UNITED SORGHUM CHECKOFF PROGRAM
Central and Eastern Plains Production Handbook

SORGHUM CHECKOFF

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

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

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

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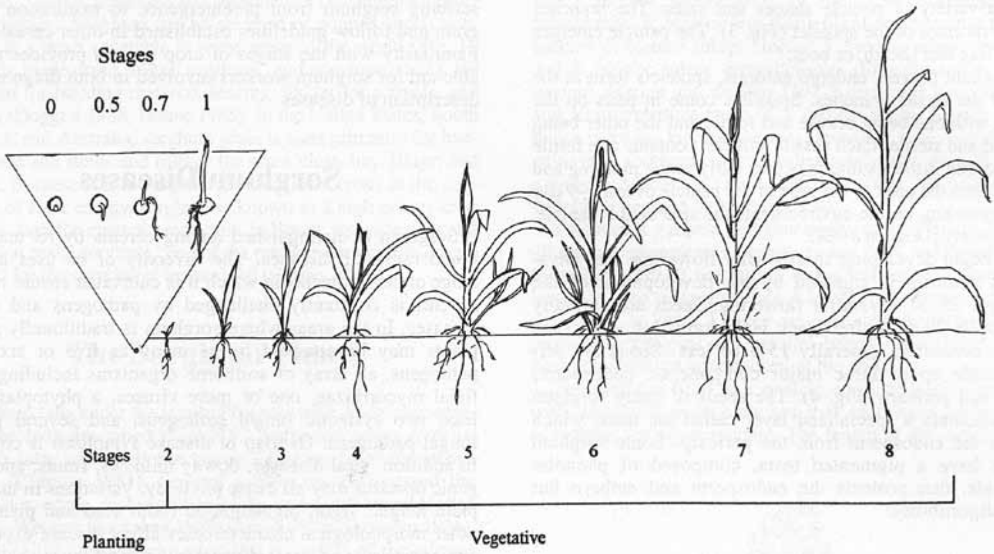
Growth Stages

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

Another common scale that is used among sorghum researchers is a more simplified growth scale. (Fig.1) GS1 would equate to stages 0-5 in this system. GS2 would represent from stages 5-10, and finally, GS3 would be from stage 10 to 11.5.

Comprehensive grain sorghum growth and development guides are available, such as Kansas State's "How a Sorghum Plant Develops" (http://www.oznet.ksu.edu, currently being revised with your sorghum checkoff dollars) and Texas AgriLife's "How a Sorghum Plant Grows," (http://agrilifebookstore.org). Either of these guides provides pictures of different growth stages, graphs of cumulative nutrient uptake relative to growth stages (KSU), or approximate heat unit requirements (base temperature 50ºF, maximum 100ºF) for attaining a particular growth stage (Texas AgriLife).

Refer to Appendix A, page 113, for more information about the sorghum plant.



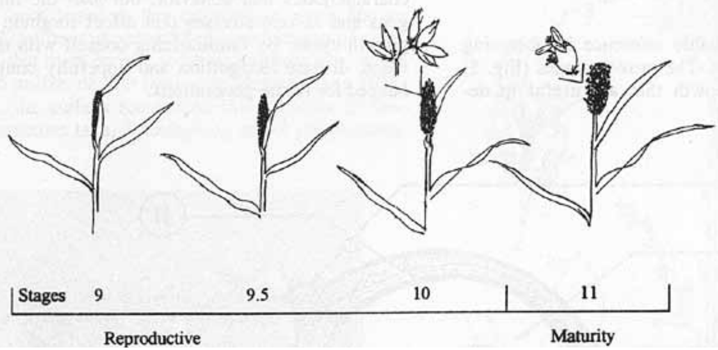


Fig. 1. Stages of sorghum growth: Stage 0: 0.0 planting; 0.1 start of imbibition; 0.5 radicle emergence from seed (caryopsis); 0.7 coleoptile emergence from seed (caryopsis); 0.9 leaf at coleoptile tip; Stage 1: emergence; Stage 2: first leaf visible; Stage 3: third leaf sheath visible; Stage 4: fifth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

A summary of sorghum growth and development is outlined below including:

- Key growth stages
- In-season management suggestions (fertility, post-emerge herbicide applications, irrigation)
- In-season insect activity, their potential effect on the crop, and scouting timing suggestions

Growth Stages	Description and Management Tips
Emergence	Coleoptile visible at soil surface. Coleoptile is the first leaf and is shorter than the later emerging leaves and has a rounded tip (leaf #1).
3-Leaf	Collar of third leaf is visible (once a leaf's collar forms the leaf no longer expands). This stage occurs approximately 10 days after emergence, depending on soil temperature, moisture, planting depth, etc. Slow emergence may lead to more injury from pre-emerge herbicides. Insects: Corn leaf aphids may infest the whorl and greenbugs may infest the leaves although not likely.
4-Leaf	Collar of fourth leaf is visible approximately 15 days after emergence.

Growing point differentiation (GPD)

This key growth stage and its importance are largely unrecognized and unappreciated by producers. The stage occurs approximately 30 to 35 days after emergence, perhaps a few days longer for full-season hybrids, and sooner for early maturity hybrids. It generally corresponds with the 7 to 8 leaf stage. Sorghum can tolerate significant stress from drought, hail, and even freezing temperatures prior to this stage, **however, stress at this stage can significantly impact yield.** Growing point is now above the soil surface, and the plant is approximately 12 to 15 inches tall. The plant may have lost one to three leaves from the bottom of the plant and is entering a period of rapid growth.

The maximum potential number of spikelets and seeds per spikelet is a major component of maximum yield potential and are determined over a period of seven to 10 days.

*Managemen*t: When applying mid season nitrogen in one application, ideally the N should be available in the root zone by GPD, and **irrigation, if available, is recommended to ensure that the growing point is not subject to moisture stress during GPD.** Both good fertility and moisture enhance GPD and the subsequent yield potential. Dryland producers can enhance GPD by applying N early and ensuring that plant population is modest so that each plant has sufficient moisture for good spikelet and seed set.

A note about brace roots, sorghum standability and possible cultivation: Brace roots are key to sorghum's standability. If it appears brace roots are having trouble entering the soil (likely more common for sorghum planted on top of beds where the soil is hotter and drier), then cultivation may be needed to move soil around the base of the plant. If this must be done, ensure that any pruning of the expanding root system is minimized after 30 days.

Flag leaf visible

- Tips of the flag leaf (last leaf, comma which will be smaller) visible in the whorl.
- The last three to four leaves may not be fully expanded.

Insects: Greenbug population may begin to rapidly increase.

Boot

- Leaf collars of all leaves now visible.
- Sorghum head is enclosed in the flag leaf sheath.
- Potential head size has been determined closer to GPD.
- Peduncle is beginning to elongate.
- Stress at this time will reduce the length of the peduncle.

Management: Maximum water use occurs at this stage. Crop will respond very favorably to irrigation at this stage. Historically, this stage of growth is the optimum time to apply limited irrigation if crop is stressed. If you delay up to

20% of N past GPD, the final N should be applied within 60 days of planting or mid-boot, whichever comes first.

Insect: Corn leaf aphids begin to decrease. Greenbugs may be approaching an economic threshold.

Heading

- 50% of the plants in the field have visible heads.

Insects: Greenbugs may be at economic threshold levels.

Flowering

- Occurs when 50% of the plants are in some stage of bloom.
- A plant is considered to be flowering when bloom progresses half way down the head.
- Peduncle is rapidly elongating.
- Flowering occurs over a four to nine day period.
- Stress or herbicide drift can lead to blasted heads.

Insects: Greenbugs may continue as a problem, and mummies may be present. Begin checking for headworms. Sorghum midge potential should be evaluated. For the South Plains and the northern Rolling Plains, sorghum flowering by August 1 will most likely escape significant midge damage potential, but a June 30 flowering is needed in the Concho Valley and lower Rolling Plains to minimize midge potential.

Soft dough

- Grain can be easily squeezed between the fingers.
- Eight to 12 functional leaves remain.
- One half of grain dry weight has accumulated.
- An early freeze will result in shriveled light grain.
- Susceptible to bird damage.

Insect: Greenbugs may continue as a problem. Mummies should be increasing. Continue to check for headworms.

Hard dough

- Cannot squeeze grain between the fingers.
- Three-fourths of grain dry weight has accumulated.
- Water stress during grain fill may cause lodging.

Insect: Greenbugs and headworms should be on the decline.

Black layer

- Dark spot appears on the tip of the kernel.
- Maximum total dry weight is achieved.
- Depending on the heat, an individual seed from flower to black layer is typically 30 to 35 days, but could stretch to 40 days or more in prolonged cool fall conditions.
- Sorghum maturation slows significantly once nighttime temperatures drop below 45°F.
- Grain is 25 to 35 % moisture.

Management: If harvest aids are used, label guidelines target application no sooner than

black layer and grain moisture are less than 30%.

Modified from 'Sorghum development and key growth stages.' Brent Bean, Extension Agronomist, and Carl Patrick, Extension Entomologist (retired), Texas AgriLife Extension Service, Amarillo.

Determining Leaf Stage

Grain sorghum is numbered by the fully-sized leaves that have a developed collar. If the seventh leaf (rounded coleoptile leaf is number one) has a collar, even though two to three other newer leaves may be visible, the plant is at leaf stage 7. Some herbicide labels cite leaf stage for timing, usually a limitation of further herbicide applications. The lower leaves may be crumbling and even missing, but by counting back from the last fully formed collar as leaves alternate from one side of the plant to the other, one can usually determine leaf stage, at least within one leaf.

Sorghum Yield Components

Sorghum yield is based on three factors: number of heads, head size, which includes the number of seeds, seed size, and test weight. Although these factors may compensate for each other, for both irrigated and dryland production, the number of seeds per head is the greatest component of yield. This does not mean that having as many seeds as possible per acre gives the best yields. Individual heads have the best yield potential for the environment with high fertility and adequate moisture per head, even if there are not a lot of heads.

Tillering is often left out of the discussion on yield potential, and its expression can significantly enhance yield in many instances, but tillering may actually limit yield when drought stress is significant, diminishing the size and yield potential of the primary head. For this reason, reduced tillering hybrids have often performed better in West Texas dryland.

