Grain Sorghum Production in the Mid-South

A regional production guide for Illinois, Kentucky and Tennessee

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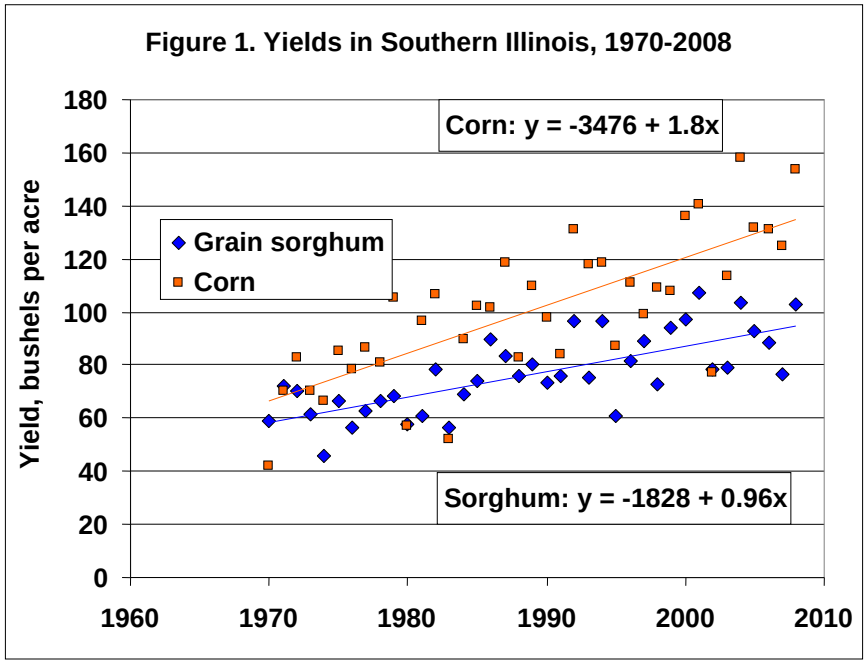
This publication was made possible by funds provided by the

United Sorghum Checkoff Program

INTRODUCTION

On a global basis, grain sorghum *(Sorghum bicolor (L.) Moench)* ranks 6th in production among the cereal grains behind wheat, rice, maize (corn), soybean, and barley. It ranks 4th after rice, corn, and wheat for human consumption (FAO, 2007). The United States is the largest producer and exporter of grain sorghum with slightly over 20% of the global production produced on just over 8% of the world acreage devoted to sorghum production (FAO, 2007 and U.S. Grains Council, 2008). In the United States, grain sorghum ranks 5th in production behind corn, soybean, wheat, and alfalfa. The leading states in order of production are Kansas, Texas, Nebraska, Missouri, and Oklahoma (U.S. Grains Council, 2008). Illinois, Kentucky and Tennessee produce smaller amounts of sorghum, but Illinois ranks 6th in U.S. grain sorghum production (U.S. Grains Council, 2008).

A substantial amount of the grain sorghum produced in the United States is exported with the remainder being utilized predominantly as livestock feed, pet food, bird seed, and industrial uses. As much as 35% of domestic sorghum production goes to produce ethanol and its various co-products (National Grain Sorghum Producers Association). A majority of the ethanol production from sorghum occurs in the state of Kansas (Kansas Grain Sorghum Producers Association). With demand for renewable fuel sources increasing, demand for co-products like sorghum-DDG (distillers dried grain) will increase as well due to sorghum's favorable nutrition profile (U.S. EPA). Sorghum grain has slightly higher protein and lower fat than corn grain. In general, sorghum has about 95% of the nutritional value of corn. Sorghum needs to be ground, cracked, steam flaked, and/or roasted to enhance the nutritional value and digestibility to livestock.



With so much more effort devoted to breeding corn compared to breeding sorghum, corn yields have increased more quickly than grain sorghum yields over recent decades, making grain sorghum less competitive. For example, in grain sorghum producing areas in Illinois, corn yields have nearly doubled since 1970 while yields for grain sorghum have only increased by about 60% (Fig 1). In states like Tennessee, acreage has been reduced by 75% since 1985, consequently fewer grain handlers accept grain sorghum seed, limiting production to primarily six counties in the western part of the state.

