UNITED SORGHUM CHECKOFF PROGRAM

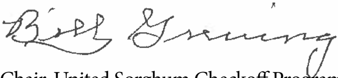
Mid-South Production Handbook

SORGHUM CHECKOFF

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

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

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



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United Sorghum Checkoff Program

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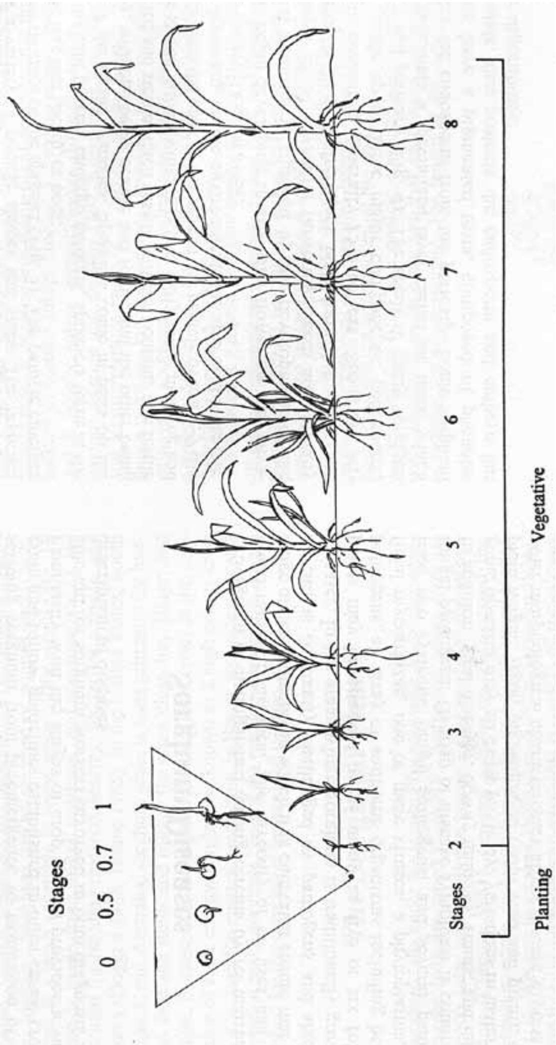
Growth Stages

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

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

Refer to Appendix A, page 65, for more information about the sorghum plant.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Planting
Vegetative

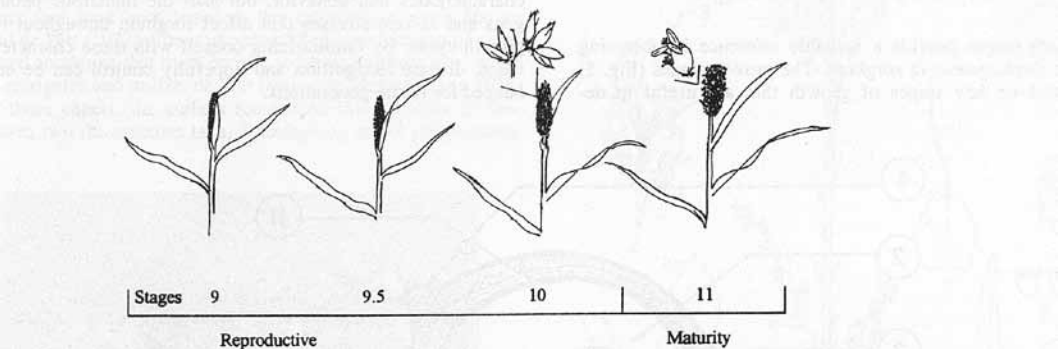

Fig. 1. Stages of sorghum growth: Stage 0: 0.0 planting; 0.1 start of imbibition; 0.5 radicle emergence from seed (caryopsis); 0.7 coleoptile emergence from seed (caryopsis); 0.9 leaf at coleoptile tip; Stage 1: emergence; Stage 2: first leaf visible; Stage 3: third leaf sheath visible; Stage 4: fifth leaf sheath visible; Stage 5: Panicle differentiation and start of tillering; 5.1 main shoot and one tiller; 5.9 main shoot and several tillers; Stage 6: stem elongation (late vegetative stage); Stage 7: flag leaf visible, whorl; Stage 8: booting (end of vegetative stage); Stage 9: panicle just showing, inflorescence emergence; Stage 10: anthesis (50% of panicle flowering); Stage 11: maturity; 11.1 grains at milk stage; 11.2 grains at early dough stage; 11.3 grains at late dough stage; 11.4 grains at physiological maturity (black layer, approximately 30% seed moisture); 11.5 mature grain (seed moisture approximately 15%). (Courtesy K. Cardwell). *For more information see Appendix A, page 65.*

Hybrid Selection

The criteria for selecting grain sorghum hybrids are similar to those for selecting corn hybrids. Yield, maturity, stalk strength (standability) and disease resistance are all important. Selecting sorghum hybrids suitable to the climate with excellent yield potential and with tolerance or resistance to certain diseases is critical to high yields. Full season hybrids have yielded better in variety trials than early hybrids when planted in May. An earlier-maturing hybrid may be needed if planting after mid-June or as a double crop after wheat. Because of the limited acreage of grain sorghum in the eastern United States, most hybrids are developed and tested in the Great Plains and may not have been extensively tested under Mid-South conditions.

Commercial seed companies publish more detailed information about the agronomic characteristics and specific disease resistances of their hybrids. An ideal hybrid should have good seedling vigor, some resistance to anthracnose (primary cause of stalk rot), charcoal rot resistance and good stalk strength. Low lodging scores in local test plots are a good indication a hybrid has the potential to stand better when under stress.

Physical characteristics to be considered are head exsertion (the distance between the sorghum head and the upper most leaf) and head type (i.e. – compact, semi-compact, or open). The distance between the head and leaves can be from zero to eight inches and is of major importance when it comes time to harvest. The grain itself may be mature and ready for harvest but the plant material may still be green. The mature grain needs to be harvested with as little green material as possible because this green material, which can be sticky due to accumulated sugars, can cause problems with harvest and drying. Hybrids with greater head exsertion send less foliage into the combine at harvest. A harvest aid or desiccant may be needed to reduce the amount of green material in hybrids with low head exsertion.

The head type can affect the amount of pest damage to the seed and the quality of grain drying. Grain insects may be more difficult to scout and treat with the compact head types versus the open head types. The open and semi-compact hybrids will dry quicker in the field and are thought to be less susceptible to damage from head diseases.

