UNITED SORGHUM CHECKOFF PROGRAM

MID-ATLANTIC PRODUCTION GUIDE

SORGHUM THE SMART CHOICE

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

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

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

Funded by:

United Sorghum Checkoff Program

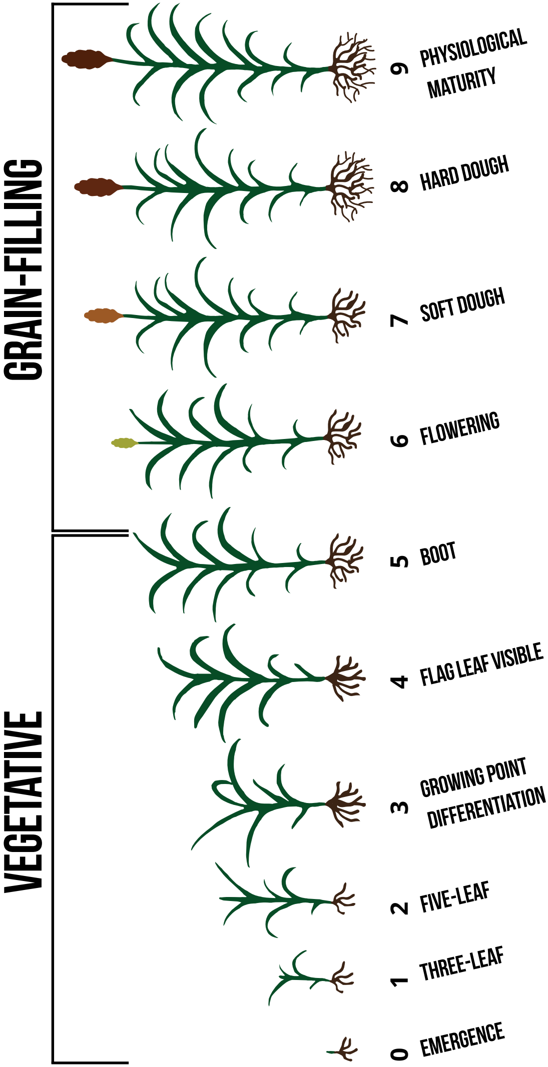
4201 N. Interstate 27
Lubbock, TX 79403
806-687-8727
www.sorghumcheckoff.com

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 final leaf is visible. 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

Hybrid selection is critical to the success of the sorghum crop. Hybrids can be broken into three categories: early, medium and late. Generally, early hybrids reach flowering in 45-55 days. Medium hybrids flower in 55-65 days and late hybrids take longer than 65 days to flower. Most of the hybrids available in the Mid-Atlantic are late hybrids. Research trials have shown that on soils with good water-holding capacity or when sorghum is grown in years with good rainfall, late hybrids work well. Good examples are AgriPro AP2838, DeKalb DKS44-41 and Pioneer 83G66. However, when planting sorghum on droughty soils or when planting as a double-crop behind Irish potatoes, wheat or barley, early to medium hybrids work best. Early hybrids reach flowering before water stress sets in and can reach maturity before a frost.

Currently there is no official variety test for grain sorghum. Producers should rely on local tests or use on-farm comparisons to identify the best hybrids for their soils. Table 2 shows the results of a hybrid performance trial conducted in 2008. Maturity refers to the number of days to flowering or mid-bloom, and the anthracnose rating is on a scale of 1-10 with 10 being excellent resistance and 1 being poor resistance. While limited to only a few hybrids, this is the latest information we have for hybrid response on sandy soils.

TABLE 2. SORGHUM HYBRID COMPARISON TRIAL. NORTH CAROLINA, 2008.

