Grain Sorghum Production Handbook

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Contents

Growth and Development of the Sorghum Plant

Some may wonder why the recommendation for the use of 2,4-D on sorghum reads, "Apply as a broadcast spray when sorghum plants are from 6 to 8 inches tall." Certainly, broadleaf weed control may be needed at earlier or later times; however, this height represents a particular time in the development of the sorghum plant. Understanding how the sorghum plant grows and develops will help in understanding what will affect its growth. It also will help explain the reasons for specific production practices discussed in this publication.

Sorghum seed is the smallest of the spring-planted crops; therefore, its early growth usually will be slower than that of corn or soybeans. In fact, growth is not very rapid up to the 8-inch height previously mentioned, while the plant establishes a root system and starts to take up nutrients much more rapidly.

Shortly after reaching the 8-inch height, the growing point of the plant—at this time still below or just at the soil surface—changes from producing leaves to producing the head. For a medium-maturity sorghum, this occurs about 30 to 35 days after emergence. This is a critical point in the development of the plant since its total number of leaves will be determined. At this point, when the plant has completed about 5 percent of its growth, it has taken up 10 to 15 percent of the nutrients it will use during the entire season.

During the next 30 to 35 days, until flowering, the plant grows rapidly. It produces much of the leaf area, which will be important during the grain-filling period. During this time, the head develops and the stalk grows rapidly. First, the lower portion of the stalk grows, pushing the head up into the flag leaf sheath into the boot stage.

Later, the upper stalk—the peduncle, which holds the head—grows rapidly, pushing the head out of the flag leaf sheath where flowering and pollination can occur. If something happens during this stage of growth, the head may not fully emerge from the sheath, may not be fully pollinated, or may cause problems at combining. This period, from when the head first starts to form until flowering, is a time for rapid growth and rapid nutrient uptake. At flowering, the plant will have produced about half of its total weight at maturity; however, between 60 and 70 percent of the total nutrient uptake already will have occurred.

The final stage of growth, from flowering to physiological maturity, is the important grain-filling period. During this time, total production of the plant is going into the grain. Materials stored in the stalk are being moved into the grain, and the plant is taking up approximately the final one-third of the nutrients. If drought occurs, both uptake and growth may be limited.

The end of this period occurs when the grain is no longer increasing in dry weight. This physiological maturity is not harvest maturity. At physiological maturity, the grain moisture will be 25 to 40 percent, and it must dry considerably before it can be harvested and placed in conventional storage. For high-moisture grain or early harvest and artificial drying, sorghum can be harvested at any time after physiological maturity.

Returning to the example of 2,4-D application, the 8-inch plant height corresponds to the plant's stage of development (head formation). Similarly, if the following discussions on production practices are related to the crop's stage of development, their effects will be better understood. A more detailed explanation of sorghum-plant growth may be found in *How a Sorghum Plant Develops,* K-State Research and Extension publication S-3.

Selection of Grain Sorghum Hybrids

Veteran sorghum producers remember going from a handful of standard varieties (Midland, Martin, Westland, Redlan) to the confusion of the hundreds of hybrids offered since the late 1950s under many private brands with numbers or names. Growers enjoyed the 20- to 30-percent yield advantage the first hybrids had over varieties and found the effort involved in careful selection among hybrids worthwhile. Careful selection is the key. Simply planting hybrid seed does not ensure good performance.

To help growers identify best-adapted hybrids, the Kansas Agricultural Experiment Station conducts annual performance tests at 13 sites on a voluntary cost-sharing basis with seed companies. Thousands of hybrids have been tested since 1957. During the past several years, more than 100 hybrids submitted by 20 or more private companies were tested annually. About one-third of each year's entries were new hybrids, indicating a rapid turnover rate.

Not all hybrids sold in the state are included in tests, and hybrids are not grown at all test sites because entrants choose the test locations. The annual performance-test bulletins containing current-year data and multiyear averages can provide valuable guidance in hybrid selection. Test results from several years and locations should be examined before making selections. Small differences in yield may not be real. Be sure to look at the measures of variability (C.V.) and significance (L.S.D.) for each test.

Yield

It is not unusual for the best hybrid to out-yield the poorest hybrid on a test or farm plot by 40 bushels or more per acre. Even on a multiyear-test-average basis, hybrid yields may differ by more than 20 bushels. Because yield is the end result of many genetic and environmental influences and interactions, it is useful to study other sorghum characteristics leading to high yields in a specific farm situation.

Maturity and standability (stalk strength) are two major characteristics affecting yield in Kansas that can serve as reliable guides in hybrid selection. Yield components such as number of heads per acre, number of seeds per head, and seed weight are factors in yield, but they tend to compensate for each other. Any one of these components is too inconsistent to serve as a reliable yield predictor.

Diseases and insects often are destructive in specific locations and sometimes cause widespread damage. In terms of hybrid selection, pests should be considered on the basis of probability of a repeat problem, availability of resistance or tolerance in commercially available hybrids, practicality of chemical control, and use of hybrids best adapted to management practices that have been adjusted to avoid or tolerate pest problems.

Recent greenbug and chinch bug infestations serve as examples. Good greenbug-tolerant hybrids were available from 1976 to 1980, and chemical control generally was needed only for heavy seedling infestations and for large, persistent greenbug populations in later plant-growth stages; however, those hybrids had little or no resistance to a new strain of greenbug called Biotype E, so insecticides were the primary control method until newly adapted resistant hybrids became available a few years later. More recent strains, biotypes I and K, have added additional dimensions to the greenbug-resistance picture.

Some hybrids appear to have more tolerance to chinch bugs than others, but chemicals are the major control method. The use of systemic insecticides in the furrow at planting or as seed treatments, planting earlier or later than normal, and avoiding planting sorghum next to small grains can reduce the probability of chinch bug damage to sorghum seedlings.

Maturity

A good full-season hybrid will out-yield a good early-season hybrid every time, other conditions being equal and favorable for sorghum growth. The stalks of full-season hybrids usually are larger and stand better than earlier hybrids. The rule of thumb is to plant the latest-maturing hybrid available within the limitations of projected moisture availability, average length of growing season, and crop sequence. Hybrid selection can then be narrowed to that group of hybrids meeting the maturity criteria.

Maturity is relative in a state that varies from 800 to 4,000 feet in elevation and from nearly 40 to less than 16 inches of annual precipitation. A conservative view is that hybrids should be in the maturity class reaching physiological maturity (maximum dry-matter content of grain at about 30- to 40-percent moisture) a week or two before the average date of the first killing frost.

On nonirrigated acreage in western Kansas or on shallow soils in other areas, moisture exhaustion can be more damaging to late hybrids than frost. Earlier hybrids should be planted on those sites. Moisture stress often causes lodging problems because of incomplete development of stalk-strengthening tissue, invasion by organisms that further weaken stalk tissue, or both. By choosing hybrids that mature early enough to avoid severe moisture stress, lodging risk may be reduced.

Lodging

If a hybrid goes flat after having stood well in previous years, producers may wonder what happened. Lodging inconsistencies are common in research trials, but they usually can be explained. The maturity-moisture situation previously noted is a prime source of lodging variability because timing of moisture exhaustion in relation to the plants' growth stage is important, not only to degree of reduced yield but also to susceptibility to invasion by organisms, such as charcoal rot, that cause lodging.

The interaction of hybrid maturity and environmental stress is important in hybrid selection. Planting two or more hybrids that differ slightly in maturity will help ensure adverse environmental conditions will not affect total grain sorghum production.

As discussed, early hybrids have more lodging problems than late hybrids. If early hybrids must be grown, producers should recognize the risks and harvest as early as possible, using high-moisture grain storage or grain dryers if economically feasible.

In any maturity group—early, medium, or late—there are hybrids that consistently lodge worse than others. They should be avoided, especially on fields with a history of frequent lodging. The best sources of information are seed companies, performance-test results, personal experiences, and Extension agents.

Be willing to …

- spend considerable time searching for improved hybrids. It can pay big dividends.
- look at a broad base of information on hybrids of interest. Avoid reliance on only one source of hybrid-performance information.
- look at hybrids from several companies.
- learn hybrid names or numbers. Each company has only one brand but many hybrids.
- try hybrids on a small scale and keep harvest records.
- plant two or more hybrids of differing maturity to spread out risk of damage from adverse weather conditions.

Keep alert for …

- hybrids with resistance to pests threatening the next crop. New strains of pests, such as greenbugs and maize dwarf mosaic virus, appear from time to time, so it is important to keep up with new developments in both pests and hybrids.
- hybrids with tan plant color. White grain has been around for several years, but new hybrids with white grain and a tan plant may appear on the market soon. These hybrids produce excellent food-quality grain without the discoloration problems that can occur with white grain produced on hybrids with a red or purple plant. White-on-tan (white grain produced on tan plants) sorghum may provide the opportunity for a price premium in some food and poultry-feed markets.
- high-tannin hybrids. Avoid hybrids high in tannin unless severe bird-damage potential exists and the grain can be utilized on-farm. Marketing high-tannin grain through normal channels can be difficult.

Seedbed Preparation and Planting Practices

Grain sorghum needs a warm, moist soil well supplied with air and fine enough to provide good seed-soil contact for rapid germination. A number of different tillage and planting systems can be used to get these conditions. These systems may involve primary or secondary tillage or no tillage operations prior to planting.

An ideal seedbed should accomplish these goals:

- control weeds,
- conserve moisture,
- preserve or improve tilth,
- control wind and water erosion, and
- be suitable for planting and cultivating with available equipment.

One goal of seedbed preparation is to provide a means of profitable crop production while minimizing soil erosion due to wind and water. Tillage and planting systems accomplishing this goal are often referred to as conservation tillage systems. Conservation tillage is an umbrella term including reduced-till, mulch-till, ecofallow, strip-till, ridge-till, zero-till, and no-till. The emphasis in conservation tillage is erosion protection, but moisture, energy, labor, and even equipment conservation may be additional benefits. Conservation tillage will be an integral part of many conservation plans for highly erodible fields as a result of the conservation compliance provisions of the 1985, 1990, and 1996 farm bills.

Table 1. *Soil Losses for Various Tillage Systems in Soybean, Corn, and Wheat Residue*

Tillage system	Corn residue[1] Cover %	Corn residue[1] Soil loss (tons per acre)	Soybean residue[1] Cover %	Soybean residue[1] Soil loss (tons per acre)	Wheat residue[2] Cover %	Wheat residue[2] Soil loss (tons per acre)
Plow, disk, disk, plant	4	10.1	2	14.3	–	–
Chisel, disk, plant	13	18.3	7	9.6	–	–
Disk, disk, plant	–	–	5	14.3	–	–
Disk, plant	15	6.6	9	10.6	–	–
Plow, harrow, rod-weed, drill	–	–	–	–	9	4.2
Blade (three times), rod-weed, drill	–	–	–	–	29	1.2
No-till plant or drill	39	3.2	27	5.0	86	0.2

[1] Silty clay loam, 5-percent slope, 2 inches applied water at 2.5 inches per hour.
[2] Silt loam, 4-percent slope, 3 inches applied water at 2.5 inches per hour.
Source: E.C. Dickey, University of Nebraska-Lincoln

Erosion Protection

In conservation tillage, the soil surface is protected from the erosive effects of wind, rain, and flowing water. Resistance to these erosive agents is achieved either by protecting the soil surface with crop residue or growing plants or by increasing the surface roughness or soil permeability. Soil erosion losses for different tillage systems are shown in Table 1.

