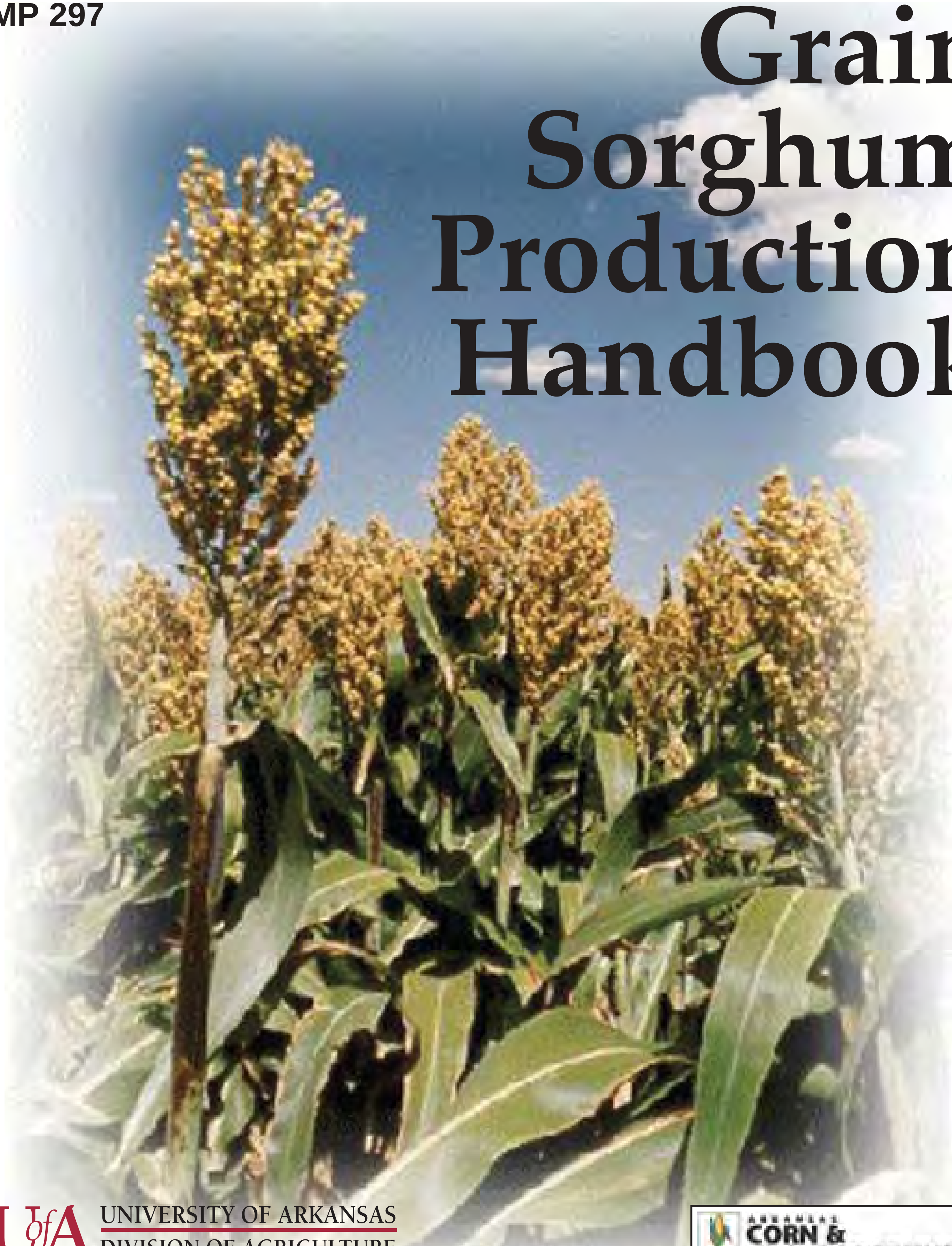
MP 297

Grain Sorghum Production Handbook



UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE

Cooperative Extension Service

ARKANSAS CORN & GRAIN SORGHUM BOARD

University of Arkansas, United States Department of Agriculture, and County Governments Cooperating

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Introduction

Leo Espinoza and Jason Kelley

Grain sorghum is one of the most versatile crops, capable of growing well under contrasting climatic conditions. Although grain sorghum is mostly grown in the U.S. for animal feed, it is the dietary staple of people in more than 30 countries. Some types are also used in making unleavened bread, cakes, wallboard, starch, dextrose, syrup, brooms, ethanol, high quality wax and even vodka and other alcoholic beverages.

Yield records in Arkansas go back as far as 1929. Generations of Arkansas farmers have seen their yields increase from 17 bushels per acre to a high of 86 bushels per acre in 2001, or nearly 1 bushel per acre per year (Figure Intro-1). Records show that grain sorghum acreage has ranged between 4,000 and 940,000 acres during the last 72 years, with an average close to 200,000 acres per year. Planted acres peaked in the mid 1980s, perhaps due to a weak demand for soybeans as well as attractive prices (Figure Intro-2). Since then, grain sorghum acres have come down to the long-term normal.

Prices higher than normal, rotational benefits for nematode control, as well as biomass production for the management of precision-leveled fields, have all contributed to the increase in acreage observed during the 2002 and 2003 seasons.

Grain sorghum acreage expanded in most of the traditional grain sorghum producing counties in 2002. Phillips, Lee, Crittenden, Mississippi and St. Francis counties saw their grain sorghum acreage increase between 72 and 177 percent as compared to the 2001 season. The mentioned counties are also the largest producing ones, with Phillips ranking first with close to 30,000 acres (Figure Intro-3).

Although state average yields are in the 75 to 85 bushels per acre range, it is not uncommon for many Arkansas farmers to obtain yields in excess of 100 bushels per acre, provided they manage their grain sorghum crops properly. Yields from fields under the verification program have ranged between 100 and 112 bushels per acre.

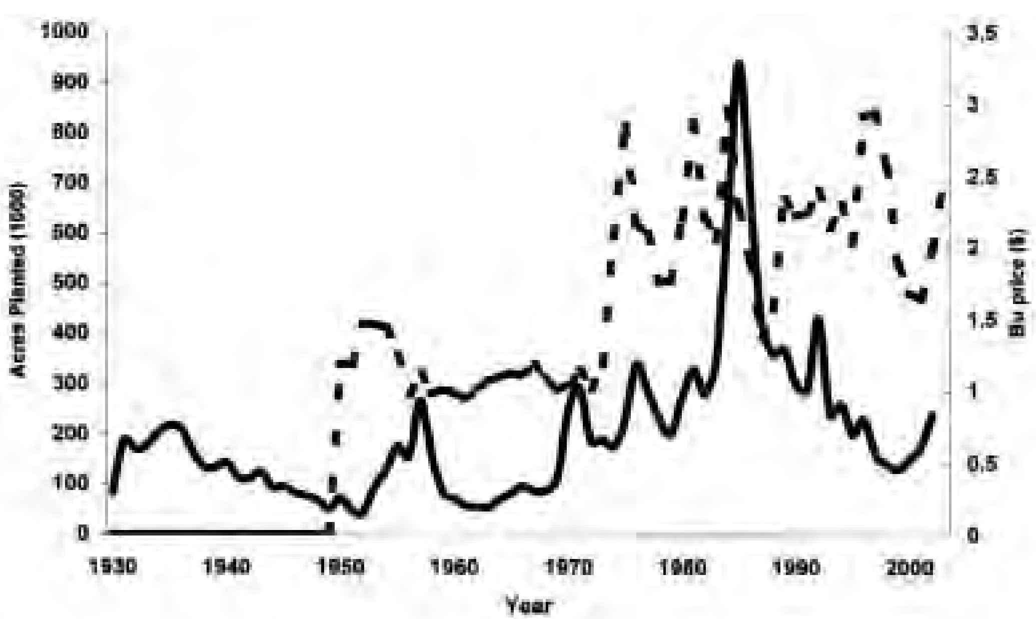

Figure Intro-1. Grain Sorghum Yields Between 1929 and 2002 and Associated Price. Arkansas Agricultural Statistics Service

The Corn and Grain Sorghum Research Verification Program (CGSRVP) began in 2000, funded almost solely by Arkansas growers through check-off contributions. The CGSRVP uses Extension management recommendations to produce a high yielding, economical grain sorghum crop. Information from the CGSRVP fields is used to improve and refine recommendations to meet the needs of Arkansas grain sorghum farmers and identify areas which need additional research. Economic information is collected on each CGSRVP field to estimate crop expenditures and returns.

Extension specialists and researchers with the University of Arkansas Division of Agriculture developed this handbook, with the financial support of Arkansas grain sorghum growers through the Arkansas Corn and Grain Sorghum Promotion Board.

The materials presented here should be used as a reference guide to increase the reader's understanding of topics such as hybrid selection, soil and water management, plant nutrition, integrated pest management, harvesting and safety considerations in the production of grain sorghum under Arkansas conditions. Due to constant changes in laws that regulate pesticide use, the reader is encouraged to contact the appropriate Extension office for the most current information.

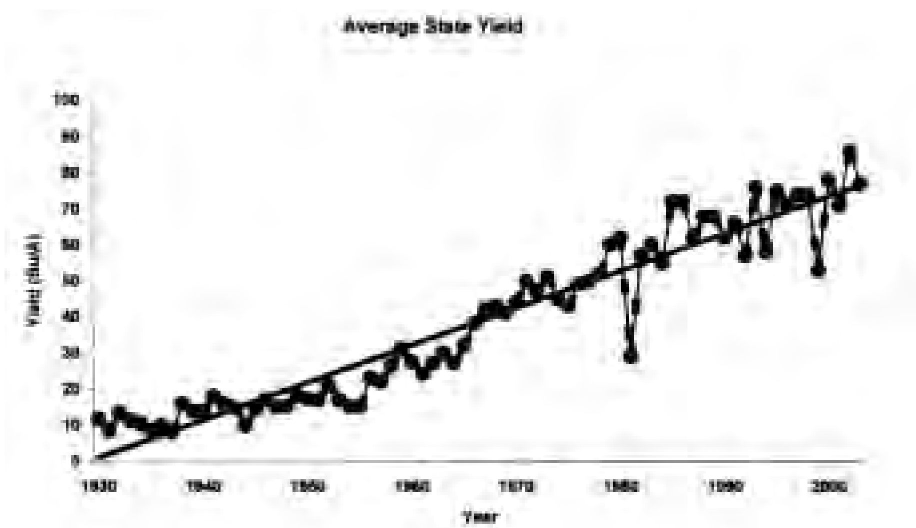

Figure Intro-2. Average Grain Sorghum State Yields Between 1929 and 2002. Arkansas Agricultural Statistics Service.

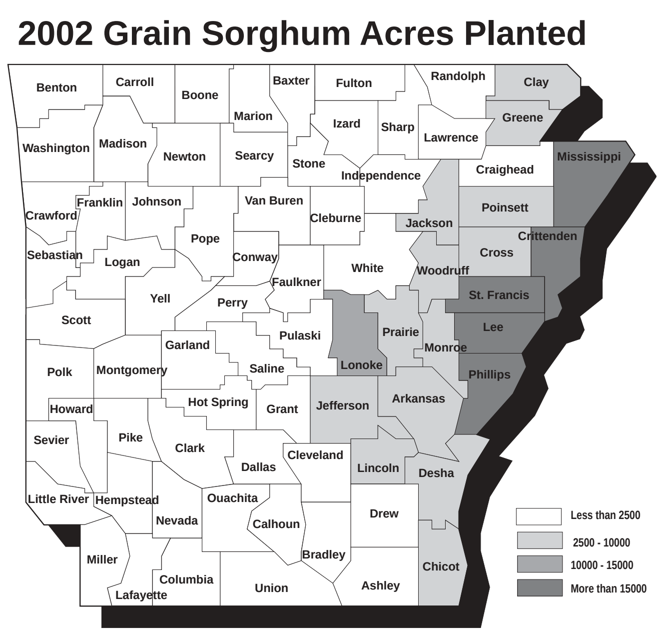

Figure Intro-3. Grain Sorghum Acres Planted During the 2002 Growing Season.

1 - Growth and Development

Jason Kelley

Grain sorghum is an important feed grain crop grown in Arkansas. The plant's ability to produce respectable yields under adverse growing conditions has made it a popular crop for many producers. However, many producers have the perception that grain sorghum will produce good yields with minimal management inputs. In reality, grain yields are often reduced by environmental stresses and poor management. Like any other crop, grain sorghum will respond to optimum growing conditions and proper timing of management inputs for maximum yields. Understanding how the grain sorghum plant develops is critical for understanding the crop's needs and planning management inputs for maximum yields.

Understanding how the grain sorghum plant develops begins with learning the structures and anatomy of the plant. Figure 1-1 shows a young plant with three fully developed leaves. A leaf is counted when the collar (the point where the leaf blade and sheath attach) is visible. Identification of individual leaves early in the growing season may also be aided by considering the shape of the leaf. The first leaf visible at emergence is the coleoptile leaf and has a round tip. If the lowest leaf is pointed, then at least one leaf has been lost. Figure 1-2 shows a plant in the boot stage. All leaves are fully expanded and the flag leaf is the last leaf to emerge and is considerably smaller than the other leaves. The head (panicle) emerges from the flag leaf sheath and is supported by the peduncle. Figure 1-3 represents a plant that has headed and is at physiological maturity. The head emerges from the flag leaf sheath and is supported by the portion of the stalk called the peduncle.

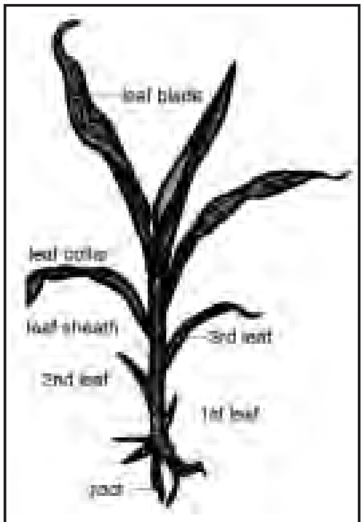

Figure 1-1. Grain sorghum plant in the 3-leaf stage.

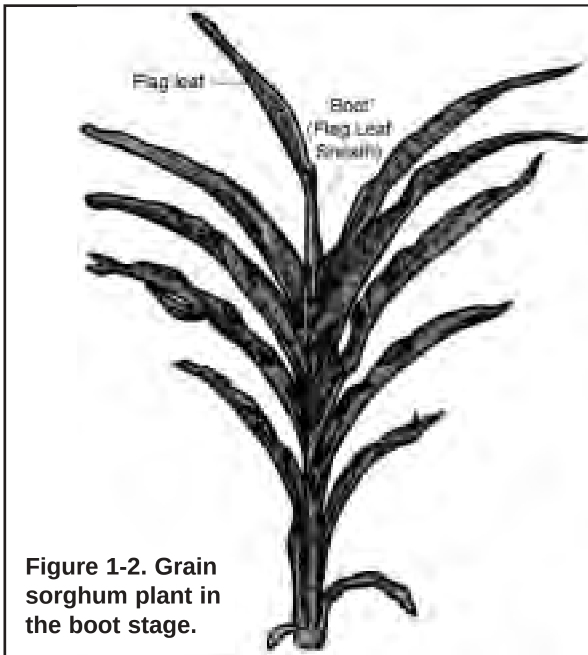

Figure 1-2. Grain sorghum plant in the boot stage.

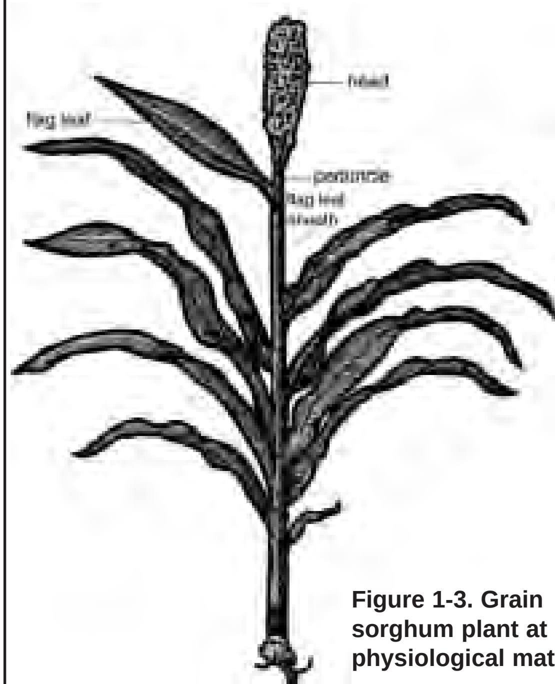

Figure 1-3. Grain sorghum plant at physiological maturity.

Growth Stages

Grain sorghum goes through three distinct stages of development after emergence – seedling development, panicle initiation and reproduction. The time required for the plant to go through each stage is dependent upon hybrid maturity and temperatures encountered during the growing season. In Arkansas, the plant will spend approximately 35 days in each stage. Grain sorghum planted early in the season when temperatures are still cool will progress through the stages more slowly than grain sorghum planted later in the season when temperatures are warmer. Each growth stage is discussed in detail below.

Growth Stage I (Seedling Development)

The seedling development stage is characterized by vegetative growth. The plant develops leaves and tillers, which ultimately support grain formation and growth. The duration of the Growth Stage I is largely dependent on air temperature and the hybrid maturity. The more leaves formed by the plant, the longer maturity. Early maturity hybrids typically produce 15 leaves per plant, while medium and late maturity hybrids produce 17 and 19 leaves each. The plant can tolerate stress from drought, hail and freezing temperatures in Growth Stage I with little negative effect on grain yields. Sunny days with temperatures below 65°F promote tillering when the plants are in the 4- to 6-leaf stage. Plant densities less than three plants per foot of row promote tillering. Panicles of tillers are often smaller and flower later than those of the main stem. Tillers formed can compensate somewhat for low plant populations.

Growth Stage II (Panicle Initiation)

The stage begins with panicle initiation and continues to flowering. This growth stage is the period when reproductive structures of the panicle form and the maximum number of seeds per panicle is set. During this period, plants are especially sensitive to any type of stress such as temperature extremes, nutrient deficiencies or water deficits or excess, any of which may reduce the potential seed numbers. It is considered the most critical period for grain production since seed number per plant accounts for 70 percent of the grain yield. The rate of water uptake increases rapidly during this period. If the crop is irrigated, it is important that the crop not be allowed to stress at the beginning of this stage when the potential number of seeds per plant is being set.

At the boot stage (Figure 1-2) all leaves are now fully expanded, providing maximum light interception. The head has now developed to nearly full size and is enclosed in the flag leaf sheath. Peduncle elongation is beginning and will result in exertion of the head from the flag leaf sheath. Potential head size has been determined. Moisture stress at the boot stage may prevent the head from exerting completely from the flag leaf sheath, which may cause harvest difficulty. The crop will respond favorably to irrigation at this stage. Following the boot stage, the peduncle grows rapidly extending the head through the flag leaf sheath.

Growth Stage III (Reproduction)

The final growth stage begins with flowering and continues until physiological maturity. Flowering begins when yellow anthers appear at the tip of the head five to seven days after head exertion. Over the next four to nine days, anther development progresses down the head. The plant is considered at half bloom when flowering has progressed half way down the head. Many grain sorghum hybrids grown in Arkansas require approximately 75 days from emergence for the plant to reach half bloom. The most critical time for water begins about one week before head emergence or the boot stage and continues through two weeks past flowering.

Scouting for sorghum midge is critical at flowering. One midge per head can lower grain yield 10 to 20 percent. After flowering, seed development begins and progresses through development stages of milk, soft dough, hard dough and physiological maturity over a 25 to 45 day period after flowering, depending on hybrid and growing conditions. Kernels reach their maximum volume approximately 10 days after flowering during the milk stage. The seed is soft and a white milky fluid appears when the seed is squeezed. The soft dough stage occurs approximately 15 to 25 days after flowering when 50 percent of the seed weight has been accumulated and little to no fluid appears when the seed is squeezed. The grain is very susceptible to bird and head webworm feeding during the soft dough stage. When the seed is in the hard dough stage, the grain cannot be squeezed with the fingers and approximately 75 percent of the seed weight has been accumulated.

Drought stress during the soft or hard dough stage can result in shriveled grain with a low test weight. Physiological maturity occurs when a black-layer appears immediately above the point of kernel attachment in the floret near the base of the kernel. The seed moisture is approximately 30 to 35 percent and has reached its full potential weight. Grain harvest can begin at approximately 20 percent moisture with no mechanical damage to the seed.

Growing Degree Units

Grain sorghum follows a predictable pattern of growth from planting through physiological maturity. The duration between growth stages is closely dependent upon the air temperatures and relative maturity of the hybrid. The number of days required for a hybrid to reach maturity depends primarily on location, date of planting and temperature. A hybrid labeled as being in half bloom at 75 days may take fewer or more days to reach half bloom, depending on growing conditions. Because daily minimum and maximum temperatures vary from year to year and between locations, the number of days from planting to physiological maturity varies and is not a good predictor of crop development. A better system to estimate crop development is the growing degree unit (GDU) system.

Growing Degree Unit Calculation

GDU = (Daily max. air temp + daily min. air temp)/2 - 50

Example: 86°F for a high temp and 60°F for a low temp

86 (high) + 60 (low) = 146

146/2 = 73

73-50 = 23 GDU

The base temperature or lower temperature limit of grain sorghum development is 50°F, while the upper limit is 100°F. Air temperatures greater than 100°F are entered as 100°F and temperatures less than 50°F are entered as 50°F. The key growth stages of sorghum and the cumulative GDUs (from planting) required to reach each growth stage are illustrated in Table 1-1. Because grain sorghum hybrids differ in maturity, the table illustrates cumulative GDUs expected for early and late maturing hybrids.

Table 1-1. Cumulative Growing Degree Units (F) from Planting to Successive Growth Stages for Short and Long Season Grain Sorghum Hybrids.

	Cumulative GDUs (F)	
Growth Stage	**Short Season Hybrid**	**Full Season Hybrid**
Planting	---	---
Emergence	200	200
3-leaf	500	500
4-leaf	575	575
5-leaf	660	660
Panicle Initiation	924	1365
Flag Leaf Visible	1287	1470
Boot	1683	1750
Heading	1749	1890
Flowering	1848	1995
Soft Dough	2211	2310
Hard Dough	2508	2765
Black Layer	2673	3360

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Vanderlip, R. L., *How a Grain Sorghum Plant Develops*, Kansas State University, January 1993.

Gerik, T., B. Bean, and R. Vanderlip, *Sorghum Growth and Development*, Texas Cooperative Extension Service. 2003.

2 - Cultural Practices

Jason Kelley

Site Selection

Grain sorghum is adapted to be grown on a wide range of soils throughout Arkansas. Like many crops, grain sorghum will likely produce greatest yields on deep fertile well-drained loamy soils. Grain sorghum has an extensive root system and may be more tolerant than corn of soils with a shallow hardpan. However, don't expect soils that produce poor soybean or corn crops to produce a bumper crop of grain sorghum. The best soils for other crops will also produce the highest grain sorghum yields.

Planting Date

Grain sorghum can be planted over a wide range of planting dates. However, in general it is recommended that it be planted as early in the spring as possible. Grain sorghum planting should be delayed until the soil temperature in the morning warms to 65°F 2 inches below the soil surface. Early planted grain sorghum takes advantage of ample rainfall that typically falls during the months of May and June and avoids excessive heat and drought that may occur in August. Early planting may also avoid some insect pressure such as sorghum midge, corn earworm and head webworms that are often associated with later planted grain sorghum.

Grain sorghum can be planted as a double crop following wheat harvest. Yields are generally lower than earlier planted grain sorghum and insect pests such as sorghum midge, corn earworm and head webworm are of greater concern in later planted grain sorghum and may need to be controlled with an insecticide. Late planting also delays harvesting which may lead to greater field losses due to wet conditions and greater potential for blackbird feeding of grain before harvest.

Planting Depth

The ultimate goal is to plant the grain sorghum seed as shallow as possible and still obtain good soil to seed contact. When planting early in the spring when soils are cool and wet and rainfall is likely to occur soon after planting, a planting depth of 0.75 to 1 inch is best. Later in the season as soils warm the planting depth may be increased to a maximum depth of 1.5 inches. Planting deeper than 1.5 inches is not recommended.

Grain sorghum seedlings can emerge when the seed is planted deeper than 1.5 inches, but the seedlings are slow to emerge, and final stand numbers may be reduced. Before emergence the plant is totally dependent upon the food reserves in the seed from the endosperm for survival. Slow emerging plants risk depleting these reserves, which are important to early plant growth immediately following emergence. Planting into soils that are too dry for seed germination or are too wet for good seed furrow closure is not recommended and planting should be delayed until soil conditions improve.

Seeding Rates

Recommended seeding rates will vary according to whether the crop will be irrigated or grown under dryland conditions. Under irrigated conditions, a population of 75,000 plants per acre is recommended. When determining seeding rate, assume that approximately 80 percent of the seeds planted will develop into a plant. For dryland conditions, a plant population of 50,000 plants per acre is recommended. Table 2-1 shows the number of seed required per 10 feet of row for various plant populations and row spacing. Table 2-2 shows the approximate pounds of seed per acre that would be required for various seeding rates.

If replanting is considered due to perceived low plant population, remember the grain sorghum plant has a tremendous ability to adapt to its growing conditions. Research conducted by neighboring states suggests that plant populations as low as 30,000 may result in slightly lower yields, but may not be low enough to warrant replanting. Grain sorghum is known for its ability to produce under moisture limiting conditions. Plant populations greater than necessary reduce the plants' ability to cope with moisture stress and produce plants with smaller stems which are more susceptible to lodging.