Freeze Damage & Hail Injury

Grain sorghum is occasionally hit by a late freeze that may damage leaves, but sorghum may face hail damage in the spring and early summer. Early freeze injury often has little effect on sorghum as the growing point remains below the soil surface for several weeks after germination. Early hail-damaged sorghum has surprisingly little loss in yield potential provided the plants remain healthy. For example, a 50% leaf removal five weeks after germination (near growing point differentiation) reduces yield potential about 5%. Losses are substantially higher for older plants.

For further information on these conditions consult Texas AgriLife Extension's "Assessing Hail and Freeze Damage to Field Corn and Sorghum," B-6014 (http://agrilifebookstore.org, or your county Extension office).

Hybrid Selection

Selection of appropriate hybrids is foundational for successful grain sorghum production. 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.

Although yield components such as number of heads per acre, number of seeds per head, and seed weight are important for determining yield, they tend to compensate for each other. Any one or specific combinations of these components is too inconsistent to serve as a reliable yield predictor. Maturity, standability (stalk strength), and pest resistance are the major characteristics affecting hybrid performance in the Central and Eastern Plains.

Maturity. A good full-season hybrid will almost always out-yield a good early-season hybrid, other conditions being equal and favorable for sorghum growth. The stalks of full-season hybrids tend to be larger and stand better than those of 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 region that varies from 800 to 1,800 feet in elevation and from nearly 40 to less than 25 inches of annual precipitation. A conservative view is that hybrids should be in the maturity class reaching physiological maturity (black layer or maximum dry-matter content of grain at about 30 to 40% moisture) a week or two before the average date of the first killing frost. To assure adequate time to mature before frost, select and plant sorghum hybrids so they bloom by early to mid-August in south-central and southeast Nebraska and by late August or early September in north-central and northeast Oklahoma.

In the Central and Eastern Plains, the optimum hybrid maturity varies with soil depth and texture, growing season, planting date, and precipitation distribution. In the Eastern Plains with deep soils and low probability of an early fall frost, fuller-season hybrids can be planted through June. If planting is later than early June in the central plains, earlier maturing hybrids should be selected. On shallow soils, 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. 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.

Crop rotations and sequencing can influence hybrid choice as well. Producers wishing to plant wheat in the fall after a sorghum crop should select hybrids that will mature early enough to allow timely sorghum harvest and wheat planting. Early maturing hybrids combined with chemical desiccants (e.g. glyphosate, diquat) applied after physiological maturity (black layer) can speed dry down and move up harvest, increasing the probability of success for the following wheat crop.

Standability. If a hybrid lodges after having stood well in previous years, producers may wonder what happened. The timing of moisture exhaustion in relation to the plants' growth stage is a prime source of lodging variability. Post-flowering drought stress not only reduces yield, but also increases susceptibility to invasion by organisms, such as charcoal rot, that cause lodging.

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 sure to look at lodging notes from several trials before deciding if a hybrid is more or less prone to lodge.

Disease and Insect Resistance. Diseases and insects often are destructive in specific locations and sometimes cause widespread damage. When selecting hybrids, pest resistance 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.

Hybrid differences in susceptibility have been documented for sooty stripe, fusarium stalk rot, charcoal rot, viral diseases (maize swarf mosaic virus and sugarcane mosaic virus), northern corn leaf blight, rust, downy mildew, head smut and others. The importance of resistance to various diseases depends on the cropping system and grower practices. For example, no-till cropping systems increase the probability of some diseases such as sooty stripe, especially if sorghum residue remains from previous crops. Fungicidal seed treatments may adequately control sorghum downy mildew in some cases.

Greenbug populations have shifted over the years making hybrid tolerance traits obsolete over time. 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. Unfortunately, those hybrids had little or no resistance to greenbug Biotype E when it appeared, so insecticides were the primary control method until 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.

Historically chinch bugs have been a concern in the northern and eastern parts of the Central and Eastern Plains region. Some hybrids appear to have more tolerance to chinch bugs than others, but insecticides 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. The latest generation of systemic, insecticidal seed treatments have proven to be quite effective in preventing early-season damage from chinch bugs.

Head Exertion. Many companies rate hybrids for head exertion – the extent to which the head emerges from the boot, especially under moisture-limiting conditions. In some hybrids, the peduncle may not elongate enough to fully expose the head when soil moisture is limiting during heading. With poor head exertion, the portion of the head still wrapped in the sheath of the flag leaf can have poor seed set or may be more susceptible to grain molds if rains come after pollination and grain fill. While it is preferable to have fully exposed heads to maximize yield, the negative effects of incomplete head exertion are more pronounced in some hybrids than in others.

Seed and Plant Color. Producers often prefer hybrids with a certain seed color based on their opinion of how well seedlings emerge in stressful conditions. Although laboratory studies have documented greater stress germination and elongation for seedlings with the purple plant characteristic, no differences in these measures of seed vigor were attributed to seed color. Field studies have shown greater seedling emergence for red seed than for white seed, but the white seeded types had greater yields. Adequate emergence and high yields have been exhibited by hybrids of all seed and plant color combinations. Specific hybrid and seed lot performance are probably more important than seed or plant color. Select hybrids with above-average seedling vigor when planting early or in no-till systems.

Summary. The surest way to select hybrids that will perform well on your farm is to:

- Spend sufficient time searching for improved hybrids.
- Look at hybrids from several companies.
- Look at a broad base of information on hybrids of interest. Avoid reliance on only one source of hybrid-performance information. Use results from company tests, county strip trials, and university performance tests to select a small set of hybrids to try on your farm.
- Try this subset of hybrids on a small scale and keep harvest records. This is becoming easier every year with the widespread use of guidance/auto-steer technology and yield monitors. Be sure to replicate comparisons in such a way that you can be confident of your conclusions.
- Plant two or more hybrids of differing maturity to spread out risk 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.

Planting

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 achieve these conditions. These systems may involve primary or secondary tillage or no tillage operations prior to planting. Seedbed preparation should provide a means of profitable crop production while minimizing soil erosion due to wind and water. Conservation tillage systems (e.g. reduced-till, mulch-till, ecofallow, strip-till, ridge-till, zero-till and no-till) provide erosion protection, These systems also provide the additional benefits of moisture, energy, labor, and even equipment conservation.

An ideal sorghum production system should provide the following at planting:

- Weed-free conditions
- Conserve moisture
- Preserve or improve soil tilth
- Reduce wind and water erosion
- Result in adequate stand establishment.

Tillage and Rotations. 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, in the Eastern Plains where water erosion is the primary concern, leaving 30 % residue cover after planting reduces soil loss to acceptable levels. The actual level of residue required to minimize soil loss will vary with each field. 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, but uniform residue distribution, effective weed control, proper seed placement, correct planter adjustment, soil testing, and fertilizer management are important for success.

Crop sequencing and rotation becomes increasingly important in systems with little or no tillage and greater amounts of surface residue cover. Long-term research at Manhattan, Kan., documents the importance of rotation in no-till cropping systems, showing a 16 bushel per acre advantage for rotated sorghum compared with continuous sorghum in no-till (Table 1). Results from long-term studies at Belleville, Kan., and Mead, Neb., lead to the conclusion that sorghum rotated with soybeans almost always yields more than continuous sorghum, regardless of how much nitrogen fertilizer was applied. A four-year no-till study at Hesston, Kan., documented that sorghum after wheat produced 12 bushels per acre more than sorghum after sorghum (Table 1). Sorghum after soybean produced 10 bushels per acre more than after sorghum. Sorghum after double-crop sorghum yielded about the same as continuous sorghum.

No-till grain sorghum planting is best suited to

Table 1. Grain Sorghum Yields as Affected by Tillage System and Previous Crop at Two Locations in Eastern and Central Kansas

Previous Crop	Manhattan Conventional Tillage	Manhattan Reduced Tillage	Manhattan No-Till	Hesston No-Till
	bu/acre			
Sorghum	85	85	83	91
Soybean	87	89	99	100
Wheat				103
Double-Crop Soybean				100
Double-Crop Sorghum				89

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 and seedlings 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 strip-till, may be better choices in those situations.

Planting Practices

Row width. Most grain sorghum is planted in 30-inch rows because other row crops have performed well at that row spacing Historically, 30-inch rows performed better than wider rows, and narrower rows have not consistently yielded better than 30-inch rows. Results from nearly 20 studies comparing row spacings can be grouped into three categories:

1. Greater yields with narrow rows (10, 15 or 20 inches vs. 30 inches). This response was observed in about half of the studies, all of which were in environments that had yields greater than 110 bushels per acre.

2. Greater yields with wider rows (30 inches). This response was seen in about a quarter of the studies, all of which were in environments with yields of 100 bushels per acre or less.

3. No response to row spacing. This response was

observed in about a quarter of the studies, most often in high-yielding environments.

An advantage of narrow rows is that plants 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 2, recommended plant populations are given for specific rainfall regimes. When seeding in narrow rows in high-yielding environments, populations that are 25 to 30% higher than these recommendations may be able to capture slightly higher yields. Higher seeding rates also should be used with later planting dates because sorghum plants tend to produce fewer productive tillers with warmer temperatures during the vegetative growth stages.

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

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.

Table 2. Grain Sorghum Recommended Plant and Seed Spacing

	Average annual rainfall (inches)			
	23-26	26-32	>32	Irrigated
	Plants per acre[1]			
Population	35,000	45,000	70,000	100,000
	Within-row seed spacing at planting assuming 65% field emergence			
15-inch rows	7.8	6.0	3.9	2.7
30-inch rows	3.7	3.0	1.9	1.4

[1]Populations may be increased or decreased by 25% from these values, depending on expected growing conditions without significantly affecting yields.