Performance testing of commercial grain sorghum hybrids is not currently being done in Illinois or Kentucky, but hybrid test results are available from Tennessee and nearby states such as Missouri. Consult these and other tests to identify hybrids with excellent yield potential across multiple locations or environments. Hybrids are evaluated for yield and lodging in Tennessee in small plot replicated trials and in large strip plot county demonstration trials *http://www.tennesseetrials.com*. Compared to corn, there are fewer commercial grain sorghum hybrids to choose from, so deciding what to plant is less challenging.

Planting

<u>Site Selection</u>. Grain sorghum is adapted to a wide range of soils throughout the Mid-South region, but it is often placed on less-productive soils. If higher yields are desired, grain sorghum needs to be planted on soils that produce higher corn, cotton, or soybean yields. Even though grain sorghum is relatively drought resistant, it produces its best yields on deep, level soils rather than on drought-prone hillsides. It is common to see increased sorghum acreage in years following a drought as producers attempt to avoid two successive years of crop failure. Because chances of dry weather are not above normal the year after a drought year, it makes more sense to plant grain sorghum consistently on those fields with lower productivity for corn than to try to guess what the weather will be like in a given year.

<u>Seedbed Preparation</u>. Seedbeds should have plenty of moisture, be suitable for good seed-to-soil contact and relatively weed free. These conditions can usually be obtained with light tillage or with no-tillage and burndown herbicides. Most planters used to plant grain sorghum are already set up to plant into no-till conditions.
<u>Seed Treatments</u>. When selecting sorghum herbicides, consult the label or contact your seed or herbicide retailer to see if a seed safener, such as Concep® or Screen®, might be needed. Using such herbicides without the safener seed treatment

can result in severe crop injury. Insecticide seed treatments should be considered in areas where local university data supports such use.

<u>Planting Date</u>. The optimum planting period for grain sorghum varies some by region. Planting grain sorghum from May 1 to June 1 results in highest yields in Kentucky and Tennessee, while in Illinois, the best date to start planting ranges from mid-May in southern Illinois to late May in northern Illinois. Grain sorghum is a warm season plant and emergence is best when soils are at least 60˚to 65˚F in the upper two inches of soil and warm weather is expected to continue. Grain sorghum prefers soil conditions similar to soybean, and germinates rapidly when soil temperatures are near 70° F. Soils in the Mid-South will often reach these temperatures prior to May 1.

Early planted sorghum usually has less damage from sorghum midge and worm pests. May planted sorghum will receive adequate rainfall in the spring for vegetative growth and will bloom during July when rainfall amounts are lower, thus reducing occurrence of head diseases.

Later planting results in lower yields and higher moisture grain at harvest. Grain sorghum can be planted after wheat harvest, but soil moisture supply should be adequate to achieve good stands, and double-cropping sorghum will be more successful on soil with better water-holding capacity. Hybrids used in late planting situations should be early maturing in order to reach maturity before frost.

Planting Depth. Sorghum seed is smaller than corn seed and tends to emerge less vigorously. It should be planted shallow enough for easy emergence but deep enough to assure good contact with moist soil. Adequate seed coverage makes plant emergence more uniform in a field. **Sorghum should be planted one inch deep under most situations.** Seeds should be placed to moisture, but no deeper than about one inch in heavy soils and about two inches in sandy soils. Planting into a moist, warm seedbed allows for quick germination and uniform stands. Planter units should be set to firm the soil around the seed to expedite germination and emergence.

Because sorghum seedlings are slow to emerge, care is needed when using reduced- or no-till planting methods. Surface residue usually keeps the soil cooler and may harbor insects that can attack the crop, causing serious stand losses, especially when the crop is planted early in the season. No-till sorghum may have to be planted slightly deeper to ensure adequate seed coverage. Be sure that the planting slot closes well.

Row Spacing. Since grain sorghum is planted on fewer acres than corn or soybean by most producers in the Mid-South, row width is generally that which is used for corn and soybean. Row-spacing experiments in Missouri have shown that narrow rows produce more than wide rows (Table 1), but recent University of Illinois experiments produced mixed results. In two of eight site-years, both in 2004, yields were significantly higher for the 30-inch row spacing (Table 2). Grain sorghum in 30-inch rows facilitates inter-row cultivation, which can help with weed control.

Narrow rows can make the crop more competitive with weeds, and they work well if weeds can be controlled without cultivation. Narrow rows are suggested for late planted sorghum if the equipment is available. Grain sorghum in 15- or 7.5-inch rows will usually have less lodging. Using a split-row planter to plant 15-inch rows may be a good option in fields where weeds can be controlled.

Table 1.

Yield of Grain Sorghum as Affected by Row Spacing in a Missouri Trial (Conley et al. 2005)*

Row Spacing(inches)	Yield (bu/Acre)
7.5	125.5
15	117.7
30	116.8

*Data is in 2-year averages

Table 2.
Yield of Grain Sorghum as Affected by Row Spacing in University of Illinois Trials, 2003-2005

Row	2003			2004			2005		03-05
Spacing	DSAC	BRC	BARC	DSAC	BRC	BARC	DSAC	BRC	AVG
	bu/acre								
15”	90	99	39	83	122	117	64	48	83
30”	89	101	39	86	136	127	63	50	86
ANOVA †	NS	NS	NS	NS	***	**	NS	NS	

DSAC -= Dixon Springs, BRC = Belleville, BARC = Brownstown

† NS = Non-Significant, ** = Significant at P = 0.05, *** = Significant at P = 0.01

<u>Plant Population</u>. Grain sorghum seeding rates depend upon soil type, soil fertility, soil moisture and seasonal rainfall. The number of grain sorghum seeds per pound can vary from 10,000 to 20,000. Years ago, seeding rate recommendations were expressed as pounds of seed per acre, which caused overplanting with small-seeded hybrids. Too-high plant populations can cause lodging problems and yield loss. Targeting a specific plant population and adjusting seed drop rate for the row width used is a much more accurate way to plant sorghum. Most grain sorghum hybrids have about 16,000 seeds per pound.

Seeding rates of 60,000 to 100,000 viable seeds per acre are sufficient for maximum yields regardless of row spacing. Some nearby states are evaluating twin-row sorghum at seeding rates of 100,000 plants per acre or above, but little data is available at this time. If planting into soils where drought is expected, use the lower population. In irrigated fields, a final population of 75,000 plants per acre is adequate based on University of Arkansas information.