Hybrid	Maturity (days)	Grain Moisture	Yield (bu/A)	Anthracnose Rating
DeKalb A603	72	14.9	97	2
DeKalb DKS53-67	70	15.2	115.4	0
DeKalb DKS54-00	72	14.7	96.9	3
DeKalb DKSs54-00	72	14.7	98.5	3
Monsanto MSE 532	72	15.3	123.6	---
Monsanto MSE 536	75	14.5	112.7	---
NC+ 7B51	70	14.9	106.3	---
Pioneer 82G0	73	15.1	116.8	5
Pioneer 83G15	73	13.1	117.3	1
Pioneer 83G66	72	16.7	117.3	7
Pioneer 84G62	72	15.5	114.9	3
Pioneer 85G46	69	15.7	111.8	5

Tillering

Hybrids express differences in tillering. Early planting and low populations foster increased tillering. Although tillering is one important means by which sorghum hybrids may adapt to their environment, producers should be cautious about high-tillering hybrids where drought stress is expected. In contrast, low tillering hybrids reduce the possibility that early favorable conditions lead to increased tillering, only to have drought and heat increase, leaving the plant with too little moisture per head hence reducing actual yield.

Lodging

Standability is important for grain sorghum. Companies rate their own hybrids for lodging resistance, but significant lodging only occasionally shows up in Texas AgriLife Extension hybrid trials and it is often not even reported. Drought stress and limited moisture conditions can lead to charcoal and other stalk rots, which cause lodging, especially when plant populations are high. Coastal wind and storm damage can also make strong standing sorghum hybrids more valuable.

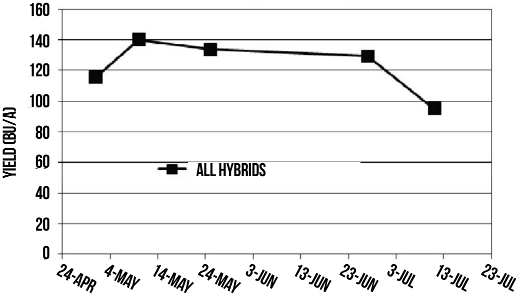
Weathering

This is particularly important for grain sorghum grown along the Atlantic coast. Hybrids that 1) can better withstand storm damage, 2) do not deteriorate after maturity while they await harvest in the event of extended rain, and 3) minimize germination in the head are a plus.

PLANTING

The planting period for grain sorghum is very wide. Research in Virginia and North Carolina shows high yields can be obtained from planting dates ranging from May 1-July 1 (Figure 1). Optimum planting dates for consistent yields fall from May 10-June 15. Double-cropped sorghum could be planted as late as July 10, but later dates result in a crop that will not mature until late fall and will increase the risk of an early fall frost damaging the crop. Generally, on sandy soils that are more drought prone, an early planting date (early to mid May) is the best choice. This gives the crop plenty of opportunity to reach head exertion without the risk of moisture stress. However, sorghum has been grown successfully as a double-crop behind potatoes, barley or wheat on both mineral and organic soils.

FIGURE 1. SORGHUM YIELD WHEN PLANTED ON DIFFERENT DATES IN EASTERN NORTH CAROLINA



The keys to acceptable yields when planting sorghum as a double-crop behind potatoes or wheat are to select an early- to medium-maturing hybrid and to plant in narrow rows.

Seeding Rate and Row Spacing

Seeding should be done in seeds per acre not pounds per acre. Like wheat, sorghum seed varies greatly in the number of seeds per pound, and this can impact the number of plants seeded. In most cases, sorghum should be planted to achieve final plant populations of 100,000-120,000 plants per acre (Figure 2). At 85 percent emergence this would require 130,000-150,000 seeds planted per acre (Table 2). However, when planting on droughty or sandy soils seeding rates should be reduced to achieve final plant population of 90,000 plants per acre. Emerging sorghum seedlings are fragile and can be easily destroyed by insect feeding or soil drying. Percent emergence will often be less than 75 percent when planting in cool, wet soils or when planting using no-till practices. When planting early or when planting under no-till conditions, the use of an in-furrow insecticide, Gaucho® or Cruiser®, seed treatment is recommended.