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.

$$\frac{43{,}560 \text{ sq. ft.}}{\text{acre}} \times \frac{12 \text{ in.}}{30 \text{ in.}} \times \frac{3 \text{ plants}}{\text{foot-row}} = 52{,}272 \text{ plants per acre}$$

Formula 2. Seeds or plants per foot-row

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

Example 2.

$$\frac{\text{70,000 seeds or plants}}{\text{43,560 sq. ft./acre}} \times \frac{\text{30 in.}}{\text{12 in.}} = \text{4 seeds or plants per foot-row}$$

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

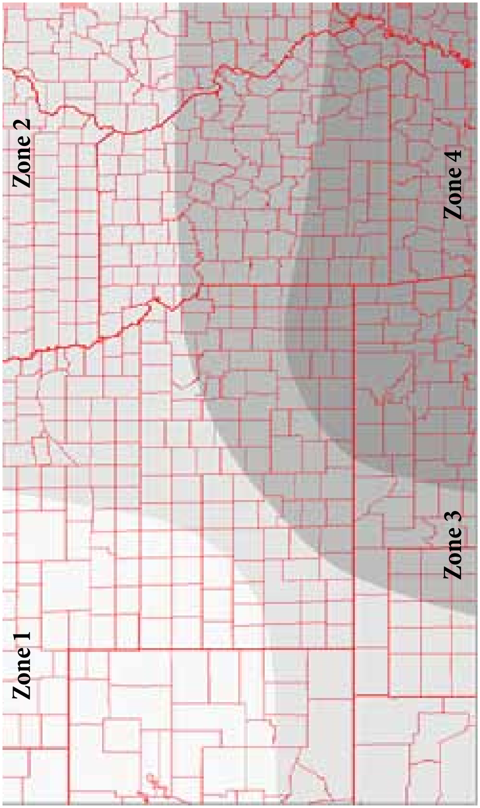
Non-uniform stands and replanting. Results from studies examining the effect of within-row gaps in various patterns and frequencies indicate that sorghum yields are not reduced unless gaps are at least 9 feet long or a sufficient number of 3-foot to 6-foot gaps reduce stands by 30% or more. Compensation occurs by increases in the number of heads per plant and the number of seeds per head in neighboring plants both within a non-uniform row and in adjacent rows.

Planting 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 1. 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°F. 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 enough time to mature before a damaging fall freeze. Use earlier-maturing hybrids if planting is delayed into late June or July.

Seeding depth. The optimum planting depth differs with soil types and moisture conditions. In heavier soils, a planting depth of 1 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. Planting into soils that are too wet can result in sidewall compaction, which can inhibit early root growth or poor closure of the seed furrow, which can reduce germination and emergence.

Figure 1. Suggested Grain Sorghum Planting Dates

Area	Dates
Zone 1	May 15 to June 20
Zone 2	May 10 to June 25
Zone 3	May 1 to June 25
Zone 4	April 20 to May 10, June 5 to June 30



Irrigation

Grain sorghum has a drought-tolerant reputation; therefore, it is a viable crop choice for some irrigators with low-capacity wells and limited water because a good yield response to limited water applications are possible. However under full irrigation, corn generally becomes the preferred feed-grain crop due to its ability to produce more grain per unit of added water in high-yield situations. The average yield of grain sorghum has increased over time with irrigated yield increasing at about 0.6 bushels per acre per year since 1974.

Water-use Requirements. Grain sorghum will use about 18 to 22 inches of water to produce a normal yield. The total amount of irrigation water needed depends on the season and the amount of soil water stored in the root zone. Dry-year-irrigation estimates (NRCS Irrigation Guide) for grain sorghum range from about 15 inches in western growing regions to less than 7 inches in eastern growing regions. 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 2. 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, similar to the peak use rate of any field crop at full cover and active growing conditions.

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% 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 water from significant soil depth (Table 3).

Irrigation Management. In addition to being able to extract water from a great depth within the root zone (Table 3), 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% available water. For grain sorghum, however, the soil water can be depleted to an average of 30 to 40% available water before grain yields are severely reduced. 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.

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, limited water applications during the growing season of about half the full irrigation requirement for well watered conditions (6 to 8 inches) will often produce 80 to 90% of the full yield potential under most circumstances.

On deep, silt loam soils, one or two relatively large irrigation applications (4 to 6 inches), can produce near-maximum yields compared to three or four in-season irrigations. Timing those irrigations during periods of peak demand will maximize yield and water use efficiency (Table 4). Although pre-plant irrigation can be effective on deep soils, it is not recommended if any in-season irrigation is planned. In most years, sufficient rainfall is available to recharge the upper root zone, making pre-plant irrigation an inefficient water-use practice.

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. Under-irrigation can quickly result in yield-limiting stress. A 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.

• The typical 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.

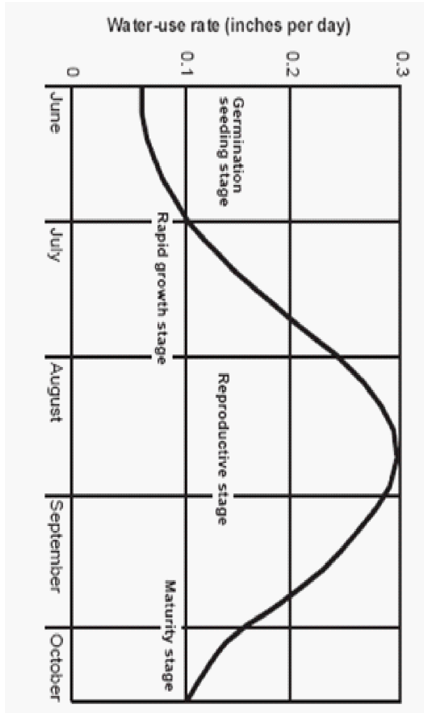


Figure 2. Characteristic water-use pattern of grain sorghum

Table 3. Water-Extraction Patterns Under Different Soil-Water Conditions, Garden City, Kan.

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

Table 4. Grain Sorghum Yield Response to Limited Irrigation and Timing, Scandia, Kan.

Irrigation Frequency and Timing	Yield (bushels/acre)
No Irrigation	111
Irrigation at Boot	136
Irrigation at Boot + Grain Fill	145

Fertilizer Requirements

Grain sorghum is grown throughout the Central and Eastern Plains 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 soils. Total nutrient uptake by sorghum is similar to that of corn and wheat at comparable yields. Table 6 shows that harvesting only the grain removes considerably less nutrients than if the entire crop is harvested for silage or forage.

Fertilizer and lime needs can best be determined by soil tests with supporting experience and field-history information. However, soil tests are 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. 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 your soil testing laboratory 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 the Central and Eastern Plains shows nitrogen credits for legumes grown in rotation with sorghum can be substantial. Table 7 summarizes nitrogen credits for legumes in rotation with sorghum and the basic nitrogen recommendation adjustment for these credits. Figure 1 shows the value of including a legume in a rotation. When no nitrogen was applied, grain sorghum grown in annual rotation with soybean yielded 29 bushels per acre greater than continuous sorghum. When averaged over all applied N-rates, rotated sorghum yielded 19 bushels per acre greater than continuous sorghum. Continuous sorghum yield continued to increase with increasing N rate up to 90 lbs. per acre, whereas yield of rotated sorghum was maximized with application of 60 lbs. N per acre.

Nitrogen recommendations can be calculated by using these factors:

N Rec= (Yield Goal x 1.6)-SOM x 20)-Profile N-Manure N-Other N Adjustments + Previous Crop Adjustments

Where:

- N Rec: nitrogen recommended in lbs. per acre
- Yield goal: a realistic yield goal in bushels per year
- % SOM: percent Soil Organic Matter
- Profile N Test: lb. N.acre= 0.3 x Sampling Depth (inches) x ppm Profile Nitrate-N (2 foot sampling depth.) Default value of 30 lb. N/acre if sample not taken.
- Manure n: previous year's manure (50 lbs. for last year, 20 lbs. for two years ago, and zero for no manure history)
- Previous Crop Adjustment: Use Table 7 for previous legumes, 20 lbs. for fallow (if no profile N test) and zero for all other previous crops.

Field comparisons of nitrogen sources 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. If urea or urea containing N-fertilizer is surface applied and not incorporated by tillage or does not receive one-half inch of rainfall or irrigation within 24 hours, there is potential for ammonia loss. Enough ammonia loss to reduce crop yields can sometimes occur when urea or UAN is applied to a warm and moist soil heavily covered with crop residue. 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% of the total nitrogen has been taken into the plant.

Nitrogen applications should be timed so nitrogen is available when needed for this rapid growth. Pre-plant nitrogen applications can be made in late fall or spring (except on sandy soils) with little concern for leaching loss. On sandy soils, pre-plant nitrogen applications should be delayed until spring, 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.

Active optical sensing systems have been shown to be useful in measuring crop biomass early in the growing season and using that measurement to predict final yield. Coupled with a well fertilized reference strip and an unfertilized check strip, to provide an estimate of the soils nitrogen supply to the crop sensors may provide an accurate nitrogen recommendation. The sensor technology seems to work best 35 to 45 days after planting; however this provides only a narrow window of opportunity to fertilize the crop. Producers may want to apply a base level of nitrogen on sorghum at planting to ensure optimum yield.

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 8.

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 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 lbs. of nitrogen plus potash per

Table 5.
Price of Common Nitrogen Fertilizers in Dollars per Pound of Nitrogen For Various Amounts of Nitrogen

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

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. Research indicates that, 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 needs (Table 9). Potassium removal is much greater with silage than with grain production. Therefore additional potassium should be considered in cropping sequences including forage sorghum. Potassium deficiencies are most likely to be found in claypan soils with shallow rooting depths and on sandy soils.

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. These sources differ little in potassium availability for crops. 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 that lodging occurs due to many factors—weather stress, insect and disease damage, hybrid stalk strength, 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 lbs. 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.

Chloride. For many grain crops, chloride has been reported to have an effect on plant diseases

by either suppressing the disease organism or improving overall plant health and allowing the plant to withstand infection. Chloride responses have been noted even in absence of disease, suggesting some soils may not be able to supply needed amounts of chloride. Soil test calibration experiments have shown that when soil test chloride levels (0 to 24 inches) are less than 20 to 30 lbs. per acre, responses to applied chloride are likely. Chloride is a very mobile element in soils, similar to nitrogen, and a 24-inch sample is needed to adequately gauge soil chloride content. Table 10 illustrates the value of chloride application on grain sorghum. On a Crete silt loam soil in north-central Kansas application of chloride on a deficient soil (12 lb. Cl/acre) resulted in a yield increase of 11 bushels per acre over the unfertilized check.