University of Illinois seeding rate experiments conducted from 2003 through 2005 (Table 3) showed no significant yield increases across the different seeding rates within locations. When averaging the entire study across years and locations, there was only one bushel per acre difference between the 60,000 and 120,000 seeds per acre planting rate. This shows that grain sorghum has an excellent ability to compensate for low plant populations. There is clearly no need to plant more seeds 'just to be safe' in full season conventional tillage sorghum.

Divide the desired plant stand by the germination given on the seed tag to determine the actual seeding rate. For example, if a seed tag says 85 percent germination and you want to establish 90,000 plants per acre, 90,000÷0.85 = 105,882 planted seeds per acre. If there is reason to believe that emergence percentage may be less than the germination, then divide by expected establishment percentage instead of germination. When planting into no-till, especially as a double crop, it is best to assume that only 65 to 75 percent of what is planted will become a viable plant so divide by that percentage.

Seeding rates are independent of row width. Table 4 illustrates seed number per foot of row that is needed to achieve a desired population of sorghum for a specific row width. Pounds of seed per acre based on seed size are indicated for desired populations (example: if you desire to plant 80,000 seeds per acre and a hybrid has 15,000 seeds per pound, this is equivalent to 5.3 pounds of seed/acre).

Table 3.

Yield of Grain Sorghum as Affected by Seeding Rate in University of Illinois Trials, 2003-2005

Seeding	2003			2004			2005		03-05
Rate	DSAC	BRC	BARC	DSAC	BRC	BARC	DSAC	BRC	Average
‘000/ac					Bu/acre				
60	88	99	36	86	123	125	63	48	84
90	88	99	38	87	130	123	64	49	85
120	91	101	43	80	134	117	63	50	85
ANOVA †	NS	NS	NS	NS	NS	NS	NS	NS	

DSAC = Dixon Springs, BRC = Bellevill, BARC = Brownstown

† NS = No Significant differences

Table 4.
Seeding Information for Grain Sorghum

Row Width (inches)	Desired Seeds Per Acre					
	60,000	70,000	80,000	90,000	100,000	110,000
	Seeds per Foot of Row					
40	4.6	5.4	6.1	6.9	7.7	8.4
38	4.4	5.1	5.8	6.35	7.3	8.0
30	3.4	4.0	4.6	5.2	5.7	6.3
20	2.3	2.7	3.1	3.4	3.8	4.2
15	1.7	2.0	2.3	2.6	2.9	3.2
7.5	0.8	1.0	1.2	1.3	1.5	1.6
Seeds/Pound	Pounds of Seeds per Acre					
11,000	5.5	6.4	7.3	8.2	9.1	10.0
12,000	5.0	5.8	6.7	7.5	8.3	9.2
13,000	4.6	5.4	6.2	6.9	7.7	8.5
14,000	4.3	5.0	5.7	6.4	7.1	7.9
15,000	4.0	4.7	5.3	6.0	6.7	7.3
16,000	3.8	4.4	5.0	5.6	6.3	6.9
17,000	3.5	4.1	4.7	5.3	5.9	6.3

Fertilization

The philosophy of fertilizer recommendations differ by state but there are several similarities. Consult state fertilizer guides for specific guidelines.

Soil Test. Although grain sorghum is not an extremely heavy user of nutrients, it does require proper fertilization for optimum production. Be sure to include regular soil testing to aid in determining lime, phosphorus and potassium requirements. Soil tests are recommended every two to four years and each soil sample should represent no more than 20 acres (5 acres in Illinois).

Lime. Lime rates are generally tied to the soil test pH values. In Tennessee, lime is recommended when water pH is below 6.0. If lime is needed, it can be applied any time before planting. In Kentucky, agricultural lime applications are triggered when water pH is 6.2 or less.

Phosphorus and Potassium. While potassium is required in relatively smaller amounts than phosphorus, potassium is the primary nutrient that helps regulate stomatal control in leaf tissue and promotes stalk strength. The regulation of stomata helps the plant take in CO_2 and release O_2 in reducing lodging losses at harvest. Specific recommendations for P and K fertilizers follow.

Illinois: Farmers are encouraged to build soil test P levels to between 40 and 50 pounds per acre depending upon the supplying power of the soil, and to build soil test K levels to between 260 and 300 pounds per acre. Once these levels are reached, they are maintained by applying crop removal rates of nutrients. Grain sorghum yields of 80, 100 and 120 bushels per acre would remove 34, 42 and 50 pounds P_2O_5 per acre and 17, 21, and 25 pounds K_2O per acre, respectively.

Kentucky: Fertilizer phosphorus is recommended when soil test levels drop below 60 pounds of P_2O_5 per acre (30 ppm using a 6" soil test, 20 ppm using a 10" soil test) and fertilizer potassium is recommended when soil test levels drop below 300 pounds of K_2O per acre (150 ppm using a 6" soil test, 20 ppm using a 10" soil test). Rates are tied to soil test results.

Tennessee: Recommended amounts of K_20 and P_20_5 range from 30 pounds per acre for both nutrients on medium testing soils to 60 pounds per acre for low testing soils and are usually applied immediately before or at planting time. **For soils testing high in phosphate and potassium, no additional fertilizer is recommended.** Fertilizer may be effectively applied in the fall if fields are not subject to severe erosion or flooding.

Nitrogen.

In general, sorghum production needs application of 1.0 pound of nitrogen per bushel of expected yield. This amount needs to be adjusted for soil test results as well as nitrogen credit from legumes. If beginning a no-till program, an additional 20 to 30 pounds of nitrogen needs to be applied to account for nitrogen immobilization due to the increased residue with no-till. This immobilization effect should disappear by the third year into the no-till program.

Illinois: The response to nitrogen is somewhat erratic, due largely to the extensive root system's efficiency in taking up soil nutrients. For this reason, and because of the lower yield potential, in the past the maximum rate of total nitrogen suggested was about 125 pounds per acre. For sorghum following a legume such as soybean or clover, the nitrogen rate may be reduced by 20 to 40 pounds per acre. More recent research data conducted by the University of Illinois from 2003-2005 at Brownstown, Dixon Springs, and Belleville (8 site-years) suggests an economic approach using the price of nitrogen per pound and the price per bushel of grain sorghum (Tables 5 and 6).

Kentucky: About 100 to 125 pounds of N per acre are recommended for sorghum in most crop rotation systems. The higher rate would be used on soils that are poorly drained. When grain sorghum follows a field that has been in pasture for four years or less, the nitrogen rate can be reduced to 75 to 100 lbs. N per acre and if sorghum follows a field that has been in pasture for five years or more, then nitrogen rates can be dropped to 50 to 75 lbs. of N per acre.