While grain sorghum costs less to produce and is more drought tolerant than corn, sorghum yields under good production conditions tend to be lower than corn yields. Sorghum can require more special handling at harvest. Full season grain sorghum is typically planted in fields that are less productive while corn is planted in the more productive fields. Fields that are slow to dry out in the spring and late-season replant situations where nitrogen or a triazine-containing herbicide has been applied to the field may support sorghum planting instead of corn. Grain sorghum can also yield as much as late-planted corn as a double crop following wheat, and may produce higher returns. When commodity prices of corn and grain sorghum are similar, grain sorghum may be a better option when it is so late that predicted corn yields are less than half those of an early-planted crop, especially on drought-prone soils. As a general rule of thumb, grain sorghum may be a better crop option than corn whenever the expected corn yield is less than 100 bushels per acre.

GROWTH AND DEVELOPMENT OF GRAIN SORGHUM

Grain sorghum is a grass crop similar to corn, but sorghum has more tillers (Figure 2) and more finely branched roots than corn. Most commercial sorghum cultivars are hybrids containing two or more dwarfing genes that limit height to three to four feet at the flag leaf, producing a more compact plant that is easier to harvest. Sorghum seed is small and seedlings can be less vigorous than corn. Plants produce new leaves every three to five days depending on temperature. Sorghum is a true warm season crop and day-time temperatures above 90˚F result in maximum photosynthesis. The grain sorghum head (panicle) can be compact, semi-compact or open depending on hybrid. Sorghum is mostly a self-pollinating plant but it can cross pollinate. Hybrid maturity is based on the number of days from planting to head emergence. Sorghum flowers begin to open and pollinate with a few days after the panicle has completely emerged from the boot. Pollen shed occurs first from blooms at the top of the head and progresses downward for 6 to 9 days. There are typically 500 to 1500 grains per head depending on plant population and soil moisture. Seed color is red, yellow or bronze with yellow or white endosperm color. Grain sorghum is a more drought tolerant plant compared to corn because: 1) sorghum is self pollinating (there is less chance of pollination problems common in corn); 2) the waxy coating on stem and leaf surfaces helps limit water loss,; and 3) the root system of grain sorghum extracts water efficiently.

Figure 2 illustrates the different growth stages of the sorghum plant. The growth stages will be the same for different sorghum hybrids, though the number of days to reach a particular stage will differ depending on the relative maturity of a hybrid.

Figure 2 The growth stages of the sorghum plant. Stage 0-- Emergence, coleoptile visible at the soil surface; Stage 1-- 3 visible leaf collars; Stage 2-- 5 visible leaf collars, rapid root development, critical stage for pest management; Stage 3 -- Growing Point Differentiation, 8 leaf collars, leaf number is determined; Stage 4-- Flag Leaf Visible; Stage 5--Boot, head extended into the flag leaf sheath, potential head size determined, soil moisture is critical; Stage 6--Half Bloom, flowering half way down the head, seed number and weight determined, soil moisture is critical; Stage 7-- Soft Dough, grain has doughy consistency and seed dry matter accumulation increases; Stage 8--Hard Dough, grain content is hard; Stage 9--Physiological Maturity, maximum dry matter accumulation, formation of dark spot on side of kernel opposite embryo, seed is at 25-35% moisture content. Figure copyrighted by the University of Illinois.

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 0 to 8 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.

Consideration should also be given to the market class (endosperm color) and bird resistance, which may be associated with palatability to livestock. The red- and bronze-colored hybrids have a more bitter taste than the cream- or white-colored types. In many of the recent hybrid performance trials in nearby states, more hybrids with red- and bronze-colored endosperm have been entered. This may be due to several factors such as less bird damage, marketability, or the need for segregated storage.

Compared to corn, there are fewer commercial grain sorghum hybrids to choose from, so deciding what to plant is less challenging. Performance testing of commercial grain sorghum hybrids is not currently being done in Illinois, Kentucky or Tennessee. Some data from 2010 is available from Tennessee and more recent data are available from Missouri and Arkansas. High performing sorghum hybrids will stay on the market for several years and there is much less turnover compared to corn or soybean. Consult these and other tests to identify hybrids with excellent yield potential across multiple locations or environments.

PLANTING

Site Selection. Grain sorghum is adapted to a wide range of soils throughout the mid-South region, but it is often placed on less-productive soils than is corn. If higher yields are desired, grain sorghum needs to be planted on soils that produce higher corn or soybean yields. Even though grain sorghum is relatively drought resistant, it produces its best yields on deep, level soils 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.

Seedbed Preparation. 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. Many planters used to plant grain sorghum are already set up to plant into no-till conditions and sorghum does not need to be planted deep.

Seed Treatments. If certain herbicides are going to be used in grain sorghum, then a 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.

Planting Date. 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 2 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 1 inch deep under most situations.** Seeds should be placed to moisture but no deeper than about 1 inch in heavy soils and about 2 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 are 2-year averages.