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 Plains, lime is recommended for sorghum on soils with a pH of 6.0 or less. In the Central Plains, 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. Research has demonstrated a need for some secondary and micronutrients in some situations (e.g. zinc and iron), but others are typically not limiting. Calcium and magnesium are relatively abundant in most soils in the Central and Eastern Plains. 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%). 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 the Central Plains 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 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 on soils where erosion or leveling has exposed a 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, but the chelates are generally three to five times more effective per lb. of metal. 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.

Figure 3. Effects of Rotation and Nitrogen Rate on Grain Sorghum Yields, Belleville, Kan. (1982-2002).

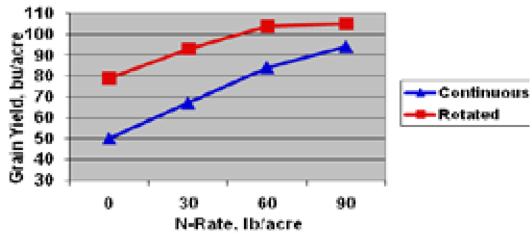


Table 6. Nutrient Content of Above ground parts of Grain Sorghum

Yield	Plant Part	Dry Matter	Nitrogen	Phosphorus	Potassium	Calcium	Sulfur	Magnesium
bu/a		lb.	lb.	lb. P_2O_5	lb. K_2O	lb.	lb.	lb.
100	Grain	5,080	95	30	25	3	10	7
	Stover	6,750	70	12	100	15	8	13
	Total	11,830	165	42	125	18	18	20
140	Grain	6,780	120	60	30	5	14	10
	Stover	7,980	80	16	120	20	12	15
	Total	14,760	200	76	15	25	26	25
180	Grain	8,510	145	70	35	7	18	13
	Stover	9,520	95	20	135	25	20	18
	Total	18,030	240	90	170	32	38	31

Table 7. Nitrogen Credits for Legumes in Rotations (With Stand Destruction Tillage)

Alfalfa	
Excellent Stand (> 5 plants/sq ft)	-120 lb. N/A
Good Stand (2-5 plants/sq ft)	-80 lb. N/A
Fair Stand (1-2 plants/sq ft)	-40 lb. N/A
Poor Stand (< 1 plant/sq ft)	0 lb. N/A
Red Clover	
Excellent Stand	-80 lb. N/A
Good Stand	-40 lb. N/A
Fair Stand	0 lb. N/A
Sweet Clover	
Excellent Stand	-110 lb. N/A
Good Stand	-60 lb. N/A
Poor Stand	0 lb. N/A

For No-Till production reduce N credit adjustment by 50%
Source: "Using Legues in Rotation" Pub. No. L-778, Kansas State University Research and Extention, Manhattan, KS 66506

Table 8. Phosphorus Sufficiency Recommendations for Grain Sorghum

Soil Test P	Yield Goal, bu/A				
	40	80	120	160	200
(ppm)	Lb. P_2O_5/A				
0-5	50	55	60	65	70
5-10	35	40	45	45	50
10-15	20	25	25	30	30
15-20	15	15	15	15	15
20+	0	0	0	0	0
Crop Removal	16	32	48	64	80

Grain Sorghum Sufficiency

P Rec= [50 + (0.16 x Yield Goal) + (Bray P x -2.5) + (Yield Goal x Bray P x -0.008)]

If Bray P is greater than 20 ppm, then only a NP or NPKS started fertilizer suggested

If Bray P is less than 20 ppm, then the minimum P Recommendation = 15 lb. P2O5/A

Source: "Soil Test Interpretations and Fertilizer Recommendations" Pub. No. MF-2586, Kansas State and Extension, Manhattan, KS 66506

Table 9. Potassium Sufficiency Recommendations for Grain Sorghum

Soil Test K	Yield Goal, bu/A				
	40	80	120	160	200
(ppm)	Lb. P_2O_5/A				
0-40	75	80	85	90	95
40-80	45	50	55	60	60
80-120	20	20	25	25	25
120-130	15	15	15	15	15
130+	0	0	0	0	0
Crop Removal	10	21	31	42	52

Grain Sorghum Sufficiency

K Rec= [58 + (0.17 x Yield Goal) + (Exch K x -0.616) + (Yield Goal x Exch K x -0.0013)]

If Exch K is greater than 130 ppm, then only a NKP or NPKS started fertilizer is suggested

If Exch K is less than 130 ppm, then the minimum K Recommendation = 15 lb. K2O/A

Source: "Soil Test Interpretations and Fertilizer Recommendations" Pub. No. MF-2586, Kansas State and Extension, Manhattan, KS 66506

Table 10. Grain Sorghum Response to Chloride (3-year average), Bellvelle, Kan.

Chloride	Yield
lb./acre	bu/acre
0	120
20	131
40	133
LSD (0.05)	5

Soil test chloride= 12 lb./acre (0 to 24 inches)

Weed Control

Weed control in grain sorghum remains a challenge and is best achieved with an integrated approach using crop rotation, good crop production practices, herbicides and/or tillage. This integrated approach enhances the ability of sorghum to compete with weeds. 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 include crabgrass, foxtails, shattercane, longspine sandbur, prairie cupgrass, fall panicum and witchgrass. In grain sorghum, the use of pre-emergence grass herbicides is essential to get adequate control of most of these grass species. Planting crops in rotations that allow the use of pre or post grass herbicides can prevent weed seed production during that growing season and can reduce the weed seed-bank. Because grass seed viability in soil is relatively short for many of these species, maintaining grass weed control for four to five years can greatly reduce the grass weed pressure in future growing seasons. Thus, it is also important to prevent these grass weeds from producing seed during a fallow period. Grass weeds that produce seed during a fallow period (i.e. in wheat stubble following wheat harvest) replenish the seed bank,

creating problems for the subsequent sorghum crop. Do not plant grain sorghum when a severe shattercane or Johnson grass infestation is expected.

Common annual broadleaf weeds in sorghum include kochia, Russian thistle, Palmer amaranth, waterhemp, redroot and tumble pigweed, venice mallow, velvetleaf, cocklebur, morning glory, devils claw and sunflower. Successful control of annual weeds requires planting the crop into a weed-free environment and other management practices designed to promote crop emergence before weed emergence. Timely post-emergence applications to small broadleaf weeds following a pre-emergence herbicide provide the most effective season long weed control. Sorghum should remain nearly weed free the first four to five weeks after planting to prevent yield loss from weed competition.

Perennial weeds such as field bindweed, common milkweed, hemp dogbane, bur ragweed (woolly leaf bursage), tumble windmill grass and johnsongrass also may infest sorghum fields. Perennial weeds can be suppressed, but often are difficult to kill. Cultivation between the rows, directed herbicide applications with drop nozzles, and certain broadcast herbicides are helpful in suppressing perennial weeds in the sorghum crop. Crop rotation with alternate herbicides and additional control measures during fallow periods will help control perennials. Fall herbicide applications following sorghum harvest and prior to a killing freeze can provide control of some perennial species like bindweed and bur ragweed.

Crop rotation is a key component of integrated weed management because it can reduce weed pressure by varying the timing and types of tillage and herbicides used in the system. This is the most effective control for shattercane and johnsongrass in sorghum. Fallow periods and rotation with glyphosate-tolerant summer crops such as soybeans, corn, and cotton or winter crops such as wheat and canola, will greatly reduce weed numbers with timely weed control to prevent weed seed production during the rotational period.

Delayed sorghum planting provides opportunities for effective weed control. In tilled seedbeds, field cultivation prior to planting will control emerged weeds and stimulate the onset of an additional flush of weed germination, 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 often reduced because few weed seeds remain in the germination zone near the soil surface. No-till especially reduces the large seeded broadleaf weed populations. Using "stale seedbed" techniques are especially effective in late seeded crops. Although delayed sorghum planting can help mange weeds in certain situations, it increases the risk of crop failure due to a fall freeze prior to physiological maturity. Late planted sorghum and shorter season hybrids often have inherently lower yield potential.

Weed Control Strategies Prior to Planting.
When sorghum follows wheat from the previous year, weeds must be controlled in the wheat stubble to prevent weed seed production. Using glyphosate and 2,4-D or dicamba can provide excellent broad-spectrum weed control. An atrazine application in late October or into November will help control volunteer wheat and other winter annual weeds, and should keep the field relatively weed-free for a no-till sorghum planting the following spring. The addition of glyphosate is important if winter annual grasses are present. The addition of 2,4-D will help provide adequate winter annual broadleaf weed control.

Repeated herbicide (glyphosate + growth regulators) applications or tillage before sorghum planting can effectively control weeds. Tilled ground is not likely to provide adequate protection from soil erosion by wind and water. Timely herbicide applications can substitute for tillage in no-till systems to increase water conservation and reduce soil erosion.

On fine-textured soils in 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 in the fall. 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 a burndown herbicide application. Where weed pressure is light and mainly broadleaf weeds, a March or early-April application of atrazine with crop-oil concentrate and 2,4-D can control winter annual weeds such as mustards and mares tail, and provide control of most germinating weeds up to planting. Early spring applied atrazine is a best management practice (BMP) to minimize off-site atrazine movement as there is little potential for loss in surface-water runoff compared to later planting-time applications. Leaving these weeds uncontrolled until the final burndown after or just prior to grain sorghum planting can result in inadequate weed control.

If annual grasses and tough broadleaf weeds like velvetleaf emerge as planting time nears, glyphosate and one pint of 2,4-D ester should be applied at least one week before planting. In addition to killing emerged annual weeds, this treatment can be very effective on established perennials such as field bindweed and hemp dogbane. Soil-residual grass herbicides can be added with these foliar-applied treatments for extended weed control. A new herbicide, Sharpen, is a PPO inhibitor and can provide excellent control of broadleaf weeds, including mares tail. Sharpen should be applied with crop oil or methylated seed oil and can be tank-mixed with glyphosate. Use high surfactant oils when mixing with glyphosate.