Tennessee: Sixty to 90 (60-90) pounds of nitrogen per acre should be applied to grain sorghum immediately before planting, at planting or side-dressed within four weeks after planting. Response to the higher rate would most likely occur when grain sorghum follows a non-legume, is grown no-till, or is grown on soils with restricted drainage or which have textures with more clay than silty clay loam. Nitrogen sources containing urea are more susceptible to losses when surface applied to moist soils followed by three or more days of rapidly drying conditions without rainfall.

Adequate nitrogen, potassium and phosphorus are needed for excellent sorghum yields. However, grain sorghum typically does not respond to the addition of nutrients other than N, P and K.

Table 5. Recommended N application rates (lb/acre) for grain sorghum based on grain sorghum price and N fertilizer price following soybeans. An extra 20-40 pounds of N may be warranted when sorghum follows corn or a grass crop.

Table 5.
Recommended Nitrogen Application Rates (lb/acre) for Grain Sorghum based on grain sorghum price and N fertilizer price.

N Price	Grain Sorghum Value ($/bu)									
($/lb)	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50	$6.00	$6.50	$7.00
$0.25	78	84	88	91	93	95	97	98	99	100
0.30	72	78	83	87	90	92	94	96	97	98
0.35	65	73	78	83	86	89	91	93	94	95
0.40	58	67	74	78	82	85	88	91	92	93
0.45	51	61	69	74	78	82	85	87	89	90
0.50	45	56	64	70	75	78	81	84	86	88
0.55	38	50	59	66	71	75	78	81	84	86
0.60	31	45	54	61	67	72	75	78	81	83
0.65	24	39	49	57	63	68	72	76	78	81
0.70	18	33	45	53	60	65	69	73	76	78

Note: Rates based on grain sorghum following a previous crop of soybean. Using 20-40 pounds per acre more N may be warranted when sorghum follows a previous corn or grass crop.

Table 6.
Price of Common Nitrogen Fertilizers in Dollars per Pound of Nitrogen For Various Amounts of Nitrogen

		Cost per Ton										
Nitrogen Fertilizer	Percent of N	$250	$300	$350	$400	$450	$500	$550	$600	$650	$700	$750
Anhydrous Ammonia (NH3)	82%	0.15	0.18	0.21	0.24	0.27	0.30	0.34	0.37	0.40	0.43	0.46
Urea	46%	0.27	0.33	0.38	0.43	0.49	0.54	0.60	0.65	0.71	0.76	0.82
UAN (32-0-0)	32%	0.39	0.47	0.55	0.63	0.70	0.78	0.86	0.94	1.02	1.09	1.17

Weed Control

Weeds should not be allowed to compete with grain sorghum. Normally, all weeds should be controlled with tillage and/or herbicides prior to planting grain sorghum. Most herbicides used in grain sorghum are selective, meaning that they kill certain weed species and do not harm the crop or certain other weed species. In addition, many herbicides require applications on small weeds. Grain sorghum producers need to pay close attention to weeds that emerge in a sorghum field and to try to control them before they get too large.

Do not plant grain sorghum into fields heavily infested with Johnsongrass (*Sorghum halapense*). Johnsongrass is a very close relative to grain sorghum (*Sorghum bicolor*) making chemical control of Johnsongrass in grain sorghum extremely difficult. In addition, Johnsongrass is extremely competitive and it harbors several diseases and insects that attack grain sorghum.

In general, grain sorghum should be planted in fields with relatively low weed pressure. The lower weed pressure can be achieved with aggressive weed management in the preceding crops (i.e. soybean). Grasses are typically more challenging than broadleaves to control with herbicides in grain sorghum.

Prior to planting. Weeds can be removed prior to planting grain sorghum either by tillage or with herbicides. A field cultivator or chisel plow are probably the best options for tillage. Table 7 shows several available herbicides with sorghum applications approved on the label.

In no-till situations, herbicide programs involving glyphosate or paraquat plus 2,4-D and atrazine are usually very good options. Expert® (S-metolachlor + atrazine + glyphosate) and Sequence® (S-metolachlor + glyphosate) are premixes containing glyphosate and are suitable for killing vegetation before planting in no-till fields.

At planting. Several herbicides can be applied at planting for grain sorghum. Dual II Magnum® (S-metolachlor), Micro-Tech® (alachlor) and Outlook® 6E (dimethenamid-P) or premixes of these herbicides with atrazine, all can be applied at planting, as long as seed is treated with either Concep® or Screen® safener. Atrazine alone (up to 1.2 pounds active ingredient per acre) can be applied at planting without a safener. Milo-Pro® 4L (propazine) can be applied without a safener.

Postemergence or Foliar. Herbicides that can be applied after grain sorghum has emerged include Aim® (carfentrazone), Basagran® (bentazon), Buctril®(bromoxinyl), 2,4-D Amine, Rage D-Tech® (carfentrazone + 2,4-D), dicamba, Weedmaster® (dicamba + 2,4-D), Starane® (fluroxypyr), Permit® (halosulfuron), Yukon®

(halosulfuron + dicamba) and Prowl® (pendimethalin). Prowl® should not make contact with brace roots and drop nozzles are suggested on larger plants. Paraquat can be applied postemerged if directed with drop nozzles. Most of the foliar herbicides have crop height limitations. Some allow the use of directed spray for later applications.

Interrow cultivation can be conducted in relatively flat soils where grain sorghum is grown in rows wide enough to accommodate the equipment. If interrow cultivation is used, set the shovels only as deep as necessary to remove the weeds.

For more specific information on herbicide options, timings and use rates, consult the local state extension weed control publication.

- In Kentucky, refer to AGR-6 Weed Control Recommendations for Field Crops *(http://www.ca.uky.edu/agc/pubs/agr/agr6/01.pdf)*.
- In Tennessee, refer to PB1580 Weed Control Manual for Tennessee Field Crops *(http://www.utextension.utk.edu/weedcontrol/weedcontrol.html)*.
- In Illinois, check IAPM-09 2009 Illinois Agricultural Pest Management Handbook *(http://ipm.illinois.edu/pubs/iapmh/02chapter.pdf)*.