Row Spacing

Grain sorghum can be planted in a wide range of row spacing, generally ranging from 6 to 40-inch rows. Grain sorghum will likely be planted using the same equipment as planting soybean, corn or cotton and row spacing will be dependent upon the equipment the producer is currently utilizing. Grain sorghum can also be planted using a grain drill which would allow for narrow row spacing, down to 6 inches. Taping or plugging every other or every third opener on a grain drill gives producers more freedom to change row spacing. Planting in wide rows (36 to 40 inches) will not likely maximize grain sorghum yields.

Research from other states has indicated that yields were maximized when using rows as narrow as 10 inches, especially when the crop was irrigated or when conditions were favorable for high yields. When conditions were not ideal for maximum yields, such as in a dryland production system, row spacing had less of an impact on grain yield. Late planted grain sorghum, such as double crop following wheat may yield more when planted in narrow rows.

Hybrid Selection

Many agronomic factors should be considered when choosing a grain sorghum hybrid. Yield is considered the most important factor in hybrid selection, but maturity, stalk strength and disease resistance are also very important criteria to evaluate. In general, a full season hybrid should be selected. A good full season hybrid will generally out yield a good early season hybrid, provided that conditions are equal and favorable for growth. If grain sorghum is planted extremely late, a shorter season hybrid may be required.

If plant lodging has been a problem in the past, growers should scrutinize a given hybrid's ratings for stalk strength, stalk rot and charcoal rot resistance and stay green ratings. These ratings can give a producer indications of the hybrid's ability to stand under adverse growing and harvesting conditions. If grain sorghum is grown in narrow rows, particular attention should be given to the lodging ratings, since narrow row spacing may be more prone to lodging.

Table 2-1. Grain Sorghum Seeding Rate Information.									
Seeding Rate (seeds per acre)	Row Spacing (inches)								Final Population at 80% Emergence
	7	10	15	20	30	36	38	40	
	Seeds per 10 Feet of Row								
45000	6.0	8.6	12.9	17.2	25.8	31.0	32.7	34.4	36000
47500	6.4	9.1	13.6	18.2	27.3	32.7	34.5	36.3	38000
50000	6.7	9.6	14.3	19.1	28.7	34.4	36.3	38.3	40000
52500	7.0	10.0	15.1	20.1	30.1	36.2	38.2	40.2	42000
55000	7.4	10.5	15.8	21.0	31.6	37.9	40.0	42.1	44000
57500	7.7	11.0	16.5	22.0	33.0	39.6	41.8	44.0	46000
60000	8.0	11.5	17.2	23.0	34.4	41.3	43.6	45.9	48000
62500	8.4	12.0	17.9	23.9	35.9	43.0	45.4	47.8	50000
65000	8.7	12.4	18.7	24.9	37.3	44.8	47.3	49.7	52000
67500	9.0	12.9	19.4	25.8	38.7	46.5	49.1	51.7	54000
70000	9.4	13.4	20.1	26.8	40.2	48.2	50.9	53.6	56000
72500	9.7	13.9	20.8	27.7	41.6	49.9	52.7	55.5	58000
75000	10.0	14.3	21.5	28.7	43.0	51.7	54.5	57.4	60000
80000	10.7	15.3	23.0	30.6	45.9	55.1	58.2	61.2	64000
85000	11.4	16.3	24.4	32.5	48.8	58.5	61.8	65.0	68000
90000	12.1	17.2	25.8	34.4	51.7	62.0	65.4	68.9	72000
95000	12.7	18.2	27.3	36.3	54.5	65.4	69.1	72.7	76000
100000	13.4	19.1	28.7	38.3	57.4	68.9	72.7	76.5	80000
Linear feet of row per acre	74674	52272	34848	26136	17424	14520	13756	13068	

Table 2-2. Grain Sorghum Seeding Rate Based on Seeds per Pound.

Grain Sorghum Seeding Rates																		
	Seeding Rate (Seeds per Acre)																	
	45000	47500	50000	52500	55000	57500	60000	62500	65000	67500	70000	72500	75000	80000	85000	90000	95000	100000
Seeds per Pound	Pounds of Seed per Acre Required																	
11000	4.1	4.3	4.5	4.8	5.0	5.2	5.5	5.7	5.9	6.1	6.4	6.6	6.8	7.3	7.7	8.2	8.6	9.1
12000	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.3	6.7	7.1	7.5	7.9	8.3
13000	3.5	3.7	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.2	6.5	6.9	7.3	7.7
14000	3.2	3.4	3.6	3.8	3.9	4.1	4.3	4.5	4.6	4.8	5.0	5.2	5.4	5.7	6.1	6.4	6.8	7.1
15000	3.0	3.2	3.3	3.5	3.7	3.8	4.0	4.2	4.3	4.5	4.7	4.8	5.0	5.3	5.7	6.0	6.3	6.7
16000	2.8	3.0	3.1	3.3	3.4	3.6	3.8	3.9	4.1	4.2	4.4	4.5	4.7	5.0	5.3	5.6	5.9	6.3
17000	2.6	2.8	2.9	3.1	3.2	3.4	3.5	3.7	3.8	4.0	4.1	4.3	4.4	4.7	5.0	5.3	5.6	5.9
18000	2.5	2.6	2.8	2.9	3.1	3.2	3.3	3.5	3.6	3.8	3.9	4.0	4.2	4.4	4.7	5.0	5.3	5.6

3 - Drainage and Irrigation

Phil Tacker, Earl Vories and Gary Huitink

Drainage

Adequate drainage is necessary for maximum grain sorghum production. It is highly recommended that grain sorghum be planted on raised rows or beds, especially on fields that are relatively flat. Grain sorghum is typically planted early when low temperatures and significant rainfall are likely. Raised rows or beds reduce the effect that cold, wet soil conditions have on planting and early crop development. Rolling fields that have significant slopes may not need raised rows or beds for drainage, but may still benefit from the beds warming up faster than flat seed beds. Poor drainage hampers field operations from field preparation through harvest and limits the effectiveness of irrigation. Eliminating poorly drained areas preserves natural soil productivity by reducing field rutting that requires additional tillage. Poorly drained areas reduce yields and often require the most tillage. Water infiltration is also reduced if soil is tilled when it is too wet. Good field drainage complements all crop production practices and makes it possible to consider reduced or no-till grain sorghum production. **The goal for drainage is to have minimal standing water on a field 24 hours after a rainfall or irrigation.**

Surface Drainage

Field surface smoothing and forming can improve the surface drainage of a field. Use land planes to smooth out the high spots and fill in the low areas so that the field has a more uniform slope toward drainage outlets. Low areas that are larger than 100 feet across or that require more than 6 inches of fill should be overfilled and compacted before being planed. Make an effort to accurately determine a field's drainage flow pattern. Deciding where water will drain by simply looking at the field is not always easy. Some limited surveying of field elevations can be very helpful in determining where to place tail water furrows and field drain outlets.

Poor drainage area in grain sorghum field.

Precision grading of a field provides a positive method of improving surface drainage as well as making furrow irrigation possible. If a field is being considered for precision grading, the soil should be evaluated to determine what problems might occur if deep cuts are made in some areas. The cut areas may expose soil with reduced production capability. County soil survey reports, published by the Natural Resources Conservation Service (NRCS, formerly SCS), can help identify soils with unproductive subsoils. Taking several deep (more than 6 inch depth) soil cores or samples may be beneficial if a problem soil is suspected. Poultry litter application may improve the productivity of cut soils.
An Extension publication, *Soil and Fertilizer Information Article 2-90*, Poultry Litter as an Amendment for Precision Graded Soils, reports on results of litter application studies.

Precision grading is limited to fields with slopes of less than 1 percent, or the cost can be prohibitive. **If possible, the finished grade in the primary slope direction should range from 0.1 to 0.5 percent**

(0.1 to 0.5 ft. per 100 ft.). This range provides good surface drainage without increasing erosion potential. Slopes of less than 0.1 percent are suitable for cross slopes but should be limited to slope lengths of a quarter mile or less. Slopes less than 0.1 percent are more difficult to construct with precision, and they tend to develop more low areas and reverse grades. It is also recommended to consider putting a field to grade in only one direction (i.e., zero cross slope) if it doesn't require a significant amount of extra cost. Building a permanent pad or elevated road on one or more sides of a field should also be considered in the grading plan. Settling often occurs in deeper fill areas and should be "touched up" before planting if possible. The land grading design should consider the type of drain outlets and the number required for the field. If possible, it is best to provide an outlet point for every 20 acres.

An elevation survey of the field is required before any design work can be done. Survey information can be entered into a computer program that evaluates possible drainage options for a field and determines the cuts and fills required. Most land grading contractors offer the computer program design, and it is sometimes available through NRCS. The lowest expected elevation of the field should be determined before grading begins to assure that water will drain into the surrounding ditches adequately and not back up onto the field. It may be necessary to divide the field into shorter segments to ensure that the runoff leaves the field. Precision grading is usually expensive and is a long-term investment for increasing production efficiency and potential and the market value of the land. Government funded conservation programs sometimes offer cost sharing on precision grading and/or other conservation best management practices. Information on these programs can be obtained through NRCS.

Good surface drainage is even more important if grain sorghum is planted flat rather than on raised rows or beds. Low areas in a flat-planted field are likely to have poor production for obvious reasons. Drain furrows to these areas can be used to reduce the effect on the crop. Shallow and narrow drain furrows can be constructed with several different types of equipment. The equipment should spread the soil evenly away from the drain furrow, so flow into the furrow is not restricted. Construct drain furrows in the low areas of a field rather than putting them in randomly. They should generally run with or at a slight angle to the natural slope of the field but not across the direction of the slope. Furrows should have continuous positive grade to assure that the water will be directed off the field. A drain furrow is not complete until it is connected to a ditch or pipe of adequate size to carry excess water away from the field.

An important component of field drainage is the ditch system that receives the excess water and carries it away from the field. Flow restrictions in these ditches can cause excess water to remain on a field. Drainage ditches should be maintained and routinely cleaned out to effectively handle the drainage water from a field. **No tillage or reducing tillage limits the sediment leaving fields and minimizes the sedimentation that occurs in drainage ditches.** Ditch outlets and drainage structures should also be checked to assure that they are functioning properly and are not becoming restricted. Beavers often cause problems by damming ditches, culverts and drainage pipes. A Beaver Pond Leveler pipe has the potential to reduce these problems in certain situations. This device is described in Extension publication FSA-9068, *Flood Water Management With a Beaver Pond Leveler*. It may be necessary to work with neighboring farms and/or the Drainage District to correct common drainage problems. Planned drainage improvements could impact areas classified as wetlands. If this possibility exists, contact the local NRCS staff to see what help they can provide. Typically, they can visit the site and determine if there are drainage restrictions.

Internal Drainage

Many Arkansas soils, with the exception of the sandier (coarse) soils, have limited infiltration and/or internal drainage. Some clean-tilled silty soils tend to seal or crust over at the surface after rainfall or irrigation, restricting the movement of water into the soil surface and the root zone. Infiltration may be improved through crop residue management. Maintaining crop residue reduces surface sealing and crusting so water moves into the soil more freely. This improves the infiltration and water-holding capacity of the soil.

Naturally occurring restrictive soil layers and those formed by tillage equipment restrict internal soil drainage. The restrictive soil layers reduce the rooting depth and water reservoir available to the grain sorghum plant. Shattering these layers prior to planting a grain sorghum crop is recommended to improve plant root development and internal drainage. A soil probe or shovel can be used in several areas of a field to determine if restrictive soil layers are a problem. Digging up root systems and observing the rooting depth and pattern can also help determine if there is a restriction. Restrictive soil layers are commonly shattered by using a subsoiler or ripper-hipper in the field. The depth and thickness of the restrictive layer usually determines which implement should be used. **The restrictive layer must be dry enough for the deep tillage implement to extend just below the bottom of the restrictive layer so it is effectively lifted and shattered.** If the restrictive layer begins at 8 inches and is 2 to 3 inches thick, the tillage shank must penetrate 10 to 12 inches deep. In-row subsoiling is more effective than random subsoiling paths due to the re-compaction caused by subsequent trips of the implement. The in-row pattern also reduces the likelihood the field will be too soft in the spring to support equipment and delay early field preparations. High-residue subsoilers or ripper-hippers are suggested for maintaining the same row location year to year. Surface tillage, especially disking, quickly reforms restrictive layers and should be avoided, if possible.

Irrigation

Grain sorghum is the most drought tolerant row crop produced in Arkansas. This does not mean that it will thrive in dry conditions but it will typically do better than corn, cotton or soybeans under the same conditions. Grain sorghum requires adequate and well-distributed moisture during its April through August growing season for maximum yields. Reasonable yields may be obtained without irrigation in years that have good rainfall patterns and growing conditions. However, when rainfall is not adequate the yield is reduced. Drought stress can also contribute to charcoal rot, which in severe cases can result in crop failure. These potential risks are the basis for recommending irrigation of grain sorghum when possible.

Grain sorghum showing signs of drought stress.

Yield

Several hybrids in the Arkansas Grain Sorghum Performance Tests have irrigated yields of 7,500-8,000 pounds per acre in good years. The non-irrigated average yields for these hybrids are usually 500 to 1,000 pounds per acre less. The four-year (2000-2003) average irrigated yield for the Grain Sorghum Verification Program is 7,500 pounds per acre and the non-irrigated average is 5,340 pounds per acre. **The yield goal for irrigated grain sorghum is 7,000 to 7,500 pounds per acre in good years with good production practices and management on productive soils.**

Water Needs

The total amount of water that a grain sorghum crop needs during the growing season may vary from 16 to 24 inches depending on factors such as weather conditions, plant density, fertility, soil type and days to maturity. In most seasons, the amount of water needed will be about 20 inches. The inches of irrigation water required will vary depending on the beginning soil moisture and the rainfall received during the growing season. **The irrigation system needs to be capable of providing at least 10 inches of irrigation water to assure a good yield potential.**

The period when the water needs of the grain sorghum plant are greatest is when irrigation is most critical. Figure 1 shows this period for grain sorghum to be from boot through bloom when the water need ranges from 0.2 to 0.3 inches per day.

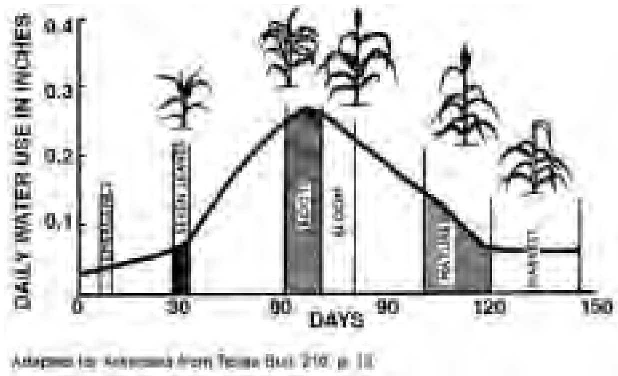

Figure 3-1. Grain Sorghum Water Use Curve

Moisture stress anytime after planting can affect plant development and reduce yield potential. The amount of yield loss is dependent on the growth stage of the grain sorghum when moisture stress occurs. Table 3-1 shows the general relationship of potential yield reduction due to moisture stress at different growth stages.

Table 3-1. Potential Yield Reduction From Moisture Stress at Different Growth Stages of Grain Sorghum

Growth Stage	% Yield Reduction
Emergence to 8 leaf stage	10-15
Boot to bloom	30-50
Soft dough to maturity	10-20

Grain sorghum's daily water needs are relatively low in the first 3 to 4 weeks of vegetative growth, and rainfall is usually adequate to meet the water demand during this period. Young grain sorghum plants have a remarkable ability to recover from moisture stress. However, rainfall or irrigation following an extended dry period early in the crop season can result in undesirable sucker growth. If it is relatively dry when the crop emerges and rainfall doesn't occur in the first 2 to 3 weeks, irrigation may be needed. At about 30 days after emergence, the grain sorghum should have approximately 7 fully developed leaves. At this time, the growth rate increases and the potential head size will soon be determined. The water uptake increases and irrigation is often needed at this time to activate the fertilizer and avoid moisture stress.

If nutrient and water needs are met, rapid plant growth continues as it approaches the boot stage. At this time the crop's water need is increasing to its greatest daily use. Moisture stress during this period can limit the head exertion ability of the plant. Irrigation during the next 3 to 4 weeks of boot and bloom period may be critical to meet the crop water needs. Once the grain is developed the water use begins to decrease because the kernels start to progressively harden as they dry and the crop approaches maturity. Although the daily moisture need starts to decrease after bloom, the plant is still going into the critical grain fill period. Grain fill progresses from soft dough to hard dough and then physiological maturity during the next 3 to 4 weeks. If rainfall doesn't occur during this time, irrigation will be needed to protect the yield. Table 3-2 shows the estimated range for daily crop water use as the crop develops.

Table 3-2. Estimated Grain Sorghum Water Use in Arkansas

Days after planting	Inches per day
0-30 (early plant growth)	0.05-0.10
30-60 (rapid plant growth)	0.10-0.25
60-80 (boot and bloom)	0.25-0.30
80-120 (grain fill to maturity)	0.25-0.10

Irrigation Scheduling

The timing of irrigation is commonly referred to as irrigation scheduling. Correct timing is critical to maximizing yield. **Having the ability to irrigate is important, but it is also essential that a grower have the ability and commitment to apply irrigation in a timely manner.** Too often, growers irrigate by the appearance of the crop. Visual stress, especially during reproductive growth, results in yield loss. Even if irrigation is started at the first sign of visual stress, there is still some amount of time required to finish irrigating a field. The result is that the crop in the last area of the field to be irrigated suffers even greater yield-limiting stress.

Irrigation timing decisions can be improved if the soil moisture can be determined. Determining the soil moisture by visual observation or by kicking the soil surface is difficult and can be misleading. The "feel" method can be used to determine the soil moisture condition more accurately. This method involves using a shovel or soil probe to pull a soil sample from the root area. In general, if the soil forms a hand-rolled ball, the soil moisture is adequate. A key to this method is to take samples across the field at different depths in order to better determine the soil moisture for the field. The challenge is to determine when to begin irrigation so the entire field can be irrigated before any part becomes too dry. Satisfactory results with the "feel" method can be achieved with experience.

Soil moisture can be determined more precisely with tensiometers. A tensiometer is a sealed, water-filled tube with a vacuum gauge on the upper end and a porous ceramic tip on the lower end. The tensiometer is installed in the seedbed at a depth where the majority of the roots are located. A 12-inch depth is commonly used for surface irrigation, but if a hardpan exists then the tensiometer is placed just above the restrictive layer. Shallower settings at about 8 inches deep are recommended for center pivots. Two or three tensiometers per field are recommended to avoid a problem should one of the tensiometers quit working. Starting irrigation at a vacuum gauge reading of about 50 centibars on silt loam and clay soils, and at approximately 40 centibars on sandier soils, is recommended. In addition to tensiometers, there are other soil measurement devices that are fairly reliable and effective when checked and maintained properly. However, the time and effort that this requires usually results in most producers not being able to use them very effectively.

Soil moisture accounting is used to calculate the soil-water balance in the root zone throughout the growing season. This method is sometimes called checkbook irrigation scheduling because a record is kept on the water that enters and leaves the soil like an account balance is maintained in a checkbook. Two forms of the checkbook procedure are available – the Checkbook User's Guide and the Irrigation Scheduling computer program. The Checkbook User's Guide is used to keep a written record of the soil moisture balance when a computer is not available. It is a three-page handout that shows how to use a water usage chart and a water balance table to monitor the soil moisture. The water usage chart shows an estimate of how much water the crop uses each day based on the maximum temperature and the age of the crop. Daily water use and rainfall amounts are entered into a water balance table. Maximum temperature data can be taken from the weather, newspaper, etc., but the rainfall should be measured with a gauge at each field. Adding and subtracting these numbers in the table determines the soil moisture deficit. Table 3-3 shows the recommended allowable deficits that are included in the User's Guide to help determine when to irrigate.

Table 3-3. Allowable Deficits – Grain Sorghum

Predominant Soil	Flood, Furrow or Border Irrigation (Inches)	Pivot Irrigation (Inches)
Clay	2.5	2
Silt Loam w/pan	2	1.5
Silt Loam wo/pan	3	2.5
Sandy Loam	2.5	2
Sandy	2	1.5

w/pan – restrictive layer at 10 inches or less below soil surface
wo/pan – without shallow restrictive layer

The Checkbook User's Guide, water usage charts and water balance tables are available through your county Extension office at no cost. This method does require some record keeping, but it can be helpful in deciding when to irrigate.

If a computer is available, the Irrigation Scheduling computer program can be used for the record keeping. This program operates much like the Checkbook method just described except that the computer does the calculations. It uses daily maximum temperatures and rainfall measurements at the field to determine the field's soil moisture deficit. **The program also has the option to predict when irrigation will be needed in the next 10 days if no rainfall occurs.** This offers a real benefit to managing irrigation labor and sharing irrigation water with other crops. The program is used in research and Extension irrigation studies and demonstrations conducted in Arkansas. Growers in Arkansas, Mississippi, Louisiana, Tennessee, Kentucky and Missouri are successfully using the program on their farms. The program is downloadable from the following Extension web page address: http://www. aragriculture.org/computer/schedule/default.asp.

Irrigation Termination

As the crop approaches physiological maturity, a decision on when to stop irrigating has to be made. **The goal is to maintain adequate soil moisture until the grain sorghum reaches physiological maturity.** This ensures that the kernels can obtain their maximum weight so the crop's full yield potential will be achieved. The decision is best made toward the end of the season by a field determination of the maturity of the crop and the soil moisture status. An initial consideration is how many days it has been since planting. If it has been 90 days since planting, then it may be within 3 weeks of maturity and a field check should be made.

The soil moisture situation at hard dough development can be used to help determine when irrigation can be ended. **The general recommendation is to maintain good soil moisture up to the point that the milo heads are at 50 percent hard dough**. This can be determined by the heads being 50 percent colored, which indicates the hard dough formation. If there is 50 percent color (hard dough) and good soil moisture exists from a recent surface irrigation or rain, then irrigation can be terminated. However, if the soil is becoming dry at this point, then additional irrigation is needed to assure maximum seed weight and yield. A final irrigation at this stage should be as quick a flush as possible with flood (levee), border or furrow irrigation. If the grain sorghum is irrigated with a center pivot, then it is recommended that the color (hard dough) development be at 75 percent with good soil moisture before stopping irrigation.

Irrigation Methods

The surface and sprinkler irrigation methods used on grain sorghum have different characteristics that determine which would be the best for a particular situation. No one method can be labeled as the best – each has its place.

Flood (Levee) Irrigation

Flood irrigation with levees should really be thought of as flush irrigation. The challenge is to get the water across the field as quickly as possible. This is especially important if the grain sorghum is small and planted flat rather than on a raised row or bed. **It is also critical that irrigation is started before the crop experiences drought stress. If plants are drought stressed and then subjected to an extended wet soil condition, plant development can be delayed and some plants may die.**

Levee irrigated grain sorghum field.

Levees should be marked early to strengthen the commitment to pull levees and irrigate when needed. If the grain sorghum in the levee mark has been allowed to grow very much, it may be necessary to bush-hog the levees before they are pulled. This helps avoid problems caused by having too much plant material in the levee. Spacing of the levees depends on the field slope, but spacing on an elevation difference of 0.3 to 0.4 feet between levees is common. A narrower spacing of 0.2 to 0.3 feet elevation difference may be necessary on very flat fields or when trying to irrigate flat planted grain sorghum that is less than 6 inches tall. Levees are usually broken in several places or completely knocked down to get the water into the next bay. Rebuilding the levee in time for the next irrigation is often difficult because the levee area tends to stay wet. Some growers install gates or spills in the levees to avoid irrigation delays due to rebuilding the levees between irrigations. When possible, it is recommended that a few gates or spills be installed in the outside levee to provide better field drainage when a big rain occurs during or soon after the irrigation. The outside spills can be opened to avoid the "blowing out" of levees.

It is recommended that water not be allowed to stand on any area for longer than two days. This can be difficult on big flat fields. Some growers are able to divide a big field into two smaller fields so they can better manage the water when they start irrigating. If this isn't practical, then providing multiple water inlets to the field can be helpful.

Multiple inlets help avoid running water too long at the top of the field in order to get water to the bottom of the field. One multiple inlet method is to water the upper half of the field from the pump discharge or riser and then run irrigation pipe or tubing from the discharge down the field to water the lower half. A canal or flume ditch alongside the field can also be used for multiple inlets. The water can be directed from the ditch through cuts or spills into individual bays down the length of the field.

Another possibility is to run tubing the full length of the field and install several of the 2.5-inch plastic gates in each bay. These slide gates are adjustable from completely closed to fully open. When fully opened they deliver 65 to 75 gallons per minute (gpm) and they are reusable from year to year. The decision can then be made on how many bays to water at one time based on the available flow and the size of the bays. This method can be used by laying the tubing on a permanent outside levee or road along-side a field. However, with this installation, all of the water will tend to go to the low end of the tubing. When this occurs, some type of restriction has to be put on or under the tubing (choke-rope, barrel, etc.) in order to hold water back up the slope. Another option is to run the tubing over the levees. Heavier tubing (9 to 10 mil) has been laid over levees successfully as long as it is going down slope. The 9 to 10 mil grade tubing is better than the 6 to 7 mil in multiple-inlet-type applications.

Levee irrigation becomes even more of a challenge if the soil is allowed to crack severely before irrigation is started. Multiple inlets can help offset this challenge, but it is still important to irrigate on time. Planting on a raised bed or row as recommended provides improved drainage and helps avoid some of the water management challenges of levee irrigation. Planting on beds and using multiple inlets with spills installed in the levees may provide the best water management capability with flood (levee) irrigation.

A minimum irrigation capacity of 15 gpm per irrigated acre is recommended for levee irrigation. At this rate, about four days would be required to complete an irrigation. Starting late would increase the time required, resulting in severe drought stresses in the last portion of the field to get water. Opportunities for getting more pumping capacity to a field should be explored and developed whenever possible so the pumping time required to irrigate a field can be reduced. Although levee irrigation presents a challenge, it can be done successfully. There are many producers who consistently produce high yields by paying close attention to the precautions and recommendations that have been presented.

