is a combination of applied irrigation water, stored soil water and in-season precipitation. Individual TAM inputs can be managed to optimize the grain yield return per unit of water available.

Evapotranspiration

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

Over the 10 year period from 2000-2009, the peak daily grain sorghum ET was approximately 0.33 inches at the USDA Conservation and Production Research Laboratory in Bushland, Texas. Sorghum water use commences during planting (May-June), peaks during late July and early August, and continues through harvest. **Under fully irrigated conditions, seasonal sorghum ET will range from 22-27 inches.** Total water needed by the crop typically decreases moving north through the Southwest High Plains. The actual amount of water required by the crop in any given year will depend on climatic conditions and the amount of water stored in the soil profile. **Typical irrigation requirements to fully meet the need of the crop will range from 10-18 inches in most years.**

In the Southwest High Plains, irrigation of sorghum ranges from full irrigation for maximum yield to very limited irrigation where growers attempt to maximize water use efficiency. Irrigation water is the one controllable crop water source and, when managed properly, can optimize yield returns of all crop inputs, including soil water and in-season precipitation.

Grain sorghum is generally one of the later-planted summer crops. This allows for the soil profile to accumulate water prior to planting and often means the reproductive stage begins after the hottest weather of the summer passes. Water use rates for the various growth stages are shown in Figure 4. Average peak water use rates are about one-third of an inch per day, although occasionally a single-day peak use might approach 0.45 inch per day.

Grain sorghum develops an extensive root system, which can extend to six feet in a friable soil.

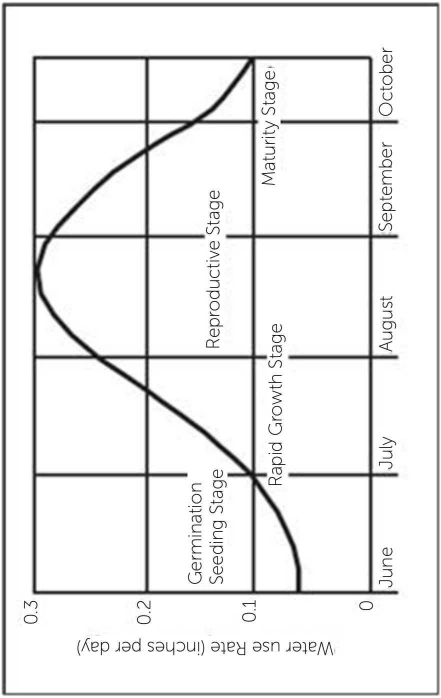


FIGURE 4. CHARACTERISTIC WATER USE PATTERN OF GRAIN SORGHUM

Irrigation scheduling usually accounts for only the upper three feet of the root zone since most of the water extraction will occur in this region. About 75 percent of water use will occur in the upper half of the root zone. Under stress conditions, when the upper zone becomes water-limited, the crop will use water from significant soil depth (Table 12).

In addition to being able to extract water from a great depth within the root zone (Table 12), grain sorghum is able to extract soil water at a lower percentage of available soil water without yield loss when water is limited in the upper root zone. **The general irrigation-management recommendation is to maintain soil water at or greater than 50 percent available water. For grain sorghum, however, the soil water can be depleted to an average of 30-40 percent available water before grain yields are severely reduced.**

Irrigation timing is critical to maximize water use efficiency under limited irrigation. **Although pre-plant irrigation can be effective on deep soils, it is not recommended if any in-season irrigation is planned.** In most years, sufficient rainfall is available to recharge the upper root zone, making preplant irrigation an inefficient water use practice. Key water use periods occur 35 days after emergence during the formation of the seed head, during the flag leaf-boot stage, and during early grain fill. Table 13 gives an outline of sorghum development and when irrigation might be applied for a fully irrigated crop.

TABLE 12. WATER-EXTRACTION PATTERNS UNDER DIFFERENT SOIL-WATER CONDITIONS, GARDEN CITY, KS

Depth (feet)	Normal (no stress), %	Moderate Stress, %	Moderate to Severe Stress, %
0-1	31.4	25.3	7.5
1-2	23.2	18.9	7.3
2-3	18.4	19.9	14.8
3-4	13.4	17.9	24.9
4-5	7.6	11.7	24.4
5-6	6.0	9.3	21.0