Table 7.
Herbicides currently available for use in grain sorghum (check your state extension guides for labels, specific use rates, etc)

Product †	Active Ingredient(s)	Required Seed Treatment	Timing ‡	Products with Same Active Ingredient (may be a different formulation)
2,4-D Amine	2,4-D amine		POST	
Aatrex Nine-O	atrazine		PP,PPI,PRE	
Aim EW	carfentrazone		POST, DES	
Atrazine 4L	atrazine		PP, PPI, PRE	
Banvel	dicamba		POST	Clarity, Oracle, Sterling
Basagran	bentazon		POST	
Bicep II Magnum	S-metolachlor + atrazine	CONCEP or SCREEN	PP, PPI, PRE	Cinch ATZ
Buctril 2EC	bromoxynil		POST	
Bullet 4WDL	alachlor + atrazine	SCREEN	PP, PPI, PRE	Lariat

Duall II Magnum	S-metolachlor	CONCEP	PP, PPI, PRE	Cinch
Expert 4.88L	S-metolachlor + atrazine + glyphosate	SCREEN		
Gramoxone	paraquat		PP, PRE, PD, DES	Firestorm Parazone
Inteon			DES	
Guardsman Max				
5E	atrazine			
Micro-Tech	alachlor	SCREEN	PP, PPI, PRE	Intrro
Milo-Pro 4L	propazine	SCREEN	PP, PPI, PRE	
Outlook 6E	dimethenamid-P	CONCEP or SCREEN	PP, PPI, PRE	
Permit 75DF	halosulfuron		POST	
Prowl	pendimethalin		POST	Pendimax
Rage D-Tech	carfentrazone		POST	

Roundup PowerMax	glyphosate		PP, PRE, DES	Roundup, Gly-Star, Mad Dog, Many Others
Sequence 5.25L	S-metolachlor + glyphosate	CONCEP or SCREEN	PP, PRE	
Sodium Chlorate	sodium chlorate	DES		Defol 6
Starane	fluroxypyr		POST	
Touchdown	glyphosate		PP, PRE, DES	Roundup, Gly-Star, Mad Dog, many others
Weedmaster	dicamba + 2,4-D		POST	
Yukon 67.5 WDG	halosulfuron + dicamba		POST	

† Listing of a product name is not an endorsement of that product or company. Product names change regularly. Please consult your state extension publication on weed management for specific use rates, target weed species, etc.
‡ PP = preplant, PPI = preplant incorporated, PRE = preemergence, POST = postemergence, PD = post-directed spray, DES = dessication or harvest aid

Please read and follow all label requirements for your state or region.

Harvest Aids and Chemical Desiccants.
Grain sorghum does not dry to safe levels normally in the field. In addition, mature grain sorghum is prone to harvest losses from lodging, birds, insects, molds and poor weather. A chemical desiccant or a killing frost will hasten field drying, and artificial drying is normally required before marketing or storing grain sorghum.

Harvest aids help kill both green weeds and the sorghum plant, thus providing some reduction in moisture from plant matter. Glyphosate (Roundup PowerMax®, Touchdown®, others) used as a harvest aid should be applied after grain moisture has reached 30 percent or less. Glyphosate products are slow acting and may not reduce grain moisture. Desiccants are intended to hasten the drydown of weed and sorghum foliage, and may cause small decreases in grain moisture. Sodium chlorate (Defol 6®, others) is a chemical desiccant and should be applied seven to 10 days prior to anticipated harvest date.

Insect Management

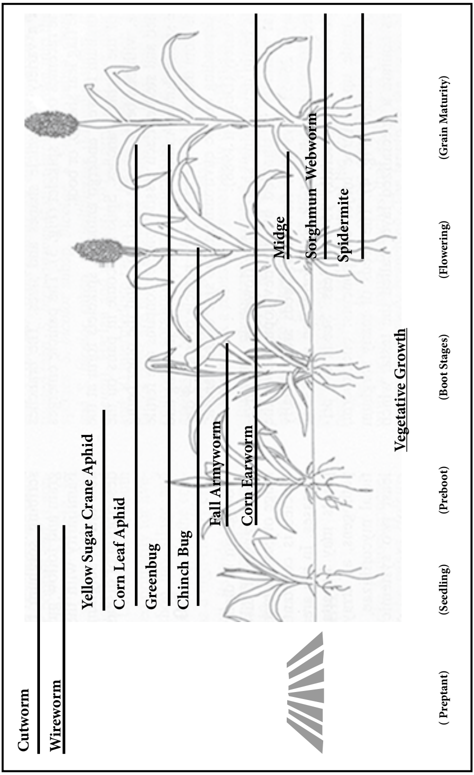

Fig. 2. consists of data compiled by the University of Arkansas Extension service which outlines the timeframe (shown in darkened line) when common insect pests are more likely to occur during the sorghum growing season.

A number of insects can attack sorghum during the growing season in the Mid-South. The most common insects found at planting are cutworm, wireworm and grubs. Mid- and late-season insects commonly found include greenbugs and other aphids, sorghum midge, flea beetles, grasshoppers, fall armyworm, corn earworm, sorghum webworm and spider mites. The extent of damage by insects in grain sorghum is often related to the planting date. The greenbug is more common in early planted sorghum, while the sorghum midge, corn earworm, fall armyworm and sorghum webworm are more severe in late-planted sorghum.

Seed insecticide treatments such as clothianidin (Poncho®), thiamethoxam (Cruiser®) and imidicloprid (Gaucho®) are fairly new for use in sorghum and have good efficacy on many below ground soil pests and early seedling pests of sorghum such as flea beetle, chinch bug or stink bug. Many granular insecticide products for control of rootworm in corn can be used in grain sorghum. A number of foliar insecticides provide excellent control of sorghum leaf and grain pests.

Basic identification and threshold information are included below for some of the most troublesome insect pests in grain sorghum. Refer to the extension publication in your state for specific treatment recommendations for these insects as control options may vary by state. In Kentucky refer to ENT-24: Insecticide recommendations for grain sorghum (milo) and IPM-5: Kentucky IPM manual for grain sorghum. In Tennessee, use PB1768 2009 Insect Control Recommendations for Field Crops. In Illinois, refer to IAPM-09 2009 Illinois Agricultural Pest Management Handbook.

Greenbug (Photo 1)* 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. Reproductive potential is very high compared to other aphids. The greenbug injects a toxic substance in its saliva that causes red spots on leaves where it feeds. Treatment for greenbug is suggested once there are one or two greenbugs on the majority of the plants in the seedling stage and when leaves show damage or when one or more leaves are dying on larger sorghum plants.