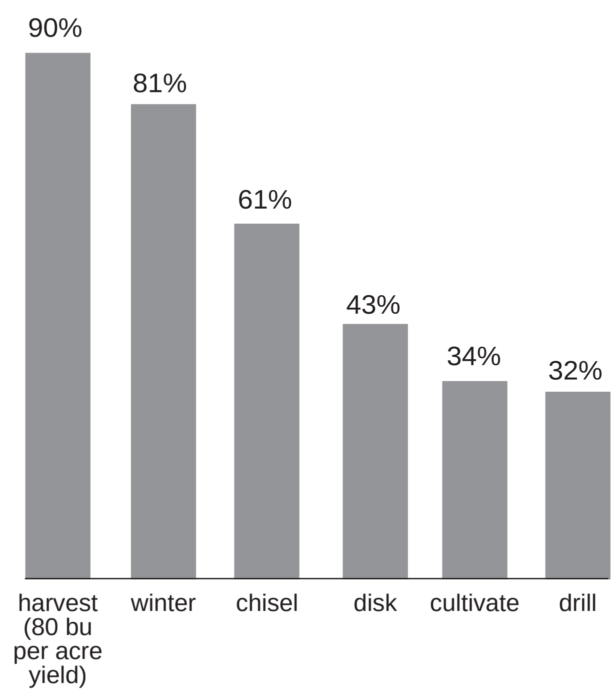
A common goal of conservation tillage systems is to reduce soil erosion losses below the soil-loss-tolerance or "T" value. Soil-loss tolerance is an estimate of the maximum annual rate of soil erosion that can occur without affecting crop productivity during a sustained period. Soil-loss tolerances for Kansas cropland are normally in the range of 4 to 5 tons per acre per year. Soil-loss tolerances for specific soil series can be found in soil surveys or from Natural Resources Conservation Service (NRCS) personnel.

The amount of residue necessary for erosion protection depends on several factors, such as climate, soil erodibility, surface roughness, field length, slope length and steepness, cropping practices, and conservation practices. Generally, leave 30 percent residue cover after planting where water erosion is the primary concern. Where wind erosion is a concern, 1,000 pounds per acre of flat, small grain residue or its equivalent is required during the critical wind-erosion period. It is important to be aware of crop-residue levels to stay in compliance with the conservation provisions of the 1996 farm bill.

It may be helpful to estimate the residue on the surface to evaluate the tillage options available for next year. This calculation is explained on the Residue Fact Sheets (available from K-State Research and Extension offices). A computer program also is available. An example output is shown in Figure 1.

After an 80-bushel-per-acre sorghum yield, the average soil surface will be about 90 percent covered with crop residue. After overwintering and some limited tillage (one chiseling, one disking, and one field cultivation), the soil will still be about 30 percent covered after planting. Results may differ from actual

Figure 1. *Sorghum Residue Cover Reduction with Successive Tillage Operations*



residue levels in the field, depending on initial residue amount after harvest, tillage speed, and soil-moisture content. It is best to estimate residue in the field to check for conservation-compliance. Residue amounts can be estimated by comparison with pictures of various residue covers, line transect method, or stepping out the residue (boot method).

In Kansas, almost 40 percent of the harvested sorghum acres will end with less than 15 percent ground cover before the next crop is planted. Only 25 percent of the sorghum acres is in reduced-till, no-till, or ridge-till, leaving more than 30 percent ground cover at all times. The actual level of residue required to minimize soil loss on fields may vary from these limits. NRCS personnel can provide assistance in determining residue needs.

Conservation tillage alone may not adequately protect the soil from erosion. In these situations, conservation tillage can be integrated with other practices—such as terracing, contouring, strip cropping, and windbreaks—to provide erosion protection.

Long-term research in Kansas has shown grain sorghum can be grown successfully in conservation-tillage systems (Table 2). Careful management and planning are important. Uniform residue distribution, effective weed control, proper seed placement, correct planter adjustment, soil testing, and fertilizer management are important in conservation-tillage grain sorghum production.

No-till grain sorghum planting is best suited to moderately and well-drained soils. Soils often remain cooler and wetter through the growing season under no-till conditions. This is particularly true in heavy residue. While wetter soils are an advantage during dry periods, at planting time they can mean slower germination, delayed maturity, and a longer period when seeds are susceptible to pests. These conditions can result in reduced yields in no-till situations, particularly in cool, wet springs and on poorly drained soils. Other conservation-tillage systems, such as reduced-till or ridge-till, would be better choices.

Many producers trying no-till grain sorghum for the first time do so after soybeans. Fewer planting problems are encountered in this sequence as soybeans produce less residue than other crops, the residue is easily managed, and the soil is generally loose and mellow. Soybeans typically produce 45 pounds of residue per bushel of grain, whereas corn, grain sorghum, and wheat produce 60, 60, and 100 pounds of residue per bushel of grain, respectively.

Table 2. *Long-term Yields of Grain Sorghum Grown under Various Tillage Systems* [1]

Location (soil type)	Rotation	No. of years tested	Yield (bushels per acre) No-till	Reduced-till	Conventional-till
Finney County (Santana loam)	WSF	11	65	63	58
Ellis County (Harney sil)	WSF	20	45	51	51
Riley County (Smolan sil)	continuous	8	79	–	80
Franklin County (Woodson silt-clay)	continuous	6	59	64	66
	S-SB	6	70	72	77

[1] Yields averaged across other treatments.

Planting Practices

Row width. Most grain sorghum is planted in 30-inch rows because other row crops have performed well that way, and that is the row width of most equipment. Historically, 30-inch rows performed better than wider rows, and narrower rows have not consistently yielded better than 30-inch rows. Plants in narrower rows shade the soil quicker, improving weed control and reducing soil erosion.

Seeding rate. Seeding rates or plant populations vary depending on rainfall and growing conditions. In Table 3, recommended plant populations are given for specific rainfall regimes. The within-row seed spacing is given based on 65-percent field emergence. In Figure 2, average annual rainfall regimes are presented to help determine seeding rates.

Two formulas can be used in calculating plant populations and seeding rates.

Formula 1. *Plant population or seeding rate*

$$\frac{43{,}560 \text{ sq.ft.}}{\text{acre}} \times \frac{12 \text{ in.}}{\text{row spacing (in.)}} \times \frac{\text{seeds or plants}}{\text{foot-row}}$$

Example 1.

$$\frac{43{,}560 \text{ sq.ft.}}{\text{acre}} \times \frac{12 \text{ in.}}{30 \text{ in.}} \times \frac{3 \text{ plants}}{\text{foot-row}}$$

= 52,272 plants per acre

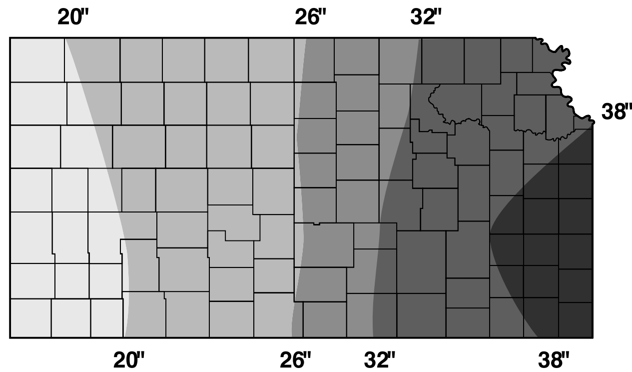
Table 3. Grain Sorghum — Plant and Seed Spacings

Recommended population and spacing	Average annual rainfall (in inches) <20	20-26	26-32	>32	Irrigated
Plant population	24,000	35,000	45,000	70,000	100,000
Within-row seed spacing at planting: [2]					
15-inches	11.3	7.8	6.0	3.9	2.7
30-inches	5.7	3.7	3.0	1.9	1.4

[1] In plants per acre. Plant populations may be increased or decreased by at least 25 percent from the values given, depending upon the expected growing conditions, without significantly affecting yields.

[2] Assuming 65-percent field emergence. Calibration of planters should be based on seed spacing. Seeding rates based on pounds per acre have little meaning since seed size commonly varies from 13,000 to 24,000 seeds per pound.

Figure 2. Average Annual Rainfall for Kansas



Formula 2. Seeds or plants per foot-row

$$\frac{\text{seeding rate or plant population}}{\text{43,560 sq. ft./acre}} \times \frac{\text{12 in.}}{\text{row spacing}}$$

Example 2.

$$\frac{\text{70,000 seeds or plants}}{\text{43,560 sq. ft./acre}} \times \frac{\text{12 in.}}{\text{30 in.}}$$

= 4 seeds or plants per foot-row

If the optimum plant population for a particular field is 45,000 plants per acre, the seeding rate needs to be adjusted to reflect expected field emergence. Only 65 to 70 percent of planted seeds will emerge, and those figures should be used to estimate field emergence.

To calculate the seeding rate follow this formula:

$$\frac{\text{desired plant population per acre}}{\text{percent field emergence}} = \text{seedling rate per acre}$$

Example:

$$\frac{\text{45,000 plants per acre}}{0.65} = \text{69,000 seeds per acre}$$

Hybrid seed size varies, so planting in terms of pounds of seed per acre results in large differences in plant population and wastes money. Although there may be emergence differences due to seed size, generally no yield differences are found.

Sorghum plants may tiller and compensate for thin stands. Large heads (more seeds per head) can compensate for thin stands. Heads produced by late tillers may be immature when the head on the main stem is mature, resulting in harvest and storage problems. Seed weight can compensate for reduced seed number to a limited extent.

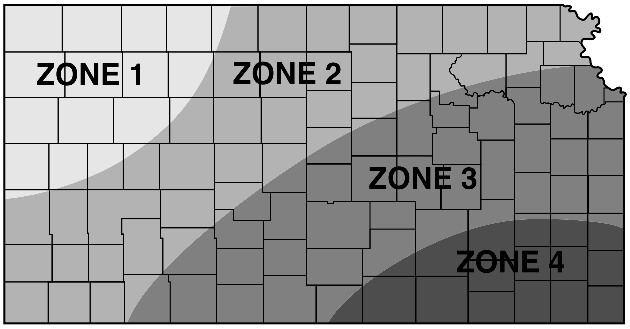
High plant populations result in fewer tillers and are necessary under irrigation and in higher-rainfall areas. Excessive stands produce plants with smaller stems and are more susceptible to moisture stress and lodging.

Seeding date. There is a wide range in planting dates for grain sorghum. Planting should be timed so flowering avoids the hottest, driest period of summer. Suggested planting dates are given in Figure 3. Utilizing several planting dates is suggested to spread the risk of one planting date flowering during a stress period.

Quick germination and emergence occur when the soil temperature is 70 degrees Fahrenheit. Planting too early results in delayed emergence and reduced stands. Plants from early plantings may be taller and more vegetative than later plantings. Late plantings may not allow the crop to mature before a damaging fall freeze. Based on the time grain sorghum blooms, probabilities of sorghum maturing before a freeze can be calculated. Figure 4 shows those probabilities for bloom dates from August 4 to August 29. With late plantings, earlier-maturing hybrids should be used.