When planting between May 1 and June 1, row widths from 10-20 inches yield the best (Figure 3). Row spacings of 30- or 36-inch rows have less yield potential. However, on extremely droughty soils, 30-inch rows can give more consistent yield results from year to year. This is due to the fact that water can be stored in the middle of the interrow area and is available during heading and flowering when the sorghum plant's need for water is the greatest. When planting after June 1, sorghum yield tends to be greater when drilled at spacing less than 15 inches.

Figure 2. Sorghum yield at two different plant populations on an organic soil in eastern North Carolina

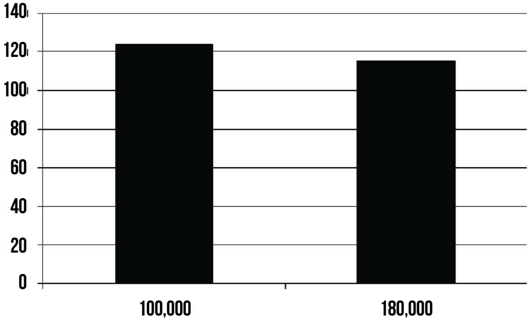


Figure 3. Effect of row spacing on grain sorghum yields at three different planting dates in North Carolina

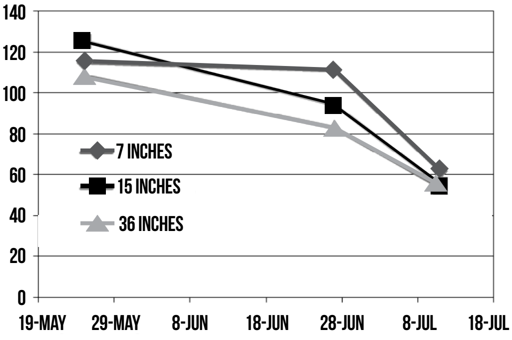
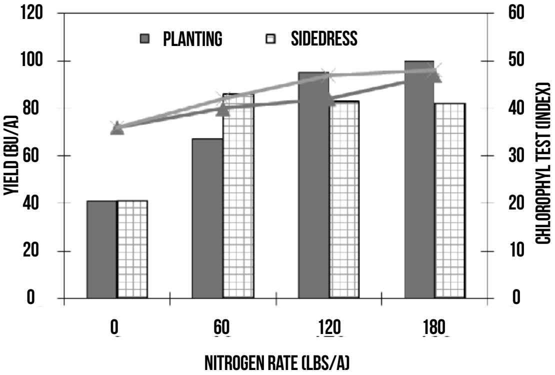


TABLE 2. SUGGESTED SORGHUM SEED SPACING (INCHES) IN ROW AT DIFFERENT ROW SPACING

	Target Plant Populations (plants/A)				
Row Width	**80,000**	**90,000**	**100,000**	**120,000**	**150,000**
10	6.66468	5.92416	5.331744	4.44312	3.554496
15	4.44312	3.94944	3.554496	2.96208	2.369664
20	3.33234	2.96208	2.665872	2.22156	1.777248
30	2.22156	1.97472	1.777248	1.48104	1.184832
36	1.8513	1.6456	1.48104	1.2342	0.98736
40	1.66617	1.48104	1.332936	1.11078	0.888624

When planting after June 15, increase seeding rates by 20,000 seeds per acre.

FIGURE 5. GRAIN SORGHUM YIELDS AT FOUR DIFFERENT NITROGEN RATES APPLIED AT PLANTING OR SIDEDRESS IN NORTH CAROLINA



NUTRIENT MANAGEMENT

Grain sorghum requires less nitrogen than corn, but has similar requirements for phosphorous and potassium. Between 30-50 lbs of P_2O_5 per acre and 50-70 lbs or K_2O are recommended for sorghum based on soil test levels. Sorghum does not respond well to starter fertilizer with phosphorus and potassium. It is better to have sufficient levels of phosphorous and potassium in the soil prior to planting than to supplement.