Corn leaf aphid (Photo 2)* The corn leaf aphid has a bluish-green body about 1/16th inch long with black cornicles (tailpipes at the end of the abdomen), 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 pest later in the growing season.

**Photos found in Appendix B, page 68*

Yellow sugarcane aphid (Photo 3)* Adults and nymphs are bright yellow to light green in color with two double rows of darker spots down the top of the abdomen. Feeding causes reddening of sorghum leaves and may transmit viral diseases. This aphid feeds on the underside of sorghum leaves in mid- to late-season, and can reach numbers large enough to require treatment. Treat when one or two aphids are found on most seedling plants and damage is visible or when one or more leaves show severe damage on larger plants.

Corn earworm (Photo 4)* 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 1.5 inches long and feed on grain heads. Treatments should be applied when two or more small larvae or one large (greater than 1/2 inch) larva is found per head.

Fall armyworm (Photo 5)* Fall armyworm larvae have a dark head capsule and a prominent inverted Y on the front of the head. Body color is greenish to brownish with brownish to black strips on the sides of the body. Check whorls of young, late-planted sorghum and inside grain heads of more mature plants. Treat when an average of two or more small larvae or one large (greater than 1/2 inch) larva is found per head.

Sorghum webworm (Photo 6)* These are small, greenish, hairy caterpillars with four reddish brown stripes down the back. Full-grown larvae are about 1/2 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 three to four or more larvae are found per grain head.

Sorghum midge (Photo 7)*
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.

During a single day of adult life, each female lays about 50 yellowish-white eggs in flowering spikelets of sorghum. Eggs hatch in two to three days. Larvae are colorless at first, but when fully grown, are dark orange. Larvae complete development in nine to 11 days and pupate between the spikelet glumes. Shortly before adult emergence, the pupa works its way toward the upper tip of the spikelet. After the adult emerges, the clear or white pupal skin remains at the tip of the spikelet.

A generation is completed in 14 to 16 days under favorable conditions. Sorghum midge numbers increase rapidly because of multiple generations forming during a season. Midge numbers also increase when sorghum flowering times are extended by a range of planting dates or sorghum maturities. Sorghum midges overwinter as larvae in cocoons in spikelets of sorghum or Johnsongrass. Johnsongrass spikelets containing diapausing larvae fall to the ground and become covered with litter. When sorghum is shredded, spikelets containing larvae fall to the ground and are disked into the soil. Sorghum midges emerging in spring do so before flowering sorghum is available, and these adults infest Johnsongrass. Sorghum midges developing in Johnsongrass disperse to fields of sorghum when it flowers. Early-season infestations in sorghum are usually below damaging levels. As the season progresses, sorghum midge abundance increases, especially when flowering sorghum is available in the area. Numbers often drop late in the season.

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 midges has various proportions of normal kernels scattered among non-kernel-bearing spikelets, depending on the degree of damage.

Effective control of sorghum midge requires the integration of several practices that reduce sorghum midge abundance and their potential to cause crop damage. The most effective cultural management method for avoiding damage is early, uniform planting of sorghum in an area so flowering occurs before sorghum midges reach damaging levels. Planting hybrids of uniform maturity early enough to avoid late flowering of grain heads is extremely important. This practice allows sorghum to complete flowering before sorghum midges increase to damaging levels. Cultural practices that promote uniform heading and flowering in a field are also important in deciding on treatment and in achieving acceptable levels of insecticidal control. To reduce sorghum midge abundance, use cultivation and/or herbicides to eliminate Johnsongrass inside and outside the field. Where practical, disk and deep plow the previous year's sorghum crop to destroy overwintering sorghum midges.

Multiple insecticide applications are used to kill adults before they lay eggs. Sorghum planted and flowering late is especially vulnerable to sorghum midge. To determine whether insecticides are needed, evaluate crop development, yield potential and sorghum midge abundance daily during sorghum flowering. Because sorghum midges lay eggs in flowering sorghum grain heads (yellow anthers exposed on individual spikelets), they can cause damage until the entire grain head or field of sorghum has flowered. The period of susceptibility to sorghum midge may last from seven to nine days (individual grain head) to two to three weeks (individual field), depending on the uniformity of flowering.

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

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

Because they are relatively weak fliers and rely on wind currents to aid their dispersal, adult sorghum midges usually are most abundant along edges of sorghum fields. For this reason, inspect plants along field borders first, particularly those downwind of earlier flowering sorghum or Johnsongrass. If no or few sorghum midges are found on sorghum grain heads along field edges, there should be little need to sample the entire field. However, if you find more than one sorghum midge per flowering grain head in border areas of a sorghum field, inspect the rest of the field.

Sample at least 20 flowering grain heads for every 20 acres in a field. For fields smaller than 20 acres, sample 40 flowering grain heads. Flowering heads are those with yellow blooms. Avoid plants within 150 feet of field borders. Record the number of sorghum midges for each flowering head sampled and then calculate the average number of midges per flowering head. Almost all of the sorghum midges seen on flowering sorghum heads are female.

Next, calculate the number of flowering heads (yellow blooms present) per acre. Record the number of flowering heads along a length of row equal to 1/1000 of an acre. As an example, for a row spacing of 40 inches, 13.1 row feet is equal to 1/1000 of an acre. Make counts in at least four areas of the field. If flowering (plant maturity) is highly variable across the field, additional sites should be sampled. Average all counts and multiply by 1000 to estimate the number of flowering heads per acre. If there is only one head per plant, then the number of flowering heads per acre is equal to the percent heads in bloom multiplied by the number of plants per acre.

Sorghum midge density per acre is then calculated as the mean number of midges per flowering head times the number of flowering heads per acre. For example, if there are 30,000 flowering heads per acre and scouting records show an average of 0.5 sorghum midge per flowering head, then there are an estimated 15,000 sorghum midges per acre (0.5 sorghum midge per head x 30,000 flowering heads per acre). The percentage of flowering heads changes rapidly during bloom and should be determined each time the field is sampled. Studies have shown that the larvae from a single female sorghum midge will destroy an average of 45 grain sorghum kernels. The seed weight of sorghum hybrids averages 15,000 seeds per pound (range of 12,000 to 18,000, depending on the hybrid). A loss of 45 kernels per midge, therefore, represents 0.0030 pounds (1.364 grams) of grain.