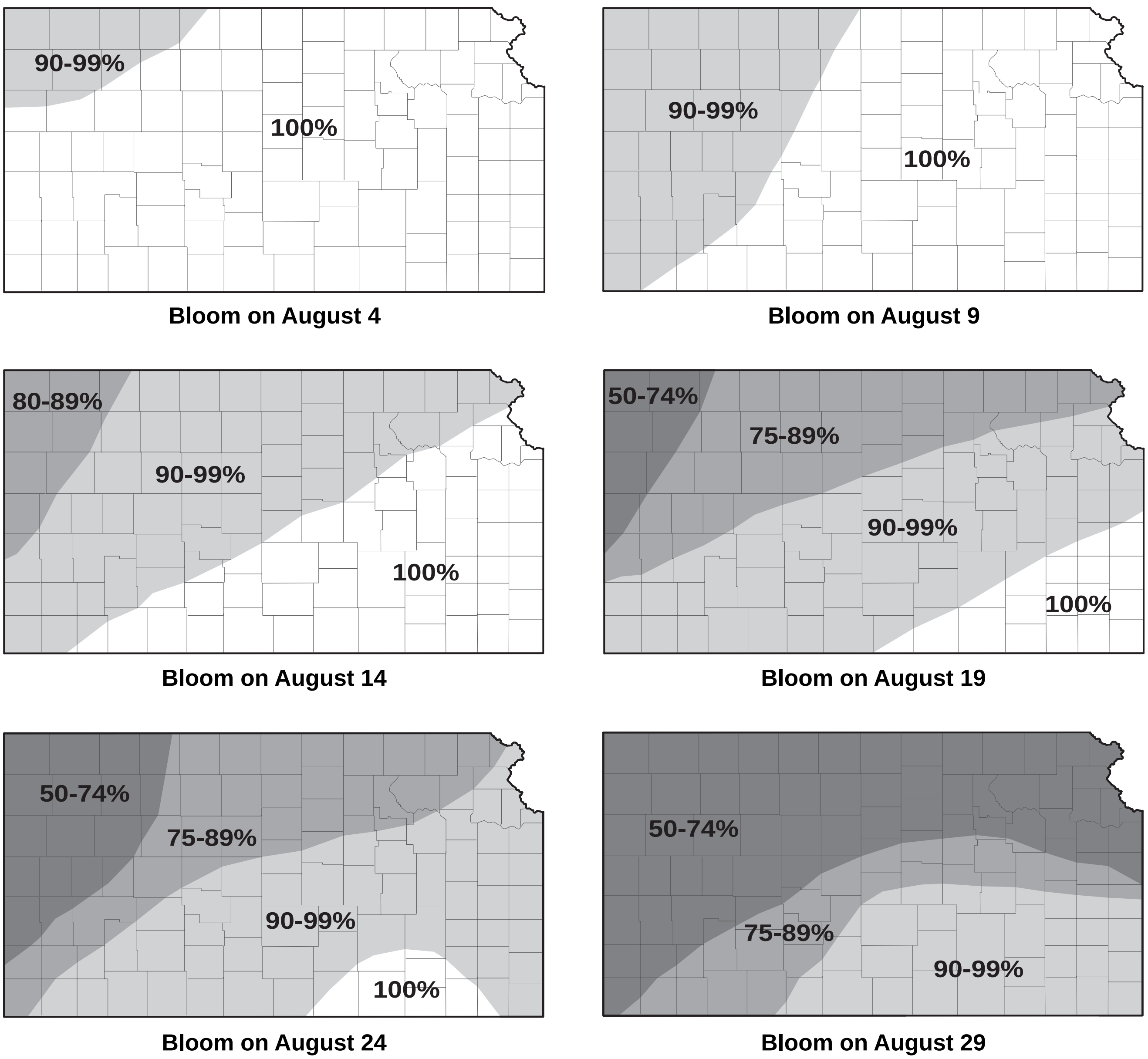
Seeding depth. The optimum planting depth differs with soil types and moisture conditions. In heavier soils, a planting depth of l inch is satisfactory. In sandy soils, seeds can be placed 2 inches deep without problems. Sorghum seeds can emerge from plantings deeper than 2 inches, but seedlings are slow to emerge, and final stand numbers may be reduced. The seed should be well covered with soil for excellent seed-soil contact to aid germination.

Figure 3. *Suggested Grain Sorghum Plating Dates*



Zone 1: May 15 to June 10
Zone 2: May 15 to June 20
Zone 3: May 15 to June 20
Zone 4: May 1 to May 15, June 5 to June 25

Figure 4. *Probability of Sorghum Maturing before Freeze for Flowering Dates from August 4 through August 29*



Weed Control

Weed control in grain sorghum is best achieved with an integrated approach based on crop rotations and herbicides or tillage, which enhances the ability of sorghum to compete with weeds.

Integrated Weed Management

Before planting grain sorghum, fields should be evaluated for annual and perennial weeds. The current year's weed-management program should be based on field notes from previous years that show weed species present, their relative abundance, and locations of perennial-weed infestations.

Common grassy weeds in Kansas include crabgrass, foxtails, shattercane, longspine sandbur, and panicums such as fall panicum and witchgrass. Common annual broadleaf weeds include kochia, the pigweeds, venice mallow, velvetleaf, cocklebur, devilsclaw, and sunflower. Successful control of annual weeds requires planting the crop into a weed-free environment and other management practices designed to get the crop up before the weeds.

Perennial weeds such as field bindweed, common milkweed, hemp dogbane, bur ragweed, and Johnsongrass also may infest sorghum fields. Perennial weeds can be suppressed, but they are difficult to kill. Cultivation between the rows, directed herbicide applications with drop nozzles, and certain broadcast herbicides are helpful in suppressing perennial weeds.

Crop rotation reduces weed pressure by varying the timing and types of tillage and herbicides. This is the most effective control for shattercane and Johnsongrass in sorghum. Fallow periods and rotation with summer crops such as soybeans, or winter crops such as wheat, will greatly reduce weed numbers, provided weed control is adequate to prevent seed production.

Delayed sorghum planting provides opportunities for effective weed control. In tilled seedbeds, field cultivation prior to planting will control emerged weeds, reducing weed-seed stocks in the soil. The last tillage before planting should be very shallow to avoid bringing new weed seed to the soil surface. In no-till seedbeds, herbicides are used to control emerged weed seedlings. Once several flushes of weed seedlings have been killed without further soil disturbance, weed pressure is decreased because few weed seeds remain in the favorable germination zone near the soil surface. Such "stale seedbed" techniques are especially effective in late-seeded crops.

Weed Control Strategies Prior to Planting

Repeated tillage before sorghum planting can effectively control weeds, but it is not likely to provide adequate protection from soil erosion by wind and water. Herbicides may substitute for some or all preplant tillage.

One strategy, where sorghum follows the previous year's wheat, is to control weeds in wheat stubble with Roundup and 2,4-D or dicamba then follow with an atrazine application in late summer. Atrazine controls volunteer wheat and other winter weeds and should keep the field relatively weed-free for a no-till sorghum planting the next spring. In central and eastern Kansas, atrazine should be applied after the end of August to reduce the potential for atrazine loss in surface runoff.

On the fine-textured soils of central and eastern Kansas, no-till planting of sorghum into standing wheat stubble may be hindered by wet soils. An alternative to no-till planting is to chisel the stubble after wheat harvest, leaving a rough but protected and porous surface. Apply atrazine and crop-oil concentrate to volunteer wheat and other winter weeds. A single pass with a field cultivator in spring is usually sufficient to assure a weed-free seedbed for sorghum planting.

Sorghum planted into soybean or row-crop stubble normally requires no seedbed preparation other than weed control. Where weed pressure is light and consists mainly of broadleaf weeds, a March or early-April application of atrazine with crop-oil concentrate and 2,4-D can control winter weeds, such as mustards and marestail, and most germinating weeds through planting. Early-spring-applied atrazine is a best management practice (BMP) as there is little potential for loss in surface-water runoff compared to later planting-time applications.

If annual grasses and tough broadleaf weeds like velvetleaf are emerged as planting time nears, Roundup and 2,4-D ester should be applied about a week before planting. In addition to killing all emerged annual weeds, this treatment can be very effective on established perennials such as field bindweed and hemp dogbane. Soil-residual grass herbicides are often added to these foliar-applied treatments for extended control.

Herbicides Applied at Planting

It is critical that fields be weed-free at planting time. Soil-applied herbicides for grass and pigweed control in the growing crop include Dual, Frontier, Partner, and Ramrod. Dual, Partner, and Frontier may be shallowly incorporated or surface applied, and they require the use of seed treated with Concep safener. These soil-applied herbicides do not control shattercane or large-seeded broadleaf weeds such as cocklebur, velvetleaf, venice mallow, devilsclaw, and sunflower.

The rate of atrazine applied to the soil surface at planting should not exceed 1 pound per acre because surface-applied atrazine is especially vulnerable to loss in surface-water runoff during May and June. Alternatives for using higher rates of atrazine at planting time include surface application before April 15, preplant incorporation, or application in bands over the sorghum row.

Herbicides Applied Postemergence

The only foliar-applied herbicide that controls annual grasses in sorghum is atrazine with crop-oil concentrate, and this must be applied to very small grass seedlings. Application rates of more than 1 pound per acre are not considered best management practices because of high potential for atrazine loss in surface-water runoff.

Several foliar-applied herbicides are available for broadleaf-weed control. Products such as bromoxynil plus atrazine, Laddok S-12, Marksman, and Shotgun all contain about 0.5 pound atrazine along with other herbicides. They should be applied when sorghum is in the three- to six-leaf stage and weed sizes conform to label guidelines.

Peak and Permit are two recently developed sulfonylurea herbicides for sorghum that work by inhibiting the function of the acetolactate synthase (ALS) enzyme. They are often tank-mixed with dicamba or atrazine to control a broader spectrum of weeds and to help control ALS-resistant species, which are immune to those types of herbicides.

A common mistake is applying postemergence herbicides too late for optimum weed control. Bromoxynil (Buctril and Moxy), bentazon (in Laddok), and atrazine all kill weeds through foliar contact and do not move through the plant; therefore, weeds may recover even after having lost their leaves. Systemic herbicides are translocated from the foliage throughout the plant and are more effective on larger annual weeds and may help control perennial weeds such as field bindweed.

Dicamba (Banvel or Clarity) and 2,4-D are among the least expensive herbicides for broadleaf-weed control in sorghum. These herbicides act as growth regulators, often causing temporary leaning and brittleness in sorghum plants. Such plants are more vulnerable to wind and cultivator damage. Application to sorghum more than 8 inches tall should be made with drop nozzles to reduce potential for sorghum injury.

Cultivation of Sorghum Rows

Cultivation remains an option for control of weeds between bands of herbicides and for later-emerging weeds. Heavy, high-residue cultivators can be effective even in no-till planted sorghum. They also can be used as backup where herbicides have performed poorly and where perennial weeds have not been controlled. Electronic guidance systems can increase cultivating speed and efficiency by reducing operator fatigue and cultivator blight.

Fertilizer Requirements

Grain sorghum is grown throughout Kansas under a wide range of climatic conditions. Sorghum is considered very efficient in utilizing nutrients from the soil because of a large fibrous root system; however, profitable responses to fertilization can be expected on many Kansas soils. Total nutrient uptake by sorghum is similar to that of corn and wheat at comparable yields.

Nutrient content of the grain and stover for a sorghum crop of 100 bushels per acre is shown in Table 4. The data show that harvesting only the grain removes considerably less nutrients than if the entire crop is harvested for silage.

Fertilizer and lime needs can best be determined by soil tests with supporting experience and field-history information. Soil tests are, however, no better than the sample collected in the field. Interpretations of soil tests and resulting fertilization recommendations are made based on many years of research conducted across the state. Fertilizer rates are targeted for optimum yields assuming yield potential is not restricted by other growth-limiting factors.

Nitrogen

Nitrogen is the element most frequently lacking for optimum sorghum production. Nitrogen recommendations will vary with expected yield, soil texture, and cropping sequence.