Nitrogen rates for optimum sorghum yields range from 80-125 lbs of nitrogen per acre (Figure 5). In heavy residue or when little or no nitrogen is available from the previous crop, some nitrogen applied in a band at planting can be beneficial. Otherwise, the best time to apply nitrogen to grain sorghum is at sidedress (when sorghum is 10-12 inches tall). On most soils, 120 lbs of nitrogen per acre applied at sidedress will produce excellent results. Nitrogen fertility is important for high sorghum yields. Nitrogen must be available from 12 inches to flowering for a good sorghum crop. Lack of nitrogen at heading can result in failure to set seed (head blasting).

<u>Nitrogen (N)</u>

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

Other considerations are crop rotation and soil organic matter content. In addition, nitrogen will be made available from soil organic matter during the growing season. For every percent organic matter present, a nitrogen credit of 20 pounds can be given.

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

Field comparisons of nitrogen sources indicate little agronomic difference between sources when properly applied. For no-till or reduced-till systems that leave almost 100 percent residue cover, materials containing urea should be injected residue

Table 3. 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

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, 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. Table 4 gives the recommendation of phosphorus needed using the Mahlich-3 or Bray-P1 procedures.

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

TABLE 4. 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 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.

<u>Potassium (K)</u>

Potassium deficiencies are also best determined through soil testing. Typically, the areas of the 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 5.

TABLE 5. POTASSIUM RECOMMENDATIONS FOR GRAIN SORGHUM

Soil Test K (ppm)	Yield Goal (bu/A)				
	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. 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 (Zn) 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 with 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.

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.

* Photos found in Appendix B, page 80.

WEED CONTROL

The best option for weed control on organic or mineral organic soils is to use Concep-treated seed (safened seed) and a mixture of Dual and atrazine at 1-1.33 qt of Dual and 1-1.5 qt atrazine. Another alternative is to use safened seed and Lasso (Intro) and atrazine. On organic or mineral-organic soils a post emergence application of atrazine and Clarity is very effective in controlling most broadleaf weeds but is limited in grass control. On sandy soils with less than 1 percent organic matter the only alternative is to use safened seed with Lasso (Intro) or Concep-treated seed with Dual and then follow with a post emergence application of 2,4-D and Clarity. Post emergence applications of 2,4-D and Clarity can be very effective. Sorghum should be treated after it is 4-6 inches tall but before it reaches 12 inches. The chemical manual states sorghum is more sensitive to 2,4-D or Clarity than corn. This is true if 2,4-D or Clarity is applied after sorghum is 12 inches tall. Before this stage, sorghum is actually more tolerant to these chemicals than corn.

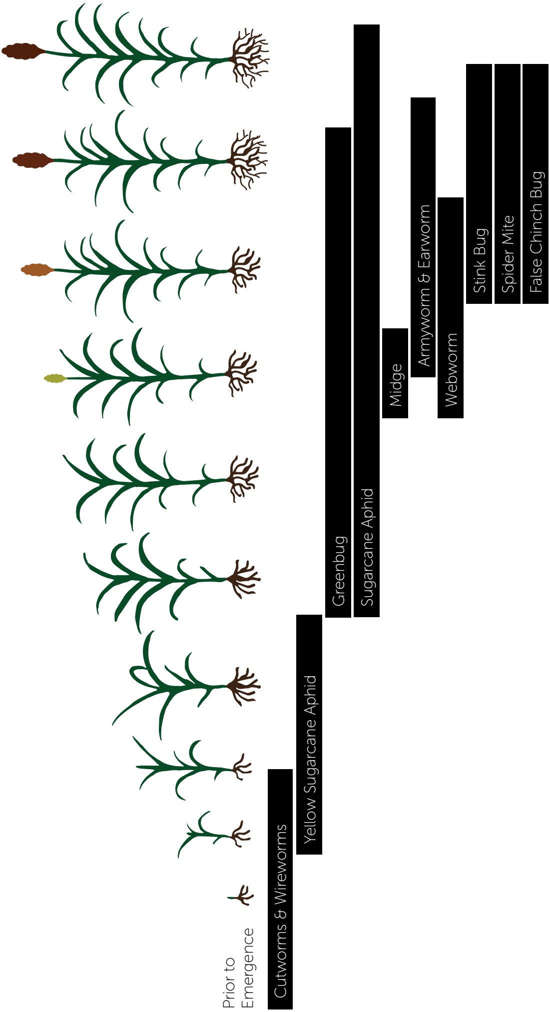
For grass control, Buctril can also be applied post emergence up to 14 inches tall. Unfortunately, Buctril is not effective against common grass species such as nutsedge, bermudagrass and goosegrass. In severe cases, Lorox could be applied using drop nozzles to clean up a grass problem. Some damage to the sorghum crop will occur when using these products.