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

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

For example, assume field scouting yields an average of 1.1 sorghum midges per flowering head and field sampling shows the number of flowering heads is 18,000 per acre. (This is equal to a plant population of 90,000 with 20 percent of the heads flowering and one head per plant.) If the value of the crop is estimated to be $4.00 per 100 pounds and the cost of control is $5.00 per acre, the above equation yields the injury level as:

$$\frac{\$5 \times 33{,}256}{\$4 \times 18{,}000} = 2.3 \text{ sorghum midges per flowering head}$$

In this example, the field density of 1.1 sorghum midges per flowering head is below the injury level and treatment would not be justified. If the field is scouted two days later and the sorghum midge density is again 1.1 midges per flowering head, but now the number of flowering heads has increased to 45,000 per acre (50 percent of the plants now have a flowering grain head in a plant density of 90,000 per acre and one head per plant), the injury level is now:

$$\frac{\$5 \times 33{,}256}{\$4 \times 45{,}000} = 0.9 \text{ sorghum midges per flowering head}$$

In this example, the field density of 1.1 sorghum midges is now above the economic injury level of 0.9 per flowering head and treatment would be justified. This shows the importance of considering the number of flowering heads (grain susceptible to midge damage) in estimating the economic injury level.

Economic injury levels, as determined from the above equation, are shown in Table 8 for a range of typical treatment costs per acre, market values per 100 pounds of grain and numbers of flowering heads per acre. Use the equation for estimating injury levels for your actual control costs, crop value and number of flowering heads per acre.

Table 8. Estimated economic injury levels for sorghum midge for a range of factors. (This table is only a guide. Use the equation in the text to estimate the economic injury level in your field.)

		Economic injury level - mean number of midges/flowering head		
Control costs, $/acre	**Crop value, $100 lbs**	**Flowering heads = 18,000/acre**	**Flowering heads = 455,000/acre**	**Flowering heads = 67,500/acre**
5	6	1.6	0.6	0.4
5	7	1.3	0.5	0.34
5	8	1.2	0.5	0.3
6	6	1.9	0.8	0.5
6	7	1.6	0.7	0.4
6	8	1.4	0.6	0.35
7	6	2.2	0.85	0.6
7	7	1.9	0.75	0.5
7	8	1.6	0.65	0.45

Insecticide residues should effectively suppress sorghum midge egg laying one to two days after treatment. However, if adults still are present three to five days after the first application of insecticide, immediately apply a second insecticide treatment. Several insecticide applications at three-day intervals may be justified if yield potential is high and sorghum midges exceed the economic injury level (Table 9).

Table 9 Remarks

Cyfluthrin - If one or two applications are made, green forage may be fed or grazed on the day of treatment. If three applications are made, allow at least 14 days between last application and grazing

Cyhalothrin - Do not graze livestock in treated area or harvest for fodeder, silage or hay.

Table 9. Suggested insecticides for controlling sorghum midge

		Days from last application to:	
Insecticide	Application Rate	Harvest	Graze
Chlorpyrifos (Lorsban ® 4E)	8 oz	30	30
Cyfluthrin (Baythroid ® 2E)	1.0-1.3 oz		14, See remarks
Cyhalothrin			See remarks
(Karate ® IE) (Warrior ® 1E)	1.92-2.56 oz		
Esfenvalerate (Asana ® XL)	2.95-5.8 fl oz	21	-
Malathion (Fyanon ® ULV)	8-12 oz	7	7
Methomyl (Lannate ®) (2.4LV), (90WSP)	12-24 oz 4-8 oz	14 14	14 14
Zeta-cypermethrin (Mustang Max ®)	1.28-4.0 fl oz	14	45

Diseases

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

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

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

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

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

Table 10. The following diseases with descriptions are from PPA-10a "Kentucky Plant Disease Management Guide for Corn and Sorghum".

Disease:	**Bacterial Stripe**
Cause:	Burkholderia andropogonis (syns. Pseudomonas andropogonis)
Symptoms:	Long, narrow brick-red to purplish-red stripes, becoming tan when dry. Lesions are bound by secondary veins.
Key Features of Disease Cycle:	Bacteria survive in infected seed and in undecomposed sorghum residue. Warm, humid weather favors infection. Generally does little damage.
Management:	Use clean seed. Rotate away from grain sorghum for two years. Control weeds, especially shattercane (Sorghum bicolor). Use resistant hybrids, especially for reduced tillage and no-tillage fields.
Disease:	**Fusarium head blight**
Cause:	Fusarium moniliforme
Symptoms:	The head becomes infected first while stalk tissue at and immediately below the head become infected later. Cream to pink fungal growth can occur on grain.
Key Features of Disease Cycle:	The fungus can occur in seed or crop residue. Spores are spread by air. Warm moist conditions provide a favorable environment for disease development.
Management:	Timely harvest of grain at proper moisture. Hybrids with pigmented seed coats are more tolerant grain mold. Hybrid with dense, compact heads could be more damaged.

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

Harvesting

Grain quality at harvest is influenced by grain variety, weather and combine adjustment. Minimizing grain damage to maintain quality requires good handling, drying and cooling equipment and conscientious stored-grain management.

Grain sorghum is harvested with a combine with a grain table with a rigid header, a flex header in the rigid position, and a row crop header. Guards that help pick up heads are recommended if heads are drooping or stalks are lodged. Sorghum stalks are generally much wetter than corn stalks at harvest, and they may be sticky from sugars. Stalk material pulled into the harvester is more likely to clump in the combine, thus increasing harvest losses, and residue can also collect in the hopper with grain. 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.

Handling. Grain sorghum may need to be cleaned before storing 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 to 22

percent moisture if a suitable heated-air system is available for drying the crop. Harvesting above 22 percent 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 two to four 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 four feet. After drying, cool the grain and move it to another storage bin before the next day's harvest. A three-foot depth of sorghum is equivalent in resistance to four-foot depth of corn at an airflow rate of 10 cubic feet per minute. 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 five to 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 one to two 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 6 months) 13 percent moisture
- Long term storage (6 months or longer) 11 to 12 percent moisture

Storing Grain Sorghum. Aeration is one of the most important management tools available to producers for maintaining grain quality in storage. Aeration extends the storage life of grain by removing odors, preventing moisture accumulation and controlling conditions favorable 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 to 15°F lower than the grain temperature. Average outside temperature can be taken as the average of the high and low temperatures over a three to five 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 Sample Grade, with U.S. No. 1 being the highest quality (Table 11). Value of grain sorghum follows this grading system. Proper harvesting, drying and storing are important to achieving the higher grades.