Herbicides Applied at Planting. It is critical that fields be weed-free at planting and remain nearly weed-free the first several weeks of the sorghum life cycle to optimize yield potential. Soil-applied pre-emergence herbicides for grass and pigweed control in sorghum include: Dual II Magnum, metolachlor, Cinch, Outlook and Intrro (there are several other generic herbicides). These herbicides may be shallowly incorporated or surface applied, and require the use of sorghum seed treated with a safener. These soil-applied herbicides do not control shattercane or large-seeded broadleaf weeds such as cocklebur, velvetleaf, venice mallow, morning glory, devils claw or sunflower. These herbicides are most effective when applied with atrazine, and often are marketed in a prepack mixture. Examples include: Bicep II Magnum, Bicep Lite II Magnum, Bullet, Lariat, Guardsman Max and G-Max Lite. Additional generic herbicides exist containing these same active ingredients. In addition, Degree Xtra, which contains encapsulated acetochlor (grass and small seeded broadleaf weeds) and atrazine, is registered for use in sorghum. These prepack mixtures that include atrazine provide broad spectrum grass and broadleaf weed control; however do not adequately control most large seeded broadleaf weeds, shattercane, or some triazine-resistant broadleaf weeds. Two examples of problematic triazine-resistant weeds commonly found in the Central and Eastern Plains are Palmer amaranth and kochia.

Several newer herbicides may help control large seeded broadleaf and triazine-resistant weeds. Sharpen contains a PPO inhibiting herbicide, saflufenacil, that provides burndown broadleaf weed control and very short residual broadleaf weed control including control of large seeded broadleaf weeds. The 1 to 2 ounce per acre rate of Sharpen however, will provide perhaps one to two weeks residual broadleaf weed control. Sharpen will need to be applied with one of the chloracetamides or one of the prepackage mixtures of a chloracetamide and atrazine listed above. Lumax or Lexar contain the HPPD inhibiting herbicide mesotrione (Callisto) plus Dual II Magnum and atrazine. Lumax is the low atrazine load version of these prepack herbicides. Lumax or Lexar can provide excellent control of grasses and broadleaf weeds including velvetleaf and triazine-resistant Palmer amaranth and kochia. Lumax and Lexar should not be used on sandy soils because of excessive risk of crop injury and sorghum stand loss.

The rate of atrazine applied to the soil surface at planting should not exceed 1 lb. per acre, especially where soils are vulnerable to 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. (Photos 1-3)*

Herbicides Applied Post-emergence. Post-emergence herbicides should be applied to small weeds for optimum weed control. Bromoxynil (Buctril, Moxy and others), carfentrazone (Aim and others), 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. This is especially true on larger weeds. Systemic herbicides such as 2,4-D, Banvel, Starane, Peak, Permit, Paramount and Yukon are translocated from the leaf surface throughout the plant and are more effective on larger annual broadleaf weeds; however larger weeds become increasingly difficult to control. Some of these systemic herbicides may help control perennial weeds. Paramount is especially effective for control of field bindweed, and Permit and Yukon are some of the more effective herbicides for control of yellow nutsedge.

The only foliar-applied herbicides that can control annual grasses in sorghum are atrazine with

*Photos found in Appendix B page 111

crop-oil concentrate, or 5.3 to 8 ounces of Paramount with methylated seed oil. For adequate control, these herbicides must be applied to very small (one to two inch) grass seedlings. Atrazine at more than 1 lb. per acre is not considered a best management practice, especially where there is high potential for atrazine loss in surface-water runoff. Current work is underway to develop sorghum hybrids that will tolerate grass herbicides that normally kill grain sorghum. This new technology will allow post-emergence annual grass control in grain sorghum, but will be an option only on the non-GMO herbicide resistant sorghum hybrids.

Fewer herbicides are available for broadleaf-weed control in sorghum than in corn or soybean. Products such as bromoxynil plus atrazine, Laddok S-12, Marksman, and Shotgun all contain about 0.5 lb. 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, Permit and Ally are sulfonylurea herbicides used in sorghum that work by inhibiting the function of the acetolactate synthase (ALS) enzyme. These herbicides are often tank-mixed with dicamba, 2,4-D and/or atrazine to control a broader spectrum of weeds and to help control ALS-resistant weed species that may be immune to ALS inhibiting herbicides. Additional herbicides available for post-emergence broadleaf

weed control are Aim (carfentrazone) and Priority (Aim + Permit). Aim is a PPO inhibitor, and can help control triazine and ALS resistant weeds if applied when weeds are small. Aim is especially effective for control of velvetleaf. If Ally is used, it is essential to tank-mix with 0.25 lb. 2,4-D amine as the 2,4-D amine reduces the grain sorghum response to Ally. 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, especially if applied when sorghum is less than 2 inches in height. 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. Application of 2,4-D or dicamba after sorghum exceeds 15 inches tall, may result in sterility and severe yield reductions. There is limited evidence that suggests sorghum hybrids may vary in their response to these growth regulator herbicides, but all hybrids are susceptible to damage, especially if the herbicides are misapplied. (See photos 4-6)*

Cultivation of Sorghum Rows. Cultivation remains an integrated option for control of emerged weeds, however it has become very unpopular because of fuel costs, time and labor involved. Cultivation can be an emergency backup where herbicides have performed poorly

*Photos found in Appendix B page 112

and where perennial weeds have not been controlled. Electronic guidance systems can increase cultivating speed and efficiency by reducing operator fatigue and cultivator blight. Heavy, high-residue cultivators can be effective even in no-till planted sorghum.

Grain Sorghum Weed Control in the Eastern Great Plains

The Eastern Great Plains has a diversity of climatic conditions, soil types, cropping systems and weed species which affect weed management decisions in the region. Weed control in grain sorghum may utilize an integration of mechanical, chemical and cultural methods to help sorghum compete with weeds. Conditions that are favorable for quick germination allows grain sorghum a competitive advantage over weeds. Unfavorable conditions including delayed emergence, cool and wet soils, deep planting depth, seedling diseases, and seed quality may result in increased seedling stress due to weed interference and/or crop injury due to herbicide application. Weed interference in grain sorghum causes reduced yields, harvest interference and losses, grain contamination with debris, and increased weed seed in the soil seed bank. Weed interference greater than two weeks after sorghum emergence generally reduces yields depending on the environmental conditions, weed species and density. Research has shown over a 3% reduction in sorghum yield for every week of grass competition, while pigweed densities up to 30/ft^2 in irrigated sorghum reduced grain yield nearly 50%. In Nebraska, weed interference with velvetleaf was dependent on the sorghum hybrid that was selected. Perennial weed management may require an integration of cultivation, crop rotation, fall herbicide applications prior to frost, delayed burndown application, broadcast herbicide application, and directed herbicide application to control or suppress these weeds. A combination of chemical and mechanical weed control is generally very effective for grain sorghum production.

Cultivation effectively reduces weed interference from between the crop rows. Although cultivation is usually not an option in narrow-row sorghum production, canopy development in narrow rows is quicker. Narrow-row spacings (less than 30 inches) can reduce the amount of light available to seedling weeds. In Kansas, narrow row sorghum reduced weed growth up to 45% and increased yield over 30 bushels per acre when compared to 30-inch rows. Effective chemical weed control depends on matching the correct herbicide timing and rate with the weeds present in the field. Table 11 provides a guide for weed response to herbicides at suggested application rates in the Eastern Great Plains. Several tank-mixture or pre-mix combinations with herbicides such as 2,4-D, dicamba or atrazine are available. Only combinations reported from multiple sources in the Eastern Great Plains states were reported. It is reasonable to combine the weed control ratings for individual products for pre-mix and tank-mixture components. Individual state weed control guides in the Eastern Great Plains are available annually with label and weed management updates.

A clean field at planting is desirable using tillage or a burndown herbicide such as gramoxone, glyphosate or glyphosate plus 2,4-D or dicamba can be utilized for no-till planting. Pre-emergence herbicides are commonly used to control weeds in grain sorghum due to the cost-effectiveness and lack of available post-emergence grass herbicides. Pre-emergence herbicides must be applied prior to weed germination. Irrigation or rainfall following application is important for activation of these herbicides to ensure adequate herbicide uptake by the weed. Excessive rainfall may result in temporary crop injury, and under normal growing conditions these symptoms are usually temporary. Fields with high populations of grass weeds may need to be avoided since limited post-emergence grass control options are available. Atrazine is commonly applied in combination with chloroacetamide herbicides (Dual II Magnum, Intrro, or Outlook) as a pre-mix or tank-mixture. Since grain sorghum lacks tolerance to several grass and broadleaf herbicides, application recommendations must be carefully followed. When using chloroacetamide herbicides, seed must be treated with a safener such as Concept or Screen, to prevent injury caused by these herbicides. Recommended pre-emergence

herbicide rates are based on the amount of residue cover present, whether the soil is highly erodible, soil texture (coarse, medium, or fine), preplant incorporated or preplant surface application, organic matter and specific weed management issues such as grass weed species and yellow nutsedge. In addition, herbicide rates such as atrazine applied on highly erodible soils have been limited to reduce the potential for surface water runoff loss. Best management practices have been developed to reduce herbicide losses in surface water runoff in the Eastern Great Plains. Herbicide losses generally occur following an atrazine application especially when soils remain wet for extended periods of time. Fall applications in areas of the Eastern Great Plains help avoid risks associated with runoff losses. This is beneficial for controlling winter annual weeds and reducing the need for a burndown herbicide application and preplant tillage. However, some areas in the Eastern Great Plains do not allow fall applications of atrazine. Producers should refer to specific state and region recommendations for such applications. In addition, specific restrictions on use are also dependent on local conditions such as specific watershed regulations or requirements.

Tillage prior to planting can effectively control winter annual and early spring annual weeds; however, tillage causes the soil to be susceptible to wind and water erosion. Tillage allows a producer to incorporate atrazine and companion herbicides such as Dual II Magnum, Outlook and Intrro which can reduce atrazine runoff up to 60%. Reduced rates and banding herbicides can also be utilized to reduce the amount of herbicides applied per acre. Reduced rates of atrazine are available in pre-mixes such as Bicep Lite II Magnum, Cinch ATZ Lite or G-Max Lite to minimize runoff loss in sensitive watersheds. Cultivation or post-emergence herbicides can be utilized in conjunction with reduced rates and banding to provide good control of weeds. Rates of atrazine may increase when incorporated prior to planting, applied as an in-row band or applied to soils that are not highly erodible. A post-plant incorporation of Prowl or Treflan with a sweep type or rolling cultivator can be used to extend residual grass control until sorghum is 12 inches tall.