A soil test for available nitrogen in the soil profile is encouraged where nitrogen or manure applications have been excessive relative to yields. The profile nitrogen soil test is used to reduce nitrogen application so accumulated available nitrogen is utilized. Consult *Soil Testing Laboratory,* MF-734 for instructions on proper soil sampling and handling. Samples should be taken to a depth of 2 feet and must be air-dried after collection to minimize mineralization in handling and shipping.

Another important consideration in determining the optimum nitrogen rate is cropping sequence. Research in Kansas and adjoining states shows nitrogen credits for legumes grown in rotation with sorghum can be substantial. Table 5 summarizes nitrogen credits for legumes in rotation with sorghum and the basic nitrogen-recommendation adjustment for these credits.

Nitrogen recommendations can be calculated by using these factors:

N_{rec} = [YG × 1.25] STA – PCA – PYM – PNST

where

N_{rec}: nitrogen recommended in pounds per acre

YG: a realistic yield goal in bushels per acre

STA: soil texture adjustment (1.1 for sandy soils and 1.0 for medium and fine textures)

PCA: previous crop adjustment [use Table 5 for previous legumes, 20 pounds for fallow (if no profile nitrogen test) and zero for all other previous crops]

PYM: previous year's manure (50 pounds for last year, 20 pounds for 2 years ago, and zero for no manure history)

PNST: profile nitrogen soil test results —

surface: ___ ppm N × .3 × ___ depth (in) = ___ lbs/acre

subsoil: ___ ppm N × .3 × ___ depth (in) = ___ lbs/acre

profile N = ___ lbs/acre

Note: If no available nitrogen test is run, then use default value of 30 for PNST.

Table 4. *Approximate Amount of Nutrients in a 100-bushel-per-acre Sorghum Crop*

	Quantity in pounds	
Element	Grain	Stover
Nitrogen (N)	84	95
Phosphorus (P_2O_5)	42	20
Potassium (K_2O)	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

Source: Adapted from the National Plant Food Institute.

Table 5. *Nitrogen Credit for Legumes in Rotations*

Previous legume	Nitrogen credit (pounds per acre)
Alfalfa	
>80% stand	100 to 140
60-80% stand	60 to 100
< 60 % stand	0 to 60
Second year	½ of first-year credit
Red clover	40 to 80
Sweet clover	100 to 120
Soybeans	30 to 60

Example:

Expected yield = 100 bushels per acre
Soil texture = silt loam
Previous crop = sorghum
Previous manure = none
Soil test = 15 ppm for top 6 inches
10 ppm for 6 to 24 inches

N_{rec} = (100 bu/acre × 1.25 lbs/bu) 1.0 – 0 – 0 – 81[(a)]
= 44 lbs/acre

[(a)] [15 ppm × 0.3 × 6 in] + [10 ppm × 0.3 × 18 in] = 81 lbs/acre

Field comparisons of nitrogen sources conducted by K-State researchers indicate little agronomic difference between sources when properly applied. For no-till or reduced-till systems that leave almost a complete residue cover, materials containing urea should be injected below the residue to minimize volatilization and immobilization losses. Source selection should be based on cost (applied), availability, adaptability to farm operation, and dealer services.

Nitrogen application for grain sorghum can be made at various times with equal results on most soils. Nitrogen utilization is quite rapid after the plants reach the five-leaf stage; by boot stage, 65 to 70 percent of the total nitrogen has been taken into the plant. Nitrogen applications should be timed so nitrogen is available when needed for this rapid growth. Preplant nitrogen applications can be made in late fall or spring (except on sandy soils) with little concern for leaching loss. On sandy soils, preplant nitrogen applications should be delayed until spring, sidedressed, or split with part in the spring and part sidedressed. If nitrogen is applied sidedress, the applications should be made by shortly after the five-leaf stage.

Application of nitrogen through the irrigation system has been quite satisfactory on sandy soils. Application of nitrogen through irrigation systems under other soil conditions is possible, but the fertilizer distribution is no better than the water distribution. No nitrogen material that contains free ammonia should be used when applying through a sprinkler system unless special precautions are taken. A small amount of nitrogen also may be applied in starter fertilizer.

Phosphorus

Phosphorus application should be based on a soil test. Consistent responses to phosphorus fertilization have generally occurred on soils testing very low or low in available phosphorus where yield potential is not restricted by low rainfall. With medium-testing soils, responses have been erratic and normally quite small. Phosphorus applications are recommended on medium-testing soils for their potential yield response and to maintain the soil in a highly productive condition. Phosphorus recommendations are shown in Table 6.

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

Preplant applications can be made in the fall or spring and should be thoroughly incorporated because phosphorus does not move appreciably in the soil. With no-till or reduced-till seedbed preparation, preplant-knifed or banded at seeding are preferred over broadcast.

Liquids, solids, and varying chemical forms of phosphorus (ortho- and polyphosphates) are available. K-State research indicates, in general, all are agronomically equal. Selection of a phosphorus source should be made on the basis of cost, availability, and adaptability to the operation.

Potassium

As with phosphorus, a soil test is the best guide to potassium need (Table 7). Potassium removal is much greater with silage than with grain production. Additional potassium should be considered in cropping sequences including forage sorghum because of the greater potassium removal. Potassium deficiencies are most likely to be found in southeastern Kansas and on sandy soils in other areas of the state.

Table 6. *Phosphorus Recommendations for Sorghum*

	Soil test for phosphorous (ppm)				
	Very low	Low	Medium	High	Very high
	<5	5-12	13-25	26-50	>50
	pounds per acre of P_2O_5				
Irrigated	50-70	30-50	20-30	0-20	none
Nonirrigated	40-60	30-40	20-30	none	none

Table 7. Potassium Recommendations for Sorghum *

	Soil test for potassium (pp2m or lbs/acre)				
	Very low <40	Low 40-80	Medium 81-120	High 121-160	Very high >160
	pounds per acre of K_2O				
Irrigated	80-100	60-80	40-60	20-40	none
Nonirrigated	60-80	40-60	20-40	0-20	none

* If silage is produced, add 40 K_2O to the recommendation.

Potassium should be applied preplant-broadcast, preplant-knifed, or banded at seeding. Broadcast applications should be thoroughly incorporated to get the potassium in the root zone. The most common potassium source is muriate of potash (potassium chloride); however, potassium sulfate, potassium nitrate, potassium-magnesium sulfate, and mixed fertilizers are good potassium sources. Little difference in potassium availability exists among them. Selection should be based on cost, availability, and adaptability to the farm operation.

Lodging of grain sorghum at maturity can be a problem in many areas of Kansas and can result in considerable harvest loss. Research has shown lodging occurs due to many factors—weather stress, insect and disease damage, hybrids, date and rate of planting, and nutrient imbalance. Adequate potassium is essential for sturdy stalks, and research has shown potassium fertilization can reduce lodging on medium- to low-testing soils. Recent research has shown adequate chloride may be as important as potassium in stalk strength. Potassium chloride at 40 to 50 pounds per acre supplies adequate chloride.

High application rates of potassium fertilizer for insurance against lodging is not recommended. Fertilization with proper levels of all nutrients plus good crop-management practices in general is the best way to minimize lodging. Weather conditions play a major role in lodging, and they cannot be controlled.

Liming

Lime recommendations are intended to maintain productive soils. Sorghum is not the most responsive crop to lime, but liming of acidic soils should not be ignored. Although yield increases may be small, liming is a sound farming practice. In the eastern third of Kansas, lime is recommended for sorghum on soils with a pH of 6.0 or less. For the rest of Kansas, lime is recommended for sorghum on soils of pH 5.5 or less. If sorghum is grown in a cropping system that includes legumes, the pH should be maintained at the optimum pH for the legume.

Other Elements

Secondary and micronutrient research has demonstrated a need for zinc and iron in some situations. Calcium and magnesium are relatively abundant in most Kansas soils. Liming of acidic soils supplies sufficient calcium, and a deficiency of this element would not be expected. Research with boron, copper, and manganese has not revealed any consistent responses, and these elements should not be a problem for optimum sorghum yields.

Sulfur may be lacking on sandy soils low in organic matter (less than 1.5 percent). On irrigated sandy soils, sulfur would only be of concern when sulfur levels in the irrigation water are low. Much of the irrigation water in Kansas contains an appreciable amount of sulfur. Current sulfur soil tests, when used alone, are poor predictors of sulfur deficiency. Farmers with sandy soils low in organic matter and a low sulfate soil test should try sulfur to ascertain the likelihood of a sulfur response.

The need for zinc (Table 8) and iron can be predicted by soil tests. Zinc is most likely deficient on areas where the topsoil has been removed and under high-yield conditions. Iron deficiency is most likely to occur in the western half of Kansas on soils where erosion or leveling has exposed highly calcareous subsoil, which also is low in organic matter and has a high pH.

Zinc usually is applied in conjunction with phosphorus and potassium, and time and method of application discussed in those sections are applicable to zinc. Inorganic and organic (chelate) sources of zinc are available for application with the chelates generally being three to five times more effective per pound of metal. Remember, however, small application rates are more effective if banded close to the seed.

No economical source of iron for soil application is currently available for correction of iron deficiency in sorghum. Foliar sprays of iron and manure application are the most effective methods of correcting iron chlorosis.

Table 8. Zinc Recommendations for Sorghum

	DTPA-extractable zinc (ppm)		
	Low <0.5	Medium 0.5-1.0	High >1.0
	pounds per acre of zinc *		
Irrigated	8-10	2-5	none
Nonirrigated	2-5	none	none

* Based on the use of zinc sulfate as the source of zinc.

Irrigation

Grain sorghum peaked in popularity as an irrigated crop in the early to mid-1980s (Figure 5) and remains one of the top five irrigated crops in the state. Corn, wheat, soybeans, and alfalfa are the other four. Currently, about 250,000 acres of the 3 million irrigated acres in Kansas are planted to grain sorghum.

Grain sorghum has a drought-tolerant reputation; therefore, it is a choice for some irrigators with low-capacity wells and limited water. Good yield response to limited water applications are possible. Under full irrigation, corn generally becomes the preferred feed-grain crop due to increased yield potential.

Water-use Requirements

Grain sorghum will use about 18 to 22 inches of water to produce a normal yield in the western part of Kansas. Its use requirements will be 1 to 2 inches less in the eastern part of the state. The total amount of irrigation water needed depends on the season and the amount of soil water stored in the root zone.

Figure 5. *Kansas Acreage Trends for Irrigated Corn, Grain Sorghum, and Wheat*

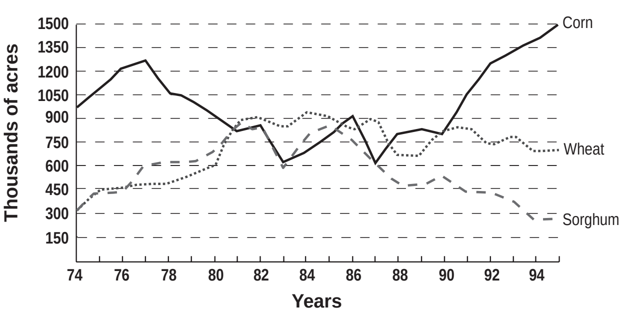
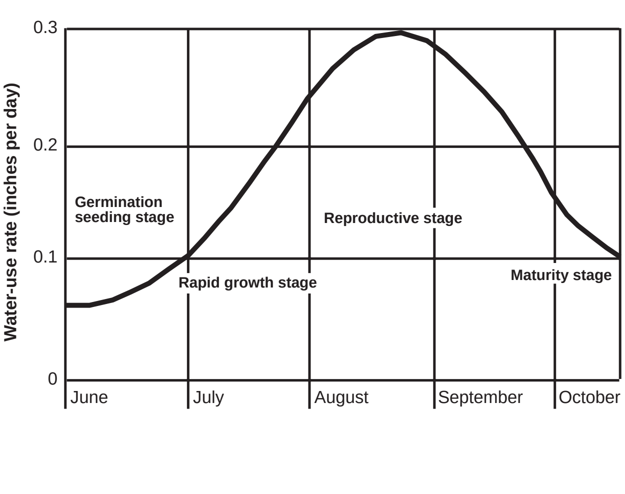


Figure 6. *Characteristic Water-use Pattern of Grain Sorghum*



Dry-year-irrigation estimates (*NRCS Irrigation Guide*) for grain sorghum range from about 15 inches in southwest Kansas to less than 7 inches in southeast Kansas. Irrigation estimates for years with average rainfall are from about 13 inches in the west to 4 inches in the east. These range estimates are for well-watered conditions.