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

Row Spacing	2003			2004			2005		03-05 Average
	DSAC	BRC	BARC	DSAC	BRC	BARC	DSAC	BRC	
	---------- *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 $P = 0.01$

Plant Population. 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 are 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.

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% 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 60 to 70% of what is planted will become a viable plant.

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 1 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.

These 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. Additionally, 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 hybrid has 15,000 seed 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 Rate	2003			2004			2005		03-05 Average
	DSAC	BRC	BARC	DSAC	BRC	BARC	DSAC	BRC	
'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 = Belleville, 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	6.5	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 anytime 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 fight moisture stress and good stalk strength can aid in reducing lodging losses at harvest. Specific recommendations for P and K fertilizers are listed below.

Illinois: Farmers are encourage 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) and fertilizer potassium is recommended when soil test levels drop below 300 pounds of K_2O per acre (150 ppm). 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.

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 (Table 5).

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 4 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 5 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 Nitrogen Application Rates (lb/acre) for Grain Sorghum based on grain sorghum price and N fertilizer price.

N Price ($/lb)	Grain Sorghum Value ($/bu)									
	$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	90	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.

WEED CONTROL IN GRAIN SORGHUM

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. In no-tillage 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, but propazine has crop rotation restrictions that could hinder options for a following crop.

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 post-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. In Tennessee, refer to PB1580 Weed Control Manual for Tennessee Field Crops. In Illinois, check IAPM-09 2009 Illinois Agricultural Pest Management Handbook.

Table 6. 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-metoloachlor	CONCEP	PP, PPI, PRE	Cinch
Expert 4.88L	S-metolachlor + atrazine + glyphosate	CONCEP or SCREEN	PP, PRE	
Gramoxone Inteon	paraquat		PP, PRE, PD, DES	Firestorm, Parazone
Guardsman Max 5E	dimethenamid-P + atrazine	SCREEN	PP, PPI, PRE	
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

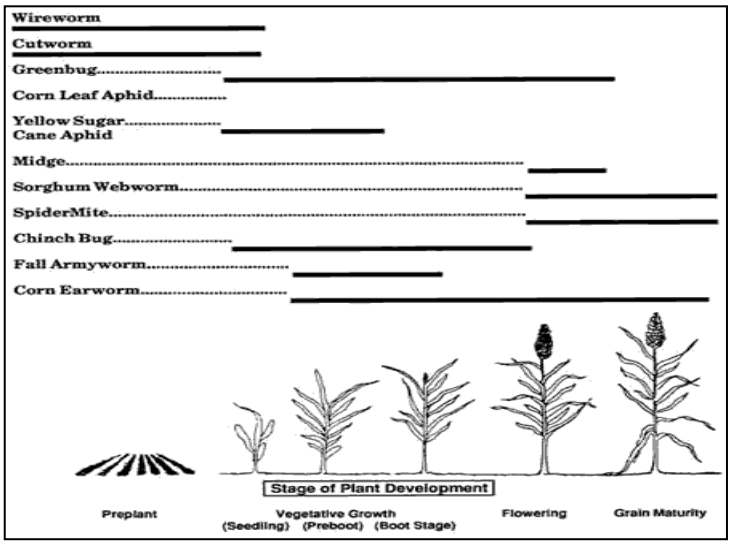
HARVEST AIDS AND CHEMICAL DESICCANTS

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 ten days prior to anticipated harvest date. Diquat (Reglone Desiccant®) can be used as a desiccant if grain sorghum is harvested for seed but cannot be used for grain sorghum harvested for feed.

INSECT MANAGEMENT IN GRAIN SORGHUM

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.

Figure 3 is a chart developed 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.



Seed insecticide treatments such as clothianidin (Poncho®) 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 Insect Control Recommendations for Field Crops. In Illinois, refer to IAPM-09 Illinois Agricultural Pest Management Handbook.

Greenbug 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 two leaves are dying on larger sorghum plants.

Corn leaf aphid 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.

Yellow sugarcane aphid Adults and nymphs are 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 1 or 2 aphids are found on most seedling plants and damage is visible or when one or more leaves show severe damage on larger plants.

Sorghum midge The adult of this insect is a tiny, orange fly that emerges from various seeds, particularly Johnsongrass. The small fly lays eggs on the blooming sorghum heads. Tiny maggots emerge that drill into individual seeds, resulting in blasted seed heads. Planting the entire crop within a short span of time brings on uniform blooming and helps reduce damage. Planting in early May usually avoids heavy infestation. Check fields in early bloom and start control if one of the gnat-like midges per grain head is present.

Corn earworm 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 one or more larvae is found per head.