Furrow Irrigation

Furrow irrigation can be a very effective irrigation method. **One of the biggest requirements for furrow irrigation is that the field must have a positive and continuous row grade.** This usually requires precision land grading, which can be rather expensive. However, the grading results in positive field drainage that greatly enhances production. As discussed earlier, the row grade should be in the range of 0.1 to 0.5 percent, and row grades between 0.15 and 0.3 percent are especially desirable for furrow irrigation. The row length to be furrow irrigated is another key consideration. Row lengths of 1,500 feet or less generally water more effectively than longer rows. Row lengths less than 1/4 mile are usually required if sandy soils are to be irrigated effectively.

When row lengths cannot be altered, it may be necessary to control the furrow stream flow by adjusting the number of rows that are irrigated at one time. Experience shows that in most situations it is desirable to get the water to the end of the row in about 12 hours. Watering so long that the top of the row is over-watered can cause problems in this area, especially if it rains and stays cloudy soon after the irrigation. This is a concern with the expanded use of irrigation tubing with punched holes for furrow irrigation. The tendency is to punch holes in the tubing as long as water still comes out of them without much concern for how long it will take to water out the row.

Growers find that on some fields with good beds, they can use small holes with small furrow streams for up to 24 hours on a furrow irrigation set without risk of over-watering or damaging the crop. This is desirable from the standpoint of operating the tubing in sets without having to plug and open holes. The caution is to water according to what is more effective for the field and crop rather than what is easiest.

Another approach that can limit or avoid the opening and plugging of holes and the tendency to irrigate for too long is to run parallel tubing across the field. One run of tubing would go across the first half of the rows and have holes punched for each middle to be irrigated. A longer run of tubing is then laid behind the shorter tubing. Beginning where the shorter tubing ends, holes are punched in the longer tubing for the middles irrigated across the remainder of the field. This allows row sets to be changed by unhooking one run of tubing from the irrigation well or riser and hooking up the other run. If more than two sets are required for a field, then alternate rows may be irrigated to avoid the laying of additional tubing. It is also possible to get multi-valved fittings that can accommodate three or more sets and reduce the amount of tubing needed to avoid the plugging and unplugging of holes.

Furrow irrigation requires a water supply of at least 10 gpm per irrigated acre, and more capacity is desirable if available. At 10 gpm per acre, about five days should be expected to complete an irrigation. Practices like waiting until morning to change sets when rows water out at night can add significantly to the time, making it difficult to finish the field before it is time to begin the next irrigation. A well-defined furrow is needed to carry the irrigation water. Planting on a good bed is the most desirable option for having a good water furrow. If a bed is not used, then it is necessary to cultivate with a furrow plow that moves enough soil from the middle of the rows so that a good furrow is created. Some producers prefer to water alternate middles under certain conditions. Watering alternate middles can result in getting across the field quicker and not leaving the soil as saturated as it might be if every middle were irrigated. Then, if rain comes soon after the irrigation, it is possible for it to soak into the soil rather than run off or collect and stand in low spots. Producer preference and experience, along with the crop and field condition, will determine whether it is best to water every middle or alternate middles. Alternate middle irrigation will usually result in having to come back with the next irrigation somewhat sooner than when every middle is watered.

Furrow irrigation by necessity requires that there be some amount of tail water runoff from the ends of the rows. All the middles will not water out at the same rate, especially those that are wheel-track middles. Also, cracking soils can make furrow irrigation management more challenging. However, irrigating on the appropriate schedule will reduce the problems associated with extensive soil cracking.

Border Irrigation

Border irrigation may be a method to consider on fields that are planted flat rather than on raised beds or rows. Borders are raised beds or levees constructed in the direction of the field’s slope. The idea is to release water into the area between the borders at the high end of the field, flushing a large volume of water over a relatively flat field surface in a short period of time. The borders guide the water down the slope as a shallow sheet that spreads out uniformly between the borders.

Border irrigation is best suited for precision graded fields that have slope in only one direction. All field preparations should be done with the field’s primary slope, and planting should be with or at a slight angle to the primary slope. Planting across the slope tends to restrict the water flow, especially on fields with less than 0.1 percent slope. Fields with slope in two directions are not as well suited to border irrigation. However, it may still be possible if the side slope is less than 0.05 percent and the spacing between borders is relatively narrow.

The spacing between borders is dependent on soil type, field slope, pumping capacity, field length and field width. A clay soil that cracks is sometimes difficult to irrigate, but with border irrigation, the cracking actually helps as a distribution system between the borders. This factor also makes it possible to use borders on clay fields that have a slight side or cross slope. The tendency on fields with side slope is for the water to flow to the lower side and not spread out uniformly between the borders. The soil cracks lessen this affect because the water will spread laterally as it follows the cracking pattern. The border spacing on clay soil will generally be between 200 and 300 feet with the narrower spacing on fields with some minimum side slope.

The border spacing on sandy and silt loam soils that tend to seal or crust over is more of a challenge than with the cracking clays. Side slope on these soils results in the border spacing having to be narrower in order for the water to spread uniformly between the borders. The border spacing on soils that seal or crust over will generally range between 100 and 200 feet with the narrower spacing on fields that have some minimum side slope.

The pumping capacity and field dimensions (length and width) are used to determine the number of borders needed and how many can be irrigated in a reasonable time. **The desired pumping capacity for border irrigation is 12 gpm per irrigated acre. Calculations can be made to estimate the time required to irrigate a border, and it is usually possible to work toward approximately 12 hour set times, which fit very well for managing water and labor.**

The border can be constructed in a variety of ways and with different types of equipment. It is also possible to plant on the borders if they are constructed before planting. A settled border height of 2 to 3 inches is all that is needed on ideal fields with no side slope, but a 3 to 6 inch settled height is required if the field has side slope or if the field has shallow depressions or potholes. **If the border is constructed with a disk type implement, an effort must be made to fill the ditch left at the base of the border so it will not act as a drain furrow.** The borders need to stop at least 30 feet from the low end of the field so they will not restrict drainage. The water can be delivered into the area between the borders from a canal, gated pipe or irrigation tubing. The 2.5-inch plastic gates that deliver 65 to 75 gpm each can be installed in the tubing so sets can be changed by opening and closing the gates. If gates are installed in the irrigation tubing, the heavier 9 to 10 mil tubing should be used. When holes are punched in the tubing, the parallel tubing layout discussed with furrow irrigation may need to be used in order to avoid plugging and unplugging holes.

If border irrigation can be used on a field that is usually flood irrigated, then it can provide certain advantages:

1. less production area lost with borders than with levees,
2. improved ability to irrigate small grain sorghum,
3. don't have to repair or rebuild border between irrigations, thus a potential for time and labor savings,
4. field drainage is not restricted by borders and
5. possibility of planting on the borders.

Border irrigation will not work on all fields, and it should really only be considered when the grain sorghum is planted flat. There is not adequate space in this publication to cover all of the details associated with border irrigation. However, more information is available through your local county Extension office.

Center Pivot Irrigation

Center pivots offer the ability to irrigate fields that have surface slopes that make it impossible or impractical to irrigate with surface methods. They also offer more water management options than surface irrigation. **The need for good surface drainage still exists with pivot irrigation and should not be overlooked.**

Pivots are best suited for large square-, rectangular- or circular-shaped fields free of obstacles such as trees, fences, roads, power poles, etc. Field ditches are also a concern if the pivot towers must cross them. Pivots can cover a range of acreage depending on the allowable length, but the common 1/4-mile, full circle system will cover approximately 130 acres of a 160-acre square field. **It is possible to tow a pivot from one field to another, but it is usually best for a system not to be towed between more than two points during the season.**

Pivots provide the ability to control the irrigation amount applied by adjusting the system's speed. This gives the operator advantages for activating chemicals, watering up a crop and watering small plants. It is also possible to apply liquid fertilizer and certain pesticides through the system. This is called chemigation, and it can be especially applicable to grain sorghum for sidedress or late-season applications of fertilizer. **Any chemicals that are to be applied through the system**

Center pivot irrigation on grain sorghum.

must be specifically labeled for chemigation. The label will give fairly specific application requirements and recommendations if a chemical is approved for chemigation application. Any pivot system used for chemigation must have some specific equipment and safety devices installed. Information on equipment requirements and chemigation is available through most center pivot dealers or companies. General information on chemigation can be obtained through the local county Extension office.

It is recommended that a pivot have a water supply of at least 5 gpm per acre that is irrigated. At that rate, nearly four days are required to apply a 1-inch irrigation. A water supply less than this leaves no room for break down time without the risk of getting behind in meeting the crop water needs. The capacity for a towable system should be greater to account for the added time needed to move the system. It is recommended that pivot irrigation be applied early enough to avoid the deeper soil moisture being extracted early in the season. If the deeper moisture is used early in the season, it becomes difficult for a pivot to keep up with the water demand unless rainfall replenishes the deep moisture. A pivot irrigation will typically soak about 8 inches of the root zone and has very little chance of replacing moisture any deeper. The goal is to save the deeper moisture for when irrigation is terminated and the crop uses the deeper moisture to take it to maturity.

Most pivots are equipped with low-pressure sprinkler packages, and many are mounted on drops that release the water closer to the soil surface. This is desirable as long as the system application rate is matched to the soil and field characteristics so excessive runoff is avoided. If a field has a rolling surface and a soil that tends to crust or seal over, this should be taken into account in the sprinkler package selection. The application amount can be adjusted to reduce runoff to some degree, and most producers find that applying 3/4 to 1 inch works best. Minimum tillage that leaves crop residue on the surface can help reduce runoff problems. It might also be possible to put in narrow width (1 inch or less) slots at a depth of about 8 inches in some of the middles. This can be done with something like anhydrous shanks in order to give the water a path for soaking in rather than running off a sealed or crusted-over soil surface. To reduce rutting and sticking problems, the nozzles at the towers are sometimes changed from 360° full circle to 180° half circle coverage directed away from the tower.

One of the biggest advantages of pivot irrigation is the limited labor required for operating the system. The biggest challenge with center pivots is the initial cost. However, they offer some advantages that can justify the initial cost, especially when surface irrigation is not possible and the cost is spread over an expected service life of at least 15 years.

When considering the different irrigation methods, it is important to remember that any method that is well planned and is properly installed, operated and maintained can give the results desired. **Every method requires time to irrigate the whole field, so it is very important that irrigation be started early enough that no part of the field suffers moisture stress.**

Arkansas Situation

Consistent and profitable grain sorghum production in Arkansas is more attainable if irrigation is available. Once irrigation is in place, the irrigation operating cost for each irrigation is typically $3 to $6.50 per acre. This cost is usually justified by the yield increase that can result from the irrigation. The maximum profit usually results when the maximum yield is obtained, so the irrigation goal is to obtain the maximum yield by preventing crop moisture stress. **Irrigation is not a cure-all. Maximum yield and profit will be achieved only when irrigation is coupled with other production practices that establish profitable yield potentials.**

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4 - Fertilization and Liming

Leo Espinoza

In Arkansas, grain sorghum is traditionally grown in the less productive soils and often under dryland conditions, resulting in yields below the potential of the crop. Plants develop an aggressive root system that increases the ability of this crop to mine the soil for nutrients and water. Grain sorghum performs better than most crops under limiting conditions, but considerably higher yields are obtained if grown under optimum water and nutrient conditions.

Soil pH

Nutrient Availability

Grain sorghum grows best at soil pH values between 6 and 7.5, since this is the pH range at which most nutrients are more easily accessible to plant roots. Aluminum and/or manganese toxicity may become a problem in more acid soils (pH below 5.5), while phosphorus and/or magnesium may be deficient at this same pH.

Certain micronutrients may become limited in many alkaline soils (pH above 7.5), but deficiencies are seldom seen in grain sorghum fields in Arkansas. With the exception of molybdenum, the micronutrients become less available for plant uptake as the soil becomes more alkaline (pH above 7.5). However, most grain sorghum varieties grown in the state are fairly tolerant of alkaline soils on which they are grown. Iron and/or zinc deficiency, a common problem in highly alkaline soils of Texas and other western states, is seldom a problem in grain sorghum fields in Arkansas.

They are called micronutrients because they are used in small amounts compared to the macronutrients (see insert). For instance, while a good sorghum crop may use 150 pounds of nitrogen per acre, it may use only 0.5 pound per acre of zinc, copper and manganese. However, micronutrient deficient conditions may reduce expected yields considerably if not corrected.

Macronutrients
Nitrogen
Phosphorus
Potassium

Secondary Nutrients
Calcium
Magnesium
Sulfur

Micronutrients

Iron	Copper
Zinc	Molybdenum
Manganese	Cobalt
Boron	Chlorine

The secondary elements – calcium, magnesium, and sulfur – are generally considered adequate in soils unless plant and soil tests indicate otherwise. The University of Arkansas soil testing lab routinely tests for calcium, magnesium and “available” sulfur. Soil test calcium and magnesium levels are usually adequate, as long as lime needs are met.

Most sulfur in soils is in unavailable forms, associated with organic matter and clay. Sulfur, in the sulfate form, becomes available in small amounts at various times throughout the year. Sulfate-sulfur may be either taken up by growing plants or leached downward by water movement. For this reason, sulfates usually accumulate in subsoils that contain more clay than the topsoils. Therefore, soil tests for S are difficult to interpret unless the subsoil is also tested. Leaf analysis is useful in evaluating the S status of a plant during the growing season. Plants may have low levels of S early in the growing season, but as the plant roots extend into the S-rich subsoil, or as S is released from organic matter, S levels in plants increase.

Lime Recommendations

Lime applications should be based on soil tests. The University of Arkansas recommends lime when the soil pH is below 5.7, except where rice is in the rotation (Table 4-1). Recommended rates range from 1 to 3 tons per acre. If rice is not in the rotation, lime rates are based on soil pH and calcium content (Table 4-2). The more acid and the heavier the soil, the higher the rate of lime recommended. Continued cultivation, and the use of chemical fertilizers, especially those containing ammonium and sulfur, tends to decrease soil pH over time. Irrigation with water high in calcium carbonate will increase soil pH.

Table 4-1. Lime Recommendations for Grain Sorghum When Rice Is in the Rotation.

Soil pH	Lime (tons/acre)
Above 5.5	0
5.3 – 5.5	1
5.0 – 5.2	1.5
Below 5.0	2.5

Dolomitic lime (red lime) is the preferred source where soil test magnesium levels are below 75 pounds per acre. This usually occurs on the well- to excessively-drained acid soils away from the major rivers. If lime is needed, it is better to apply it during the fall to allow it enough time to react with the soil. Liming materials may have different Relative Neutralizing Values (RNV). The RNV of a material is based on its fineness and Calcium Carbonate Equivalent (CEC), with finer materials reacting quicker than coarse materials. An Ag lime with a CCE of 110 is “stronger” than an Ag lime with a CCE of 90, consequently less volume would be needed to increase the pH of a given soil.

Pelletized lime is sold in Arkansas at a considerably higher price than bulk agricultural lime. This material is produced from the finest lime particles, which are then bonded together with lignosulfonates (among several products) during the pelletizing process. The amount of pelletized lime to use should be between 60 to 75 percent of the amount of regular agricultural lime, depending on the source of the material. For instance, if the recommendation calls for 1 ton (2,000 pounds) of lime, only 1,200 to 1,500 pounds of pelletized lime would be required to raise the pH to the desired level.

On sandy or silt loam soils, where rice is in rotation and well water is used for irrigation, lime is recommended only after intensive soil and water testing. Separate soil samples should be collected near the water inlet, near the water outlet and also from the middle of the field. Water quality should also be determined. Apply lime based on Table 4-1 for the water outlet area regardless of the water’s calcium or bicarbonate content. If the water tests below 3 milliequivalents of calcium per liter, then the inlet area should also be limed according to Table 4-1.

These recommendations are designed to avoid zinc deficiency of the succeeding rice crop. Lime should be applied as far in advance of the grain sorghum as possible but not just before rice. About six months is needed for the applied lime to become completely effective.

Collecting soil samples in grids, for lime recommendations, may result in significant savings for producers. In some fields, the variability of soil pH is so high that savings in the range of 30 to 50 percent of the recommended lime have been achieved.

Table 4-2. Lime Recommendations for Grain Sorghum When Rice Is Not in the Rotation.

Soil pH	Soil Test Calcium (Lb/A by Mehlich 3 Extraction)			
	Below 1000	1000 - 3000	3000 - 4500	Above 4500
	------------ Tons/A ------------			
Above 5.7	0	0	0	0
5.2 – 5.7	1	1.5	2	2.5
5.0 – 5.2	1.5	2	2.5	3
Below 5.0	2	2.5	3	3

Fertilizer Recommendations

Nitrogen Rates and Sources

Nitrogen is probably the most limiting nutrient in grain sorghum production in Arkansas, with nearly 50 percent of the nitrogen removed with the grain, in contrast to 67 percent and 17 percent for phosphate and potash, respectively (Table 4-3). Total recommended N rates range from 60 pounds per acre for nonirrigated grain sorghum double-cropped after small grain to 150 pounds per acre for irrigated grain sorghum where yields are expected to exceed 6,000 pounds per acre. The normal recommendation for irrigated grain sorghum is 120 pounds per acre, compared to 100 pounds for nonirrigated (Table 4-4). A rough rule of thumb is that, based on the yield level, 2 pounds of actual nitrogen (N) are required for each 100 pounds of grain produced.

Figure 4-1 shows the typical nitrogen uptake pattern for a grain sorghum plant. It appears that the plant does not use much N during the first 20 days, but by the time the plant is 60 days old, it has used close to 60 percent of the total N. Consequently, a third to one-half of the total N is usually applied preplant. The remainder should be sidedressed by the sixth-leaf stage. An exception to this is where the entire recommended N is applied preplant as anhydrous ammonia, or for nonirrigated grain sorghum following small grain.

The remaining N not applied preplant should be sidedressed by the sixth-leaf stage. Some producers choose a three-way split, with a portion of the N (normally 100 pounds urea) being applied at the boot stage, making sure the fertilizer is applied after the dew has evaporated to avoid significant leaf burning. Fertilizer burn is more likely if liquid N is used when air temperature exceeds 80 degrees. Ground application equipment can be used for topdressing until the plants get so tall that stalk breakage is a problem. Small amounts of N may also be applied by overhead sprinkler irrigation systems.

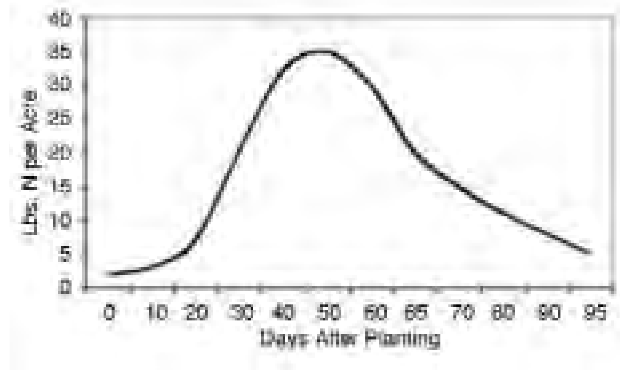

Figure 4-1. Typical nitrogen uptake pattern of a grain sorghum plant.

Animal manures, particularly poultry litter, may be used as supplements to commercial fertilizer. Rates should be based on soil test results and the nutrient content of the manure, keeping in mind that not all of the nitrogen in the manure becomes plant available the first year, and that applying manure based on N requirements may supply P in excess of plant needs. Where higher rates of animal manures are used, plant analysis should be used to monitor N needs for possible adjustments during the growing season.

Table 4-3. Nutrients Removed in a 100 bu/A Grain Sorghum Crop.

	N Lb/A	% of Total	P_2O_5 Lb/A	% of Total	K_2O Lb/A	% of Total
Grain	84	47	42	67	22	17
Stover	95	53	20	33	107	83

Table 4-4. Recommended N Rates for Grain Sorghum Based on Yield and Irrigation System.

	Irrigated		Nonirrigated	
	---------------------- Yield (lbs/A) ------------------			
	< 6000	> 6000	< 5000	> 5000
Single crop	120	150	100	130
Double crop after small grain	100	130	60	90

Common N sources include urea, ammonium sulfate, ammonium nitrate, liquid N and, to a minimum extent, anhydrous ammonia. Ammonium sulfate also supplies sulfur. All sources of N are effective if applied properly (Table 4-5).

Preplant Fertilizer

Starter applications can be of benefit, especially with grain sorghum seeds being small and lacking all the nutritional reserves of other crops such as corn. Liquid as well as dry N and P sources are available. Starter fertilizers can be applied by band application of either solid or liquid sources. An example of a solid material is 18-46-0, while a common liquid source is 10-34-0. One hundred pounds of these materials banded near the seed serves as a "pop-up" source of P. Another approach is to broadcast the recommended preplant N-P-K fertilizer and then "hip up" the row. This places a large portion of the preplant fertilizer near the row. All or part of the recommended fertilizer may be applied preplant. But large amounts of fertilizer, especially those high in K, should not be concentrated near the row or salt damage to seedlings may occur. This is particularly true for grain sorghum planted after June 1 or where it cannot be irrigated.

Phosphate and potash rates are based on soil test levels and may be applied either in the spring or in the fall (Table 4-6). If grain sorghum will be planted after wheat, the P and K needed for both crops may be applied to the wheat. In that case, no additional P or K is needed for direct application to the grain sorghum.

Table 4-5. Nitrogen Sources for Grain Sorghum.

Situation	Preferred Sources[1]
Preplant	Urea, DAP, AS
Sidedress	Urea[2], DAP, AS, 32% UAN

[1]DAP = diammonium phosphate, AN = ammonium nitrate, AS = ammonium sulfate, UAN = urea ammonium nitrate solution.

[2]Urea post applied onto dry soil.

Table 4-6. Recommended P and K for grain sorghum.

Soil test P	Lbs P_2O_5/A	Soil test K	Lbs K_2O/A
Above 100	0	Above 275	0
60 – 100	30 - 40	186 – 275	40 – 60
Below 60	60	125 – 185	60 – 90
		Below 125	90 - 120

Plant Analysis

Plant analysis is a more direct indicator of plant nutrition than are soil tests. However, care must be taken in interpreting plant analysis values because of environmental and cultural factors that may interfere. If a deficiency is suspected, collect whole plant samples if the grain sorghum is less than 12 inches high, making sure they are free of soil since that will contaminate the samples. If the plant is more than 12 inches high but prior to heading, collect several fully developed leaves below the whorl. If the plant is at heading, sample the second leaf from the top of the plant. Table 4-7 shows reference sufficiency ranges for grain sorghum grown in the southern United States. This table may be used as a guide for all plant food elements in leaf or whole grain sorghum plants. Keep in mind that collecting the appropriate plant part is critical for the identification of nutritional disorders. Certain elemental ratios are also important. Ratios larger or smaller than those in Table 4-8 indicate possible plant nutrient imbalances or errors in testing or reporting.

Table 4-8. Desired Elemental Ratios in Plant Tissue.

N/K = 0.8 to 1.6
N/P = 8 to 12
N/S = 10 to 20
K/Mg = 8 to 16
Fe/Mn = 2 to 6

Table 4-7. Reference Tissue Sufficiency Ranges for Grain Sorghum According to Growth Stage.

Growth Stage	Nutrient							
	N	P	K	Mg	S	Fe	Zn	Cu
	------------- % ------------					---------- ppm ----------		
Seedling	3.9	0.2-0.5	2.0	0.2-0.6	0.24	75-400	12-150	4-20
Vegetative	3.0-4.0	0.2-0.4	2.0	0.2-0.5		75-200	12-100	2-15
Flowering	2.5-4.0	0.2-0.35	1.4	0.2-0.5		65-100	12-100	2-7

5 - Major Insect Pests of Grain Sorghum in Arkansas and Their Management

Paul McLeod and Jeremy Greene

Grain sorghum production in Arkansas has been erratic until recent years both in yield per acre and in number of acres planted. The low level of profitability has often caused the crop to be viewed as a "last resort" planting. Many potential pests of grain sorghum have often been ignored. Among these pests, insects often attack and may severely impact yield of grain sorghum in Arkansas. However, the low potential for profit has often prevented the producer from actively managing insect pests. As yields have increased in recent years, however, grain sorghum is beginning to be viewed as a crop with greater potential for profit and interest in management of all pests is increasing.

Much of the insect management information for Arkansas grain sorghum production is based on data from other states. However, with the formation of the Arkansas Corn and Grain Sorghum Promotion Board in 1998, funding became available for research on grain sorghum insects and substantial progress has been made. Initial surveys have now been completed on insects and their impact on grain sorghum throughout the state. Major insect pests have been identified and their distribution within the state has been established. Much has been learned on the biology of major insect pests and this information has enabled the improvement of insect management on grain sorghum.

Although much of the research on sorghum insects has only recently been completed and numerous additional studies are needed, substantial knowledge has been gained. The next step in the process was to provide the grain sorghum producers of Arkansas with this information in a usable production manual. The objective of this manual chapter is to provide the producer with the most current information on identification, biology and management of insect pests of grain sorghum in Arkansas. Emphasis has been placed on the major insect pests and their management. Additional insects, now considered to be minor pests, may pose greater threats in future years. Also, new species may migrate into the state. Thus, continual research is needed to identify these changes and develop management strategies. As these findings become available, updates to the production manual will be made. Additional information can be found on websites maintained by the University of Arkansas Department of Entomology (http://comp.uark.edu/%7Epjmcleod/) and the Cooperative Extension Service (http://www.aragriculture.org/pestmanagement/insects/grain sorghum).

From a producer's perspective the major insect pests of Arkansas grain sorghum can be divided into three groups, i.e., those attacking seed and seedlings early in the season, the sorghum midge and those that feed directly on the seed during later season. Early-season pests include a diverse group of insects. Among the most damaging are chinch bugs, cutworms, aphids and wireworms. Probably the most destructive insect pest of Arkansas grain sorghum is the sorghum midge that attacks during flowering. Late-season insects that feed directly on seed include corn earworms, fall armyworms, sorghum webworms and stink bugs. Discussions of the major pests follow.