Grain sorghum is generally one of the later-planted summer crops. This allows for the soil profile to accumulate water prior to planting and often means the reproductive stage begins after the hottest weather of the summer passes. Water-use rates for the various growth stages are shown in Figure 6. Average peak water-use rates are about 0.3 inch per day, although occasionally a single-day peak use might approach 0.5 inch per day. Table 9 shows estimated water-use rates for various growth periods.

Grain sorghum develops an extensive root system, which can extend to 6 feet in a friable soil. Irrigation scheduling usually accounts for only the upper 3 feet of the root zone since most of the water extraction will occur in this region. About 75 percent of water use will occur in the upper half of the root zone. Under stress conditions, when the upper zone becomes water-limited, the crop will use significant deep water as illustrated in Table 10.

Irrigation Management

Grain sorghum is a crop that lends itself to a limited irrigation-scheduling program. For high-water-holding-capacity soils, like medium-textured silt loams or heavier clay loams, one or two in-season irrigations

Table 9. *Average Daily Water-use Rate by Phenologic Periods for Irrigated Grain Sorghum Grown under Unlimited Soil Moisture for Plant Development, Garden City*

Time	Water use, inches per day
Emergence to 12-inch height	0.16
12-inch height to boot stage	0.27
Boot to heading stage	0.29
Heading to milk stage	0.25
Milk to soft dough stage	0.20
Soft dough to maturity	0.13

Source: Technical Bulletin 113

(6 to 8 inches) will produce 80 to 90 percent of the full yield potential under most circumstances.

Review of research trials in western Kansas demonstrates the utility of grain sorghum as a limited-irrigation crop (Table 11). In general, one or two irrigation applications, which were generally large (4 or 6 inches), provided near-maximum yield potential as compared to treatment with three or four in-season irrigations. These trials were on deep silt loams. Although most of these trials included a preplant irrigation, preplant irrigation is not recommended if any in-season irrigation is planned. In most years, sufficient rainfall is available to recharge the upper root zone, making preplant irrigation an inefficient water-use practice.

In addition to being able to extract water from a great depth within the root zone (Table 10), grain sorghum is able to extract soil water at a lower percentage of available soil water without yield loss when water is limited in the upper root zone. The general irrigation-management recommendation is to maintain soil water at or greater than 50 percent available. For grain sorghum, however, the soil water can be depleted to an average of 30 to 40 percent available water before grain yields are severely reduced (Figure 7). Scheduling based on soil-water depletion or crop-water use (evapotranspiration or "ET") rates would be recommended when full irrigation of grain sorghum is intended.

Full and limited irrigation of grain sorghum on sandy soils require more-frequent and smaller irrigation applications, which matches the capability of center-pivot systems commonly used to irrigate sandy soils. Irrigation scheduling using evapotranspiration or by maintaining a given soil-water-depletion balance may be most useful in this condition where low-water-holding capacity and restricted root zones present challenges to irrigation management. Underirrigation can quickly result in yield-limiting stress. Single, large irrigation can result in nutrient leaching and inefficient water use due to deep percolation.

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

Irrigation Summary

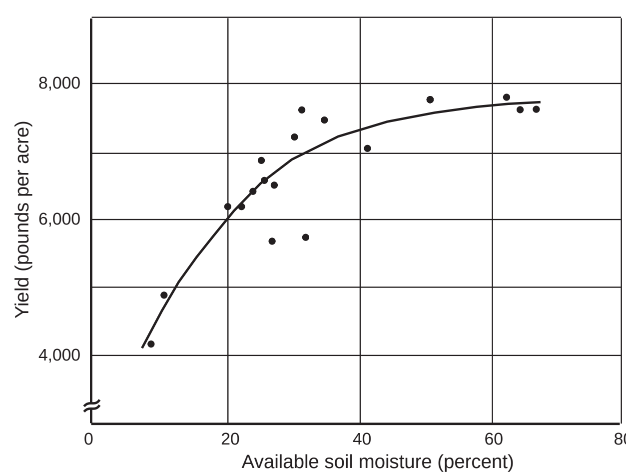
- Grain sorghum's water-use rate is similar to other summer crops and peaks at about 0.3 inch per day. The peak use begins at approximately initiation of the reproductive stage.
- Seasonal water need is 18 to 22 inches.
- Irrigation requirements vary from less than 6 inches in the east to about 15 inches in the west under well-watered conditions in normal years.
- Grain sorghum has an extensive root system, and its drought tolerance makes it suitable for limited irrigation.

Table 10. *Water-extraction Patterns under Different Soil-water Conditions, Garden City*

Depth (feet)	Normal (no stress)	Moderate stress	Moderate to severe stress
0-1	31.4%	25.3%	7.5%
1-2	23.2	18.9	7.3
2-3	18.4	19.9	14.8
3-4	13.4	17.9	24.9
4-5	7.6	11.7	24.4
5-6	6.0	6.3	21.0

Source: Technical Bulletin 113

Figure 7. *Percent Available Soil Water to the 4-foot Depth Prior to Irrigations*



Source: Conservation Research Report #5, 1965

Table 11. *Summary of K-State Irrigated Grain Sorghum Tests in Western Kansas (Bushels per Acre)*

Treatment description	Garden City 1954-59	Colby 1970-72	Tribune 1974-77	Garden City 1976-78	Garden City 1976-82	Colby 1978-79	Colby 1982-85
Nonirrigated	32						
Preplant (pre)	77	101	94	99	110	93	
Pre + early vegetation (ev)	102	107			124		
Pre + ev + boot	112			129	123		
Pre + ev + boot + milk	116	107	106	129		101	
Pre + boot or bloom		102	103	120	118	101, 97	
Pre + boot + head		106	100			105	
Pre + soft dough or milk			104			100	
Pre + boot + milk		105	105				
Pre + head + milk		102	101				
Pre + 50% depletion				128	134		
July		106			105		
August		103					
July & August		112					
Scheduled based on:						Colby (1982-85)	
1.4 × ET (excess irrigation)						105	
1.2 × ET (excess irrigation)						98	
1.0 × ET (normal irrigation)						106	
0.8 × ET (limited irrigation)						99	
0.6 × ET (limited irrigation)						94	
0.4 × ET (limited irrigation)						85	

Major Sorghum Diseases

Diseases of sorghum, like those of other crops, vary in severity from year to year and from one locality or field to another, depending upon environment, causal organisms, and the host plant's resistance. Estimates of annual sorghum yield losses in Kansas average about 5 percent.

The total eradication of disease in sorghum is not economically feasible, so growers must try to minimize their damage through an integrated pest-management system. Planting resistant hybrids; providing optimum growing conditions; rotating with other crops; removing infested debris; planting disease-free seed; proper seedbed preparation; and accurate application of herbicides, insecticides, and fungicides are all methods that can be used to minimize losses from disease.

Although sorghum is susceptible to many diseases, there are only a few that cause or have the immediate potential to cause economic losses in Kansas on a regular basis. They are described in Table 12.

Note: Disease and insects with asterisk (*) are illustrated on the inside back cover.

Table 12. *Sorghum Diseases*

Disease and cause	Symptoms	Occurrence	Control
Seed rot Mostly fungi: *Fusarium* *Rhizopus* *Aspergillus* *Penicillium* *Pythium*	Thin, uneven stands. Weak emergence. Shoots appear yellow. Seeds show general rot, blackened embryos, reddened and necrotic roots.	Most noticeable following prolonged periods of cool, wet weather just after planting. Poorly drained soil.	Captan is routinely used as a seed treatment. Metalaxyl is recommended for Pythium control.
Seedling rot Damping-off Same as for seed rot	Death at or prior to emergence. Rots observed at the soil line. Thin, uneven stands.	Same conditions as for seed rot. Also may occur during hot weather at emergence.	Same as for seed rot.
Seedling blight * *Fusarium* is the principal pathogen	Stunted growth, discolored leaves (reddish), red to black roots with dead areas.	Same as for seed rot. Also may occur in hot weather at time of secondary root development	Avoid acidic soils (pH <5.5). Acid amide herbicides may increase seedling blight severity.
Root rot Soilborne fungi	Plants easily uprooted. Outer portion of roots easily strips off and is red, gray or black. Top growth is stunted.	Generally present every year. Most important under adverse growing conditions.	See Fusarium stalk rot.
Stalk rot Fusarium stalk rot * *Fusarium* spp. See Extension Bulletin L-741, *Stalk Rots of Corn and Sorghum*	Premature death of plants. Roots usually show considerable rot. Infected stalk tissue is discolored with salmon to dark red hues predominating.	Disease is favored by abundant moisture and moderate temperatures following head initiation	Some hybrids are more resistant than others. Continuous cropping, high nitrogen levels, high plant populations and loss of leaf area to insects, disease or hail tends to intensify stalk rots.
Charcoal rot *Macrophomina phaseolina* See Extension Bulletin L-741	Chlorosis of the head stalk is the first symptom. Stalk disintegration with numerous small, black bodies (sclerotia) scattered throughout.	Most apt to occur in light or shallow, drought-stressed soils. Disease may be present only in scattered areas of the field.	Some hybrids are more resistant than others. Reduce plant populations to avoid stress. Later-maturing hybrids often escape infection.