INSECT MANAGEMENT

The two main pest problems in grain sorghum in the Mid-Atlantic are birds and corn earworm. Bird damage can be avoided by planting large areas and avoiding planting small fields near heavily wooded areas. There are no easy methods of getting rid of birds. Bird-resistant sorghum hybrids are available but have less desirable feeding characteristics and are usually discounted at the market. Corn earworms can be a significant problem. Earworms attack the flowers and kernels of sorghum. In early August, earworm moths move from maturing corn fields and attack sorghum that flowers from August through early September. The damaging pest is the hairy caterpillar that is usually light green, tan, or yellow with a broad lighter strip down the side. It has small black spots, an orange head, and curls up when disturbed. Sorghum, particularly sorghum planted after June 1, should be scouted for corn earworms from flowering to maturity. Earworms can be easily controlled through the use of insecticides such as Warrior®. However, significant damage often occurs before the problem is recognized and treated.

There are few other significant insect pests that affect grain sorghum in the Mid-Atlantic. Billbugs do not reproduce on grain sorghum. However, they have been known to feed on small sorghum plants. It is rare to find significant billbug damage to sorghum.

FIGURE 5. OUTLINE OF WHEN THE MOST COMMONLY FOUND INSECTS IN SORGHUM IN THE HIGH PLAINS ARE AN ISSUE BASED ON GROWTH STAGE OF THE CROP



Sugarcane Aphid

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 6).

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

TABLE 6. 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

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. **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.

<u>Best Management Practices for Sugarcane Aphid Control</u>

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.

Greenbug

(Photo 2) The greenbug is a small, light green aphid with a dark stripe down its back, usually found on the underside of leaves. Early-planted sorghum is more likely to be infested by this pest. The greenbug injects a toxic substance in its saliva that causes red spots on leaves where it feeds. The threshold for when to treat for greenbug varies with growth stage. See Table 7 for when to treat sorghum for greenbug.

TABLE 7. 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 to boot yellowing of leaves and before any entire leaves on 20% of plants are killed
Boot to Heading	At death of one functional leaf on 20 percent of plants
Heading to Hard Dough	When greenbug numbers are sufficient to cause death of two normal-sized leaves on 20 percent of plants

Corn Leaf Aphid

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

Yellow Sugarcane Aphid

(Photo 2) Adults and nymphs are bright yellow to light green in color and covered with small spines with two double rows of darker spots down the top of the abdomen. **Feeding on sorghum causes reddening and yellowing of leaves and may transmit viral diseases.** Early infestations of yellow sugarcane aphid can quickly reduce stands, but in recent years this aphid tends to be more of an issue 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.

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 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.

*Photos are located in Appendix B on page 80.

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 Mid-Atlantic 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 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 various regions are described in Table 8.