Early-Season Insect Pests
Aphids
Chinch bugs
Cutworms
White grubs
Wireworms

Insect Pests Attacking at Bloom
Sorghum midge

Late-Season Insect Pests
Corn earworms
Fall armyworms
Sorghum webworms
Stink bugs

Aphids Including the Greenbug, Corn Leaf and Yellow Sugarcane Aphid, Homoptera: Aphididae

Description

Aphids found on Arkansas grain sorghum are minute (<1/8 inch long), blueish-green insects (Photo 5-1*). Clear membranous wings may be present but wingless forms are more common. Aphids occur in colonies which contain different size nymphs and adults. As the newly born nymphs increase in size, molting occurs and the white exoskeleton is left on the leaf surface.

Distribution, Damage and Impact

Aphid species that attack grain sorghum occur throughout the state. Among the aphids found on grain sorghum in Arkansas, the greenbug is generally the most damaging. Aphids feed by inserting their stylet or beak into the plant tissue and removing plant sap. Large amounts of sap are removed and the partially digested contents are excreted onto the plant surface in the form of a clear sticky honeydew. A dark gray mold may later form on the honeydew. The level of injury in Arkansas grain sorghum is often low and beneficial organisms may provide sufficient control. Aphids also transmit viral diseases but aphid control is not effective in viral disease management.

Life History

Aphids are capable of overwintering on alternate host plants in Arkansas. Also, winged aphids are carried into the state on winds coming from more southern areas each spring. Adults colonize grassy hosts and grain sorghum seedlings and reproduce asexually through the summer. Development of nymphs is rapid and many generations occur each season. Foliar insecticides applied for control of other insects may reduce beneficial insect populations and result in an aphid population increase.

Management

Excessive aphid populations on actively growing grain sorghum may be managed with **foliar insecticides** but the benefits may be very limited. Numerous **beneficial organisms** affect aphids, including naturally occurring insect pathogens, parasites and predators and insecticide use may reduce their effectiveness. Some grain sorghum hybrids possess some level of **resistance** to the aphid.

Insecticide Recommendations for Aphids on Grain Sorghum

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Chinch Bug, *Blissus leucopterus leucopterus*, Heteroptera: Lygaeidae.

Description

Chinch bug adults are true bugs, i.e., the front half of the forewing is hardened while the rear portion is membranous. Color is generally black but the light-colored wings give the appearance of a white band across the midsection (Photo 5-2). Adults are only about 3/16 inch long. Immatures vary greatly in appearance. Newly hatched nymphs appear as minute reddish/orange specs on sorghum stalks and foliage (Photo 5-3). As nymphs develop, color changes from orange to dark gray or black. All nymphs are wingless.

Distribution, Damage and Impact

In Arkansas, chinch bug populations have varied greatly during the past four years. Few were detected during 1999 and 2000 except for Lafayette County in extreme southwest Arkansas. Surveys during the last two years, however, have detected chinch bugs throughout the state. Outside of Arkansas, chinch bug occurs in all states east of the Rocky Mountains and into southern Canada. On seedling grain sorghum, adult chinch bugs can be found either on the ground or on stems near the ground, often under leaf sheaths. Here they insert their stylet mouth parts into the plant and remove plant fluids. Infested plants often become yellow and distortion of seedlings is common.

*Photos can be found on pages 35 and 36. Tables 5-1 and 5-2 can be found on page 34.

Life History

Generally adult chinch bugs migrate from overwintering sites, including grasses, into seedling grain sorghum where they mate and begin egg laying. The orange nymphs emerge and by peeling back the lower leaves on seedlings, large numbers of nymphs can often be detected. Nymphs develop for a few weeks and form the winged adult. This process continues throughout the growing season. In Arkansas about three generations of chinch bug can develop each season.

Management

Chinch bug damage is generally greater under hot, dry conditions. Plants with **sufficient moisture** are more able to outgrow the damage. Thus, irrigation during periods of drought may reduce the impact of chinch bugs on grain sorghum. Irrigation also may aid the uptake of insecticides applied to the seed or soil.

In areas with a history of chinch bug problems, it may be beneficial to use **seed treated with insecticide or to apply a soil insecticide** at planting. However, chinch bug populations may experience great fluctuations between years and preventative soil or seed insecticides may not always be justified. In areas with a history of chinch bug problems and where treated seed or soil insecticides are used, it is suggested that a small portion of the field be left untreated and periodically checked for chinch bug. The final approach at chinch bug management is with the use of **insecticide sprays** applied to the foliage of seedling grain sorghum.

The chinch bug threshold is variable and depends on the rate of plant growth and size. Slow growing smaller plants are most susceptible to severe damage. A general threshold for chinch bug has been established on seedlings less than 6 inches in height. Foliar treatments should be justified when 20 percent or more of the sampled plants harbor a minimum of two chinch bugs per plant. Fields should be sampled in several areas due to the variability in chinch bug distribution. Because the chinch bug is often found between the leaf sheath and stem, spray coverage is critical. Foliar insecticides must be applied in a minimum of 20 gpa and directed at the top of the seedling. Also, surfactants will likely increase effectiveness.

Insecticide Recommendations for Chinch Bug on Grain Sorghum

See Tables 5-1 and 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Cutworms Including the Black Cutworm, *Agrotis ipsilon*, Lepidoptera: Noctuidae

Description

Cutworm larvae are dark gray to black caterpillars that can generally be found just below the soil surface feeding on seedling grain sorghum. Although larvae are minute (<1/8 inch long) at hatching, they are not likely to be detected until they are at least 1/2 inch long. At maturity, larvae are almost 1.5 inches in length (Photo 5-4). The caterpillars have three pair of true legs on the thorax and five pair of fleshy "prolegs" on the abdomen.

Distribution, Damage and Impact

Cutworms occur throughout the U.S. and throughout Arkansas. Recent surveys have detected large populations near Stuttgart and Des Arc. Larvae feed on emerging seedlings and often cut off the plant near or below the soil surface. Several adjacent plants within the drill line can be killed by a single cutworm. Also, rough or cloddy soil appears to harbor larger cutworm populations.

Life History

Cutworms generally are capable of overwintering as pupae in soil in Arkansas especially in southern counties. In addition to adults emerging in late winter from the overwintered pupae, adult moths fly into Arkansas from more southern states. Moths lay eggs on many weed hosts and crops, including grain sorghum. Newly hatched larvae can produce "shot holes" in grain sorghum foliage. Larger larvae often cut the seedling and feed below the soil surface. Where damage occurs, larvae can be detected by removing the upper layer of soil near a damaged plant. The number of generations per year varies from one to three depending on cutworm species.

Management

The first step in cutworm management is proper **crop rotation**. Grain sorghum that follows grain sorghum or planting grain sorghum in recently turned pastures tend to have more damage from cutworms. Also, adults are attracted to fields with weeds on which eggs are laid. Thus, **early seedbed preparation** prior to planting reduces the likelihood of cutworm damage. Providing a minimum of two weeks of host-free time prior to planting should reduce the attractiveness of the field to cutworm adults. No or reduced till fields are more susceptible to economic losses from cutworms.

Also, seed beds prepared during wet conditions are often cloddy. This may later harbor increased numbers of cutworms. Bed knockers or flat rolling beds can reduce the chances of developing damaging cutworm populations. In areas with histories of cutworm problems, **treated seed or soil insecticides** applied at planting may be justified.**Foliar insecticide sprays** may be used to reduce cutworm populations but early scouting for damage is critical. Foliar insecticide sprays should only be used when the damage levels exceed the threshold of 6 to 8 percent of the seedlings with cutworm damage above the surface of the ground or 2 to 4 percent of the plants cut below the surface. Finally, insecticide success may be reduced when late stage larvae are targeted as most of their time is spent underground.

Insecticide Recommendations for Cutworms on Grain Sorghum

See Tables 5-1 and 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

White Grub, *Phyllophaga* spp., Coleoptera: Scarabaeidae

Description

White grub is generally a term given to the larvae stage of a group of over 200 species of scarab beetles. Adult descriptions vary greatly but the most common is referred to as the May beetle. These adults are commonly found at lights during late spring and summer nights. May beetles are about 1 inch long and tan to dark brown in color. Larvae are cream-colored scarabs with a tan head capsule and dark internal markings on the end of the abdomen (Photo 5-5). Six true legs are easily seen on the thorax.

Distribution, Damage and Impact

White grubs occur in the soil of grain sorghum fields throughout Arkansas. Damage may occur when the grubs feed on underground roots. However, in recent surveys the impact of white grub has been minimal. Fields recently converted from pastures are most susceptible.

Life History

The biology of white grubs varies greatly due to the many different species. In general, adults emerge in the spring, mate and deposit eggs in a cell below the soil line. Larvae hatch and can complete their development through the summer and fall or may take two or more years to mature. Pupation occurs in the soil.

Management

In south Arkansas **avoidance of recently plowed grassy fields**, including pastures, will reduce the attractiveness of the field to adult beetles. **Rotation** of grain sorghum with broadleaf crops, especially soybean, will reduce the likelihood of damage. Use of **treated seed** or **soil insecticides** applied at planting may reduce larval populations but is not likely to be economically effective if directed only at the white grub.

Insecticide Recommendations for White Grub on Grain Sorghum

See Table 5-1 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Wireworm, Coleoptera: Elateridae

Description

Several species of wireworms occur in Arkansas and descriptions of the different species vary. In general, wireworm adults, also known as click beetles, are dark brown hard-bodied beetles. The term “click” comes from the ability to snap the hinge between the thorax and abdomen resulting in a flip that rights the upturned insect. Size varies, but adult wireworms in grain sorghum are about 1.25 inches long. Larvae occur in the soil. Although the larvae of some species are white, the most common in Arkansas is tan and at maturity about 3/4 inch in length (Photo 5-6). True legs are evident and the head is somewhat flattened.

Distribution, Damage and Impact

Wireworms occur throughout the state but the major damage resulting from their feeding has been observed in Clay County in northeast Arkansas and near Paris in Logan County. Larvae feed on newly planted seed, emerging seedlings and can be found infesting the lower stems of larger grain sorghum plants. Damage in some fields has been substantial and at times fields have been replanted due to stand loss.

Life History

The biology of wireworms is also quite variable. Some species complete two generations per year while some require up to five years for a single generation. In general, adults emerge from overwintering larvae in the spring and search for grassy fields. Eggs are laid in the soil usually where grasses are available for the larvae to feed. When grain sorghum is planted, the seed and emerging seedlings are burrowed into. Seedlings can be weakened and killed. Wireworm larvae can be found by carefully digging up weak seedlings and searching the soil. In dry conditions wireworm larvae move deep into the soil and are difficult to detect.

Management

In Arkansas **avoidance of recently plowed grassy fields**, including pastures, will reduce the likelihood of damage from wireworms. **Crop rotations**, i.e., grain sorghum following a broadleaf like soybean, will reduce damage but with wireworms that require multiple years for development, damage may be substantial. Damage also is more severe in fields where seed are slow to germinate and where seedling growth is retarded. Thus, **delaying planting** until soil is warmer may reduce the impact of the wireworms. Although the use of **treated seed** and **soil insecticides** applied at planting may provide some control, wireworm problems persist in Clay County despite insecticide application. Foliar insecticide application to seedlings is of no benefit.

Insecticide Recommendations for Wireworms on Grain Sorghum

See Table 5-1 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Sorghum Midge, *Contarinia sorghicola*, Diptera: Cecidomyiidae

Description

The sorghum midge is generally the most damaging insect pest of grain sorghum in Arkansas and without management may devastate the crop. The adult sorghum midge is a minute (<1/8 inch long) orangish “gnat-like” fly which can be detected on flowering sorghum heads. Larvae are minute orange maggots found in the seed.

Distribution, Damage and Impact

The sorghum midge occurs worldwide and throughout Arkansas. Larvae feed directly on the developing seed and may destroy all seed within each sorghum head (Photo 5-7). Where high sorghum midge populations are left unmanaged, resulting damage may be severe and yield reduction may approach 100 percent.

Life History

When temperatures climb into the 70s in late winter or spring, adult flies begin to emerge from old seed heads in which larvae have overwintered.

Wild grasses, including johnsongrass, are the initial host plants and several generations can develop within these hosts prior to flowering of grain sorghum. Because of the limited availability of the wild hosts, midge populations generally remain below damaging levels in early summer. As early planted grain sorghum begins to flower, adult flies migrate into these fields, especially into the edge of the sorghum field immediately downwind from the wild host. The flies mate and each female midge can deposit up to 250 eggs in less than two days. Larvae emerge from the eggs within two days and burrow into the developing seed. Pupation occurs on the seed and lasts for about three days. The time required for a complete generation varies from two to three weeks depending on temperature. Thus midge populations can rapidly increase and later sorghum plantings may be severely infested.

Management

The first choice of management should be **early and uniform planting**. In areas, or even within fields, where the period of sorghum flowering is extended, the sorghum midge can complete multiple generations on grain sorghum and build to damaging levels in late blooming fields. Because only the flowering stage is susceptible to midge attack, delaying subsequent grain sorghum plantings for five or six weeks may disrupt population increase. **Destruction of wild host plants, including johnsongrass**, early during the season may slow midge population development. Some **grain sorghum hybrids** possess some level of resistance to sorghum midge.

In fields with the potential for high yields and profit, it is important to scout for sorghum midge as soon as the plants begin to bloom. Scouting should be initiated when about 25 percent of the field begins to bloom. Sorghum heads on the field edges should be searched for the orangish flies. This can be accomplished by slowly approaching the plant and visually searching all sides of the head for adult midges. Also, placing a clear half-gallon plastic bag over the head and shaking the head in the bag will dislodge and capture adults. By carefully removing the bag and examining the contents, adults can be counted. Mornings with reduced winds are the best time for sampling. Within each field (80 acres or smaller) 100 heads should be counted with emphasis placed on the field borders.

The current economic threshold in Arkansas is an average of one adult sorghum midge per head. If the field possesses the potential for economic profit and the threshold is surpassed, **insecticide application** is likely warranted. Additional scouting should be completed at about two-day intervals until the soft dough stage. Adults detected at this stage are unable to infest the seed. Following harvest, grain sorghum **crop residue should be destroyed** as larvae overwinter within seed.

Insecticide Recommendations for Sorghum Midge on Grain Sorghum

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Corn Earworm, *Helicoverpa zea*, Lepidoptera: Noctuidae

Description

Adults of the corn earworm, also known as the cotton bollworm, are light tan in color and are about 1.25 inches long. Moths generally have green eyes. Eggs are near white when laid but darken just prior to larvae emergence. Larvae initially are minute, about 1/16 inch, but at maturity can reach 1.75 inches in length. Three pair of true legs occur on the thorax and four pair plus an anal pair of prolegs are found on the abdomen (Photo 5-8). Color of larvae varies greatly. Mature larvae that have developed on foliage are mostly green while those developing on seed are reddish brown with longitudinal lines. The pupal stage occurs in soil and color ranges from light tan shortly after pupation to dark brown just prior to moth emergence.

Distribution, Damage and Impact

All stages of the corn earworm can be found throughout Arkansas and resulting damage may be severe. This damage occurs in several forms, including foliar damage to young grain sorghum and direct damage to seed heads.

Life History

Adults that are active in late winter arise from two sources, i.e., overwintering pupae and flights of moths from southern areas. Adults are attracted to many host plants but flowering plants are favored. Eggs are deposited on foliage of seedling grain sorghum and larvae may consume large amounts of foliage. When accurate counts are made, however, the percentage of seedling grain sorghum plants infested with corn earworm is generally very low and control is not feasible. Later generations deposit eggs during flowering and head formation and emerging larvae feed directly on seed. Regardless of host plant structure on which the larvae develop, mature larvae move to the ground and pupate within the upper 6 inches of soil. In Arkansas three or four generations occur each year.

Management

Lepidopterous caterpillars often feed within the heads of grain sorghum and visual examination of the head my not detect all larvae. By shaking the seed head over a white bucket, the larvae will be dislodged and can be more easily counted. At least 30 plants per 80 acre field should be sampled. Thresholds for caterpillars on grain sorghum heads vary greatly due to the profit potential of the crop. In general, when lepidopterous caterpillars (corn earworm, fall armyworm and sorghum webworm) number two or more per head in grain sorghum nearing maturity, **foliar insecticides** may be warranted. Use of foliar insecticides to reduce damage may not produce economic benefits and should only be used against high insect populations. Numerous **beneficial organisms** affect corn earworm, including naturally occurring insect pathogens, parasites and predators, and insecticide use may reduce their effectiveness. **Fall plowing** to destroy and bury crop residue will reduce over-wintering populations of corn earworm. Finally, **"open headed" grain sorghum hybrids** better expose caterpillars to foliar insecticide sprays and to beneficial organisms.

Insecticide Recommendations for Corn Earworm on Grain Sorghum

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Fall Armyworm, *Spodoptera frugiperda*, Lepidoptera: Noctuidae

Description

Fall armyworm adults are large bodied moths with dark gray forewings that have lighter banding. A light spot occurs near the apex of the forewings. Mature larvae are up to 1.5 inches long and are dark brown in color with numerous black spots (Photo 5-9). The head capsule has a distinct light-colored inverted "Y."

Distribution, Damage and Impact

Fall armyworm occurs throughout Arkansas and its impact on grain sorghum is similar to that of the corn earworm. This impact occurs in the form of direct damage to seed.

Life History

In early spring adults migrate into Arkansas from more southern states, mate and seek suitable host plants for egg laying. Eggs are laid in masses that contain up to a few hundred eggs. Emerging larvae feed for two to three weeks and then pupate just below the soil surface. Multiple generations occur each year.

Management

Lepidopterous caterpillars often feed within the heads of grain sorghum and visual examination of the head may not detect all larvae. By shaking the seed head over a white bucket, the larvae will be dislodged and can be more easily counted. At least 30 plants per 80 acre field should be sampled. Thresholds for caterpillars on grain sorghum heads vary greatly due to the profit potential of the crop. In general when lepidopterous caterpillars (corn earworm, fall armyworm and sorghum webworm) number two or more per head in grain sorghum nearing maturity **foliar insecticides** may be warranted. Use of foliar insecticides to reduce damage may not produce economic benefits and should only be used against high insect populations. Numerous **beneficial organisms** affect fall armyworm including naturally occurring insect pathogens, parasites and predators and insecticide use may reduce their effectiveness. **Fall plowing** to destroy and bury crop residue will reduce over-wintering populations of armyworm. Finally, **"open headed" grain sorghum hybrids** better expose caterpillars to foliar insecticide sprays and to beneficial organisms.

Insecticide Recommendations for Fall Armyworm on Grain Sorghum

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Sorghum Webworm, *Nola sorghiella*, Lepidoptera: Nolidae

Description

Adult sorghum webworms are white moths with a wingspan of about 1/2 inch. Larvae are smaller than corn earworm and fall armyworm larvae and at maturity are only about 1/2 inch long. Many setae occur on the sides and back of the caterpillar giving it a hairy appearance (Photo 5-10). Larval color is greenish to yellowish and four red to brown longitudinal lines occur on the back.

Distribution, Damage and Impact

The sorghum webworm occurs throughout the state and the larvae damage grain sorghum by feeding directly on the seed. Impact varies considerably but in recent years sorghum webworm has produced considerable damage in late planted sorghum in eastern Arkansas.

Life History

Little is known about the biology of the sorghum webworm in Arkansas. Based on information from adjacent states, the webworm overwinters in plant debris as larvae and moths emerge in late spring. Early generations may develop on grass hosts. Adults emerging from these alternate host plants migrate to late planted grain sorghum where they mate and lay eggs. The eggs hatch in about five days and larvae feed on sorghum seed for about two weeks. Pupation occurs in plant debris and lasts for seven to ten days. The entire generation is about one month.

Management

Lepidopterous caterpillars often feed within the heads of grain sorghum and visual examination of the head may not detect all larvae. By shaking the seed head over a white bucket, the larvae will be dislodged and can be more easily counted. At least 30 plants per 80 acre field should be sampled. Thresholds for caterpillars on grain sorghum heads vary greatly due to the profit potential of the crop. In general when lepidopterous caterpillars (corn earworm, fall armyworm and sorghum webworm) number two or more per head in grain sorghum nearing maturity **foliar insecticides** may be warranted. If webworms are the only caterpillar found on grain sorghum, the threshold may be adjusted to five per head. Use of foliar insecticides to reduce damage may not produce economic benefits and should only be used against high insect populations. Numerous **beneficial organisms** affect webworm, including naturally occurring insect pathogens, parasites and predators, and insecticide use may reduce their effectiveness. **Fall plowing** to destroy and bury crop residue will reduce over-wintering populations of webworm. Finally, **"open headed" grain sorghum hybrids** better expose caterpillars to foliar insecticide sprays and to beneficial organisms.

Insecticide Recommendations for Sorghum Webworm on Grain Sorghum

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Stink bugs, Hemiptera: Pentatomidae

Description

Several stink bugs, including the brown stink bug, the green stink bug, the southern stink bug and the rice stink bug, occur on grain sorghum in Arkansas. Stink bugs are true bugs having the front half of the forewing hardened while the rear portion is membranous. Adults are about 1/2 inch long and color varies from tan to green depending on species (Photo 5-11). Immature stink bugs or nymphs resemble the adults but are wingless.

Distribution, Damage and Impact

Stink bugs occur throughout Arkansas and impact grain sorghum production by feeding during early stages of seed formation. Soft seed is fed on by the bug inserting its stylet or beak into the seed and withdrawing partially digested plant material (Photo 5-12). After the seed hardens damage from stink bugs is minimal.

Life History

Stink bugs overwinter as adults in plant debris located on field borders. In late winter or spring when temperatures approach 70 degrees, adults become active, mate and females begin to deposit eggs. Each female can deposit several hundred eggs on weed hosts. Nymphs emerge and feed on alternate hosts and cultivated plants for over one month before they form wings and disperse. In Arkansas several generations are produced each year. Populations can build to high levels in late summer and fall. Grain sorghum in early stages of head formation can sustain considerable damage during this period.

Management

Destruction of overwintering sites may play a role in stink bug population development. Because adult bugs are strong flyers, however, this practice may have little benefit. The most practical management tactic is use of **foliar insecticides**. Fields should be scouted for adult and immature stink bugs from flowering to maturity. Because of the clumped distribution of stink bug populations, efforts to scout entire fields should be undertaken. A minimum of 30 sorghum heads should be shaken into a white bucket and the stink bugs should be counted. The recommended threshold in Arkansas is five stink bugs per sorghum head. As seed mature this number should be greatly increased, i.e., 16. Numerous **beneficial organisms** affect stink bug populations, including some beneficial stink bugs, and insecticide use may reduce their effectiveness.

Insecticide Recommendations for Stink Bugs on Grain Sorghum

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

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Table 5-1. 2003 Recommendations for Insecticides Applied to Soil at Grain Sorghum Planting.						
Insecticide	**Amount of Product per 1000 row ft.**	**Aphids**	**Chinch Bug**	**Cutworm**	**White Grub**	**Wireworm**
Lorsban 15G	4-12 oz.		X	X		
Cruiser 5FS*	5.1 oz./100 lb. seed	X	X			X
Counter 15G	7 oz.	X	X		X	X
Gaucho*		X	X			X
Temik 15G	7.5 oz.	X	X			
*Seed treatment						

Table 5-2. 2003 Recommendations for Insecticides Applied to Grain Sorghum Foliage.									
Insecticide	**Amount per acre**	**Aphids**	**Chinch Bug**	**Cutworms**	**Sorghum Midge**	**Corn Earworm**	**Fall Armyworm**	**Sorghum Webworm**	**Stink Bugs**
Asana XL	2.9-9.6 fl. oz.		X	X	X	X			
Baythroid 2EC	1.0-2.8 oz.		X	X	X	X	X	X	X
Fury	1.4-2.9 fl. oz.		X	X	X	X	X	X	X
Karate 2.08 CS	0.96-1.92 oz.		X	X	X	X	X	X	X
Lannate 2.4 LV	0.75-1.5 pts.				X	X	X	X	
Lannate SP	0.25-0.5 lbs.				X	X	X	X	
Lorsban 4E	0.5 - 2 pt.	X	X	X	X	X	X	X	
Mustang Max	1.28-4.0 oz.		X	X	X	X	X	X	X
Warrior T	1.92-3.84 fl. oz.		X	X	X	X	X	X	X
Dimethoate 2.67	0.75-1.5 pts.	X							
Malathion 57	1.5 pts.	X							
Sevin XLR	1-2 qts.		X	X		X	X	X	

Photo Descriptions

The following descriptions correspond to the numbered photographs on the next two pages.

5-1 Adult and immature aphids.
5-2 Adult chinch bug on grain sorghum foliage.
5-3 Chinch bug nymph.
5-4 Mature cutworm larvae.
5-5 Mature white grub larvae.
5-6 Mature wireworm larvae.
5-7 Sorghum midge damage on grain sorghum heads.
5-8 Mature corn earworm larvae feeding on grain sorghum.
5-9 Mature fall armyworm larvae feeding on grain sorghum.
5-10 Sorghum webworm larvae feeding on sorghum seed.
5-11 Adult stink bug.
5-12 Stink bug feeding on sorghum seed.