There are fewer post-emergence herbicides available for control of weeds in grain sorghum than in corn or soybean. Post-emergence herbicide applications may be restricted based on the stage of crop development (refer to chapter 1, Growth Stages) specified on the herbicide label in order to minimize crop injury. Several post-emergence herbicides are available for control of broadleaf weeds; however few are available for control of grasses. The addition of dicamba or atrazine to several post-emergence herbicides is common to broaden the spectrum of weeds controlled and increase control of certain broadleaf weeds. Atrazine is commonly included in Laddok, Marksman, Shotgun, Banvel-k + atrazine or Buctril + atrazine to provide additional post-emergence grass control or suppression to small seedling grasses. Since there are no selective post-emergence herbicides available for control of Johnson grass or shattercane, fields with infestations of these weeds should be avoided. Current research is evaluating herbicide resistant grain sorghum for post-emergence control of Johnson grass, shattercane and other grasses that are difficult to manage in grain sorghum. Post-directed, hooded and rope wick applications are available and can be effective for control of escaped weeds in taller grain sorghum. Post-directed or hooded applications may result in severe crop injury. A hood is required to avoid drift and prevent contact with sorghum plants when applying glyphosate. A post-directed application of Lorox or Gramoxone before the crop is 15 inches tall must avoid contact with crop leaves or significant crop injury may result. Harvest aids such as Aim, Diquat and glyphosate are available to reduce the impact of weeds on harvest efficiency. Grazing and forage restrictions prevent illegal pesticide residues when herbicides are applied to grain sorghum. A period of time should occur between herbicide application and grazing or harvest for silage to avoid illegal pesticide residues. Always consult the herbicide label for specific limitations.

Herbicides used in the crop rotation such as Flexstar and Pursuit in soybean, or Exceed, Hornet, Lightning, Resolve Q and Steadfast ATZ in corn, need careful consideration since carryover from a previous crop may cause injury and stand reductions. Since grain sorghum is more drought tolerant, it may be planted when conditions were not favorable for another crop. Herbicides that were applied for that crop need to be taken into consideration prior to planting grain sorghum.

Herbicide resistant weeds such as kochia, water-hemp and pig weeds in grain sorghum have been reported in the Eastern Great Plains states. If you suspect a herbicide resistant weed, treat with a herbicide with a different mode of action and contact your local extension agent to confirm the presence of resistance in order to help manage these weeds.

Weed control
E=Excellent (>90%)
G= Good (80-90%)
F=Fair (65-80%)
P=Poor (<65%)
N=None
-= not enough information to rank

Herbicide	Crop tolerance	Broadleaves: Black nightshad, Eastern	Cocklebur, Common	Devil's-claw	Jumsonweed	Kochia[1]	Lambsquarters, Common	Morning glory species[2]	Pigweed, Redroot & Smooth[1]	Punturevine	Ragweed, Common	Ragweed, Giant	Sida, Prickly	Russian thistle	Smartweed, Annual	Sunflower, Common	Velvetleaf	Venice mallow	Waterhemp species[1]
Preplant incorporated or preemergence[3]																			
Atrazine	G	E	E-G	G-F	E-G	E-G	E	E-G	E	G	E	G	G	E-G	E	G-F	G-F	F-	E
Bicep II Magnum/Cinch ATZ[4]	G	E	E-G	G	E-G	E-G	E	E-G	E	G	E-G	G	E	E-G	G	G-F	G-F	F	E
Dual II Magnum/Cinch/Parallel[4]	G	G	P	P	P	P	G-F	P	G	F	P	P	P	P	P	P	P	P	G
Expert[4]	G	E	E-G	F	E-G	E-G	E	E-G	E	G	G	G	E-G	G	G	G-F	G-F	F	E-G
Guardsman Max[4]	G	E	E-G	F	G	E-G	E	E-G	E	G	G	G	E-G	G	G	G-F	G-F	F	E-G
Intrro/Micro-Tech/Lasso[4]	G	G	P	P	P	P	G-F	P	G	P	P	P	P	P	P	P	P	P	G
Lariat/Bullet[4] (alachlor + atrazine)	G	E	E-G	F	F	E-G	E	E-G	E	E-G	E-G	G	E-G	G	G	G-F	G-F	F	E-G
Lumax/Lexar[4]	G	E	E-G	G	G	E-G	E	E-G	E	G	G	G	E-G	G	E	G	E	G	E
Outlook[4]	G	E-G	P	P	P	P	G-F	P	G	P	P	P	P	P	P	P	P	P	G
Sharpen	G	G	G	P	P	G	G	G	G	G	G	G	G	G	G	G	G	G	G

Broadleaves

Weed control E=Excellent (>90%) G= Good (80-90%) F=Fair (65-80%) P=Poor (<65%) N=None -= not enough information to rank **Herbicide**	Crop tolerance	Black nightshade, Eastern	Cocklebur, Common	Devil's-claw	Jumsonweed	Kochia[1]	Lambsquarters, Common	Morning glory species[2]	Pigweed, Redroot & Smooth[1]	Punturevine	Ragweed, Common	Ragweed, Giant	Sida, Prickly	Russian thistle	Smartweed, Annual	Sunflower, Common	Velvetleaf	Venice mallow	Waterhemp species[1]
Postplant incorporated																			
Prowl/Prowl H_2O/Pendimax/Pendant	G-F	P	P	P	P	-	F-G	-	G	P	P	P	P	P	P	P	P	P	G-F
Prowl + atrazine/Pendimax + atrazine	G-F	E	E-G	F	G	G	E	F	E-G	F	E	G	G	F	E	G	E	G	E
Treflan[4]	G	P	P	P	P	G-F	G	P	G	P	P	P	P	P	P	P	P	P	G-F

Weed control E=Excellent (>90%) G= Good (80-90%) F=Fair (65-80%) P=Poor (<65%) N=None -= not enough information to rank **Herbicide**	Crop tolerance	Black nightshade, Eastern	Cocklebur, Common	Devil's-claw	Jumsonweed	Kochia[1]	Lambsquarters, Common	Morning glory species[2]	Rigweed, Redroot & Smooth[1]	Punturevine	Ragweed ,Common	Ragweed, Giant	Sida, Prickly	Russian thistle	Smartweed, Annual	Sunflower, Common	Velvetleaf	Venice mallow	Waterhemp species[1]
Postemergence[3,5]																			
Aim	G	E-G	F-G	F	E-G	G-F	E-G	G-F	E-G	F	F	F	F	G-F	E-G	F-P	E	G	G
Ally + 2,4-D	F	F	E	E	F	E-G	E	E	E-G	E-G	E-G	-	G	G	F	E-G	E	G	G-F
Atrazine + oil	G	E	E-G	G	E-G	E-G	E	E-G	E	G-F	E-G	G	E	F-P	E	E-G	E-G	G	E
Banvel/Clarity/Sterling Blue	F	E-G	E	P	G	E-G	G	E	E-G	G	E-G	E-G	G	E-G	E	E-G	G	F	G
Basagran	E	P	E	G-F	E	F	F	F	P	F	E-G	G	G	P	E	E-G	E-G	E-G	P
Buctril/Moxy/Brocleam/Bromox	G	E	E-G	G-F	E-G	G	E-G	E-G	G-F	G	E-G	E	P	G	E	E-G	G	E-G	F
Buctrul + atrazine	G	E	E	G	E	E	E	E-G	E-G	G	E	G	E-G	E-G	E	E	E	E	E-G
Laddok S-12	E-G	E-G	E	G	E	G	E	G	E-G	G	E	G	E	F	E	E	E	E	G

Weed control E=Excellent (>90%) G= Good (80-90%) F=Fair (65-80%) P=Poor (<65%) N=None -= not enough information to rank **Herbicide**	Crop tolerance	Black nightshade, Eastern	Cocklebur, Common	Devil's-claw	Jumsonweed	Kochia[1]	Lambsquarters, Common	Morning glory species[2]	Pigweed, Redroot & Smooth[1]	Punturevine	Ragweed, Common	Ragweed, Giant	Sida, Prickly	Russian thistle	Smartweed, Annual	Sunflower, Common	Velvetleaf	Venice mallow	Waterhemp species[1]
Postemergence[3,5]																			
Marksman/Banvel-K + atrazine	G-F	E	E	-	E	E-G	E	E	E-G	-	E	G	E	G	E	E	E-G	E-G	E
Paramount	G	F-P	P	-	P	F-P	F-P	E-G	F-P	-	F-P	-	P	F-P	F-P	F-P	P	P	P
Peak	E-G	F-P	E	E	G	G-F	G-F	G-F	E-G	E	E-G	G	G-F	G	G	E	E-G	E	F-P
Permit/Sandea	E-G	P	E	G	F	G-F	P	F-P	G	G	E-G	G	G-F	P	G-F	E	E-G	G	F
Roundup/Durango DMA/ Touchdown[6]	G	P	G	F	G	F	P	P	P	P	F	F	F-P	P	F	F	F-P	P	P
Shotgun	F-P	E-G	E	E	E	G	E	E	E	G	E	G	E	-	E	E	G	E-G	E
Starane Ultra	G-F	G-F	G	G-F	F	E	P	E-G	F-P	E-G	E-G	-	-	F	F	G	G	E-G	F-P
Yukon	F	F	E	G	G	G	E-G	G	G	G	E	E	G	G-F	E-G	E-G	E-G	G	E-G
2,4-D	P	F	E	E	G-F	F	G	E	E-G	G	E-G	G	G	E-G	F-P	G	G	G-F	G