For more information on harvesting, drying and storing in specific states, consult Kentucky's AEN-17: Harvesting, drying and storing grain sorghum, and AE-82-W: Harvesting, drying and storing grain sorghum.

Table 11.
Sorghum Grades and Grade Requirements, from the United States Standards for Sorghum, effective June 2008

Grading Factors	**Grades U.S. Nos. [1]**			
	1	2	3	4
Minimum pound limits of				
Test weight per bushel	57.0	55.0	53.0	51.0
Maximum percent limits of				
Damaged kernels:				
Heat (part of total)	0.2	0.5	1.0	3.0
Total	2.0	5.0	10.0	15.0
Broken kernels and foreign material:				
Foreign material (part of total)	1.0	2.0	3.0	4.0
Total	3.0	6.0	8.0	10.0
Maximum count limits of				
Other material:				
Animal filth	9	9	9	9
Castor beans	1	1	1	1
Crotalaria seeds	2	2	2	2
Glass	1	1	1	1
Stones[2]	7	7	7	7
Unknown foreign substance	3	3	3	3
Cockleburs	7	7	7	7
Total[3]	10	10	10	10

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

[1]Sorghum which is distinctly discolored shall grade higher than U.S. No. 3
[2]Aggregate weight of stones must also exceed 0.2 percent of the sample weight.
[3]Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones, unknown foreign substances or cockleyburs.

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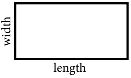
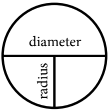
5. U.S. EPA. 2009. Crop Production. Online. *http://www.epa.gov/oecaagct/ag101/printcrop.html*

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

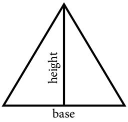
Calculations & Conversions



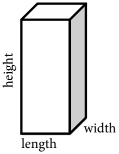
Area of a rectangle or square = length x width



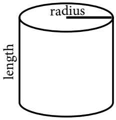
Area of a circle = 3.1416 x radius squared; or 0.7854 x diameter squared
Circumference of a circle = 3.1416 x diameter; or 6.2832 x radius



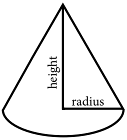
Area of triangle = base x height ÷ 2



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

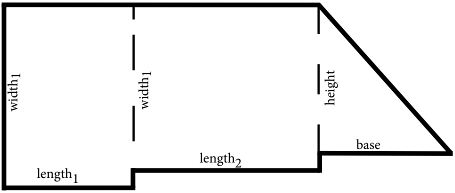


Volume of a cylinder = 3.1416 x radius squared x length



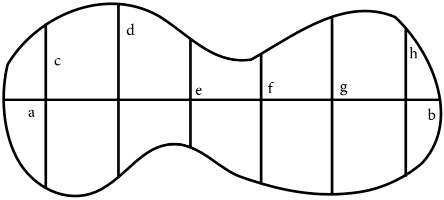
Volume of cone = 1.0472 x radius squared x height

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



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

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



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

Conversion Factors

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

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

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

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

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

Appendices

a. The Sorghum Plant

Sorghum grain is found on the panicle, commonly referred to as the head. The panicle consists of a central axis with whorls of main branches, each of which contains secondary and at times, tertiary branching. The length of the branches allows for a wide range of shapes and sizes in sorghum and for sorghums with very open panicles or sorghums with very compact panicles. The branches carry the racemes of the spikelets where the grain is found (see Figure 1). The panicle emerges at boot from the flag leaf sheath.

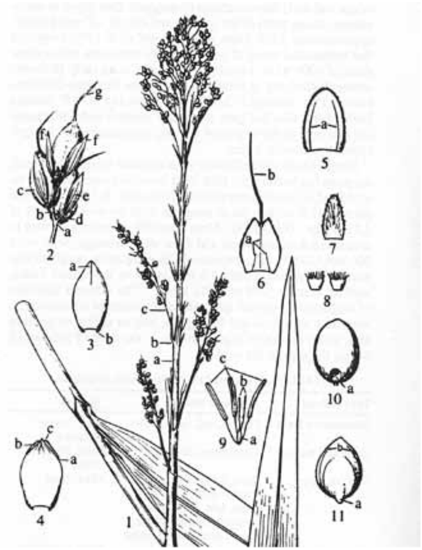


Fig. 3. The panicle of *Sorghum bicolor* subsp. *bicolor* which consists of the inflorescence and spikelets. 1. Part of panicle: a = internode of rachis; b = node with branches; c = branch with several racemes. 2. Raceme: a = node; b = internode; c = sessile spikelet; d = pedicel; e = pedicelled spikelet; 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 flowering. Seeds are normally harvested 10-20 days after black layer when moisture content is generally 15 percent or less. Black layer can be seen at the base of the grain where it attaches to the rachis branch and indicates that the grain is physiologically mature. Seeds are made up of three major components, the endosperm, embryo, and pericarp (Figure 4). All sorghums contain a testa, which separates the pericarp from the endosperm. If the testa is pigmented, sorghum will contain tannins, if not, the grain is free of tannins. None of the commercial U.S. grain sorghums have a pigmented testa and all are said to be free of tannins.

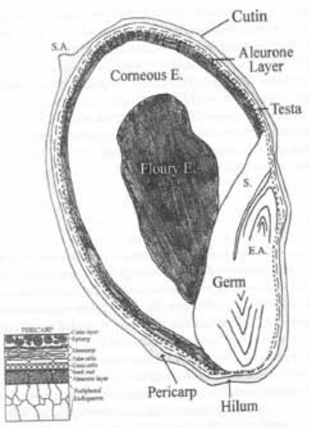


Fig. 4. Sorghum grain, showing the pericarp (cutin, epicarp, mesocarp, cross cells, tube cells, testa, pedicel, and stylar area (SA)), endosperm (aleurone layer, corneous and floury), and the germ (scutellum (S) and embryonic axis (EA). Adapted from L. W. Rooney and Miller, 1982).

b. Photos

Photo 1. Greenbug

Photo 2. Corn Leaf Aphid

*Photo 3. Yellow Sugarcane Aphid**

*Photo 4. Corn Earworm***

*Photo 5. Fall Armyworm**

*Photo 6. Sorghum Webworm**

*Photo 7. Sorghum Midge**

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

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Sorghum Facts

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

Special thanks to the Universities of Tennessee, Illinois, Southern Illinois, and Kentucky.

United Sorghum Checkoff Program

SORGHUM CHECKOFF

DISCLAIMER

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