Photogaphs are referenced throughout Chapter 5 – Major Insect Pests of Grain Sorghum in Arkansas and Their Management

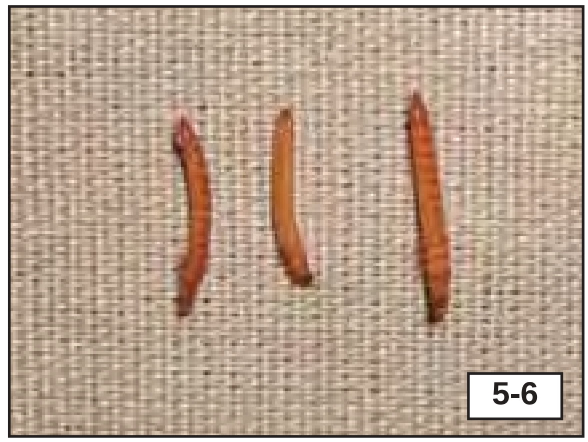
5-1

5-2

5-3

5-4

5-5



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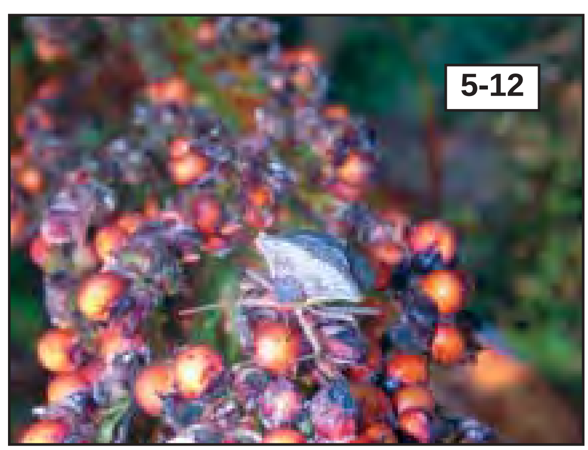

5-12

6 - Common and Important Diseases of Grain Sorghum

Dave TeBeest, Terry Kirkpatrick and Rick Cartwright

Introduction

Grain sorghum continues to be an economically important crop in Arkansas, fitting into production schedules and helping to control nematodes of both cotton and soybeans. However, numerous diseases of grain sorghum can be found wherever the crop is grown, including Arkansas. Some of these diseases have been investigated in the past and we have listed several below which are either continuing to be important pathogens that affect yields or are very common and provoke interest from producers. In addition, one new disease of grain sorghum was recently found in the United States and it is listed below as an uncommon disease for information purposes. It was discovered in one field in Arkansas in 2001 but with assistance of the producer has not reappeared in the field. It has not been found in Arkansas since that initial report.

Anthracnose

Since 1985, sorghum anthracnose, caused by a fungus, *Colletotrichum sublineolum*, has increased dramatically throughout Arkansas. It is especially common in the eastern, southeastern and southwestern grain sorghum areas. Although outbreaks have been sporadic, the disease has been a significant economic factor for grain sorghum producers in these regions.

Symptoms of leaf anthracnose usually become clearly visible about the time of boot formation. On susceptible hybrids, small circular spots develop on leaves and leaf midribs (Figure 6-1). These spots have wide margins that are red, orange, purple, or tan with straw-colored centers. As the disease progresses, the spots may increase in number and coalesce to cover most of the leaf surface. In the centers of the spots, small black fruiting bodies (acervuli) develop. These acervuli, with setae (small, black, hairlike structures protruding from the acervuli), are diagnostic characteristics of anthracnose. Use of a hand lens or a dissecting scope helps identify these structures. These symptoms are sometimes easier to recognize on the mid-vein of older leaves (Figure 6-2). The disease can also infect the stalk of grain sorghum hybrids (Figure 6-3).

Although leaf lesions are the first symptoms of infection in the field, there are four separate phases of anthracnose: seedling root rot, leaf (foliar), stalk rot and seed mold. All four phases may occur on sorghum within a single growing season. All phases can reduce yields severely. Seed rot is caused by planting infected seed or by infection of the seeds as they germinate in infested soil. The leaf phase occurs from the first true leaf through the emergence of the panicle from the boot. Generally, the leaf phase of anthracnose begins to develop very quickly near the end of the vegetative stage of the plant and near the beginning of the heading stage. If the foliar phase destroys leaf tissue prior to or during grain filling, yields may be reduced. Stalk anthracnose develops from spores produced in the foliar phase, and is spread throughout the field by splashing rain and wind.

The rate and severity of stalk and head infection are determined by the level of anthracnose resistance in the hybrid, the number of spores produced and the environment. Spores of *C. sublineolum* produced on leaves are washed into leaf sheaths by rain or dew. The spores germinate and infect the stalk above the uppermost leaf and rot the interior of the stalk. If the head and stalk are split lengthwise, a banded or marbled pattern of dark red to purple lesions interspersed with white pith tissue can be seen (Figure 6-4). This phase is most common when stem borers have been active in the plant because the borers create wounds for the fungus or carry the fungus with them into the stem. Under conducive

Figures 6-1 through 6-13 can be found on pages 45-46 at the end of this chapter..

conditions, the infections of the leaf and stems continues and leads to invasion of the panicle and seeds. Under severe conditions, infection of the panicles can prevent grain filling. Heads of infected plants generally mature earlier and are smaller and lighter in weight than uninfected heads. Because the destruction of stalk tissue limits movement of nutrients to the developing grain, the stalk phase of anthracnose can be an important factor in final determination of grain yield. Seed from infected heads may also be infected. Dark brown or black streaks encircling the seed are an indication of seed infection. Acervuli may also develop on the seed in the later stages of infection. The fungus can over-winter in the soil on refuse, on infected seed and as a small sclerotia.

Resistance to the leaf and stalk phases of anthracnose appears to be controlled by several different dominant and recessive genes, which means that sorghum can have resistance to the leaf phase, or to stalk phase or to both phases. Some hybrids can also have resistance on the leaf blade but still produce large lesions on the midveins of the same leaf. The fungus is known to be extremely variable and many of the current hybrids possess some degree of resistance to certain strains (called pathotypes) of the pathogen. Many of the inbred lines used in popular hybrids were developed for anthracnose resistance in areas of the southern U.S. where the disease was a significant problem. Some hybrids rated as resistant elsewhere are relatively susceptible to the pathotypes found in Arkansas.

Resistance of Selected Grain Sorghum Hybrids to Anthracnose in Arkansas

Anthracnose has been found on several of the University of Arkansas Experiment Stations since 1995. Because the availability and use of sorghum hybrids tends to change greatly from year to year two kinds of field tests were conducted at Rohwer, Marianna and Pine Tree to monitor the severity of the disease and to determine the levels of resistance in these grain sorghum hybrids to this disease. In the first of the field tests, disease ratings were made on all hybrids and selections in the Arkansas Variety Test Program. These tests were not artificially inoculated and results depended entirely upon the amount of the pathogen and the strains present in that test area. Individual entries in the variety test varied from year to year and often included experimental breeding lines that may or may not be released to the public under a hybrid name. Yield data on the hybrids and lines within this test are available from the Variety Test Performance Report.

In addition to the variety test, tests consisting of the highest yielding hybrids and hybrids that were the most popular among producers in Arkansas were also conducted at Rohwer, Marianna and Pine Tree. The 15 hybrids in these tests accounted for an estimated 90 to 95 percent of the grain sorghum acreage grown in the state.

Results from the 2003 entries in the Arkansas Variety Test Program are given in Table 6-1. These tests were conducted at the Cotton Branch Station, Marianna, Arkansas, and at the Pine Tree Station, Colt, Arkansas. At Marianna, none of the 41 entries in the test were rated as resistant to anthracnose, although 12 entries were rated as moderately resistant to this disease. Twenty-three (23) entries were rated as moderately susceptible and 6 entries (Dyna Gro 732B, Dyna Gro X173B, Dyna Gro X1754, Dyna Gro 715B, Terral TV97H17 and Triumph TR 461) were rated as susceptible to anthracnose. Disease severity ratings, indicating the estimated percentage of leaves infected by anthracnose, ranged from a low of 2.5 to a high of 9.5. Among the moderately resistant entries, disease severity ratings ranged from 2.5 (Garst 5515) to 7 (Terral TVX94S34, TVX95S25 and Triumph TR459). Disease severity ratings ranged from 7.5 to 9 for the hybrids rated as susceptible to anthracnose at that location.

Results from the Grain Sorghum Variety Test at Rohwer were significantly different from those at Marianna. At Rohwer, 28 of the entries were rated as resistant to anthracnose, 5 were rated as moderately resistant, 8 were rated as moderately susceptible and none were rated as susceptible to anthracnose. Disease severity ratings ranged from 1 to a high of 5.5. Among the entries rated as resistant, severity rating ranged from 1 to 2.5 indicating a relatively low level of disease on these entries. Among the entries rated as moderately resistant, the severity ratings were slightly higher ranging from 1.5 to 3. Among the 8 entries rated as moderately susceptible, severity ratings ranged from 2.5 to 5.5, indicating a slightly higher level of disease on these entries. All of the entries were examined for uniformity of the disease ratings between the two locations.

Table 6-1. Disease ratings for resistance and severity to anthracnose for 41 selections of hybrids and breeding lines entered in the Grain Sorghum Variety Test Program in 2003. Ratings were made at two locations at the hard dough stage of plant development.				
	Marianna		**Pine Tree**	
Hybrid/Entry	**Rating**	**Severity**	**Rating**	**Severity**
Asgrow A571	MS	6.5	MR	1.5
CroplanGen514	MS	8.5	R	1.5
DeKalbDKS53-11	MR	4	R	1
DekalbDKS54-00	MR	3.5	R	1
Dyna Gro 732B	S	8	MS	3
DynaGroX1738	S	9.5	R	1
DynaGro X1754	S	7.5	R	1.5
DynaGroX17F90	MR	3	R	2.5
DynaGro715B	S	8.5	R	1.5
DynaGro762B	MS	8	R	1
DynaGro780B	MS	7.5	R	2
FFR 318	MR	6	MR	3
FFR 322	MS	6	MS	2.5
Garst 5440	MS	7.5	R	1.5
Garst 5515	MR	2.5	R	1.5
Golden Acres 3694	MS	5.5	R	1
Golden Acres 444E	MS	7.5	MS	2.5
Golden Acres X2027	MS	8	R	1.5
H-502	MS	7	R	1.5
H-512	MS	8.5	R	2
Monsanto X204	MS	7.5	R	1
Monsanto X234	MS	6	MR	2.5
Pioneer 83G15	MR	3	R	1.5
Pioneer 83G66	MS	5	R	1.5
Pioneer 84G62	MS	5	R	2
South States SS650	MS	5.5	R	1.5
South States SS800	MS	8	R	1
Terral TV1050	MR	6.5	R	1
Terral TV93S72	MS	8.5	R	1
Terral TV9421	MS	9	MS	3
Terral TV96H81	MR	6.5	R	1.5
Terral TV97H17	S	7.5	R	2
Terral TVX93S16	MS	9	MR	3
Terral TVX 94S34	MR	7	MS	2
Terral TVX95S201	MR	4.5	R	1
Terral TVX95S25	MS	7	MS	2.5
Terral TVX96H202	MR	3.5	R	1
Terral TVX96H23	MS	5.5	MR	1.5
Triumph TR459	MS	7	MS	3.5
Triumph TR461	S	9	MS	5.5
Triumph TR82G	MR	4	R	1.5
Average Rating		6.5		1.8

Table 6-1 shows that most entries were rated as either resistant or moderately resistant, moderately resistant or moderately susceptible or moderately susceptible or susceptible at the two locations. However, 18 entries including an entry from Croplan Genetics, five from Dyna Gro, one from Garst, one from Golden Acres, two from H, one from Monsanto, one from Pioneer, two from Southern States and two from Terral, were rated as susceptible or moderately susceptible at Marianna while they were rated resistant at Pine Tree. The remaining 23 entries were rated uniformly or more similarly across both locations. These large differences could have resulted from the significantly higher levels of disease pressure at Marianna or from the occurrence of different strains of the pathogen at these locations. Preliminary evidence from molecular studies and from previous tests indicates that we have different strains virulent to different hybrids within Arkansas.

Results of the survey of anthracnose resistance within the 15 highest yielding or most popular hybrids in Arkansas are presented in Table 6-2. These tests were conducted at the Pine Tree Experiment Station, Colt, Arkansas, at the Cotton Branch Station at Marianna, Arkansas, and at the Southeast Branch Station at Rohwer, Arkansas. All ratings were taken at the hard dough stage of plant maturity without regard to time of year. In this test, 14 of the 15 entries were rated as resistant to anthracnose at Pine Tree and one was rated as moderately resistant to disease. At Marianna, all 15 entries were rated as resistant to anthracnose. In this case, these entries were planted in a different field and location than was the variety test. At Rohwer, 10 of the 15 entries were rated as resistant while 5 were rated as moderately resistant to infection by anthracnose. Disease severity ratings ranged from 1 to 2 at Pine Tree and Marianna and from 1 to 4.5 on 14 of the 15 entries at Rohwer. The highest severity rating (7.5) was on TV 9421 which was rated as only moderately resistant at Rohwer.

The uniformity of the rating for disease severity across the locations in this test is low; nevertheless, most of the hybrids exhibited some resistance to anthracnose at all three locations. There were significant differences noted in the reaction of some entries and all of these differences were recorded at Marianna where the 10 entries were rated as susceptible or moderately susceptible in the variety test there while rated as moderately resistant or

Table 6-2. Ratings for disease resistance and severity for selected high-yielding and popular grain sorghum hybrids grown in Arkansas. The data listed were obtained from tests conducted in 2003 at three locations in eastern Arkansas.

Grain Sorghum Hybrids	Anthracnose Ratings Across Locations					
	Pine Tree		Marianna		Rohwer	
	Rating	Severity	Rating	Severity	Rating	Severity
TV1050	R	1	R	2	R	3.5
TR 82G	R	2	R	1.5	MR	2
TV 9421	R	1	R	1	MR	7.5
DG 780B	R	2	R	1	R	3
FFR 322	R	2	R	1	MR	4
DG 751B	R	2	R	1	R	3
Pioneer 8282	R	2	R	2	R	3
Asgrow A571	MR	2	R	1	R	2
Pioneer 84G62	R	2	R	1.5	MR	4.5
SS 650	R	2	R	2	R	2
Pioneer 83G66	R	2	R	2	MR	4
SS 800	R	2	R	1	R	2.5
DKS 54	R	2	R	1	R	1
Golden Acre 444E	R	2	R	2	R	5
DK 53S-11	R	1	R	1	R	3
Average Rating		1.8		1.4		3.3

resistant at all other locations and tests. As stated above, these differences in results between the variety test at Marianna and the variety test results at Pine Tree and all three of the hybrid tests at Pine Tree, Rohwer and Marianna may reflect significant differences in the strain(s) of the pathogen present at that one location at Marianna.

The results of the 2003 tests of the best hybrids closely reproduces the results of previous years in which this test was conducted at Pine Tree and Rohwer in which all these were rated as resistant or moderately resistant to infection.

Bacterial Diseases

Bacterial Leaf Spot

Bacterial leaf spot is caused by *Pseudomonas syringae pv. syringae*. The disease is found throughout Arkansas but is more common in the southern regions of the state. Symptoms of the disease consist of an initial water soaked lesion on the lower leaves. As lesions grow and mature, they become elliptical to circular and often develop red or brown margins (Figure 6-5). As lesions dry, the centers become light colored. At this stage, leaf spot can resemble pesticide injury, physiological spotting and one or more fungal diseases. This disease is most commonly found in the spring since it is dispersed by rain and wind. As the growing season approaches summer, the disease usually becomes insignificant in severity. The bacterium overwinters in debris and in infected grasses. Control measures include crop rotation, destruction of crop residue and planting of resistant cultivars and hybrids.

Bacterial Leaf Streak

Bacterial leaf streak is caused by *Xanthomonas campestric var holcicola*. The disease is common in the warm humid areas wherever sorghum is grown. It is found throughout Arkansas. The typical symptoms of the disease include small interveinal watersoaking areas that increase in size and that become several centimeters in length and purple in color in many varieties grown in Arkansas (Figure 6-6). The purple lesions often remain between the leaf veins and may appear as stripes. In very susceptible varieties, the stripes coalesce to become blotches and leaf shredding and death may occur at this stage.

The disease is most commonly found in the spring and is favored by warm wet conditions. Under normal conditions in Arkansas, the disease becomes progressively less severe as the hot dry summer months approach. Control measures include crop rotation, destruction of crop residue and planting resistant varieties and hybrids.

Other Important Fungal Diseases

Leaf Blights

Leaf blight is caused by several fungi, including *Exserhilum turcicum*, and is widespread in many parts of the world, including Arkansas. Disease development is favored by moderate temperatures (18° to 27°C) and heavy dews or rain during the growing season. The disease can make its appearance early in the season and continue to develop throughout the growing season unless retarded by dry weather. If disease becomes established on susceptible cultivars before panicle emergence, yield losses can approach 50 percent. Symptoms of the disease include small reddish or tan spots (the color is dependant on cultivar type) that can enlarge to long elliptical reddish purple or tan lesions (Figure 6-7). These lesions can be 12 mm wide and 2.5 to 15 cm long. Sporulation of the fungus on lesions often gives them a dark gray or olive appearance on the surface.

The fungus can survive on grasses, on residue and on seeds. The disease is controlled by the use of resistant cultivars and by rotation. However, rotation is made less effective if infected grasses persist in fields or in field margins. High yielding and resistant cultivars and hybrids have been identified and are available to growers.

Charcoal Rot

Charcoal rot is caused by a soil-borne fungus, *Macrophomina phaseolina*. This can be a major disease in the drier regions of the world and has appeared in Arkansas during late summer. It appears to be especially destructive on high yielding cultivars that set and fill seed during hot, dry weather if plants are subjected to drought. Portions of fields can be affected with all plants completely lodged while other portions of the same field may appear to be healthy.

In general, the disease becomes conspicuous during the late season as plants near maturity. One symptom of the disease is lodging; however, diagnosis of infection by *Macrophomina phaseolina* is best characterized by a dried, stringy appearance of the stem near the soil line (at the fold in lodged plants) and the presence of black sclerotia in the affected areas (Figure 6-8). There is normally little if any reddening of the pith or cortex of the stems.

The pathogen is soil-borne and survives in the soil as sclerotia which provides the initial inoculum. High soil temperatures and low soil moisture are the predisposing factors for expression of the disease after flowering has occurred.

Incidence of charcoal rot can be minimized by maintaining soil moisture during the post-flowering stages. High levels of nitrogen and low levels of potassium are conditions that should be avoided. Host resistance is a complex of interacting characteristics and not generally well described.

Head Blight and Head Molds

Head blight and molds are caused by a variety of fungal pathogens. Head molds generally refer to fungi that mold the grains as they mature on the seed head. *Fusarium moniliforme*, *Fusarium semitectum*, *Curvularia lunata*, *Phoma sorghina*, *Helminthosporium* spp. and *Alternaria* spp. are generally considered to be head molds. In addition, anthracnose can also infect peduncles, pedicles and seeds on severely infected plants. The most obvious symptoms of head molds are the pink, orange or white seeds found on heads infected by *Fusarium* and by the presence of black seeds on heads infected by *Curvularia*, *Alternaria* or *Helminthosporium* (Figure 6-9). The presence of small black dots may indicate *Phoma* pycnidia or the acervuli of *Colletotrichum*. Head blight is usually reference to the infection of panicle or rachis branches that result in premature death of all or parts of a panicle. Head blights can be caused by *Fusarium* but also can be caused by *Colletotrichum*.

Head blights and molds can be partially avoided by adjusting planting dates so that plants mature during a period without frequent rains. Some sorghum genotypes are more resistant than others but none are considered to be completely resistant. Although the fungi infect seeds, there is no clear evidence that seed-borne infections greatly influence the occurrence of these fungi on seeds in subsequent crops.

Target Spot

Target spot is caused by *Bipolaris sorghicola*. The disease was found in plots at the Pine Tree station in 2001 in epidemic levels. It had not been found at these levels prior to 2001. It is a disease that should be watched carefully because it is potentially severe.

The symptoms of the disease first appear as reddish or grayish spots which later develop into elliptical, oval or more commonly cylindrical shapes (Figure 6-10). The lesions vary in size from 1 to 10 cm in length. On rare occasions the purple lesions may have a tan-colored center. Under wet conditions, numerous spores can be produced on lesions. Spores are brownish to gray in color.

The fungus attacks plants of all ages and stages. The disease can appear in early spring and can continue to develop throughout the entire year into heading. On susceptible cultivars or hybrids, lesions can coalesce to kill the entire leaf. The fungus can survive as mycelium or as spores in infected debris or on weed hosts such as johnsongrass.

Resistant hybrids or cultivars are recommended. However, very few hybrids are considered to be highly resistant. Rotations are partially effective if weedy hosts are kept to a minimum. The disease is easily dispersed from infected plants by the airborne spores.

Zonate Leaf Spot

Zonate leaf spot is caused by *Gloeocercospora sorghi*. This is a very common disease throughout Arkansas and is easily recognized but generally of little or moderate importance. Symptoms of the disease are often described as very large (3 to 8 cm) circular lesions that have alternating straw-colored and purple rings (Figure 6-11). However, many of the initial lesions are purple blotches that may have light irregularly shaped spots in the centers. The fungus overwinters in sclerotia in soil and in infected plant debris. During warm wet periods, pink to salmon colored spores may be visible on the lesions. It is known that lesions can appear within 12 hours after infection with 1 cm purple blotches developing within 24 hours of infection. The fungus is dispersed by rain and water and the disease can be severe in wet periods.

The disease is reduced by crop rotation and cultivation to control susceptible weed hosts such as johnsongrass and other grassy weeds. Cultivars and hybrids that are somewhat resistant to the disease are also available to growers.

An Uncommon Fungal Disease of Potential Significance to Arkansas

Sorghum Ergot

Sorghum ergot is caused by a fungus called *Claviceps africanae*. The disease was introduced into the U.S. a few years ago and has caused significant losses in Texas, Kansas and Nebraska. Although still present in these states, the disease has not become a significant problem throughout the region. Ergot was found in Arkansas in 2000 in White County on Pioneer Hybrid 8313. It is widely held that this variety is among the most easily infected by this fungus. The disease was not found or reported in Arkansas in 2001.

Symptoms of the disease begin shortly after flowering (Figure 6-12). The fungus usually only infects unfertilized flowers and infection results in the production of a sugary exudate on the infected flowers (Figure 6-13). The exudate contains spores that can produce still another spore which is, in turn, disseminated to infect additional flowers. After maturity, the infected seed produces an elongated black horn resembling ergot of rye but which are much larger. Control of the disease is made possible by rotation and by planting cultivars and hybrids that are resistant to infection.

Summary

Sorghum anthracnose continues to be an economic consideration in grain sorghum production in southwestern Arkansas and in other areas of the state. From 1989 through the present, significant yield losses due to this disease were found in susceptible hybrids throughout the state. Empirical information suggests that hybrid selection, planting date and environmental conditions that favor disease development and dissemination at crop maturity appear to influence anthracnose severity.

The occurrence of anthracnose and other diseases indicates that inoculum for future epidemics is present in soils or plant refuse and suggests that producers should plant resistant hybrids whenever possible. The more recent information on these diseases, especially anthracnose, suggests that a high degree of variability exists within these fungi in the world and probably within Arkansas.

Commercial hybrids are available to producers that carry a significant level of resistance to the anthracnose. Sorghum producers are strongly encouraged to consider the anthracnose resistance or susceptibility of any hybrid that may be offered for sale.

Nematodes

Plant-parasitic nematodes are not currently considered to be of economic significance on grain sorghum in Arkansas. Although, several nematode species can be found in association with grain sorghum roots in the state, there is very little reliable information available on their impact on crop performance. Grain sorghum is not a host for the soybean cyst nematode (*Heterodera glycines*) or the reniform nematode (*Rotylenchulus reniformis*), and it is a relatively poor host for the southern root-knot nematode (*Meloidogyne incognita*). Consequently, crop rotation sequences that include grain sorghum may be effective in lowering populations of these nematodes for these and other crops.

Management Recommendations for Grain Sorghum Diseases

Anthracnose has been a serious yield limiting factor for grain sorghum production in Arkansas under some conditions although the disease may not be severe in any location or field each year. It is difficult to predict at planting if the environmental conditions that will prevail near the blooming, or anthesis stage, when hybrids are most susceptible, will be favorable for anthracnose development.

Producers can have an impact on the severity of this disease and on other diseases by choosing from a number of management strategies including resistance, planting date, rotation and seed bed preparation.

Resistance

Although some of the grain sorghum hybrids that are popular in Arkansas appear to be susceptible to the local and endemic strains of a pathogen, there are also several hybrids that are resistant to diseases in each production area. New information collected from several locations shows that many lineages and strains of this fungus are found in the world and some of these occur in Arkansas. Further, the use of resistant hybrids may be the most cost-effective means of managing diseases. The tabular data in this report may aid in selection of resistant hybrids to anthracnose. It is important to remember that from experience, hybrids that were rated as resistant to anthracnose in other areas of the U.S. may not be highly resistant to the pathotype(s) found in Arkansas.

Planting Dates

Grain sorghum producers in areas where anthracnose has been a problem have found that early planting of resistant hybrids may further decrease yield losses due to this disease because flowering and grain maturation occur in an environment not conducive to disease. Care should be taken so that planting does not occur so early as to risk seed and root rot problems and not so late as to cause sorghum to head out in the cooler and wetter conditions of early fall that may favor diseases such as anthracnose.

Crop Rotation

In 2003, an anthracnose epidemic occurred in one field in which sorghum was planted for several years. Since, this pathogen and many others can survive in crop refuse, an aggressive crop rotation program is another aid to disease management, especially when coupled with use of resistant sorghum hybrids.

Seed Bed Preparation

Moldboard plowing to bury sorghum residues and eliminate grasses (e.g., johnsongrass) also may be helpful in disease management. Similarly, cutting down stalks that remain after harvest may help eliminate further build-up of the pathogens on crop residue. The residue provides the fungus with a place to survive and grow and a mechanism to spread to seedlings in the new crop.

The following photographs were referenced throughout Chapter 6 – Common and Important Diseases of Grain Sorghum.

Figure 6-1. Symptoms of anthracnose on an infected sorghum leaf.