TABLE 12. 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

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

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

Disease / Cause	Symptoms	Occurrence	Management
Zonate Leaf Spot	• Circular, reddish-purple bands alternating with tan or straw colored areas which give a concentric zonate or bull's-eye appearance • Lesion diameter may extend several inches	• Most severe during prolonged periods of high humidity	• Crop rotation • Resistant hybrids are available
Foliar Diseases Caused by Bacteria[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

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

Disease / Cause	Symptoms	Occurrence	Management
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

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 High Plains conditions, but they are generally present in some fields every year, particularly under wet, humid conditions.

[3]In the 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.

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 4). 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.

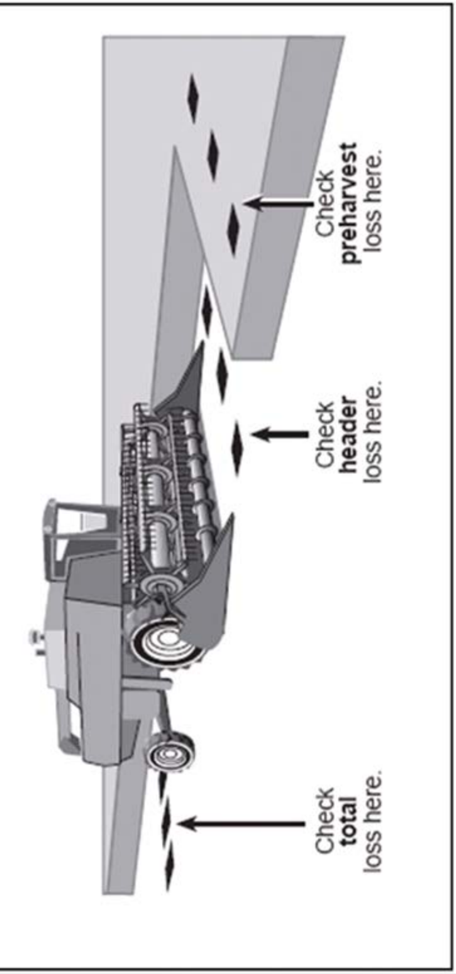
Cylinder and separation loss can be determined by subtracting the header loss from the total machine loss. It is sometimes difficult to determine if the loss is being carried over the walkers or blown across the shoe. Provided the combine does not use a straw chopper, the loss can often be pinpointed 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 6. 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 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 9). Value of grain sorghum follows this grading system. Proper harvesting, drying and storage practices are important to achieving the higher grades.

TABLE 9. 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

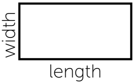
[1] Sorghum which is distinctly discolored shall not grade higher than U.S. No. 3.
[2] Aggregate weight of stones must also exceed 0.2 percent of the sample weight.
[3] Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones, unknown foreign substances or cockleburs.

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.

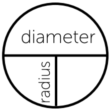
Sorghum Facts

- 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.

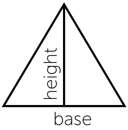
CALCULATIONS & CONVERSIONS



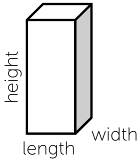
Area of a rectangle or square = length x width



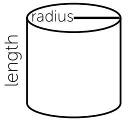
Area of a circle = 3.1416 x radius squared; or 0.7854 x diameter squared
Circumference of a circle = 3.1416 x diameter; or 6.2832 x radius



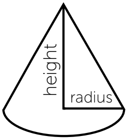
Area of triangle = base x height ÷ 2



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

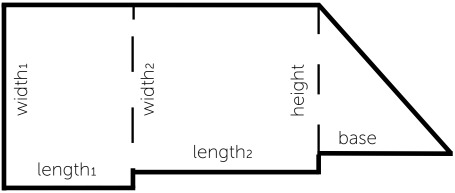


Volume of a cylinder = 3.1416 x radius squared x length



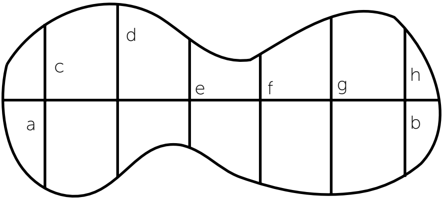
Volume of cone = 1.0472 x radius squared x height