Source: C-687 Grain Sorghum Producers Handbook

TABLE 13. SORGHUM WATER USE (ET) AND IRRIGATION TIMING ALONG WITH CROP GROWTH STAGES

Approx. Date	Crop Stage	Days After Planting	Heat Units After Planting	ET per Stage (in.)	Irrigation per Stage (in.)
1-Jun	Seeded	0	0	1.1	1.0
9-Jun	Emerged	8	200	2.2	0.0
Rapid Growth Stage					
21-Jun	3 Leaf	20	500	0.6	1.0
24-Jun	4 Leaf	23	575	0.8	0.0
28-Jun	5 Leaf	27	660	1.6	2.0
6-Jul	GPD	35	925	3.3	2.0
20-Jul	Flag	49	1290	2.8	2.0
30-Jul	Boot	59	1550	1.8	1.0
Reproductive Stage					
7-Aug	Heading	67	1710	1.4	1.0
10-Aug	Flower	70	1850	3.5	2.0
25-Aug	Soft Dough	85	2210	2.7	2.0
7-Sep	Hard Dough	98	2510	1.8	-
17-Sep	Black Layer	108	2700	3.9	-
15-Oct	Grain Harvest	136	3100	-	-

Full and limited irrigation of grain sorghum on sandy soils requires more frequent and smaller irrigation applications in order to avoid plant stress and not leach nutrients out of the root zone.

If water becomes limited at any stage of growth, grain sorghum has the ability to tolerate water stress for short periods of time. Within certain limits, grain sorghum is a drought-resistant crop. Drought stress can lead to a delay in plant maturity. If plant maturity is delayed, the crop may face frost damage in the event of an early freeze. Late-season water stress during grain filling can result in shriveled seeds, which reduces yield.

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

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 drift, leaching, evaporation and run-off all lead to decreased irrigation efficiency.

With rising energy and water costs and declining water levels, wasted or under-utilized 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 (SDI) and low elevation center pivot sprinklers (LESA and LEPA) wherever feasible. To reach sorghum yield potential, a SDI, LESA or LEPA irrigation system should be designed or nozzled at four gallons per minute per acre (GPM/acre) or higher. At lower system capacities (Table 14), irrigation should begin earlier in each crop stage to ensure soil moisture reserves are present to buffer sorghum water needs during the rapid growth and reproductive stages. Irrigation systems vary greatly in their ability to efficiently deliver water to the soil profile (Table 15).

TABLE 14. INCHES OF IRRIGATION WATER APPLIED AT VARIOUS IRRIGATION SYSTEM CAPACITIES

GPM/ Acre	Inches Applied					
	Daily	Weekly	30 Days	45 Days	60 Days	90 Days
2	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	0.16	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	0.21	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	0.27	1.86	8.0	11.9	15.9	23.9
6	0.32	2.23	9.5	14.3	19.1	28.6
7	0.37	2.60	11.1	16.7	22.3	33.4
8	0.42	2.97	12.7	19.1	25.5	38.2
9	0.48	3.34	14.3	21.5	28.6	43.0
10	0.53	3.71	15.9	23.9	31.8	47.7

TABLE 15. EFFICIENCIES FOR AGRICULTURAL IRRIGATION SYSTEMS UNDER OPTIMAL FIELD CONDITIONS

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

Irrigation Costs

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

Regardless of energy source, the following operational practices universally promote lower irrigation water costs:

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

Soil Water

In addition to providing necessary structure and nutrients to crops, soil serves as a holding reserve for water. Each soil has a certain holding capacity for plant available water (PAW), or water a plant can successfully extract from the soil. Coarse soils with rapid infiltration rates hold a minimal amount of water within the plant root zone, but nearly all the water is available for plant use. Conversely, fine textured soils hold a significant amount of water within the root zone, but a lesser percentage of the stored water is available for plant use (Table 16).

TABLE 16. AVAILABLE SOIL MOISTURE BY SOIL TEXTURE CLASS

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

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

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

In-Season Precipitation

Depending on location and weather patterns, in-season precipitation is typically a part of the water budget of irrigated sorghum, despite seasonal variations in quantity and timing. Although difficult to manage, the return on in-season precipitation can be optimized. 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 regard to irrigation scheduling, in-season precipitation should be evaluated on an effective rainfall basis. Research has shown only a portion of the water received during a precipitation event will actually become useful to the sorghum crop. To avoid overestimating water received from precipitation, a producer should only credit precipitation events greater than 0.30 inch, or the peak daily sorghum ET. Consideration should be given to forgoing or delaying irrigation only if a precipitation event is larger than the scheduled irrigation depth or exceeds soil holding capacity. The benefit of in-season precipitation can often be redeemed at the end of growing season when irrigation can be terminated earlier with sufficient water stored in the soil profile.