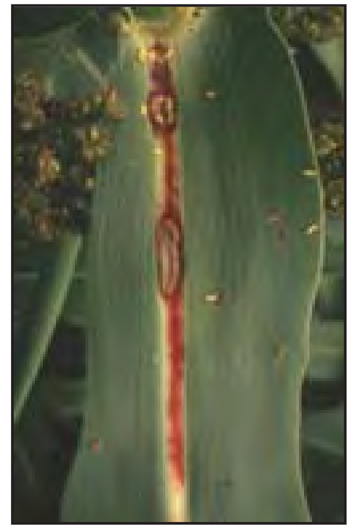


Figure 6-2. Anthracnose symptoms on a mid-vein of a sorghum leaf.

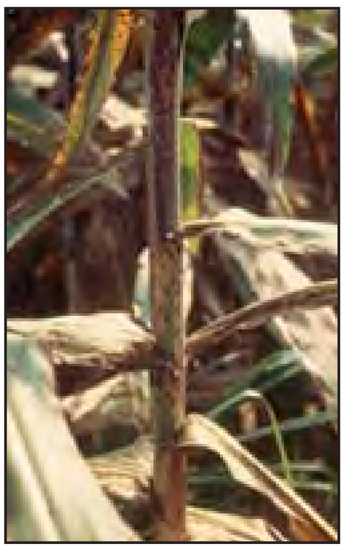


Figure 6-3. Symptoms of sorghum anthracnose on a sorghum leaf.

Figure 6-4. Stalk rot of grain sorghum caused by anthracnose.

Figure 6-5. Bacterial spot of grain sorghum.

Figure 6-6. Bacterial leaf streak of grain sorghum.

Figure 6-7. Leaf blight of grain sorghum caused by *Helminthosporium*.

Figure 6-8. Charcoal rot of grain sorghum showing a rotted and degraded stem bent at the soil line.

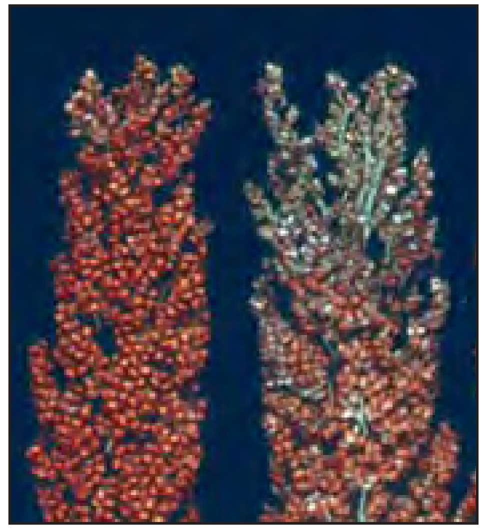


Figure 6-9. Head blight of grain sorghum caused by a *Fusarium*.

Figure 6-10. Target spot of grain sorghum caused by *Bipolaris sorghicola*.

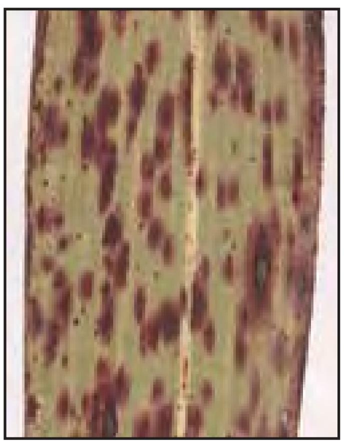


Figure 6-11. Zonate leaf spot of grain sorghum caused by *Gloeocercospora sorghi*.

Figure 6-12. Sorghum Ergot caused by *Claviceps africanae*.

Figure 6-13. Honeydew of sorghum ergot caused by *Claviceps africanae*.

7 - Weed Control in Grain Sorghum

Kenneth Smith and Bob Scott

Weed competition in grain sorghum reduces yields, causes harvesting losses and increases seed content of the soil seed bank. Even light weed infestations in the early growing season will reduce yields significantly. Grain sorghum seedlings grow slowly and are weak competitors to most weeds. Research data have shown that one pigweed plant per 3 foot of row left uncontrolled until sorghum reaches the three-leaf stage will reduce yields by 10 percent. Heavy infestations of grassy weeds may cause up to a 20 percent yield reduction in the first two weeks after sorghum germination. Late season weed infestations have less effect on produced yields, but reduce harvesting efficiency and may reduce harvested yields.

Most grain sorghum is planted in early to mid-April throughout the state to allow flowering prior to a large build-up of midge insects. Although this early planting reduces insect pressure, it adds additional stress to the grain sorghum seedling. Grain sorghum was introduced from the warmer climates of Africa and grows best when soil and air temperatures rise above 70ºF. Seedlings stressed from cool and wet soils are much more sensitive to weed competition and herbicide injury.

The most troublesome weeds in Arkansas grain sorghum include johnsongrass, morningglory, pigweed, broadleaf signalgrass, barnyardgrass, prickly sida, crabgrass and sicklepod. There are fewer control options for weed control in grain sorghum than in corn, cotton and soybeans. Grain sorghum lacks tolerance to many of the commonly used grass and broadleaf herbicides, and is occasionally injured even by herbicides labeled for use in sorghum. Unfavorable weather conditions such as cool, wet soils, delayed crop emergence, deep planting, seedling diseases, poor soil physical conditions and poor quality seed may contribute to seedling stress and herbicide injury.

Grain sorghum is almost always included in a crop rotation schedule. Herbicides such as Pursuit, Reflex, Flexstar and Typhoon applied to soybeans the previous year can remain in the soil and cause stand reductions and/or injury to sorghum. Beacon and Accent in corn and Staple and Zorial applied to cotton the previous year can also injure sorghum. Often the carryover herbicide injury is not visible in very young sorghum, but becomes apparent at the 3 to 6 leaf stage of growth.

A combination of cultivation and chemical weed control is usually most effective in grain sorghum. Cultivation can prune roots and cause plant stress if plows are too close to established plants. Effective chemical weed control is dependent upon proper weed identification and matching herbicide rate and timing to the particular weeds. Cool season weeds should be destroyed prior to planting to ensure that crop seedlings emerge competition free. Most winter weeds may be controlled with glyphosate, 2,4-D, dicamba or paraquat. (Refer to Extension MP-44 for additional information.)

Broadleaf weeds may be controlled postemergence, but there are few options for postemergence grass control. Grassy weeds are most effectively controlled with preemergence herbicide applications. Johnsongrass (*Sorghum halepensea*) and grain sorghum (*Sorghum vulgare*) are genetically very similar and there are no approved herbicides that will selectively remove johnsongrass from grain sorghum. Even light infestations of johnsongrass in other crops planted the previous year often turn into heavy infestations in grain sorghum due to lack of selective control. Fields with a history of johnsongrass or bermudagrass should not be planted to grain sorghum.

Herbicide programs for effective weed control must be developed based on weed spectrum and soil type. Your county Extension agent receives extensive training on weed identification and weed control technology and is available to assist in developing economical and effective control programs. *Recommended Chemicals for Weed and Brush Control*, often referred to as MP-44, is updated annually to reflect the most current information on herbicide label changes and revised recommendations based on research data. This publication is available from county Extension offices throughout the state.

Effective weed control programs start with clean fields at planting. It is critical to remove existing cool season weeds with cultivation or herbicides prior to planting. Glyphosate or glyphosate in combination with 2,4-D are very effective preplant herbicides.

Atrazine is the basis of most chemical weed control programs in Arkansas grain sorghum. It is estimated that greater than 90 percent of the acres planted receive at least one application of atrazine. In sites where weedy grasses are not a problem, atrazine may be the only herbicide applied. Although atrazine has some activity on grassy weeds, it is considered a broadleaf herbicide. It may be combined with the chloroacetamide herbicides such as Dual II Magnum, Outlook and Lasso to broaden the weed control spectrum. Concept treated seed must be planted if any of the chloroacetamides are to be used. These active ingredients are also sold in premixes with atrazine under different names. Bicep II Magnum and Guardsman Max are examples of atrazine plus chloroacetamide premixes that require Concept treated seed.

Preemergence herbicides are applied after the sorghum has been planted and prior to emergence. The chloroacetamides such as Dual II Magnum are taken into the weedy plants through the emerging coleoptiles and have little or no activity on emerged weeds. These herbicides must be applied before targeted weeds germinate. Atrazine is effective as a preemergence or early postemergence herbicide. Dual II Magnum, Lasso and Outlook primarily control grasses such as crabgrass, barnyardgrass and broadleaf signalgrass, but also suppress yellow nutsedge and offer some control of pigweeds. Combinations of these products with atrazine as tankmixes or premixes applied preemergence will control most seedling grasses and broadleaf weeds for three weeks.

Rainfall or irrigation is required to incorporate the herbicides with the soil for activity. This is often referred to as “activation” of the herbicide. However, large rains immediately after application may move some of the herbicide into contact with the germinating sorghum seedling and may actually be taken into the germinating seed as it imbibes water. This usually results in delayed emergence and some crop injury. Under good growing conditions, the symptoms are usually only cosmetic and the sorghum resumes normal growth seven to ten days after emergence.

Applying high rates (2 pounds active ingredient) of atrazine preemergence to sorghum is considered to be high risk. Significant stand losses and delayed development of seedlings are common following high rates of atrazine in cool, wet weather. Splitting the atrazine applications and applying no more than 1 pound active ingredient at planting followed by an additional pound early postemergence has proven to be much safer to the sorghum. In fields where grassy weeds are expected to be a problem, a chloroacetamide preemergence alone or in combination with a low rate of atrazine followed by additional atrazine early postemergence is a safe and very effective early season weed control program.

Other herbicides, such as 2,4-D, dicamba, prosulfuron (Peak) and bromoxynil (Buctril) are also effective postemergence broadleaf herbicides for use in sorghum. Paraquat (Gramoxone Max) is labeled for post directed use in larger grain sorghum to control escaped weeds. Considerable crop leaf burn is expected and this option should be used only in salvage situations where grassy weeds were not controlled earlier in the season. (See label for special precautions and injury warnings).

The absence of approved herbicides for late season weed control in grain sorghum often permits escaped weeds to hinder harvesting operations.

Sodium chlorate is an effective harvest aid that will desiccate weeds and improve harvesting efficiency. It should be applied seven to ten days prior to harvest. Other harvest aids are being tested and will be available as labels are granted. County Extension agents have the latest information on labels and use of new chemicals.

Grain sorghum is sensitive to herbicide drift from other crops. Glyphosate, Clincher, Ricestar, Select and propanil are especially damaging to grain sorghum in low rates. Symptoms may range from stand losses to non-uniform growth and delayed maturity. Grain sorghum affected by low rates of grass herbicides often suffers much more damage from midge due to the non-uniform growth and flowering throughout the field.

Herbicide resistant weeds are becoming more of a problem in all crops. Pigweeds with resistance to atrazine are common in other states, but have not been found in Arkansas at this time. Much of the Palmer amaranth in Arkansas is resistant to the ALS mode of action herbicides such as Peak. As more corn and grain sorghum are grown in Arkansas with more dependence on atrazine, triazine resistance is more likely. **If you suspect resistance after a herbicide application, treat with an alternate herbicide and contact your county Extension agent. The University of Arkansas will collect samples and test for resistance. Do not let the weeds go to seed in the field.**

8 - Harvesting Grain Sorghum

Gary Huitink

Grain sorghum challenges a combine operator's skills more than any other grain grown in Arkansas. With a properly equipped and well-maintained combine, an alert operator can reduce grain sorghum gathering and separation losses. A capable combine operator can harvest 95 percent of the total yield in a uniformly-mature, standing crop.

> Separation (grain leaving the back of the combine) is the most frequent source of high harvest loss. If gathering is complicated by lodging, uneven ripening or differing head heights, gathering loss may become much more costly than separation loss.

Fine-tuning a combine for grain sorghum can easily provide $25 to $50 more income per acre. It does not cost any more to do an expert job. Reducing field loss amounts to more profit.

Moisture

Early harvest reduces the risk of field loss due to grain shatter or lodged heads or damage due to birds, molds or sprouted kernels. Humid weather often delays field drying in Arkansas, especially after grain sorghum reaches 20 percent moisture content. Grain sorghum requires high temperatures and low ambient air humidity to allow grain moisture to dry in the field; quality may degrade during periods of high moisture.

Market dockage for high grain moisture, crop characteristics and weather conditions are important factors that influence when to begin harvest. Discounts for grain sorghum moisture begin above 14 percent moisture content. Penalties for foreign material, sprouted kernels or mold are factors that may influence harvest timing. In addition, consider your capacity to harvest, handle and dry grain sorghum during a time when other crops may be maturing and potentially competing for the same harvesting equipment. To prevent costly harvest delays or moisture discounts, provisions for drying grain sorghum should be made well before harvest. Market penalties for high grain moisture may encourage drying grain sorghum on the farm. To obtain quality grain and safe long-term storage, plan enough capacity to dry grain sorghum to 12 percent moisture content.

Twenty percent moisture content is a good recommendation for starting to cut if the heads are uniformly ripe. Field loss and kernel damage are normally lowest at this grain moisture level. Cut a sample to adjust the combine and then count field loss. If counts reveal that total field loss is below 5 percent of the grain yield, harvest that grain sorghum rapidly. Delaying harvest to reduce the cost of drying grain sorghum is likely to be offset by increased field loss and grain quality reduction.

> Timing grain sorghum harvest is equally as important as timing rice harvest in Arkansas. The greatest profit will likely result from starting harvest between 17 and 20 percent moisture content. Exposure to weather risks, field loss and kernel damage are compelling reasons to complete grain sorghum harvest before it reaches 14 percent moisture. Harvest capacity, drying facilities/market penalties and varietal characteristics influence this range slightly.

If charcoal rot is evident or lodging is a potential threat, harvest without delay. Wind and storms have caused severe field losses of 22, 39 and, in a bad storm, 53 percent of the grain sorghum yield in experiments. The larger heads are most prone to lodge, should adverse weather occur before harvest is completed. Note the "Gathering" comments in the next section.

If field loss counts indicate that gathering loss is only a few percent of the yield and threshing and separation losses are high, evaluate the reason. Threshing and separation loss typically are near minimum at 20 percent moisture content. However, the chaffer sieve may become overloaded without much warning. If the combine is adjusted properly and is in good repair, reducing forward speed or delaying harvest until the grain dries more are two possible remedies/options.

Allowing a field to dry down to 17 percent moisture has proven profitable if this contributes to a reduction of the green leaf fraction on the chaffer sieve. If uneven grain maturity is evident, it is questionable whether delaying harvest will improve income. If the stalks are drying and “open” weather with low relative humidity is expected near term, it may be profitable to watchfully wait. Cut a sample and wait two or three days and cut another sample. The trend of moisture content and the field grain loss in several samples will confirm whether to delay harvest further.

Fields that have heads well above the flag leaf dry more rapidly. Significant periods of low relative air humidity will hasten grain drying in the field. Weigh the potential for adverse weather that may cause lodging, shatter or kernel deterioration should you delay harvest. During a damp season with heavy dews and some foggy days, grain sorghum weathers and kernels may sprout, potentially penalizing a grower by putting it in “sample” grade. Quality reductions due to sprouted kernels, mold or broken kernels may often lower grain one U.S. Grade Number.

Applying a pre-harvest desiccant application dries the leaves and weeds but the effect on grain moisture content can rarely be measured. If using a desiccant reduces the green foliage (weeds or grain sorghum leaves) that will enter the combine and speeds your combine, apply a labeled desiccant on that basis. However, stalk deterioration begins when the desiccant is applied. The grain sorghum acreage that is treated should match your harvest capacity. This is due to the potential for stalk deterioration to increase grain shatter and lodging, if the treated field isn’t harvested within a week or, at most, two weeks after desiccation. Expecting a desiccant to accelerate field grain drying is unrealistic with typical Arkansas weather.

Gathering

Grain sorghum can be harvested with a grain header (rigid cutterbar), preferably with guard extensions (Figure 8-1). Typically, guard extensions are attached to every other guard in standing grain sorghum. Guard extensions provide support to guide more heads into the header in order to reduce gathering loss. Excellent cutterbar maintenance and adjustments are vital. Cut just below the heads to minimize the stem and leaf entering the combine, even if an occasional head isn’t gathered. Total field loss is typically lower if the thresher can separate the grain well without excess foliage entering the combine. Constantly adjust the cutterbar height to avoid overloading the combine separator with flag leaves; thus, restricting its capacity to harvest grain sorghum. Grain sorghum heads that extend well above the foliage are the biggest factor in maintaining a high proportion of grain in the separator. But an excellent operator must constantly adjust the header height in grain sorghum with variable head heights.

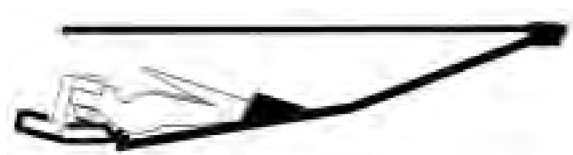


Figure 8-1. Guard extension, usually attached to every other guard, for grain sorghum.

At the proper reel speed/forward speed ratio, heads move smoothly across the cutterbar into the platform. Adjust reel speed so the pickup finger speed is 15 to 25 percent faster than the forward speed in order to minimize gathering loss. A slow reel speed, relative to travel, allows heads to fall forward over the cutterbar. Excessive reel speed, low reel position and cutting too low contribute to heads flipping over the reel bats. If the grain heads vary throughout a wide height range, fastening a “baffle” or extension above the reel bats may help to control the taller heads and reduce the loss of dropped heads. The reel hub should be positioned slightly ahead of the cutterbar. Draper headers work very well for grain sorghum.

John Deere Row-Crop Heads™ recover more grain sorghum than other options. Headers with 30-, 36-, 38- and 40-inch row spacing were sold. The Row-Crop Head™ advantage is much greater where lodging occurs. Several other attachments, including Britten Crop Savers or Roll-A-Cone attachments are advised for grain sorghum that has significant proportions of lodged heads or fields that are blown

Row-Crop Head™ is a trademark of Deere and Company.

flat. Economic justification of these header purchases depends on the grain sorghum market value and how much additional grain sorghum can be retrieved compared to your rigid cutterbar header.

Threshing

Threshing should be vigorous enough to remove mature kernels from the heads. If possible, use a combine with a threshing rotor or a rasp-bar cylinder for grain sorghum. Threshing rotors and rasp-bar cylinders thresh well without pulverizing leaves and stems into small pieces. Either of these options, with the proper threshing and separating adjustments, provide a cleaner grain sample, less grain damage and lower field loss. In fact, leaving a few random immature heads partially threshed will reduce total combine loss by improving separation.

Review your operator's manual for initial settings and fine-tune thresher speed as your field dictates and as grain moisture changes. Areas of the field with drier grain may justify a slower thresher speed.

Grain sorghum kernels are easily damaged if the thresher is operated too fast. Worn threshing components can also contribute to damaged kernels, as well as severely reducing harvesting capacity.

> Start with the manufacturer's recommendation for concave clearance, wire configuration, rotor transport vanes, grates, etc. Concave positioning isn't delicate unless wear on threshing components reduces threshing aggressiveness. It is simpler to obtain the proper concave gap first, setting it as narrow as practical. After this, make thresher speed adjustments to accommodate moisture and field conditions to maintain excellent harvesting throughout the day.

Separation

Grain sorghum stalks are normally relatively green at harvest. When heads are above the flag leaf, effective separation is fairly easy, if proper header height is maintained. Good separation can only be obtained after properly setting the other combine adjustments, including threshing. Always make only one adjustment at a time.

Ample air velocity tumbles the material on the cleaning and chaffer sieves to improve separation. Adjust the fan to tumble the material well at the front of the sieve and keep the material "floating" over the sieves. If your combine has a grain loss monitor, adjust it to warn you of excessive loss over the sieves. If your combine does not have a grain loss monitor, check the sieves frequently to assure they aren't "matting over" with green material. More air or improved air distribution is the best remedy for matting.

Over threshing or excessive forward speed (overloading the sieve) both contribute to sieve blockage and excessive grain separation loss. If stems poke into the sieve, other residue may accumulate on the sieve. First, close the chaffer extension if it catches there. Or close sieve openings slightly, if this is where the stems collect. If these steps fail, reduce threshing aggressiveness. Sometimes the concave/thresher gap is too large and narrowing it will allow a slower thresher rotation.

Monitor your combine's performance regularly in the field. Exceeding the combine's grain sorghum capacity often causes very high loss over the sieve. Count separation loss behind the combine and check the clean grain for trash content. Use a fairly narrow sieve opening that permits grain to pass through; this aids movement of residue over the sieves. Check the tailings return to maintain less than half of the content as broken plant portions.

Periodically validate the set point if you have a grain loss monitor, to assure that kernels lost over the sieve are proportional to the signal on the dial. Use the grain loss monitor to "fine-tune" the threshing and separation adjustments within each field. Changing fields may involve a change in the variety planted, date of planting, etc., so this is an important time to reassess all the combine adjustments.

> Grain sorghum may have foreign material mixed with the grain. If so, consider passing grain through a pre-cleaner before drying it or unloading it into a bin.

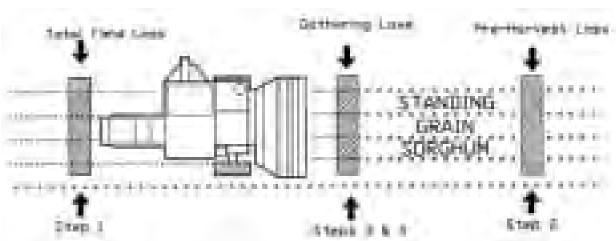
Field Loss

A field loss count helps to determine if any corrective combine adjustments are worthwhile. Counting grain sorghum remaining in the field helps manage the harvest. If your combine has a grain loss monitor, a count helps interpret the monitor signals. The procedure is:

Step 1.

Determine the total field loss by counting kernels in a 10-square foot area across the cutting width behind the combine (Figure 8-2). Depending on the seed size, 16 to 21 seed per square foot represent a loss of 1 bushel per acre. Note whether a hull contains a kernel before counting it. Grain sorghum leaf and stalk residue is difficult to sort through, but counting is the best estimate of field loss. If counts indicate total field loss is 5 percent of yield or less, resume harvesting. Loss of less than 5 percent is considered expert management. When lodging occurs, more than one-third of the crop may be lost. Follow step 2 if the source of loss needs to be identified.

Figure 8-2. Diagram showing locations to measure grain sorghum field loss.



Step 2.

Determine pre-harvest loss by counting kernels in a 10-square foot area in standing grain sorghum (ahead of the combine). Be alert for kernels caught on leaves. This count may help to determine when to harvest in order to prevent excessive pre-harvest loss.

Step 3.

Back the combine about 10 feet away from the standing crop. Mark off a 10-square foot area ahead of the cutterbar to count grain loss. One 10-inch tall head dropped from the cutterbar in this area is estimated to be roughly equal to a bushel per acre loss.

Step 4.

To determine gathering loss, subtract pre-harvest loss (Step 2) from the loss value counted across the width of the combine in step 3.

Step 5.

Threshing and separating loss is the portion of the total field loss not attributable to gathering or pre-harvest loss. Subtract both pre-harvest and gathering loss (Step 3) from total field loss (Step 1). Threshing and separation loss may be costly but a practical goal in good crop conditions is to keep loss at 2 or 3 percent of the expected yield.

Highlights

- Harvest grain sorghum early, beginning when the grain moisture content reaches 17 to 20 percent.
- Applying a pre-harvest desiccant should make combining easier; however, begin combining one week after spraying to avoid stalk deterioration that is likely to increase field loss.
- Attach guard extensions to every other guard on cutterbar headers to recover more sorghum heads. Row-Crop HeadsTM typically reduce gathering losses.
- Cut grain sorghum as high as possible to reduce leaf and stalk loading in the combine.
- Keep the pickup finger speed on the reel synchronized with forward speed, i.e. 15 to 25 percent faster.
- Threshing rotors and rasp-bar cylinders are better threshing options for grain sorghum. Refer to your operator’s manual for initial settings.
- Maintain high air velocity through the sieves. Set the grain loss monitor to warn the operator of grain loss over the chaffer sieve or check frequently to detect impending leaf accumulation.
- Examine field loss regularly. If the grain is spread uniformly over the field, 21 small kernels or 16 large kernels per square foot equal 1 bushel per acre. Maintaining field loss at 5 percent or less of the yield is usually a realistic goal.

9 - On Farm Storage and Drying

Dennis R. Gardisser

A good deal of Arkansas grain sorghum will be dried and stored on the farm each year. Grain sorghum has the highest quality it will ever have at harvest. Grain has a limited storage life. The way that grain sorghum is handled during the drying and storage process will determine how much of this quality is retained. Proper management practices may also prolong the storage life of grain.

Grain sorghum should be quickly dried down to a moisture level of about 12 percent for storage – particularly if it is going to be stored for several months. The reduction of grain moisture is done by passing relatively large quantities of dry air over the grain sorghum after it is placed in the bin. The quality of this air determines the final moisture content of the grain sorghum kernel. This “air quality” is typically referred to as the equilibrium moisture content (EMC). If the air has an EMC of 12 percent and is moved over the grain long enough, then the grain moisture will eventually reach 12 percent.

A given volume of air has the capability of holding a given amount of moisture. The amount of moisture that air can hold will depend on the quality. One way to increase drying potential or cause the grain to reach equilibrium with the air sooner is to pass larger amounts of air over the grain. Doubling the air flow will typically cut the drying time in about half.

Pass or continuous flow dryers are often utilized to speed up the drying process. These high flow driers pass very large amounts of high temperature air over the grain sorghum. Three to six moisture points may be taken from the grain in a single pass. This helps to prepare grain for shipment if the desire is to market the grain quickly. Quickly drying the grain down to values of 16 percent or less will lessen potential spread of toxins if that is a concern. In-bin drying is more gradual and may cause less stress and potential damage on the kernels.