Weed control E=Excellent (>90%) G= Good (80-90%) F=Fair (65-80%) P=Poor (<65%) N=None -= not enough information to rank **Herbicide**	Crop tolerance	Black nightshade, Eastern	Cocklebur, Common	Devil's-claw	Jumsonweed	Kochia[1]	Lambsquarters, Common	Morning glory species[2]	Pigweed, Redroot & Smooth[1]	Punturevine	Ragweed, Common	Ragweed, Giant	Sida, Prickly	Russian thistle	Smartweed, Annual	Sunflower, Common	Velvetleaf	Venice mallow	Waterhemp species[1]
Post-directed or hooded																			
Roundup/Durango DMA/ Touchdown	F	E	E	-	E	-	G	G	E	-	E	G	E	-	G	E	G	-	G
Gramoxone INteon	G	-	F-P	P	F	-	E	P	E	-	G	-	P	-	P	-	F	-	-
Lorox/Linex	G	-	G	-	-	-	E	G	E-G	-	G	-	E	-	G	-	E	-	-

	Grasses											Perennials			
Weed control E=Excellent (>90%) G= Good (80-90%) F=Fair (65-80%) P=Poor (<65%) N=None -= not enough information to rank **Herbicide**	Barnyardgrass	Broadleaf signalgrass	Crabgrass	Fall panicum	Foxtail species[2]	Goosegrass	Red rice	Sandbur species	Shattercane	Witchgrass	Woolly cupgrass	Bindweed, Field	Johnsongrass (seedling)	Johnsongrass (rhizome)	Yellow nutsedge
Preplant incorporated or preemergence[3]															
Atrazine	G-F	F-P	F	P	G-F	P	G-F	F-P	P	F	P	P	P	P	F
Bicep II Magnum/Cinch ATZ[4]	E-G	F-G	E	E-G	E	E	E-G	F	P	E-G	F	P	F	P	G
Dual II Magnum/Cinch/Parallel[4]	E-G	F	E	E-G	E-G	E	E-G	F	P	G	F	P	F	P	G
Expert[4]	E-G	E-G	E	E-G	E	E	E-G	F	P	E-G	F	F	F	P	G
Guardsman Max[4]	E-G	G-F	E	E-G	E	E	E-G	F	P	E-G	F	P	F	P	G
Intrro/Micro-Tech/Lasso[4]	E-G	G-F	E	E-G	E-G	E	E-G	F	P	G	F	P	F	P	F
Lariat/Bullet[4] (alachlor + atrazine)	E-G	F	E-G	E-G	E	E	E-G	F	P	E-G	F	P	F	P	G
Lumax/Lexar[4]	E	G-F	E	E	E	E	E-G	F	P	E	F	P	F	P	G
Outlook[4]	E-G	G-F	E	E-G	E-G	E	E-G	F	P	G	F	P	F	P	G
Sharpen	-	-	-	-	-	-	-	-	-	-	-	-	F-	P-	-

	Grasses											Perennials			
Weed control E=Excellent (>90%) G= Good (80-90%) F=Fair (65-80%) P=Poor (<65%) N=None -= not enough information to rank **Herbicide**	Barnyardgrass	Broadleaf signalgrass	Crabgrass	Fall panicum	Foxtail species[2]	Goosegrass	Red rice	Sandbur species	Shattercane	Witchgrass	Woolly cupgrass	Bindweed, Field	Johnsongrass (seedling)	Johnsongrass (rhizome)	Yellow nutsedge
Post-plant incorporated															
Prowl/Prowl H_2O/Pendimax/Pendant	E-G	-	E-G	G	E-G	E	-	E	F	-	-	-	F	P	P
Prowl + atrazine/Pendimaz/Pendant	E-G	F	E-G	G	E-G	E	-	E	F	-	-	-	F	P	F
Treflan	E-G	-	E-G	G	E-G	G	-	E	G	E-G	-	-	F	P	P

Weed control
E=Excellent (>90%)
G= Good (80-90%)
F=Fair (65-80%)
P=Poor (<65%)
N=None
-= not enough information to rank

Herbicide	Grasses											Perennials			
	Barnyardgrass	Broadleaf signalgrass	Crabgrass	Fall panicum	Foxtail species[2]	Goosegrass	Red rice	Sandbur species	Shattercane	Witchgrass	Woolly cupgrass	Bindweed, Field	Johnsongrass (seedling)	Johnsongrass (rhizome)	Yellow nutsedge
Post-emergence[3,5]															
Aim	P	Pp	P	P	P	P	P	P	P	P	P	F-P	P	P	P
Ally + 2,4-D[4]	P	P	P	P	P	P	P	P	P	P	P	F-P	P	P	P
Atrazine + oil[4]	F	F-P	F-P	P	F	P	E	F-P	P	P	P	P	P	P	P
Banvel/Clarity/Sterling Blue[4]	P	N	P	P	P	P	P	P	P	-	P	F-P	P	P	P
Basagran	N	N	N	N	N	N	N	N	N	N	N	P	N	N	G
Buctril/Moxy/Broclean/Bromox[4]	P	N	P	P	P	P	P	P	P	-	P	P	P	P	F
Buctril + atrazine	P	F-P	P	P	P	P	P	P	P	P	P	P	P	P	F
Laddok S-12	G	F	F	P	F	P	E	F-P	P	P	-	P	P	P	G

Weed control
E=Excellent (>90%)
G= Good (80-90%)
F=Fair (65-80%)
P=Poor (<65%)
N=None
-= not enough information to rank

Herbicide	Grasses											Perennials			
	Barnyardgrass	Broadleaf signalgrass	Crabgrass	Fall panicum	Foxtail species[2]	Goosegrass	Red rice	Sandbur species	Shattercane	Witchgrass	Woolly cupgrass	Bindweed, Field	Johnsongrass (seedling)	Johnsongrass (rhizome)	Yellow nutsedge
Postemergence[3,5]															
Marksman/Bancel-K + atrazine	F	F-P	F-P	P	F-P	P	E	F-P	P	P	P	P	P	P	P
Paramount[4]	F	-	F-P	P	G-F	F	-	F-P	P	F	F	E-G	-	-	P
Peak	P	N	P	P	P	P	P	P	P	-	P	F-P	P	P	P
Permit/Sandea	P	P	P	P	P	P	P	P	P	-	P	-	P	P	E
Roundup/Durango DMA/Touchdown[6]	-	-	-	-	-	-	-	-	E-G	-	-	P	E-G	E-G	P
Shotgun	G	F	F	P	F	P	E	F-P	P	P	P	P	P	P	P
Starane Ultra	P	N	P	P	P	P	P	P	P	-	P	G-F	P	P	P
Yukon	P	N	P	P	P	P	P	P	P	-	P	F-P	P	P	E
2,4-D	P	N	P	P	P	P	P	P	P	-	P	G-F	P	P	P

Weed control E=Excellent (>90%) G= Good (80-90%) F=Fair (65-80%) P=Poor (<65%) N=None -= not enough information to rank	Grasses											Perennials			
Herbicide	Barnyardgrass	Broadleaf signalgrass	Crabgrass	Fall panicum	Foxtail species[2]	Goosegrass	Red rice	Sandbur species	Shattercane	Witchgrass	Woolly cupgrass	Bindweed, Field	Johnson grass	Johnson grass	Yellow nutsedge
Post-directed or hooded															
Roundup/Durango DMA/ Touchdown	E	F	E	G	E	G	-	-	E	-	-	-	E	G	F
Gramoxone[4]	E	E	E-G	G	G	G	E	-	F-P	-	-	-	G	P	P
Lorox/Linex	F	F	G	G	G	F	P	-	-	-	-	-	F	P	-

Insect Management

Sorghum insect pests vary widely from year to year, during different times within a growing season and across the region. Greenbugs have historically caused problems throughout the region, and are still present every year, but have not reached levels of economic consequence for several years. Sorghum may still be vulnerable to greenbug damage at any growth stage, but for various reasons has not been affected. Chinch bugs are a continuous concern throughout the region, with localized infestations sufficient enough to cause seedling stand reductions, replanting or insecticide applications. Sorghum midge populations cause local concern every year in the southeast occasionally in south-central fields. Sugarcane rootstock weevils are another perennial pest in central Kansas and north central Oklahoma. Foliage-feeding insects such as fall army worms and cattail caterpillars cause concern annually, but do little economic damage. Corn earworms (sorghum headworm), fall army worms and army worms attack sorghum heads some place throughout the region every year, often requiring insecticide applications. These worms can reduce yield very quickly because they are feeding directly on the marketable product.

The following table describes the insects of most frequent concern in the Central and Eastern Plains:

Table 12. 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	Region-wide	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.	Region-wide	Wireworms
3. Early season	Plants stunted or lodged. Roots destroyed or severely pruned. C-shaped whitish grubs present.	Region-wide	White grubs

Table 12 Cont. Insects of Frequent Concern in Sorghum

Time of year/ crop growth stage	Description	Distribution	Probable insect
4. 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.	Region-wide	Flea beetles
5. 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 that 1/16 inch long; color varies from transparent to dark; some winged, some not.	Region-wide	Thrips
6. 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.	Region-wide	Cutworms

Table 12 Cont. Insects of Frequent Concern in Sorghum

Time of year/ crop growth stage	Description	Distribution	Probable insect
7. 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.	Region-wide	Greenbugs*
8. May to June on seedling plants	Plants stunted and/or wilting. Brace roots deformed. Stems, both below and above ground with signs of feeding or tunneling. Roots pruned or destroyed.	Region-wide	Wrieworms. sugar cane root-stock, weevil, chinch bugs, white grubs.