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

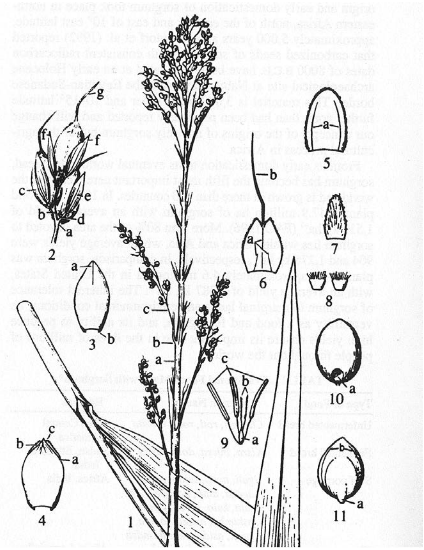


Figure 7. The panicle of Sorghum bicolor subsp. bicolor which consists of the inflorescence and spikelets. 1. Part of panicle: a = internode of rachis; b = node with branches; c = branch with several racemes. 2. Raceme: a = node; b = internode; c = sessile spikelet; d = pedicel; e = pedicelled spikelet; 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 8). 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.

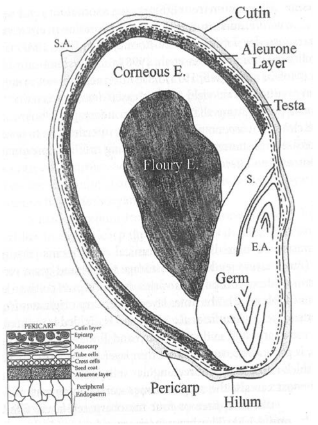


Figure 8. Sorghum grain, showing the pericarp (cutin, epicarp, mesocarp, cross cells, tube cells, testa, pedicel, and stylar area (SA)), endosperm (aleurone layer, corneous and floury), and the germ (scutellum (S) and embryonic axis (EA). Adapted from L. W. Rooney and Miller, 1982).

b. Photos

Photo 1. Iron Deficiency

Courtesy of International Plant Nutrition Institute

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

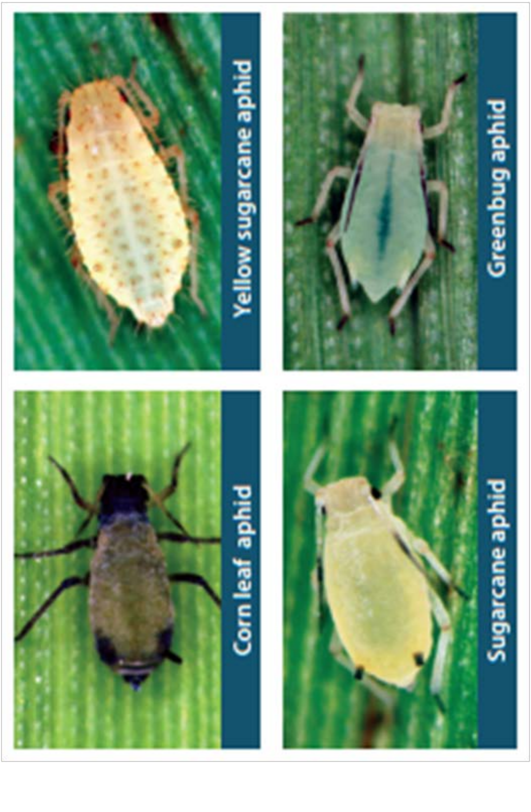


Photo 3. Corn Earworm**

Photo 4. Fall Armyworm*

***Used with permission of USDA-ARS*

Photo 5. Sorghum Webworm*

Photo 6. Sorghum Midge*

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

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