As grain bins are filled and the grain depth increases, it becomes more difficult to pass air up through the grain. As the grain depth increases, there is also less air available for each bushel of grain in the bin. High volumes of air are needed to carry the moisture away in a timely fashion when the grain is at high moisture levels. Most on-farm bins have a limited amount of available air capacity.

These criteria dictate that bins should not initially be filled too full if the grain is at a high moisture content. Once grain moistures reach 15 percent or less throughout the bin, the bin filling process may be completed. Graph 9-1 illustrates the dramatic increase in fan horsepower/capacity needed to push air through varying depths of grain. Requirements can quickly overwhelm available power as the grain depth and air requirements (CFM – cubic feet per minute) increase.

Several rules of thumb have been developed for sizing fans for drying systems[1]: (1) doubling the grain depth at the same cfm/bushel air flow rate requires 10 times more horsepower and (2) doubling the cfm/bushel air flow rate on the same depth of grain requires 5 times more horsepower.

Air flow rates for drying vary from 0.5 cfm/bushel to more than 50 cfm/bushel for commercial or batch dryers. Most on-the-farm air flow rates for drying vary from 0.5 to 6 cfm/bushel dependent on the initial moisture content of the grain and the amount of heat added to the drying air. Recommended minimum air flow rates for different moisture contents are as follows.

% moisture	**cfm/bushel**
11 to 13	0.5
13 to 15	1
15 to 18	2
18 to 20	3
20 to 22	4
>22	6

When air flow rates are less than 1 cfm/bushel, add little or no heat. A rough guide for temperature increases through the heaters at various air flow rates is as follows.

- For an air flow rate of 1 to 2 cfm, limit the temperature rise to 6°F.
- For an air flow rate of 2 to 3 cfm, limit the temperature rise to 12°F.
- For air flow rates above 3 cfm, a 20°F temperature rise is permissible. A temperature rise above 20°F is satisfactory for some feed grains when drying depths are less than 4 feet or stirring depths are used.
- Batch and/or pass dryers typically use much higher temperatures, but also have much higher air flow rates. Grain kernels may protect themselves somewhat as long as they are giving up water and there is evaporative cooling in or near the kernel.

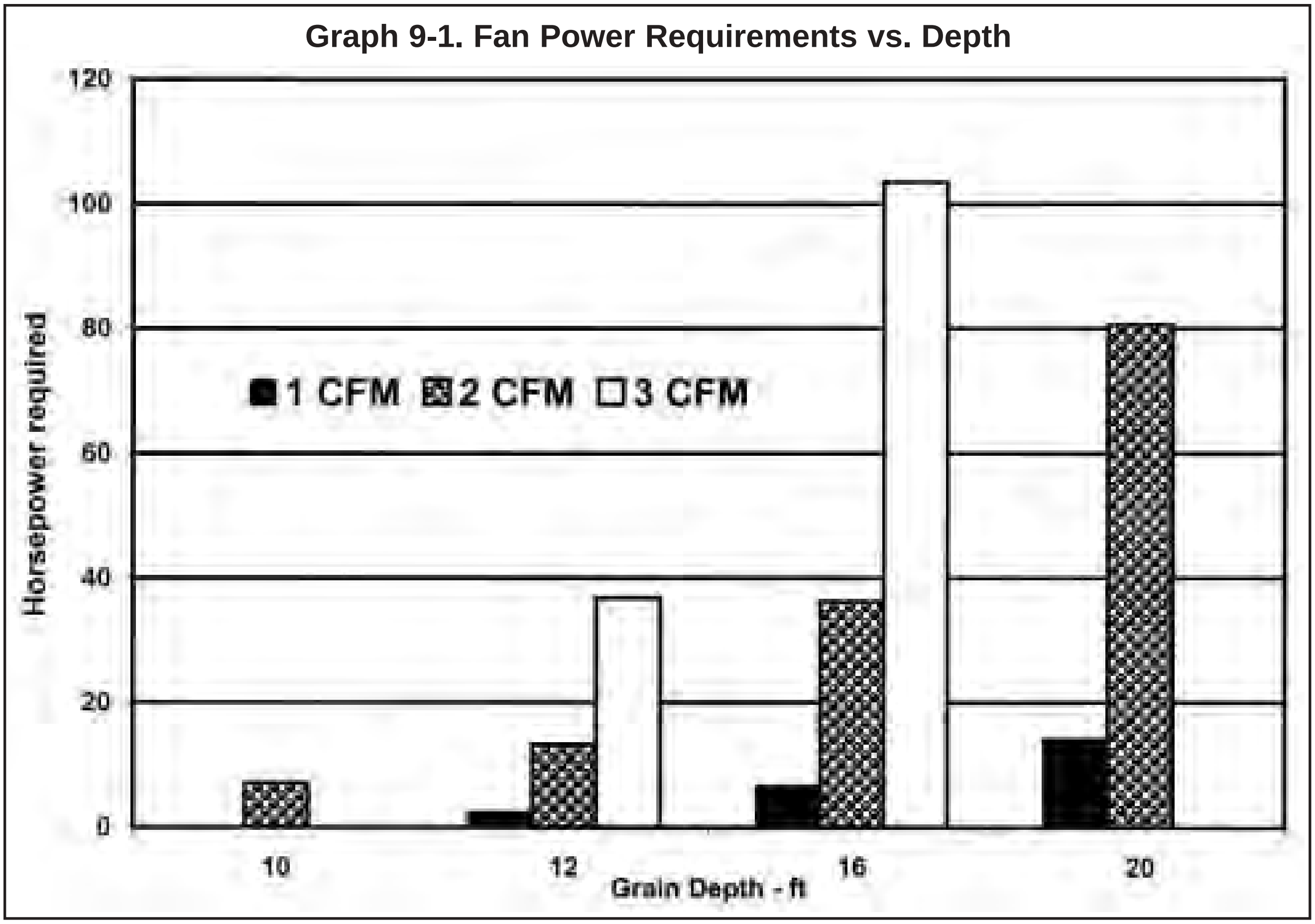
In most on-the-farm storage, the grain is subjected to modest temperatures for long periods of time. There must always be sufficient air flow to cool the upper portions of the bin to eliminate the possibility of mold development in that area. The top layers are the last segment of the bin to reach a safe moisture level.

Grain may be dried without adding any heat if the EMC is low enough. Careful monitoring of the EMC and managing drying times to optimize low values will provide the most economical drying. Many times Mother Nature simply will not provide dry enough air, particularly at night, and the addition of heat is needed to condition the air to the correct EMC.

Fan Types

Vane-axial fans supply more cfm per horsepower at static pressures below 4.0 to 4.5 inches of water, low grain depths, than centrifugal fans. For this reason, these fans are generally better adapted to shallow-depth bin drying systems, such as batch-in-bin and continuous-in-bin

[1]AE-106, *Fan Sizing and Application for Bin Drying and Cooling of Grain*, Purdue University CES.



systems, and to deep bin drying up to 20-foot depths requiring 1 cfm/bushel air flow or less. They are generally lower in initial cost, but operate at a higher noise level than centrifugal. These fans are generally not acceptable for use with bins that will also handle rice because of the high static pressures that are expected – typically, air is more difficult to move up through a column of rice.

Centrifugal fans supply more cfm per horsepower at static pressures above 4.0 to 4.5 inches of water than vane-axial fans. These are especially advantageous when the application requires relatively high air volumes through deep grain levels (12 to 20 feet), and where low noise is important. Larger diameter centrifugal fans typically move more air per horsepower.

All fans are susceptible to a reduction in the amount of air that can be moved as the static pressure increases. Air flow will be less when fan blades are coated with lubricants, dust and other foreign materials. Keep all fan blades clean for maximum performance.

Care should be taken not to mix dry grain (moisture content less than 15 percent) with moist grain (moisture content greater than 18 percent). Re-wetting may also occur if damp air is pumped through the grain.

The EMC may be determined by measuring air temperature and relative humidity. A sling psychrometer is one the best tools for measuring relative humidity, and is relatively inexpensive. A sling psychrometer works by measuring the air

temperature with a wet and dry bulb thermometer, and then using a table to determine relative humidity.[2]

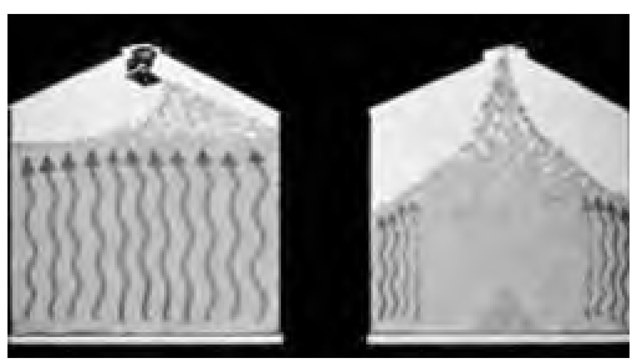
One should strive to maintain a steady EMC that is very close to the target storage moisture content. There are typically numerous days during and shortly after the harvest season when the EMC is at or below the desired level without adding any heat. At night or during damp weather conditions it may be necessary to add some heat to condition the air to a desirable EMC – or to maintain the same level available during the daylight hours.

If heat is not available, it may be better to turn the fans off at night instead of pumping in moist air. Moist air that is pumped in at night has to be removed later. This increases drying cost and may result in significant quality reductions. Fans should be turned off almost any time the EMC of the air is greater than that of the grain. The exception might be for very damp grain sorghum – to avoid heat buildup.

Stir-alls help to mix the upper and lower portions of grain in the bin. This speeds up the drying process and loosens the grain so that additional air may be moved up through the grain. Stir-alls also help to keep the grain level in the bin. Stir-alls should not be turned on unless the bottom end of the auger is about 1 foot deep in grain. They can run almost continuously after that point, when the drying fans are running. There is a concern among many producers that the stir alls may grind away at the grain sorghum if left on, but there is no

research evidence to support this. There will be a small amount of flour-like substance formed around the auger top, but the small particles were most likely already there and are just being gathered in one place with the auger action.

Grain should not be allowed to cone or pile to one side as the bin is being filled. If coning or sloping occurs, the large particles will migrate to the outside and the flour-like small particles and trash will remain at the center of the cone. This results in a very non-uniform amount of air being passed through each portion of the grain. Most of the air will pass up the outside of the bin through the larger and cleaner grain. A level height should be maintained throughout the filling process. Grain sorghum may include a lot of fines and small particles that will drastically reduce air flow up through the center of the bin if coning is allowed. Once the separation occurs, it is hard to remedy – even if the bin is later shoveled level. Do not fill a bin to a peak or until the grain touches the roof. This will interfere with uniform air flow and prevent moisture movement out of the grain surface. Level fill works best at any level!



[2]Sling Psychrometer sources: www.seedburo.com and www.forrestrysuppliers.com.

Drying Costs

$$\text{Fuel Cost (\$/bu)} = \frac{\text{(BTU/lb water x lb water removed/bu x cost of fuel per unit x 100}}{\text{(BTU/unit of fuel x burning efficiency (\%))}}$$

The number of BTUs to extract 1 pound of water will vary from 1,100 to 1,400 and is a function of how easily moisture is given up by the kernel. As the kernel begins to dry, it takes more energy to get the last bit of moisture out. A good estimate is to use an average number of 1,200 BTU/pound of water. BTUs/unit of fuel are LP Gas – 92,000 BTU/gal, natural gas – 1,000 BTU/ft^3, and electricity – 3,413 BTU/kWh. Burning efficiencies are 80 percent for LP and natural gas and 100 percent for electricity.

Long-Term Storage Management

- Cool grain off as soon as possible in the fall. Target temperatures should be initially around 60°F.
- Continue to aerate and uniformly cool grain down to 30° to 40°F if possible. This will help avoid internal moisture migration and insect activity.
- Monitor grain and aerate monthly to maintain uniform temperature and moisture levels throughout. Aerate more often if moisture or temperatures increase.
- Keep grain cool as long as possible into the early spring.
- Do not aerate in early summer unless problems develop.
- Cover fans and openings when not in use to help avoid air, moisture and potential insect movement.
- Monitor carefully and fumigate if needed. The grain surface should be inspected at least every week throughout the storage period. Walk over the grain and poke around with your arm or a rod, smelling, feeling and looking for indications of trouble. Evidence of hot spots, warming, insect infestations or other problems that start in the grain mass soon migrate to the surface. Be particularly sensitive to damp, warm or musty areas.
- Keep the area around the bins as clean as possible to avoid rodent infestations.
- Seal all areas around the bottom of the bins and keep transfer equipment sealed to keep rodents from migrating into the system.

Safety

- Always think safety around grain bins.
- Wear appropriate masks when working around dusts – particularly from moldy or spoiled grain. Exposure to and inhaling mold can cause severe allergic reactions.
- Never enter a bin when grain is being unloaded.
- Beware of crusted grain.
- It is best to work in pairs – one inside with a safety harness and one outside to assist if needed.
- Grain suffocation accidents happen all too often – think before you act or enter a bin!

These drying concepts and other details are discussed in MP213, *Grain Drying*, available at your local county Extension office. Corn drying is not overly complicated, but does require a good manager to maintain the highest corn quality.

Additional Resources

Internet resources at http://www.agcom.purdue.edu/AgCom/Pubs/AE/

AE-90, *Managing Grain for Year Round Storage*

AE-91, *Temporary Corn Storage in Outdoor Piles*

AE-93, *Adapting Silage Silos for Dry Grain Storage*

AE-106, *Fan Sizing and Application for Bin Drying/Cooling of Grain*

AE-107, *Dryeration and Bin Cooling for Grain*

AE-108, *Solar Heat for Grain Drying*

AED-20, *Managing Dry Grain in Storage*

Mid West Plan Service-Publications, 122 Davidson Hall, Iowa State University, Ames, IA 50011-3080

MWPS-13, *Planning Grain-Feed Handling* ($2.50)

MWPS-22, *Low Temperature and Solar Grain Drying* ($3.00)

10 - Estimating Production Costs for Grain Sorghum in Arkansas

Tony Windham

Grain sorghum production cost estimates are published each year by the University of Arkansas Cooperative Extension Service. The most recent edition of these publications can be located on the Cooperative Extension Service website at:

http://www.aragriculture.org/farmplanning/Budgets/default.asp.

Enterprise budgets represent a type of information that can be used by a wide variety of individuals in making decisions in the agricultural industry. They are used:

- by farmers for planning,
- by Extension personnel in providing educational programs to farmers,
- by lenders as a basis for credit,
- to provide basic data for research, and
- to inform non-farmers of the costs incurred by farmers in the production of food and fiber crops.

The purpose of these publications is to provide a systematic procedure for estimating the cost of producing grain sorghum. Users of this information should think of these budgets as a first approximation and then make appropriate adjustments using the "YOUR FARM" column provided on each budget to add, delete or change costs to reflect their specific situations.

Each budget estimates the direct and fixed expenses associated with producing grain sorghum. Input price data used in estimating direct costs are updated annually by obtaining prices from farm input suppliers throughout the crop's production area. Quantities of inputs are based on the recommendations of Extension and Research faculty within the Division of Agriculture. Data obtained from the Grain Sorghum Research Verification Program is also used in developing these estimates.

Fixed expenses include depreciation, interest, taxes and insurance and represent an average cost allocated over the entire useful life of the machinery. Various financing arrangements and tax depreciation methods can produce costs that vary significantly from these estimates in a given year. The ability to estimate the actual cost is a complex economic procedure whereby cash accounting and economic costs may vary greatly.

Each budget also includes a sequential listing of all operations used in the estimation procedure. This information can be used to determine the cost of a specific tillage operation, pesticide application or irrigation practice. The user can also compare the number of tillage operations or irrigations with their own expectations.

11 - Grain Sorghum for Forage

Wayne K. Coblentz and J. Mike Phillips

Bermudagrass is the most important warm-season perennial grass in the South, but many other grasses play an important role in a complete forage system. Annual forages such as pearl millet, sorghum-sudangrass hybrids, forage sorghums and grain sorghums can be used to supplement bermudagrass or other warm-season perennial grasses. Summer-annual forages are often planted to provide supplemental grazing, hay or silage for livestock. This is especially important for those classes of livestock that require higher nutrient densities in order to maintain acceptable weight gains or milk production.

Additionally, the establishment of these forages in the late spring may allow producers to provide periods of rest for perennial cool-season pastures, such as tall fescue or mixtures of tall fescue and legumes. By resting cool-season perennial pastures in July and August, these stands are more persistent and supply more fall grazing. Much of the land area used for the production of summer-annual forages also can be double-cropped by planting temporary winter pastures, such as wheat, rye, oats, triticale or annual ryegrass to provide forage in the late fall, winter and spring.

Forage and Grain Sorghums

Overview. There are many important factors to consider when choosing a sorghum hybrid for silage. These may include yield potential (forage and grain), maturity (full vs. short-season), forage quality and resistance to lodging, disease and insects. Many cultivars of sorghum have been selected, primarily by commercial seed companies, for once-a-year harvest as silage; these varieties are typically tall-growing types that are not really supplemental forages. They are managed much like corn grown for silage and have little regrowth potential, except in the deep South.

Grain-sorghum hybrids, which typically are shorter in height and have higher grain-to-forage ratios than forage types, also are viable options for use as a silage crop. Bird-resistant grain-sorghum varieties, which may contain elevated levels of tannins, should be avoided. Forage-sorghum varieties selected for one-time harvest as silage can take more than 100 days to mature, and are not good options for most Arkansas producers unless they have access to land suitable for row-crop production and the equipment necessary for the establishment, harvest and storage of row-crop silages.

In contrast, sorghum-sudangrass hybrids are not usually established as a row crop. Typically, these hybrids are established by broadcasting or drilling the seed, and they can be harvested as hay, silage or greenchop. Unlike forage and grain sorghums, pearl millet and sorghum-sudangrass hybrids exhibit very active regrowth after the initial harvest, and multiple harvest and/or grazing opportunities are likely. Rotational grazing systems are preferred for these forages.

Seeding Rates. Grain sorghum seed varies greatly in size (11,000 to 27,000 seeds per pound); however, forage sorghums can have as many as 55,000 to 68,000 seeds per pound. This variability with respect to seed size can have a substantial effect on plant population if planting rates are determined on a seed weight per unit area basis. Therefore, planter calibration should be based on desired seed spacing within the row rather than seed weight per unit area.

Planting rates for sorghum silage are similar to those used for grain-type sorghums. Plant populations can range from 70,000 to 100,000 plants per acre when moisture is not limiting. Generally, plant populations per unit area are held constant at the appropriate level for expected soil moisture conditions, regardless of row spacing. Planter calibration normally is based on a 65 to 70 percent emergence rate. Assuming a planter is set up for 30-inch rows, planting one seed every 2 inches would yield a plant population of 70,000 plants per acre. Forage and grain sorghums developed for one-time harvest as silage typically require herbicide strategies to control weeds. Consult the appropriate Extension personnel in your area to develop the most appropriate strategy for your specific situation.

Seeding Date. Planting date is critical for several reasons. Planting sorghum too early, when soil temperatures are too low, subjects the seed to longer attack by soil microorganisms, and can result in delayed emergence, slower initial growth and thin stands. As soil conservation recommendations encourage producers to reduce tillage and retain more crop residue in the seedbed, soil temperatures often remain cooler and the soil may remain wetter than in conventionally-tilled soils; therefore, no-till and reduced-till establishment is best suited to fairly well-drained sites.

Late plantings are more susceptible to reduced dry matter production due to slow grain fill and fall freezes that can occur before the desired maturity level for ensiling is reached. Premature frost also increases the risk of prussic acid poisoning in ruminant livestock if frost-damaged sorghum forage is immediately grazed, used as greenchop or ensiled without field wilting or field drying. Forage or grain-sorghum hybrids can exhibit a wide range in the time necessary to reach harvest maturity as silage. For instance, some hybrids reach half-bloom in as little as 50 days, while others need more than 100 days to reach the same growth stage. Proper varietal selection is an important consideration that can help to limit the risk of frost damage.

Planting Depth. Planting depth for forage-sorghum hybrids normally ranges from 2/3 inch to 2 inches, depending on soil texture and available moisture. Seeds should be planted deep in light, sandy soils that have limited moisture available near the soil surface. Good soil contact with the seed will aid germination. Quick germination and emergence will occur when the soil temperature reaches about 68°F. Sorghum seed is relatively small and this results in a slower initial growth habit, particularly before the growing point reaches ground level at about 30 to 35 days postemergence.

Row Spacing. Row spacing for forage sorghums is usually dictated by the type of harvesting equipment available to the producer; therefore, management decisions are based primarily on logistical, rather than agronomic, considerations. Rows are commonly spaced about 30 inches apart to allow producers to take advantage of direct-cut harvester heads that are designed primarily for corn silage; however, this spacing may need to be adjusted if older harvesting equipment (designed for 36-inch or wider rows) is used.

Recent developments in direct-cut technology that permit row-planted silage crops to be direct cut across or independent of the established rows will allow more flexibility during harvest. Although forage- and grain-type sorghum hybrids also can be successfully established with a drill, subsequent direct-cut harvest options (for silage) are limited. Establishment with a drill is a better option for sudangrasses, sorghum-sudangrass hybrids or pearlmillet, which are not selected for a one-time harvest as silage.

Fertilizer Needs. Fertilizer and lime needs are best determined by soil test supported by both past experience and field history information. Forage sorghums generally perform best when the soil pH ranges from 6 to 7. Harvesting grain sorghum as a silage crop will remove more nutrients from the field than harvesting only the grain; in particular, large quantities of nitrogen, phosphorus, and potassium are consumed (Table 11-1). Generally, nitrogen is the nutrient most likely to be lacking for

Table 11-1. Approximate Amount of Nutrients in a 100 Bushel/Acre Grain Sorghum Crop[1]

Element	Quantity in	
	Grain	Stover
	lbs	
Nitrogen (N)	84	95
Phosphorus (P2O5)	42	20
Potassium (K2O)	22	107
Sulfur (S)	8	13
Magnesium (Mg)	7	10
Calcium (Ca)	1.4	19
Copper (Cu)	0.01	0.02
Manganese (Mn)	0.06	0.11
Zinc (Zn)	0.07	0.14

[1]Source: Adapted from National Plant Food Institute and Vanderlip, et al. (1992).

optimum production. Typical fertilizer recommendations for nitrogen can range up to 180 pounds per acre in situations where no water stress is expected. **The large yields of dry matter that can occur when any summer-annual forage is harvested strictly as hay or silage can quickly lead to depleted levels of soil nutrients. Soil testing and the subsequent fertilizer recommendations provided by the Cooperative Extension Service are an important component of the management needed to utilize these crops effectively.**

Harvest Considerations. Typically, forage sorghums are harvested for silage when the grain is in the mid- to late-dough stages. The moisture content of these forages at mid- to late-dough stage can vary substantially. Ideally, the moisture content at harvest should be less than 70 percent to ensure proper fermentation and prevent excessive effluent losses. Frequently, forage sorghums are not that dry at harvest; these silages can be prone to heavy effluent losses, especially in upright silo types. Under these circumstances, dry matter losses also may be high, and dry matter intakes may be depressed.

Grain-sorghum varieties can be expected to have lower moisture concentrations at ensiling than forage-type sorghums (Table 11-2), which may decrease the risks of undesirable fermentations and production of excessive effluent. Overly mature, whole-sorghum grains can be digested poorly by ruminants and this problem is not adequately resolved by the ensiling process. Excessively dry silages (<60 percent moisture) may be more difficult to chop and pack properly, and drier silages frequently have a shorter bunk life at feedout.

Table 11-2. Agronomic Characteristics of Forage and Grain Sorghums From Studies in Kansas from 1984 to 1995. Adapted from Bolsen et al. (2003).

Trial	Year(s)	Number of cultivars	Type	Statistic	Days to half-bloom	Height	Whole-plant yield	Whole-plant moisture content	Grain yield
					days	feet	tons DM/acre	%	bushels/A
1	1984	6	Forage[1]	Range	- - -	- - -	5.9 - 6.6	68.3 - 75.3	11 - 83
				Average	- - -	- - -	6.2	72.4	51
		6	Grain[1]	Range	- - -	- - -	5.4 - 6.2	54.8 - 60.8	86 - 107
				Average	- - -	- - -	5.8	57.6	99
2	1986	7	Forage	Range	57 - 87	8.7 - 10.9	5.5 - 8.2	65.6 - 74.7	51 - 105
				Average	67	9.2	6.8	70.9	80
		5	Grain	Range	51 - 55	4.2 - 5.2	5.2 - 5.7	64.9 - 66.4	99 - 113
				Average	52	4.7	5.5	66.0	107
3	1986-88	35	Forage	Range	56 - 105	5.9 - 12.3	4.5 - 9.0	62.4 - 76.4	- - -
				Average	74	8.3	6.6	70.7	- - -
4	1986-87	60	Forage	Range	55 - 106	6.3 - 13.5	5.1 - 10.1	64.9 - 76.3	32 - 113
				Average	72	8.7	7.3	71.6	73
5	1990	20	Forage[2]	Range	64 - 83	6.2 - 14.3	5.7 - 8.4	57.0 - 75.5	48 - 124
				Average	74	9.3	7.2	69.2	89
6	1995	37	Forage[3]	Range	- - -	4.8 - 9.3	3.0 - 5.6	60.1 - 77.1	18 - 59
				Average	- - -	6.5	4.6	72.3	45
		3	Grain	Range	52 - 57	3.3 - 3.8	3.1 - 3.8	59.8 - 66.0	43 - 57
				Average	55	3.6	3.5	62.5	53

[1]Entries were harvested at several stages of maturity, but only data from late-dough stage are reported.
[2]One male sterile variety was omitted from calculations of days to half bloom and grain yield.
[3]Twenty cultivars produced no grain because of an early frost. They were omitted from grain yield data.