Table 12. *Sorghum Diseases (continued)*

Disease and cause	Symptoms	Occurrence	Control
Viral diseases			
Maize dwarf mosaic virus * (MDMV-A) Sugarcane mosaic virus (MDMV-B) See Extension Bulletin L-481	Mosaic patterns (alternating light and dark green areas) on whorl leaves. Cool nights (below 60 F for Strain A, below 70 F for Strain B) may cause red and necrotic areas resembling a blight. Flowering may be delayed. Seed may be underdeveloped.	Virus is carried by insects, mostly greenbug and corn leaf aphid. MDMV overwinters in Johnson-grass.	Plant tolerant hybrids. Hybrids expressing only the mosaic reaction show less reduction in yield than plants with red leaf symptoms.
Small seed Primarily MDMV	Red to black lesions develop on panicle branches. Often damage is limited to point of seed attachment-appears as a black dot inside floret. As seed shrinks it becomes a dull color	Observed when the crop matures during soft dough. Most common during cool, wet weather.	Hybrids resistant to MDMV are not immune to small seed. No practical controls at present time.
Foliar diseases caused by fungi [1]			
Sorghum ergot *Claviceps africana*	Ovary is converted to a white fungal mass visible between the glumes. Exudation of a sweet, sticky "honeydew" from the infected flowers occurs. Honeydew that drips onto leaves or soil produces a white, powdery mass during moist conditions.	Worldwide wherever sorghum is grown. Male-sterile forage sorghums and hybrid seed production fields are most susceptible.	Avoid planting male-sterile forages or hybrids with cold sterility problems. Avoid late planting. Later plantings should have increased plant populations to discourage secondary tillers.
Northern corn leaf blight *Exserohilum turcicum*	Large (2 inches or more) elliptical spots with gray centers and tan to reddish borders. Very similar to sooty stripe.	Most prevalent during prolonged periods of warm and humid weather.	Crop rotation. Resistant hybrids.
Sooty stripe * *Ramulispora sorghi*	Elongated spots that may extend several inches with broad, yellow to orange margins. A sooty-like growth is generally present on the underside of the lesion.	Oldest leaves usually are attacked first and most extensively. Yield losses of 25% or more have been recorded.	Crop rotation. Full season hybrids appear to be more resistant.
Rust *Puccinia purpurea*	Small brown pustules or blister-like growths on the upper and lower leaf surfaces.	Usually appears late in the growing season. Favored by warm, moist weather. Significant losses can occur if infection occurs early.	Resistant hybrids.
Crazy top downy mildew *Sclerophthora macrospora*	Light colored leaves become stiff, leathery, upright, with roughened, blister-like appearance. If heads appear, glumes are often proliferated to give "crazy top" symptom.	Most severe when flooding occurs on seedbeds or young seedlings. Also, in poorly drained or heavy soils. Many grasses are susceptible including wheat and corn.	Several hybrids are resistant. Avoid areas where the disease is a recurring problem . Seed treatment with metalaxyl.

Table 12. *Sorghum Diseases (continued)*

Disease and cause	Symptoms	Occurrence	Control
Foliar diseases caused by bacteria [2]			
Bacterial stripe *Pseudomonas andropogonis*	Long, narrow, reddish or tan stripes depending upon hybrids. Lesions usually confined between veins. Shiny, crusty spots from exudate generally found on underside of leaves.	Most common bacterial disease. Prevalent during cool, humid weather.	Control measures have not been warranted.
Bacterial streak *Xanthomonas holcicola*	Narrow, water-soaked, translucent streaks about 1/8 inch wide by 1 to 6 inches in length. After several days, lesions turn red.	Very common during warm, humid weather.	Control measures are not warranted
Other sorghum diseases [3]			
Sorghum downy mildew *Peronosclerospora sorghi*	Vivid green and white stripes on leaves in late spring or early summer. Leaves shredded by wind until most leaf veins are separated . Heads partially or completely sterile.	Most noticeable when sorghum is planted after sudan grass. Most common in eastern and south central Kansas.	Do not plant sorghum after sudan grass. Crop rotation. Hybrid differences in susceptibility exist. Ask seed company for list of tolerant hybrids. Seed treatment with metalaxyl.
Gray leaf spot *Cercospora sorghi*	Dark purple spots having a grayish cast during spore production. Rectangular lesions, 1/4 inch and larger.	Usually occurs late in growing season as the crop is maturing. Little, if any, losses occur.	Same as northern corn leaf blight.
Anthracnose *Colletotrichum graminicola*	Small, circular to elliptical spots 1/8 to 1/4 inch in diameter. Depending on the hybrid, lesions may be tan, orange, red, or blackish-purple.	Most prevalent in areas where periods of high humidity alternate with relatively dry periods.	Same as northern corn leaf blight.
Zonate leaf spot *Gloeocercospora sorghi*	Circular, reddish-purple bands alternating with tan or straw colored areas which give a concentric zonate, or bull's-eye appearance. Lesion diameter may extend several inches.	Most severe during prolonged periods of high humidity.	Same as northern corn leaf blight.
Head smut *Sporisorium reilianum*	A portion or all of the head replaced by smut galls.	Plants are infected in seedling stage; symptoms are not apparent until boot or heading stage. More severe in south central and southwest Kansas.	Chemical controls are not effective. Utilize resistant hybrids.

1 There are many foliar diseases caused by fungi that can occur on sorghum. Seedling blights, stalk rots, sooty stripe, rust, northern corn leaf blight, and crazy top downy mildew can cause economic losses to occur in some years and on some hybrids. Since fungicide control is not available with the exception of seed treatments, management usually consists of selecting resistant hybrids and cultural practices such as crop rotation and the removal of residue where soil erosion is not a problem.

2 Bacterial leaf spots have not been shown to cause yield losses under Kansas conditions, but they are generally present every year, particularly under wet, humid conditions.

3 The previously described diseases represent those that occasionally cause significant yield losses in Kansas and those that, though not causing economic damage, are present on a regular basis. In addition, there are a number of diseases that occur sporadically in Kansas, only a few of which have the potential to cause economic yield loss. The most notable of these is sorghum downy mildew, which has caused significant yield losses in the past, but it is now effectively controlled using resistant hybrids and chemical seed treatments.

Spray Injury

Red, brown, or black spots or streaks become evident within 7 to 10 days after application. Injury occurs most often after spraying for aphids at the heading stage. Watch for patterns that coincide with application practices. Sorghums vary in sensitivity and expression. In severe cases, elongated streaks may appear as a general blight on leaves, not unlike bacterial streak or maize dwarf mosaic virus (MDMV). Parathion-type insecticides are commonly implicated. Damp mornings and hot days seem to compound the problem. Follow label directions carefully.

Major Sorghum Insects

Insect problems in sorghum vary in different areas of the state, from season to season, and from field to field. The greenbug is generally of primary concern since it occurs statewide and is capable of causing serious damage, and sorghums are susceptible to attack at almost any time during the growing season. Chinch bugs rank high in importance in central and eastern Kansas, particularly during dry seasons. In addition, there is a relatively large group of insects that may, at times, be of local importance. Those of most frequent concern are described in Table 11. Most growers realize that not all insects found in sorghum are destructive; some are beneficial. Among those that are destructive, the amount of economic injury caused will vary according to the species, density of the infestation, the crop growth stage, and sometimes other factors. Economic injury is defined as causing a loss that would be equal to or greater than the cost of control.

For more information on insect problems and their control, obtain a copy of *Sorghum Insect Management Recommendations*, MF-742, for the current year. This publication is available either at county Research and Extension offices or from the Distribution Center, K-State, Umberger Hall, Manhattan, KS 66506. For more information on identification of sorghum insects, ask for sorghum insect picture sheets No. 1 and No. 2, and for more information on scouting techniques and damaging levels of insect populations, request a copy of *Sorghum Insect Scouting Procedures*. These last two publications are available only from Extension Entomology, K-State, Waters Hall, Manhattan, KS 66506.

Table 11. *Insects of Frequent Concern in Sorghum*

Time of year/ crop growth stage	Description	Distribution	Probable insect
1. Planting time; seed-attacking insects	Poor emergence of plants or seeds fail to germinate. Seeds mechanically injured or destroyed.	Statewide	False wireworms, seed corn beetles, kafir ants, wireworms
2. Early season	Plants stunted or lodging early in the season. Occasionally, plants die. Underground portion of stems show signs of tunneling and feeding. Hard-shelled yellowish larvae may be present.	Statewide	Wireworms
3. Early season	Plants stunted or lodged. Roots destroyed or severely pruned. C-shaped whitish grubs present.	Statewide	White grubs
4. Early season	Leaves exhibit moderate to excessive amounts of feeding damage. Some expanded leaves with rows of transverse round to oblong holes. Affected plants may be stunted or dying. Usually found in lower spots within fields corresponding to where yellow nutsedge grew last year.	Statewide	Billbugs

Table 11. *Insects of Frequent Concern in Sorghum (continued)*

Time of year/ crop growth stage	Description	Distribution	Probable insect
5. Seedlings to 6-inch plants	Upper epidermis of leaf tissue chewed away. Pattern shows as a series of streaks or whitish stripes. Definite mechanical destruction of tissue can be observed. Tiny, hard-shelled, shiny beetles, 1/16 inch long, jump rapidly when disturbed.	Statewide	Flea beetles
6. Seedlings to 6-inch plants	Similar to flea beetle injury. Small, fine white streaks present on surface of leaf tissue. Small splinter-like insects present on the plants, usually in the whorls. Less than 1/16 inch long; color varies from transparent to dark; some winged, some not.	Statewide	Thrips
7. Seedlings to 6-inch plants	Plants partially or totally cut off just above or below the soil surface. Brownish to blackish worms may be present, generally under the soil surface in the vicinity of injured plants.	Statewide	Cutworms
8. May to June on seedling plants	Small seedlings show signs of reddening, sometimes plants dying. Insects present on above-ground portions of the plant. Tiny, light green, soft-bodied insects. Or, sometimes, if insects have disappeared, numerous whitish cast skins present on foliage and soil around affected plants.	Statewide, but more common in central and eastern areas	Greenbugs *
9. May to June on seedling plants	Injury similar to #8, except affected leaves develop distinctive purplish color, older leaves may fire and turn yellow. Insects similar to greenbugs, but somewhat smaller, lemon-yellow color.	More common in eastern areas	Yellow sugarcane aphids
10. May to June; seedlings to 6-inch plants	Medium to dark green sucking insects present, especially in whorls of plants. Prominent cornicles or tail-pipes present on upper side near rear of body. Tail-pipes are darkish in color. Area around base of tail-pipes is also darkish in color. Generally no visible injury associated with these insects, even though they may be quite numerous. Also see #13.	Statewide	Corn leaf aphids *
11. May to June; seedlings to 6-inch plants	Damage generally appearing at the margin of the field and progressing inward. Small plants show signs to 6 inches high of stunting or dying. Occasionally much reddish discoloration on lower portions of plants. Partially grown or full-grown bugs feeding either above or below ground on plants. Immature bugs are reddish to blackish with a white stripe across middle of back. Adults black except for whitish wings. Adult insect about 1/8 inch long or less.	Generally in the eastern half of the state, usually in sorghum fields adjacent to wheat	Chinch bugs *
12. May to June; seedlings to 6-inch plants	Small plants dying, larger plants with the central leaves in the whorl dying. Signs of tunneling present on the underground portion of the stem. Frequently destroys the growing point. Silken tunnels may be attached to the underground portion of the plant. Slender worms up to about 3/4 inch in length may be present. Generally greenish to bluish-green. Very agile, move rapidly when disturbed.	Likely to be present in south central areas of Kansas	Lesser corn stalk borer
13. Early season; 6- to 12-inch plants	Plants lodged. Brace roots absent or appear to have dried up (common during some years). Soil dry in the area where brace roots should be developing. Often mistaken for insect injury.	Statewide	Usually physiological
14. June, July, August; whorl stage	Leaves shiny and syrupy, excessive honeydew present, aphids present in upper portions of the plant. Whitish cast skins also frequently present. Some leaves yellow with reddish blotches.	Statewide	Corn leaf aphids *

Table 11. *Insects of Frequent Concern in Sorghum (continued)*

Time of year/ crop growth stage	Description	Distribution	Probable insect
15. June, July, August; whorl or heading stages	Lower leaves shiny and sticky; excessive honeydew deposit. Light green, soft-bodied insects present on underside of leaves. Reddish areas develop on leaves where colonies are present. Leaves die where heavy infestation develops and is allowed to persist.	Statewide	Greenbugs *
16. June, July, August; whorl stage	Holes in leaves. Occasionally, plants very ragged. Damage often more severe on late-planted fields.	Statewide	Fall armyworms
17. August, September; during bloom stage	Small, light brown, fuzzy striped worms present in heads of sorghum, about 1/2 inch long when full grown.	In eastern areas, usually more common in south-east Kansas	Sorghum webworm
18. August, September; during bloom stage	Seeds fail to develop on part or most of the head Heads appear to be “blasted.” Tiny orange or red maggots occasionally present, but generally not visible except under microscope.	In eastern areas, usually more common in south-east Kansas	Sorghum midge
19. August, September	Destroys grain in the developing head. Infestation usually begins during or shortly after bloom. Worms range in size from 1/4 to 1 1/2 inches in length. Larvae possess a series of stripes on the body. Predominant color may be greenish, pinkish, to almost blackish. Head capsule uniform light brown color.	More common in the southern half of Kansas	Corn earworm
20. July, August	Visible feeding on leaves, particularly around field margins. Occasional signs of feeding on developing seeds in the head.	Statewide	Grasshoppers
21. July, August	Discoloration, browning and yellowing of lower leaves; signs of light webbing on underside of affected leaves. Tiny “crawling specks” may be present. Greenbugs sometimes also present.	More common in western parts of Kansas	Spider mites
22. July, August, September	Plant showing signs of stress; occasional poor filling of heads is visible. Clusters of reddish to blackish insects present on lower portions of the stalk.	Eastern half of Kansas	Chinch bugs *
23. July, August, September	Small, grayish insects, similar in size and shape to chinch bugs, but color is different; feeding in the heads of developing sorghum.	Statewide	False chinch bugs

* See photograph, inside back cover. Information on treatment guidelines and management approaches is available at local Research and Extension offices.