Fall armyworm 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 one or more larvae is found per head.

Sorghum webworm These are small, greenish, hairy caterpillars with four reddish brown stripes down the back. Full-grown larvae are about ½ 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 to 4 or more larvae are found per grain head.

GRAIN SORGHUM DISEASES

Grain sorghum diseases cause yield losses each year. Fungicides work best as preventative measures, and cultural practices can help minimize loss from diseases. Growers should plant hybrids that have some resistance to common pathogens, plant during the recommended planting window and rotate fields to non-grass crops when diseases have been a problem in a particular field. The fungicides azoxystrobin and propiconazole recently received a grain sorghum label for control of some soil borne, leaf or head diseases. Preliminary data indicate they are effective on certain leaf and head diseases in a wet year.

Table 7. 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:	**Head Smut**
Cause:	*Sporisorium reilianum (syns. Sphacelotheca reiliana)*
Symptoms:	At heading, large galls occur in place of the head. Head turns into mass of dark brown, powdery spores.
Key Features of Disease Cycle:	Infection occurs in seedlings from spores in the soil.
Management:	Use resistant hybrids.
Disease:	**Leaf spots & blights**
Cause:	*Setosphaeria, Collectotrichum, Cercospora, Gleocercospera, Ascophyta*
Symptoms:	Older leaves are infected first with round, oval, or rectangular leaf spots. Spots are tan, yellow, reddish or purple and sometimes have a darker margin.
Key Features of Disease Cycle:	These fungi survive in crop residue and spores are spread by air currents or by splashing rain. Normally, these diseases do not hurt yields. If the upper leaves become infected, then severe yield losses can occur.
Management:	Use resistant hybrids, especially for no-tillage. Rotate away from sorghum or corn for 1 to 2 years. Control weeds that may be a source of the inoculum. Azoxystrobin is labeled as a foliar spray for *Cercospora* (Gray leaf spot) control in sorghum.

Disease:	**Maize Dwarf Mosaic**
Cause:	Maize Dwarf Mosaic Virus
Symptoms:	Irregular, light and dark green mosaic patterns on the leaves, especially the younger leaves. Tan stripes with red borders between the veins ("red-leaf") occurs under cool conditions.
Key Features of Disease Cycle:	The virus lives in Johnsongrass rhizomes and other perennial grasses. The virus is transmitted by certain aphids. Late-planted sorghum is at greater risk.
Management:	Use tolerant hybrids and eradicate Johnsongrass and other perennial grassy weeds.
Disease:	**Root Rot**
Cause:	*Periconia, Pythium, Rhizoctonia, Fusarium*
Symptoms:	Stunting, sometimes leaf yellowing and/or wilting. Rotted roots are pink, reddish brown, or black.
Key Features of Disease Cycle:	Common fungi in soil, but not damaging unless plant is stressed. Common stresses include cool soils, poor drainage, or inadequate fertility. Vigorously growing plants are able to replace damaged roots with new roots.
Management:	Use adapted hybrids. Plant in warm (above 65°F) moist soils at the proper depth and seeding rate. Place herbicide, fertilizer, insecticide and seed properly to avoid stress or injury to seedling. Azoxystrobin is labeled for in-furrow use for *Rhizoctonia* and *Pythium* diseases.
Disease:	**Sorghum Downy Mildew**
Cause:	*Peronosclerospora sorghi*
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.
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.

HARVESTING, DRYING AND STORING GRAIN SORGHUM

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 standard sickle bar cutter. 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 to22 percent moisture if a suitable heated-air system is available for drying the crop. Harvesting below 18 percent will mean greater harvest losses. 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 2/3 to ¾ 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 4-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 5 to 10 degrees of the average outside air temperature after drying. Unheated air may be used when the relative humidity is 55% or less and the grain moisture is 15% or less.

Natural 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 degrees 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 8). Value of grain sorghum follows this grading system. Proper harvesting, drying and storing are important to achieving the higher grades.

Table 8. 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, or 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 cockleburs.				

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.

REFERENCES

1. FAO. 2007. Global Production of Grain sorghum. Online.

   http://www.fao.org/docrep/T0818E/T0818E03.htm#Chapter%202%20-%20Production%20and%utilization

2. U.S. Grains Council. 2008. Sorghum. Online.

   http://www.grains.org/sorghum

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

4. Kansas Grain Sorghum Producers Association. 2008. Kansas Ethanol Production. Online.

   http://www.ksgrains.com/ethanol/kseth.html

5. U.S. EPA. 2009. Crop Production. Online.

   http://www.epa.gov/oecaagct/ag101/printcrop.html

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