HARVESTING

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

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

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

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

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

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

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

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

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

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

To accelerate ground counts, a 1-square-foot frame may be constructed from heavy wire. It is best to take at least three ground counts at each location (Figure 5). When making ground counts for kernels, look for lost heads. **One 10-inch head in a 10-foot-by-10-foot area is approximately one bushel per acre.**

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

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

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

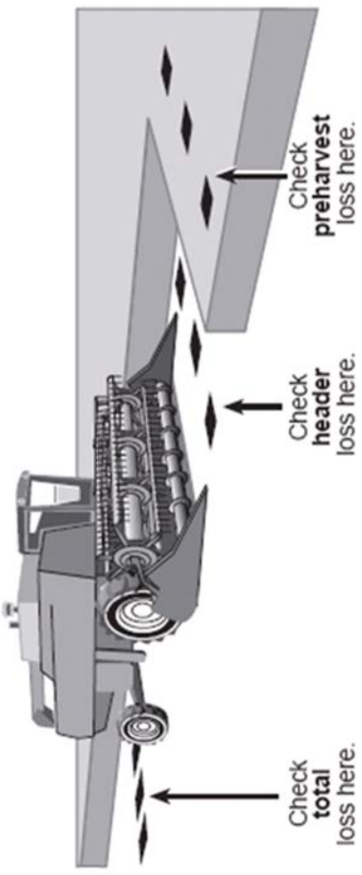
Cylinder and separation loss can be determined by subtracting the header loss from the total machine loss. It is sometimes difficult to determine if the loss is being carried over the walkers or blown across the shoe. Provided the combine does not use a straw chopper, the loss can often be pinpointed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

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

Drying and Storing Grain Sorghum

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

FIGURE 5. DETERMINING HARVEST LOSSES



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

Handling

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

Drying

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

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

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

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

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

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

Storage Moisture Content

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

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

Storing Grain Sorghum

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

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

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

Grain Quality

Sorghum grain is placed into U.S. Grade Numbers 1, 2, 3, 4 or is classified as Sample Grade, and U.S. No. 1 is the highest quality (Table 17). Value of grain sorghum follows this grading system. Proper harvesting, drying and storage practices are important to achieving the higher grades.

TABLE 17. SORGHUM GRADES AND GRADE REQUIREMENTS, FROM THE UNITED STATES STANDARDS FOR SORGHUM

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

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

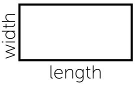
[1] Sorghum which is distinctly discolored shall not grade higher than U.S. No. 3.
[2] Aggregate weight of stones must also exceed 0.2 percent of the sample weight.
[3] Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones, unknown foreign substances or cockleburs.

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

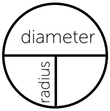
Sorghum Facts

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

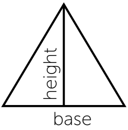
CALCULATIONS & CONVERSIONS



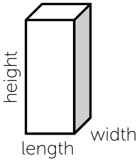
Area of a rectangle or square = length x width



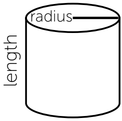
Area of a circle = 3.1416 x radius squared; or 0.7854 x diameter squared
Circumference of a circle = 3.1416 x diameter; or 6.2832 x radius



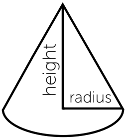
Area of triangle = base x height ÷ 2



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

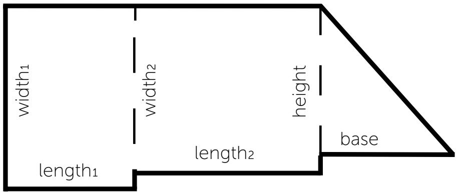


Volume of a cylinder = 3.1416 x radius squared x length



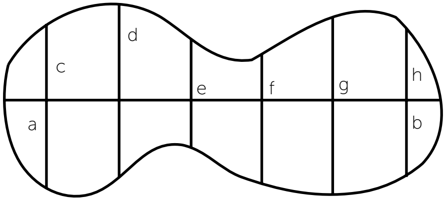
Volume of cone = 1.0472 x radius squared x height

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



Example: If b = 25′, h = 25′, L_1 = 30′, W_1 = 42′, L_2 = 33′, W_2 = 31′, then the equation is:
Area = $((b \times h) \div 2) + (L_1 \times W_1) + (L_2 \times W_2)$
= $((25 \times 25) \div 2) + (30 \times 42) + (31 \times 33)$
= 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 = $(ab) \times (c + d + e + f + g + h) \div 6$
= $(45) \times (19 + 22 + 15 + 17 + 21 + 22) \div 6$
= 870 sq. ft.