Agronomic Characteristics

It is important to remember that forage-sorghum varieties vary widely with respect to agronomic characteristics. In a summary of tests conducted in Kansas (Table 11-2), forage sorghums ranged from 5.9 to 14.3 feet tall, and whole-plant yields ranged between 3.1 and 10.1 tons of dry matter per acre. Tall-growing forage sorghums are prone to lodging, which can make harvest as silage nearly impossible with conventional row-type harvesters. Generally, the chances of lodging are decreased in shorter plants and/or in plants with larger stalk diameters. Some producers routinely use higher planting rates to limit stalk diameter and improve forage quality, but this practice can increase the risk of lodging.

Grain-type sorghums are typically shorter than forage types (< 5 feet) and the chances of lodging are greatly reduced. Whole-plant yields for grain-type sorghums are up to 35 percent less than those observed for forage types grown in common environments. Producers should be cautious about relying extensively on grain sorghums for silage production because dry matter yields can be greatly reduced in dry years. Grain yields for forage sorghums are often competitive with those of shorter grain types; however, the proportion of grain in the total silage mass is frequently less.

Forage Nutritive Value

Generally, the nutritive value of forage sorghums is far more variable across hybrids than that observed for grain sorghums. Forage-sorghum hybrids that require longer to develop, grow to tall plant heights and exhibit low grain-yield potential have poorer nutritive value than other types. The crude protein content of grain and forage sorghums can range from about 6 to 11 percent; however, grain-type hybrids typically have crude protein concentrations that are 1.0 to 3.0 percentage units higher than observed for forage types.

Neutral detergent fiber (NDF) and acid detergent fiber (ADF) fractions are generally lower in grain-type sorghums because the stover is diluted by the higher grain-to-stover ratios common to grain-type varieties. In addition, grain-type sorghums are frequently more digestible because the proportion of grain in these plants is larger than in forage types. Between the milk and hard grain stages of growth, grain yield usually increases. This may cause concentrations of NDF and ADF to remain stable or decrease with maturity, which is unusual compared to most other forages. While these trends can be observed in both grain and forage types, responses tend to be more pronounced for forage sorghums. Quality characteristics of forage and grain sorghums from tests conducted in Kansas are summarized in Table 11-3.

Feeding Comparisons

Comparisons of performance by growing cattle consuming corn, grain sorghum and forage sorghum silage diets are shown in Tables 11-4 and 11-5. Generally, average daily gains were higher and feed-to-gain ratios were lower for cattle consuming corn silage compared to either grain or forage-sorghum silage diets. When forage-sorghum hybrids had relatively low concentrations of ADF (Table 11-4), performance of cattle consuming grain-sorghum and forage-sorghum silages differed only minimally. However, when forage-sorghum hybrids were higher ADF types (Table 11-5), cattle consuming grain-sorghum silage gained 0.65 pounds per day more than cattle consuming forage-sorghum silages. The feed-to-gain ratio for cattle consuming these high-ADF forage-sorghum silages was 8.2, which compared poorly with the 7.0 and 6.0 observed for grain-sorghum and corn silages, respectively.

Prussic Acid and Nitrates

Prussic acid and nitrate poisoning may be a problem with most summer-annual forages. The prussic acid potential is high in the early stages of growth and decreases steadily in the fall until frost. It remains dangerous to livestock after frost until these plants are completely dry. This may take from one to seven days. Prussic acid concentrations are high in the leaves. Therefore, short, leafy plants have a higher prussic acid potential than tall, coarse ones. For this reason, the risk of prussic acid poisoning is greater in immature plants or in vegetative regrowth. Prussic acid can be reduced by up to 70 percent by field-wilting prior to conservation as hay or silage.

Nitrogen fertilization increases the total nitrogen, prussic acid and nitrate content of summer-annual forages. Nitrogen fertilizer should be applied with caution on any site that is drought

Table 11-3. Nutritive Value of Forage and Grain Sorghums From Six Comparative Studies in Kansas from 1984 to 1995. Adapted from Bolsen et al. (2003).

Trial[1]	Year(s)	Number of Cultivars	Type	Statistic	Crude Protein	NDF	ADF	Digestibility
					%			
1	1984	6	Forage[2]	Range	5.7 - 8.7	- - -	- - -	- - -
				Average	7.6	- - -	- - -	- - -
		6	Grain[2]	Range	8.8 - 10.5	- - -	- - -	- - -
				Average	10.1	- - -	- - -	- - -
2	1986	7	Forage	Range	6.6 - 7.8	47.3 - 60.0	29.6 - 38.5	52.3 - 58.7[3]
				Average	7.3	55.1	33.1	56.5[3]
		5	Grain	Range	9.0 - 9.8	41.9 - 48.0	22.6 - 27.5	60.7 - 63.8[3]
				Average	9.4	43.4	24.5	61.8[3]
4	1986-87	60	Forage	Range[4]	4.7 - 8.2	46.2 - 69.9	25.7 - 44.9	47.6 - 64.7
				Average[4]	6.7	54.6	33.3	56.3
6	1995	37	Forage[5]	Range	7.2 - 10.1	45.1 - 58.0	28.2 - 36.5	- - -
				Average	8.4	51.9	31.9	- - -
		3	Grain	Range	10.1 - 10.8	42.5 - 49.4	26.0 - 29.3	- - -
				Average	10.4	46.8	27.9	- - -

[1]Trial numbers correspond to those in Table 11-2.
[2]Entries were harvested at several stages of maturity, but only data from late-dough stage are reported.
[3]Determined as silage in sheep.
[4]Averaged over years. Analysis performed on fermented silage.
[5]Twenty cultivars produced no grain because of an early frost.

Table 11-4. Feeding Comparisons of Growing Cattle Consuming Corn, Grain Sorghum or Forage-Sorghum Silages. Forage Sorghum Performance Is Averaged Over Three Low-ADF Hybrids. Adapted from Bolsen et al. (2003).

	Silage Type		
Item	Corn	Grain Sorghum	Forage Sorghum
Initial weight, lbs	640	644	634
DM intake, lbs/day	19.0	19.9	18.9
Average daily gain, lbs/day	2.67	2.43	2.32
Feed:gain, DM basis	7.1	8.2	8.2
Silage moisture, %	66.7	62.3	63.1
Silage ADF, %	23.4	25.1	28.9

Table 11-5. Feeding Comparisons of Growing Cattle Consuming Corn, Grain Sorghum or Forage-Sorghum Silages. Forage Sorghum Performance Is Averaged Over Four High-ADF Hybrids. Adapted from Bolsen et al. (2003).

	Silage Type		
Item	Corn	Grain Sorghum	Forage Sorghum
Initial weight, lbs	569	569	568
DM intake, lbs/day	17.2	18.3	15.9
Average daily gain, lbs/day	2.87	2.60	1.95
Feed:gain, DM basis	6.0	7.0	8.2
Silage moisture, %	70.0	63.8	67.9
Silage ADF, %	24.2	27.8	35.3

prone. Forages that have been grown under stress can be tested inexpensively for nitrates in the laboratory.

When harvesting forages that are known or suspected to have dangerous levels of nitrates, a good management practice is to raise the cutter bar to a 6- to 12-inch height. This is effective at reducing nitrates in the harvested forage because most nitrates tend to accumulate in the lower portion of the stalk. In addition, silage fermentation can be used as a management tool; the fermentation process will normally reduce the concentration of nitrates in forages by about 50 percent. Testing for prussic acid is more expensive, and comparatively few laboratories offer this service.

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12 - Identify Hazards and Prevent Accidents

Gary Huitink, Phil Tacker and Earl Vories

Injury and death rates in almost every survey published are higher from April to September for agricultural work. Obviously, these months coincide with grain sorghum production. What can be done on your farm to prevent the trauma and cost of severe injury or death? Top managers maintain timely crop practices and also place a consistent emphasis on reducing field, traffic and shop hazards in day-to-day management.

Have a Plan to Reduce Hazards

One approach is to set long-range goals to eliminate hazards while finding safer ways to complete routine tasks. Assess the potential kinds of severe accidents and how frequently a person is exposed to that hazard. Develop a simple plan that you can follow to minimize these exposures. Serious concern should be given to the risks of road collision, tractor overturn and a person being run over or crushed by farm equipment. Consider all aspects of your farming operation to identify weaknesses, and then seek remedies.

If a person must work alone, make sure another person knows where the lone worker is and that regular contact is made. If a lone operator sees a hazardous situation, getting help to resolve it is essential. Everyone should be trained to contact the manager immediately about any serious safety concern.

Field

A few field dangers cause many Arkansas fatalities. These are tractor overturns, equipment running over victims and crushing them, jump-starting tractors, hitching equipment or folding equipment for road travel.

Most tractors used for grain sorghum production have a Roll-Over Protective Structure (ROPS). It has been well documented that the risk of serious injury from an overturn is essentially zero if the operator fastens his seat belt on a tractor equipped with ROPS! Practicing this safety habit may also reduce injury from a traffic collision. Operating a tractor, sprayer or combine too fast for conditions causes many overturns. Turning too short can cause an overturn. Misjudging your distance from an embankment can be serious, because the bank may crumble under the weight of the tractor or implement. FSA-1026, *Safe Tractor Operation*, available from your county Extension office or Extension web site www.aragriculture.org/agengineering/farmsafety, has more suggestions that may be useful for training farm help.

Table 12-1. Factors Involved in Agricultural Fatalities (1996 National Safety Council data)

Tractors	37%
All other agricultural machinery	17%
Farm trucks or other vehicles	11%
Animals	6%
All other fatalities	29%

Whether calibrating a planter or sprayer or moving a combine, don't move equipment until you **see** that everyone is out of danger. Starting a tractor in gear from the starter terminal (jump-starting) is one of the two most common reasons Arkansans have been run over. Transmission interlocks prevent tractors from starting in gear, unless the safety is bypassed. A victim doesn't have enough time to jump away from a tractor left in gear before the engine builds hydraulic pressure and the tractor rolls over him.

Whenever noise prevents you from hearing someone, stop the engine and what you're doing and move where you can talk to clear up any confusion. Hand signals are easily misunderstood, unless both of you understand the meaning of a hand movement in advance. It takes good communication and cooperation for two people to safely hitch heavy toolbars or towed implements. Make sure signals aren't confusing before moving the tractor to align the connection. Never stand between an implement and the tractor when hitching or unhitching. Quick hitches and well-constructed implement stands eliminate the need for a person between the implement and tractor.

Using a proper hitch support may prevent a dangerous hitching incident. If the hitch or lift pins do not align, movement may knock the support from under equipment; the toolbar or hitch may spring out of control or drop and crush someone's foot. Two severe accidents in 2002 may be instructive: One employee was killed trying to remove a pin when the hitch broke free and smashed his face. Another victim removed a latch pin and was crushed by a folding cultivator; the hydraulic cylinder didn't support the weight. If supports aren't sturdy, stable and at the proper height when disconnecting an implement, difficulty is likely when hitching the next time. Set the safety locks on the lift cylinders before working under a combine header. Never work under hydraulic lifts, raised truck beds, mowers or toolbars without **sturdy** supports.

Combine entanglements don't usually happen the first time it malfunctions. It's the fourth or fifth time, or later, when you're tired or irritated, in a hurry and your judgment lapses. Vibration and excessive noise dull an alert person's senses to hazards. Fatigue also slows your reaction, so take breaks for refreshment. Falls from combines, trucks, grain bins, etc., may be prevented with proper work platforms or sturdy ladders. Keep work areas neat and free of hose or electric cord loops, etc., which could pose trip hazards.

Professionals mount large implement tires with a protective cage. Mishaps while inflating tires can maim or kill. If you don't have equipment to handle tires safely, it is wiser to call a tire service company. Tires removed for repair or storage should be laid flat on the ground, leaned or secured against a post or placed in racks where they cannot fall.

Irrigation risers, discharge pipes and holes where water discharges may become hazards if they are not clearly visible. If field equipment hits a riser or washout, it could cause temporary loss of control in addition to damaging the equipment and/or the riser. Placing some type of readily visible marker at each riser and controlling weeds so they don't hide the marker should alert drivers. Anchors and guy wires to power poles located in or near fields should also be permanently marked. Putting some type of solid protection around guy wires from power poles is a good idea to help avoid clipping or dislodging them with field equipment. Fill washouts and use some erosion control structure or method to prevent large washouts under discharge pipes.

Agricultural aviators have little reaction time to dodge hazards as they apply fertilizer and pesticides. Always warn the pilot of any risks that you're aware of to help him be better prepared. If a field has aerial hazards, consider whether it would be more appropriate to use ground equipment.

Traffic and Road Transport

The National Highway Traffic Safety Association recently reported that approximately **40 percent more fatal crashes and fatalities occur in rural compared to urban areas**. Experience over the last four years in crop areas of Arkansas seems to reinforce national statistics. Changes like wider road shoulders, adding warning signs for curves with poor visibility, updating narrow bridges and, possibly, adding crossbars at railroad crossings should reduce rural traffic accidents. In some situations it may be possible to convince the town, county, state or railroad to maintain a clear right-of-way to obtain better traffic visibility.

Modern toolbars, combines and wide equipment typically require almost two normal traffic lanes. Motorists are often poor judges of the slow speed, width or weight of your implement, regardless of what you're transporting. Using an escort with flashing lights is probably the best way to alert a motorist. Being diligent to keep SMV signs, reflectors and taillights on and bright, cleaning them before entering a road, will improve their visibility during night and day.

Lock both of your brakes together and start onto a road slowly, even when traffic is heavy. Go slowly enough to manage the momentum of a tractor with a full grain cart, planter or toolbar, especially those that raise overhead. Dump all of the grain from your combine bin into a grain cart or truck prior to road travel to lower the center of gravity and gain control in a sudden emergency. Always check traffic from both directions before making a turn off a road, especially a left turn, to prevent a collision and extensive damage, if not injury.

Railroad crossings are increasingly dangerous for growers on farm equipment. Some tractor engines and cabs may tune out the diesel train noise. In order to hear better, reduce the speed of the cab fan and turn off the radio as you approach a crossing. If you gear down well in advance, you can control the load, either to stop or to proceed when the track is clear. In some cases, either historical evidence and/or community effort may help to get the railroad to add crossing bars.

General Precautions

Work can be done safely on equipment powered by electricity with a lock-out, tag-out approach. Anyone working with equipment powered by electricity should carry a lock with his personal key and tag. These are readily available from local electrical suppliers. Before starting work, always disconnect the power supply and lock the switch off. If you're interrupted by a phone call, or are not visible from the switchbox, no one else can reconnect the electricity. You can remove the lock from the switch lever after completing the work. Always use the heel of your left hand to throw lever switches and turn your face away as you move the control to minimize bad flash-fire burns.

A federal regulation intended for your personal safety prohibits anyone or any equipment from coming within 10 feet of an overhead power line. If field equipment or other traffic cannot maintain a 10-foot gap under the power line, request that your power supplier raise the power lines.

Figure 12-1. Proper method to safely bump or switch a disconnect lever on an electrical box.

Diesel-powered generators, electric-powered pressure washers and hand tools (drill, angle grinder, etc.) and welders should all be adequately grounded. Grinders, drills and other electric tools bouncing around in a truck tool box can develop shorts. If the electric service entrance at the shop is grounded with an 8-foot ground rod (National Electric Code standard), all ground wire leads, including the extra grounding plug on power cords, should be connected to reduce the risk of electrocution when a short occurs. Use electric tools on dry soil, concrete, etc., to reduce the potential of a fatal current surge passing through your body.

Someone, maybe several people on your farm, should keep current on CPR rescue techniques. The local EMT, ambulance and fire department numbers should be posted by every permanent phone and programmed on speed dials. Each one on the farm should be prepared to call emergency rescue, should an accident occur.

Observe pesticide labels for proper use, mixing and disposal. Appropriate personal protective equipment is specified on the label. The label and the Material Safety Data Sheet (MSDS) should have specific inhalation, dermal, ingestion and emergency information. If a mishap occurs, use the label to help your physician and the poison center to start the proper treatment.

Fire extinguishers on tractors and combines may also protect your safety and equipment investment. Dry chemical all-purpose 3A-40B:C or 4A-80B:C extinguishers are good choices for tractors and combines. Once a fire extinguisher is 10 years old, it is generally wise to replace it unless it exceeds requirements in a thorough test.

Irrigation

A qualified electrician should routinely check electrical circuits on irrigation pumps and center-pivot systems. Items to review are damaged wiring, proper grounding and adequate circuit protection, including immediate replacement of circuit boxes damaged by electrical storms or circuit overheating. If a box has overheated or shorted, switching the disconnect may cause arcing and severe flash burns that may take months for merely partial recuperation. Always use the heel of your left hand to throw switch levers and turn your face away to minimize your hazard exposure as you move the control.

Be cautious when working around electrical circuits, especially when opening electric control boxes and around any circuits that are hot. Wasps commonly nest in and around electric control boxes and may also appear from electric motor shrouds, gear head covers, power unit platforms, irrigation well sheds and irrigation pipe openings. In order to prevent an injury, it may be wise to keep wasp and hornet spray handy when working on irrigation wells. Stings are not only painful; they can be fatal for one who is severely allergic to insect stings. Further injury can also occur if a wasp startles you and causes you to jump back. A sudden reaction that puts you in contact with an unguarded drive or an energized electric circuit may cause permanent disability.

Entanglements may occur with irrigation well power shafts, if safety shields aren't replaced. In general, power-take-off (PTO) hazards are respected, but more emphasis needs to be placed on shielding

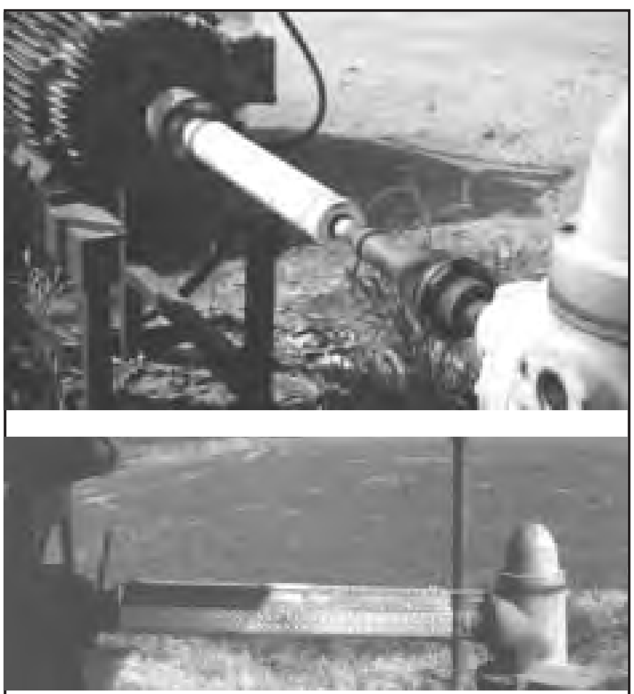

Figure 12-2. Install shields to protect anyone working around well power shafts.

unguarded power shafts on irrigation wells. Power shaft covers can be obtained from suppliers, including Menard Mfg. in DeWitt, AR (1-888-764-3130) to protect those doing maintenance around diesel, propane or electric power units. Power shafts for relifts or well pumps should be shielded; any concentric sleeves that don't spin free should be repaired or replaced.

If a power unit is not securely mounted and anchored, vibration may misalign the drive or break it loose from the supports. A loose power unit may cause a dangerous flailing power shaft or other hazards due to broken electrical wires, fuel lines or battery cables. Power units and battery mounts should be securely anchored to a substantial support platform and routinely checked for stability. A secure latch to keep the clutch of the power unit in neutral is a good safety device. This can help prevent accidentally bumping and engaging the clutch when working close to the power unit.

Typically, weather is very hot when irrigation is needed, and physical stresses may bring on heat stress. Anyone working in these conditions should drink plenty of fluids such as water and nutrient-replenishing drinks. Breaks and rest periods should be taken as needed to avoid heat stress, fatigue and exhaustion. Fatigue and exhaustion, of themselves, are health hazards, but they may also contribute to poor judgment, causing other accidents and injuries.

Reservoirs and open irrigation distribution ditches may present concerns. Normally, a clear warning on a sign about the water hazard, unusual currents around culverts, etc., and potential bank washouts will caution outdoorsmen or others who may enter. Evaluate a location with respect to residences or public access to determine whether it may attract youngsters. Gates and fencing may be used around accessible areas to prevent ATV riders or children from getting into danger. Posting no trespassing signs or a drowning warning is primarily useful only for adults.

Grain Drying

The primary grain-handling hazard is entanglement, but the potential for both suffocation under flowing grain and electrocution should also be reviewed. Certainly, all auger covers should be in place **every** time the power is engaged. In addition, don't reach across belt drives or power shafts; take the time needed to walk around your tractor or power unit. Fans and drives should be shielded to prevent anyone from getting caught. Children shouldn't be around grain handling facilities; fencing the area may be a practical choice.

A qualified electrician should routinely check electric circuits to confirm proper grounding and adequate circuit protection, including making immediate repairs of faulty wiring, conduits or control panels. Disconnect electric power and use the lock-out, tag-out procedure every time before beginning work around an auger, fan, motor or powered component. Lock out (Off) all power to the facility when it is not being used. Before tilting a truck bed, moving an auger or tall equipment, check for overhead power lines; too many times an auger is raised or pulled into a bare overhead wire. When grain bins are built or facilities are remodeled, power lines should be routed well away from any work areas so accidental contact with wires isn't possible.

When entering a grain bin, wear a NIOSH-approved toxic dust respirator for molds and dust to prevent a reaction called farmer's lung or toxic organic dust syndrome. Turn off all unloading equipment and lock out switches with a padlock before entering a bin so that someone doesn't unwittingly engage the power. This applies to all loading auger, sweep auger, stirring auger and unloading auger circuits. Don't enter a grain bin without a safety harness and tether manned by at least one adult outside the bin whose sole responsibility is aiding the entrant. Crusted grain has been a factor in a number of deaths to growers. Spoiled or caked soybeans, corn, rice or grain sorghum may bridge over a cavity and cave in onto a man if the crust suddenly fractures. If some grain is removed from a bin with a crusted surface, the undermined surface may suddenly collapse under your foot, releasing an avalanche of grain. More than 500 pounds of pull are required to move a man who is covered with grain to his shoulders. If you're covered, you can't get yourself out and you're likely to suffocate if no one is watching. More details are included in FSA-1010, *Suffocation Hazards in Grain Bins*, available from the county Extension office or on the web site listed previously.

OSHA

Only farms with 11 or more employees are required to meet all OSHA labor regulations. All growers who employ a worker, however, are to comply with these standards:

1) Roll-over protective structure (ROPS)
2) Slow moving vehicle emblem (SMV)
3) Agricultural machinery guarding (of moving parts, i.e., PTOs, combine safety shields, auger inlet covers and other moving machinery guards)
4) Anhydrous ammonia standards
5) Temporary labor camps standards
6) Pulpwood logging standards
7) Hazard communication (right to know). If you are an employer and store farm diesel fuel, pesticides, etc., then labels, MSDS information, training and a written Hazard Communication Program are required.
8) Worker protection standards for handling and applying pesticides.

If your farm is under OSHA jurisdiction, OSHA requires reporting an accident within 8 hours. They define a reportable incident as hospitalization of three or more employees in one accident or a death of one or more employees. A Washington, D.C., phone number, 1-800-321-6742, is available 24 hours a day. You can report to the federal OSHA office in Little Rock during working hours at 501-324-6291, extension 235.

If an OSHA officer requests admittance to a workplace, an employer may deny it. The officer can, however, obtain a search warrant. The inspection should include only the immediate accident scene. Inspections may result in setting a penalty or formal warnings, with penalties enforced later (often 30 days), if the hazard isn't remedied. Inspectors can ask that employees be removed from areas of imminent danger. An owner can appeal to the federal OSHA office in Little Rock, phone 501-324-6291, extension 235.

Other considerations that may be important:

1) When is a CDL operator's license required?

2) What training should be provided for all employees and others? Training at the time of employment, as tasks are assigned, and at minimum, every year, instructs every employee on farm hazards and on safe operation. Keeping signed records is the best way to document training and record your progress removing farm hazards, should a major injury or death occur on your farm.

3) Are 14-15 year-olds employed? Training for hazardous machinery operation is specified and work criteria apply to those under 18 who are employed in agriculture.

4) Are your insurance policy liability limits and deductibles appropriate for your present farm?

5) Have you considered whether workmen's compensation is feasible?

6) Are employment procedures for non-citizens applicable?

Summary

These suggestions are a start to help you manage hazards and find ways to avoid them. These hazards are only highlights. Review your techniques and farm work sites in order to reduce potential hazards.

A grower's leadership is the key to influencing employees and others on the farm. Employees must know that working safely is expected, for their welfare, as well as that of their employer. During the non-crop season, it is wise to make a careful hazard audit. Review the previous season's activities and field records to bring to mind hazards or incidents, especially considering situations when someone narrowly avoided serious injury. Evaluate equipment for proper repair and that shields and guards are in good condition and in place. Making changes may save someone's life the next season.

In most situations, **equipment isn't the underlying cause of an accident**. A single thoughtless reaction can make you a victim. Never get in a hurry. Plan ahead to ensure there is enough time to do the job properly and safely.

Contacts that May Prove Helpful

Emergency Rescue	911 or __________________	
Poisoning	1-800-222-1222	
Family Physician	__________________	
Local Electric Power Supplier	__________________	
County Sheriff	__________________	
Local Implement Dealer (assist with extrication)	__________________	
Local Implement Dealer (assist with extrication)	__________________	
Arkansas State Highway and Transportation Dept.		
(Police: Oversize and over-weight permits, etc.)	501-569-2381	
Commercial Driver's License (CDL) info.	501-682-1400	
State Fire Marshal, Arkansas State Police	501-618-8624	(Fuel storage questions)
Arkansas State Plant Board	501-225-1598	
Arkansas Department of Environmental Quality	501-372-0688	
Arkansas Department of Labor-Wage and Hour	501-682- 4501	
OSHA Consultation	501-682- 4523	
LPG (Liquefied Petroleum Gas) Board	501-324-9228	