Preharvest Desiccants for Sorghum

Grain sorghum is a perennial species. After producing seed, the plant remains green and alive until killed by tillage or freezing temperatures. This presents management problems for sorghum producers. Grain is often slow drying, and harvest is often delayed until late fall, delaying rotation to a winter crop such as wheat. Harvest delays also increase the risk of damage by wind, snow, and birds. Some Kansas sorghum producers are planting the crop earlier in the spring to spread weather risks; however, this does not guarantee an earlier harvest.

Possible Desiccants

Several chemical desiccants are available for preharvest use on grain sorghum. If applied when the grain is physiologically matured, at 25 to 35 percent moisture, sorghum yields are not adversely affected. Grain is at the correct moisture level when kernels at the bottom of the head (the last to mature) show an abscission layer (black layer) at the tip of the kernel.

Diquat may be used to desiccate sorghum grown for seed, but not for feed. Diquat is much like paraquat. Both produce a rapid foliar burn that bleaches leaves and promotes grain drying.

Foliar application of 28-percent nitrogen urea-ammonium nitrate (UAN) to desiccate sorghum was studied at K-State in the 1970s. UAN caused significant leaf desiccation, but it was not very effective in promoting drier grain unless the application was followed by warm, dry weather. There was low recovery of nitrogen by the succeeding crop, suggesting high volatilization losses following treatment.

In 1997, Roundup Ultra was labeled for use as a defoliant in sorghum grown for feed. It is not recommended for sorghum grown for seed because germination may be reduced. Roundup acts less rapidly than Diquat, or 28-percent urea-ammonium nitrate, but it is more effective in killing the sorghum plant. There is a minimum 7-day waiting period between application and harvest, but a 2- to 3-week wait should be expected for Roundup to completely kill the plant. K-State tests have shown that application of 2 pints per acre of Roundup will achieve about a 10-percent decrease in grain moisture compared to grain dried under natural conditions. Roundup may be applied aerially or on the ground and should be applied at 3 to 10 gallons per acre with water conditioned with ammonium sulfate. Application of Roundup in 28-percent urea-ammonium nitrate did not result in satisfactory desiccation, as the burn from the nitrogen interfered with the activity of the Roundup.

Preharvest desiccation of grain sorghum has several advantages over natural crop drying. For early-planted or early-maturing sorghum, it should permit an earlier harvest of drier grain. Weeds growing in the crop should be killed, and late-summer weed-seed production should be reduced. Killing the sorghum plant will halt further water use by the sorghum and permit faster rotation to the next crop.

Harvesting Grain Sorghum

Grain sorghum demands the best combine operators. Most crops have a specific problem (such as header loss in soybeans), but grain sorghum can have difficulties at nearly every point in the combining process. These problems are compounded by the fact grain sorghum often ripens unevenly.

In good-standing grain sorghum, losses can usually be kept to 5 percent of the yield, but only careful adjustment and operation of the combine makes that possible. Additional time and effort will be required, but expenses are already in the crop, and every extra bushel saved is clear profit.

There are five types of harvest loss:

Preharvest loss is typically weather-related and reduced by timely harvesting. Crops left in the field too long can be damaged by birds or field shatter. Severe weather before or during harvest can cause lodging, which makes the crop difficult to harvest.

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

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

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

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

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

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

How to Measure Combine Loss

Ground counts are tedious work, especially in grain sorghum. Nevertheless, they offer a reasonably accurate idea of how much grain is being lost. As a rule of thumb, 17 to 20 kernels per square foot are equivalent to 1 bushel per acre.

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

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

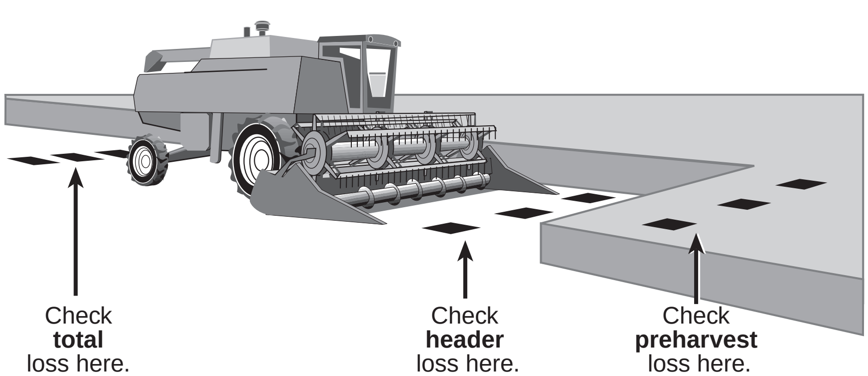
If the total loss was more than 5 percent, the next step is to determine the preharvest loss. Check this in front of the combine in the standing sorghum. Take three counts on 1-square-foot areas, then average them and divide by 20. Subtract the preharvest loss from the total loss to determine the net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

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

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

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

Figure 8. *Determining Harvest Losses*



Drying and Storage

Grain sorghum must be stored at safe moisture and temperature levels to maintain quality prior to marketing. Harvest losses can become excessive if weather conditions do not allow field drying. A low- or high-temperature drying system for handling high-moisture grain sorghum is needed on the farm or at the receiving center.

An individual sorghum seed exposed to air will dry faster than a kernel of corn. The kernel is smaller, and the interior moisture moves a shorter distance. It is harder to move air through a mass of grain sorghum as compared to corn or soybeans. As a result, both the drying and cooling rates of sorghum will be 30 to 50 percent longer as compared to corn, assuming similar grain conditions and drying or storage equipment.

Low-temperature drying systems are affected by weather. During October, the average ambient (outside) air temperature is 55 degrees Fahrenheit with a relative humidity of 65 percent. The temperature and humidity combination limits the natural air's ability to reduce grain moisture content much less than 16 percent in many years. The relative humidity of the outdoor air affects drying potential more in eastern Kansas than western Kansas. If weather conditions do not allow for field drying, low-temperature drying systems using only natural air also will be ineffective. Drying time with a low-temperature system is dependent on weather conditions.

High-temperature drying systems using artificial heat are not impaired by outdoor air conditions. Drying times will increase when drying sorghum in high-temperature dryers. The main energy source for a high-temperature (HT) dryer is propane or natural gas. Available high-temperature drying systems include layer-in-bin, batch-in-bin, continuous-in-bin, column batch, and column continuous.

Batch-in-bin dries sorghum utilizing grain-storage bins with full perforated floors but limiting the drying depth to 4 feet. The airflow is between 10 and 15 cubic feet per minute per bushel and the maximum drying air temperature is 120 to 140 degrees Fahrenheit for drying feed grain and 110 degrees Fahrenheit for drying seed. The higher air temperature (140 degrees Fahrenheit) can be used if the bin has a stirrer or recirculator. After the batch has dried, it is moved to another storage bin with an aeration system. The sorghum must be cooled immediately to avoid storage problems. Layer drying is similar, but the bin is filled in 3- to 4-foot increments. One layer dries before another layer is added.

Column drying (batch or continuous-flow) grain sorghum requires slightly lower air temperatures than with corn because of longer exposure to the high temperatures and the potential fire hazard. The drying air temperature should be 160 to 200 degrees Fahrenheit when using airflows of 100 to 200 cubic feet per minute per bushel. Measuring the grain temperature as it leaves the dryer may be desirable to avoid high-temperature damage.

If the sorghum is not cooled in the column drying, the kernels need to be cooled prior to storage. Column-dryer capacity can be increased by using dyeration or combination drying. Both processes involve moving hot grain 1 to 3 points greater than the desired storage moisture content out of the high-temperature dryer into a storage bin. With dryeration, the grain goes through a sweating process for 8 to 12 hours before fan operation. Combination drying uses a low-temperature drying system to remove the final 1 to 3 points of moisture.

The reduced drying capacity of systems with grain sorghum as compared to corn may encourage the use of higher temperatures or underdrying. Overdried grain may cause a fire and quality problems, and underdried grain may cause storage problems.

Low-temperature (LT) grain dryers are similar to layer-in-bin dryers, but the bin is filled. The fan and motor are designed to move a specified volume of air, varying from 1 to 3 cubic feet per minute per bushel of grain. These units use enough heat to warm the air 5 to 8 degrees Fahrenheit. This increases the moisture-holding capacity of the air. These units should not be operated at ambient temperatures less than 35 degrees Fahrenheit.

At ambient temperatures greater than 60 degrees Fahrenheit, there is potential for increased mold development when using low-temperature drying systems. Low-temperature drying is a slow process and may involve weeks or months, but drying costs have been comparable to high-temperature drying with good management. Typically, these systems work best for sorghum harvested at less than 17-percent moisture.

Farmers should not depend on an aeration systems to dry grain sorghum. Approximately one to two points of moisture is the maximum amount of drying that can be accomplished with an aeration system. With the low airflow rates and minimum drying capability of natural air during the fall, the drying process will be slow.

Holding Wet Sorghum

Wet sorghum cannot be stored as long as corn before spoiling and sprouting. Present recommendations regarding storing wet sorghum follow:

1. Be cautious about storing for more than a day before drying. Longer storage periods require aeration fans on the holding bins and outdoor air temperatures less than 70 degrees Fahrenheit. Wet grain should be removed from the holding bin before refilling.
2. Recognize conditions of 23- to 25-percent grain moisture and grain temperatures of 80 to 90 degrees Fahrenheit are ideal for heating, molding, and sprouting. Safety margins are narrow.
3. Consider adding aeration of 0.5 cubic foot per minute per bushel to the wet holding tank to reduce grain-heating problems. If night temperatures go between 10 and 20 degrees Fahrenheit less than day averages, aeration will be beneficial.

Storing Dry Grain Sorghum

Sorghum producers considering on-farm storage can develop a grain-storage system to store the grain for extended periods without appreciable losses in grain quality or quantity. This requires a working knowledge of what causes storage losses and how to prevent them; a storage system that will hold grain and protect it from weather, insects, birds, and rodents; an efficient, low-labor system for handling and treating the grain; and a planned program of storage management and inspection.