Conversion Factors

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

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

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

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

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

APPENDICES

a. The Sorghum Plant

Sorghum grain is found on the panicle, commonly referred to as the head. The panicle consists of a central axis with whorls of main branches, each of which contains secondary and at times, tertiary branching. The length of the branches allows for a wide range of shapes and sizes in sorghum and for sorghums with very open panicles or sorghums with very compact panicles. The branches carry the racemes of the spikelets where the grain is found (see Figure 6). The panicle emerges at boot from the flag leaf sheath.

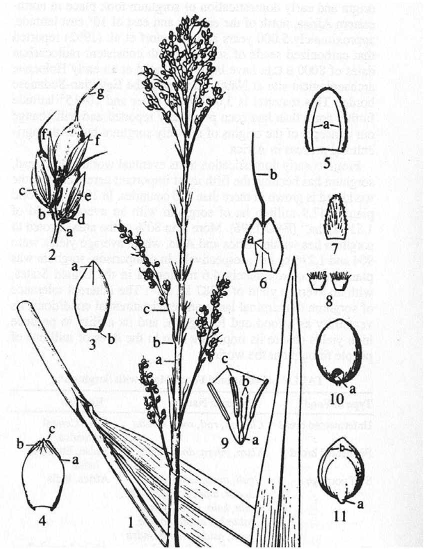


Figure 6. The panicle of Sorghum bicolor subsp. bicolor which consists of the inflorescence and spikelets. 1. Part of panicle: a = internode of rachis; b = node with branches; c = branch with several racemes. 2. Raceme: a = node; b = internode; c = sessile spikelet; d = pedicel; e = pedicelled spikelet;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

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

Seeds are made up of three major components: the endosperm, embryo and pericarp (Figure 7). All sorghums contain a testa, which separates the pericarp from the endosperm. If the testa is pigmented, sorghum will contain tannins. If not, the grain is free of tannins. None of the commercial U.S. grain sorghums have a pigmented testa and are all said to be free of tannins.

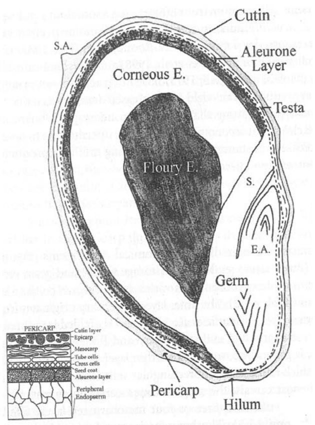


Figure 7. Sorghum grain, showing the pericarp (cutin, epicarp, mesocarp, cross cells, tube cells, testa, pedicel, and stylar area (SA)), endosperm (aleurone layer, corneous and floury), and the germ (scutellum (S) and embryonic axis (EA)). Adapted from L. W. Rooney and Miller, 1982.

b. Photos

Photo 1. Iron Deficiency

Courtesy of International Plant Nutrition Institute

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

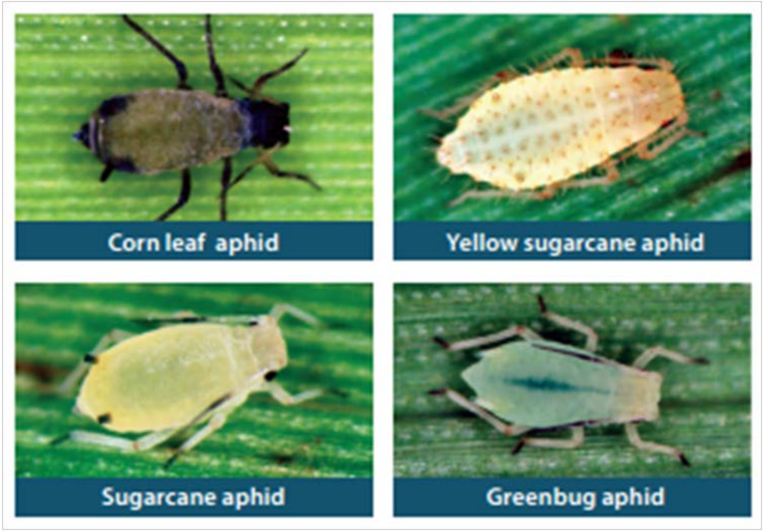


Photo 3. Corn Earworm**

Photo 4. Fall Armyworm*

***Used with permission of USDA-ARS*

Photo 5. Sorghum Webworm*

Photo 6. Sorghum Midge*

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