Prior to storage, clean bins thoroughly, treat for insect control, make sure birds and rodents can be controlled, and perform any needed repairs or maintenance to control water or grain leaks. Make sure all handling equipment, conveyors, aeration fans, drying equipment, and other items are in working condition. The bin should be treated with an approved bin-wall spray for grain sorghum.

Grain sorghum should be placed in storage when moisture content is 14 percent or less. The temperature of the kernels should be reduced to 40 to 45 degrees Fahrenheit by aeration as quickly as possible. Insect and mold growth is minimal at these temperatures. Grain sorghum that will be stored for more than 9 months should be treated with a grain protectant. Contact any county Research and Extension office for information on protectants registered for grain sorghum.

Recording the moisture and temperature of loads entering storage is helpful in managing the grain. Temperature and moisture data from the grain mass should be taken on a regular basis. It is recommended that sampling occur once a week during the first month and monthly thereafter. Visual and physical checks of grain sorghum in storage also are helpful. A grain probe may be needed to collect samples in deep bins. Any sudden increase in the temperature of the grain mass is a danger sign. If a temperature increase of 3 to 5 degrees Fahrenheit is recorded in a 1- to 2-week period, immediate corrective action is required to minimize losses. Moisture and temperature readings should be recorded for making management decisions during the storage period.

Round-storage bins are best for long-term storage, easy grain movement, management in storage, and grain-processing systems. Large bins cost less than small ones on a cost-per-bushel basis; however, multiple bins provide flexibility in storing different grains or storage based on quality. Flat storage structures can be converted to other farm uses easily at little cost. It is more difficult to mechanize flat storage for grain handling with stationary equipment, install drying or aeration systems, treat grain, and control rodents or birds. Flat storage is acceptable for short-term storage (6 months or less) or large volumes of one grain.

Storing High-moisture Grain Sorghum

Wet-grain storage accommodates the grain sorghum producer who feeds the grain or has a dependable market agreement with a feeder. It allows early harvest without drying. Structures for high-moisture grain can be either the sealed, “oxygen-free” system or open unsealed storage, such as bunker or trench silos. Sealed systems store the grain whole and process it as removed. Unsealed systems process the grain as it goes into storage.

The recommended moisture level for wet-grain storage is 25 to 30 percent. Grain-preserving acids offer a third option for storing wet grain in conventional bins. When applied as recommended, they provide good protection from spoilage. Bin walls must be protected to prevent corrosion when acids are used. The cost of acid treatment will usually equal or exceed drying costs. Both acid-treated and ensiled grains are limited to use in livestock feeding.

Profit Prospects

Total acres of grain sorghum for grain Kansas averaged almost 3.38 million acres from 1993 to 1996, or 10.8 percent of the state's crop acres. In 1996, Kansas ranked first in the United States in the production of grain sorghum for grain with 354.2 million bushels or 44.1 percent of the total U.S. production. Grain sorghum produced under irrigation represented 7.2 percent of the total grain sorghum acres from 1993 to 1996 and 10 percent of the total production.

Each producer must answer two questions when selecting crops and the acreage of each crop to produce: (1) will this choice be profitable and (2) will this add more to the total net income of the farm operation than other choices? That is, is this the most profitable choice?

The fixed or overhead costs of land and machinery ownership for grain sorghum, soybeans, corn, and wheat will be basically equal for the production period under consideration. Therefore, the variable costs associated with each crop are the costs that need to be considered when selecting a given crop. Variable costs include labor, seed, herbicide, insecticide, fertilizer, fuel, oil, repairs, crop insurance, drying, custom work, crop consulting, and miscellaneous.

Variable costs depend on the management practices used, tillage operations, labor efficiency, and type and fertility of the land. Each producer should develop the variable costs of production for grain sorghum and any other crop alternatives. Expected yield and selling price need to be determined for each crop alternative.

Budgeted variable costs by item are shown for nonirrigated grain sorghum production in western, south central, north central, northeast, and southeast Kansas and for irrigated grain sorghum production. A producer may have higher or lower costs than presented in these budgets.

The prices used in these tables are NOT price forecasts. They are used to indicate the method of computing expected returns above variable costs. These projections should be considered valid only under the costs, production levels, and prices specified. Individuals or groups using the information provided should substitute costs, production levels, and prices valid for the locality, management level to be adopted, marketing circumstances for the location, and time period involved.

The decision to plant grain sorghum or another crop alternative can be made by comparing the expected returns above variable costs for each crop. Returns above variable costs will depend on yields and prices. Each producer should use yields that are reasonable for the land or classes of land operated.

The decision to produce grain sorghum will depend primarily on the costs and expected returns for grain sorghum in comparison with other crop alternatives. However, the producer should take into account other variables such as previous crop rotation, livestock operation, and the machinery and labor requirements of each crop.

The type and amount of equipment, crop rotations, and farm size all affect the cost of producing crops. The tillage practices used and their timing also affect yields and production costs. Each producer should compute the expected returns above variable costs for the farm operation as a means of selecting the crops and acreage of each crop to produce. When computing expected returns above variable costs, consider a number of price alternatives.

***Table 13.** Expected Returns above Variable Costs for Grain Sorghum*

	Southeast	Northeast	South central	North central	Western	*Irrigated	My farm
Yield per acre	80	75	65	70	75	110	______
Returns:							
Yield per acre × $2.35	$188.00	$176.25	$152.75	$164.50	$176.25	$258.50	______
Government payments	8.20	9.34	14.79	12.78	13.23	13.23	______
Total returns	**$196.20**	**$185.59**	**$167.54**	**$177.28**	**$189.48**	**$271.73**	______
Variable costs:							
Labor	$23.22	$23.22	$20.52	$23.22	$12.96	$21.33	______
Seed	4.73	4.73	3.15	3.15	2.63	8.40	______
Herbicide	20.30	20.70	20.10	20.15	15.90	20.35	______
Insecticide	0.00	6.53	4.35	4.35	10.44	10.44	______
Fertilizer and lime	28.78	27.55	23.65	23.10	18.35	29.90	______
Fuel and oil (crop)	6.80	6.65	6.35	7.11	6.47	7.84	______
Fuel and oil (pumping)	0.00	0.00	0.00	0.00	0.00	31.77	______
Machinery repairs	14.20	15.87	13.75	15.47	12.40	16.30	______
Irrigation repairs	0.00	0.00	0.00	0.00	0.00	3.70	______
Crop insurance	0.00	0.00	0.00	0.00	0.00	0.00	______
Drying	8.00	7.50	6.50	7.00	7.50	11.00	______
Custom hire	0.00	0.00	0.00	0.00	0.00	0.00	______
Crop consulting	0.00	0.00	0.00	0.00	0.00	6.25	______
Miscellaneous	5.25	5.25	5.00	5.00	5.00	7.00	______
Interest on 1/2 variable costs (10 percent)	5.56	5.90	5.17	5.43	4.58	8.71	______
Total variable costs	**$116.84**	**$123.90**	**$108.54**	**$113.98**	**$ 96.23**	**$182.99**	______
Expected returns above variable costs	$ 79.36	$ 61.69	$ 59.00	$ 63.30	$ 93.25	$ 88.74	______

* The irrigated grain sorghum budget represents an average of the variable costs for flood and center pivot irrigation practices. Fuel-oil and irrigation repair costs will vary slightly between flood and center pivot irrigation.

***Table 14.** Estimated Variable Costs of Production*

	Southeast	Northeast	South central	North central	Western	Irrigated *	My farm
Grain sorghum	$117.00	$124.00	$109.00	$114.00	$96.00	$183.00	______
Soybeans	107.00	118.00	114.00	106.00	—	165.00	______
Corn	167.00	177.00	172.00	169.00	121.00	329.00	______
Wheat	94.00	92.00	86.00	88.00	84.00	133.00	______

* For each crop, the values represent an average of the variable costs for flood and center-pivot irrigation practices.

Table 15. ***Estimated Costs and Returns for Sorghum Compared with Other Crops for Kansas***

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
Southeast Kansas								
Grain sorghum	80	$2.35	$8.20	$196	$117	$79	$75	$4
Soybeans	28	6.00	8.20	176	107	69	75	– 6
Corn	90	2.60	8.20	242	167	75	75	0
Wheat	35	3.90	8.20	145	94	51	75	– 24

* Based on $625 per acre land at 6 percent; $3.13 per acre taxes. Depreciation, interest, and insurance on $255 per acre machinery investment equals $34.

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
Northeast Kansas								
Grain sorghum	75	$2.35	$9.34	$186	$124	$62	$86	– $24
Soybeans	35	6.00	9.34	219	118	101	86	15
Corn	100	2.60	9.34	269	177	92	86	6
Wheat	35	3.90	9.34	146	92	54	86	– 32

* Based on $800 per acre land at 6 percent; $4 per acre taxes. Depreciation, interest, and insurance on $255 per acre machinery investment equals $34.

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
South Central Kansas								
Grain sorghum	65	$2.35	$14.79	$168	$109	$59	$78	– $19
Soybeans	28	6.00	14.79	183	114	69	78	– 9
Corn	85	2.60	14.79	236	172	64	78	– 14
Wheat	35	3.90	14.79	151	86	65	78	– 13

* Based on $700 per acre land at 6 percent; $3.50 per acre taxes. Depreciation, interest, and insurance on $240 per acre machinery investment equals $32.

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
North Central Kansas								
Grain sorghum	70	$2.35	$12.78	$177	$114	$63	$75	– $12
Soybeans	28	6.00	12.78	181	106	75	75	0
Corn	80	2.60	12.78	221	169	52	75	– 23
Wheat	35	3.90	12.78	149	88	61	75	– 14

* Based on $650 per acre land at 6 percent; $3.25 per acre taxes. Depreciation, interest, and insurance on $245 per acre machinery investment equals $33.

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
Western Kansas								
Grain sorghum	75	$2.35	$13.23	$189	$96	$93	$77	$16
Corn	75	2.60	13.23	208	121	87	77	10
Wheat	40	3.90	13.23	189	84	105	77	28

* Based on 1.5 acres of land for each acre harvested. $525 per acre land at 6 percent; $3.94 per acre taxes. Depreciation, interest, and insurance on $190 per acre machinery investment equals $26.

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
Irrigated Crops								
Grain sorghum	110	$2.35	$13.23	$272	$183	$89	$143	– $54
Soybeans	50	6.00	13.23	313	165	148	143	5
Corn	190	2.60	13.23	507	329	178	143	35
Wheat	70	3.90	13.23	286	133	153	143	10

* Represents an average of flood and center-pivot irrigation practices and was based on $895 per acre land at 6 percent; $4.48 per acre taxes. Depreciation, interest, and insurance on $715 machinery and irrigation equipment investment equals $85. Center-pivot irrigation would have depreciation, interest, and insurance expenses of $116 on a machinery and irrigation equipment investment of $930. Flood irrigation would have depreciation, interest, and insurance expenses of $56 on a machinery and irrigation equipment investment of $505.

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
My Farm								
Grain sorghum	____	____	____	____	____	____	____	____
Soybeans	____	____	____	____	____	____	____	____
Corn	____	____	____	____	____	____	____	____
Wheat	____	____	____	____	____	____	____	____

a. Seedling Blight

b. Fusarium Stalk Rot

c. Sooty Stripe

Major Sorghum Diseases and Insects

d. Maize Dwarf Mosaic Virus (MDMV)

e. European Corn Borer (typical breakage)

f. Greenbug Leaf Damage

g. Corn Leaf Aphids

h. Chinch Bugs

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