Table 12 Cont. Insects of Frequent Concern in Sorghum

Time of year/ crop growth stage	Description	Distribution	Probable insect
9. May to June on seedling plants	Medium to dark green sucking insects present, especially in whorls of plants. Prominent cornicle 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.	Region-wide	Corn leaf aphids*
10. May to June on seedlings to 6-inch plants	Damage generally appearing at the margin of the field and progressing inward, Small plants show signs 0 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. Adult black except for whitish wings, Adult insect about 1/8 inch long or less.	Generally more common in the Eastern Plains, usually in sorghum fields adjacent to wheat	Chinch bugs*

Table 12 Cont. Insects of Frequent Concern in Sorghum

Time of year/ crop growth stage	Description	Distribution	Probable insect
11. 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.	Region-wide	Corn leaf aphids*
12. June, July August: whorl stage	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.	Region-wide	Greenbugs*
13 June July, August: whorl stage	Holes in leaves. Occasionally, plants very ragged. Damage often more severe on late-planted fields.	Region-wide	Fall army worms, cattail caterpillars

Table 12 Cont. Insects of Frequent Concern in Sorghum

Time of year/ crop growth stage	Description	Distribution	Probable insect
14. 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, more common in the southeast	Sorghum webworm
15. August September: during bloom stage	Seeds fail to develop on part or more 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, more common in the southeast	Sorghum midge
16. 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. Larva 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 the region	Corn earworm

Table 12 Cont. Insects of Frequent Concern in Sorghum

Time of year/ crop growth stage	Description	Distribution	Probable insect
17. July, August	Visible feeding on leaves, particularly around field margins. Occasional signs of feeding on developing seeds in the head.	Region-wide	Grasshoppers
18. 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 the High Plains, but can be found in the Central Plains	Spider mites
19. 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 Plains	Chinch bugs*

Table 12 Cont. Insects of Frequent Concern in Sorghum

Time of year/ crop growth stage	Description	Distribution	Probable insect
20. 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.	Region-wide	False chinch bugs

Diseases

Diseases of grain 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 organism(s) and host (plant) resistance. Estimates of annual sorghum yield losses to diseases in the Central Great Plains average less than 10%.

The total eradication of disease in sorghum is not economically feasible, so growers must try to minimize losses using an integrated pest management system. Planting resistant hybrids, providing optimum growing conditions, rotating with other crops, burying infested debris, proper seedbed preparation and seed placement and accurate application of herbicides and insecticides are all practices that can be used to minimize disease losses.

Although sorghum is susceptible to many diseases, there are only a few which cause or have the immediate potential to cause economic losses in the Central Great Plains on a regular basis. Sorghum is also susceptible to many physiological leaf spots. These can be easily confused with a number of commonly occurring foliar diseases so caution should be taken in making a diagnosis. University plant disease diagnostic laboratories are available to assist in making positive disease identifications.

Disease and Cause	Symptoms	Occurrence	Management
Seed Rots and Seedling Blights Pythium Blight Fusarium Blight	Thin uneven stands. Seeds may rot prior to emergence or plants may die back after emergence. Plants may show stunted growth with red to black roots.	Most noticeable following prolonged periods of cool, wet weather just after planting and in poorly drained soil. *Fusarium* may be a problem in froughty, sandy soils.	All sorghum comes pretreated with fungicides that aid in management. Efficiency of these chemicals is often decreased by long periods of poor germination and early growth conditions.
Stalk Rots Fusarium Stalk Rot 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 often predominating.	Disease is favored by abundant moisture and moderate temperatures following head initiation.	Select hybrids with good standability ratings. Avoid continous cropping, fertilize adequately and avoid leaf loss to insects or foliar disease. Hail tends to intensify stalk rot.

Disease and Cause	Symptoms	Occurrence	Management
Charcoal Rot See extension bulletin L-741	Disintegration of the lower stalk with numerous small, black bodies (sclerotia) scattered throughout.	Most apt to occur in light or shallow, drought-stressed soils. Disease may be present only in scattered areas of the field.	Some hybrids are more resistant that others. Reduce plant populations to avoid drought stress. Later-maturing hybrids often escape infection.
Foliar Diseases Caused by Fungi[1] Sooty Stripe	Elongated spots that may extend several inches with broad, yellow to orange margins. A sooty-like growth (sclerotia) is generally present on the underside of the lesion.	Oldest leaves usually are attacked first and most extensively. Yield losses of 30% or more have been recorded.	Crop rotation. Many resistant hybrids are available.

Disease and Cause	Symptoms	Occurrence	Management
Northern Corn Leaf Blight	Large (2 inches or more) elliptical spots with gray centers and reddish-tan borders. Very similar to sooty stripe but without sclerotia.	Most prevalent during prolonged periods of warm, humid weather.	Crop rotation. Many resistant hybrids are available.
Rust	Small brown pustules or blister-like growths on the upper and lower leaf surfaces starting on the lowest leaf.	Usually appears late in the growing season (late August or early September). Favored by warm, moist weather. Significant losses are rare.	Resistant hybrids.
Gray Leaf Spot	Dark purple, rectangular lesions, 1/4 inch and longer, having a grayish cast during spore production.	Same as northern corn leaf blight. Usually occurs late in growing season as the crop is maturing. Little, if any, losses occur.	Crop rotation. Many resistant hybrids are available.

Disease and Cause	Symptoms	Occurrence	Management
	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.	Crop rotation. Many resistant hybrids are available.
Zonate Leaf Spot	Circular, reddish-purple bands alternation with tan or straw colored areas which give a concentric zonate, or bull's-eye appearance. Lesion diameter may extend several inches.	Most severe during prolonged periods of high humidity.	Crop rotation. Many resistant hybrids are available.
Foliar Diseases Caused by Bacteria[2] Bacteria Stripe	Long, narrow, reddish or tan stripes depending upon hybrids. Lesions usually confined between veins. Shiny, crusty spots from exudates generally found on underside of leaves.	Most common bacterial disease. Prevalent during cool, humid weather.	Crop rotation.

Disease and Cause	Symptoms	Occurrence	Management
Bacterial Streak	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.	Crop Rotation.
Virus Diseases Maize Dwarf Mosaic Virus (MDMV-A) Sugarcane Mosaic Virus (MDMV-B)	Mosaic patterns (alternating might and dark green areas) on whorl leaves. Cool nights (below 60° F for Stain 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 lean aphid. MDMV overwinters in Johnson grass.	Most current hybrids are resistant to the more severe necrotic symptoms.

Disease and Cause	Symptoms	Occurrence	Management
Small Seed Primarily MDMV	Red to black lesions develop on panicle branches. As seed shrinks it becomes dull in color.	Observed when the crop matures during soft dough. Most common during cool, wet weather.	Most current hybrids resistant to the more severe necrotic symptoms.
Other Sorghum Diseases[3] Sorghum Downy Mildew	Vivid green and white stripes on leaves in late spring or early summer. Leaves shredded by wind until only leaf veins are left. Heads partially or completely sterile.	Most common in eastern and southern production areas of the Central Great Plains. Infections generally take place under saturated soil conditions within the first few weeks of emergence.	Crop Rotation. Resistant hybrids are available to pathotype 1.
Crazy Top Downy Mildew	Light colored leaves become stiff, rubbery and twisted. If heads appear, glumes are often proliferated to give "crazy top" symptom.	Most severe when flooding occurs on seedbeds or young seedlings, especially in poorly drained or clay soils.	Avoid areas where the disease is a recurring problem.

Disease and Cause	Symptoms	Occurrence	Management
Sorghum Ergot	Exudation of sweet, sticky "honeydew" from the infected flowers occurs. Honeydew that drips onto leaves or solid produces a white, powdery lass during moist conditions. Ovary may be converted to a white fungal mass visible between the glumes.	Occurs only sporadically in the Central Great Plains. The fungus only infects through unfertilized ovaries. It usually only occurs late in the season when colder temperatures affect pollination of late planted sorghum or late developing tillers.	Fungicide application at pollination can be made, but are usually only economical in hybrid seed production fields. Harvesting right after a rain has temporarily washed off the honeydew may prevent the clogging of harvesting equipment.
Heat Smut	A portion or all of the head is replaced by smut galls.	Plants are infected at seedling stage; symptoms are not apparent until boot or heading stage. More severe in south-central and southwest areas of the Central Great Plains.	Chemical controls are not effective. Utilize resistant hybrids.

[1]There are many foliar diseases caused by fungi that can occur on sorghum including sooty stripe, rust and northern corn leaf blight. Sooty stripe and rust can cause economic losses to occur in some years and on some hybrids. Registration of strobiluron fungicides is in progress. If and when they become available, the economics of their use should be carefully considered since they would likely be profitable only on the most susceptible hybrids and under the most severe disease pressure. Management of these diseases should primarily rely on selecting resistant hybrids and cultural practices such as crop rotation and the removal of residue where soil erosion is not a problem.

[2]Bacterial leaf diseases have not been shown to cause yield losses under Central Great Plains conditions, but they are generally present in some fields every year, particularly under wet, humid conditions.

[3]In the Central Great Plains, only seedling blights, stalk rots and sooty stripe are likely to cause economic yield losses on a regular basis. Crazy top downy mildew and sorghum downy mildew occasionally cause significant yield loss in individual fields or small areas of a field in years with excessive moisture early in the season, but they are not a widespread problem. Sorghum ergot infection is rare in the Central Great Plains, but when it does occur it can cause significant harvesting problems because the sticky honeydew can bind up combines, forage cutters and augers.

Harvesting

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% 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 can be minimized by timely harvesting. Crops left in the field too long can be damaged by birds or field shatter. Severe weather before or during harvest can cause lodging, which makes the crop difficult to harvest.

Combine size, crop acreage and available workdays dictate timeliness. Combines should be large enough to harvest the crop in acceptable time. If this is not economically feasible, custom harvesting is an option. Another option is harvesting earlier, but this must be balanced against greater drying costs. Generally, grain sorghum can be combined whenever the moisture content is less than 30%. Header loss includes shattered kernels, dropped heads and uncut heads. If a conventional reel is used, the speed of the reel bats should be slightly faster than ground speed. Operating the reel too fast will increase shatter losses, while operating too slow will cause dropped heads. Several attachments are available to improve gathering efficiency. Flexible guard extensions on grain platforms substantially reduce gathering losses in standing-crop conditions. Row attachments on grain platforms or using a row-crop head reduces losses in both standing and lodged conditions.

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

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

concave clearance than harvesting sorghum at lower moisture contents.

Shoe loss is grain carried or blown across the shoe. Kansas State University research indicates it may be the most serious and most overlooked source of harvesting loss in grain sorghum. In most modern combines, the shoe (and not the cylinder) is the first component of the combine to overload in grain sorghum. If the combine operator pushes the machine as fast as the cylinder can go, the shoe is usually losing large quantities of grain. In one series of tests, a 33% increase in ground speed caused shoe loss to increase by more than 4% 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 one 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 ft. X 10 ft. area is approximately one bushel per acre.

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

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

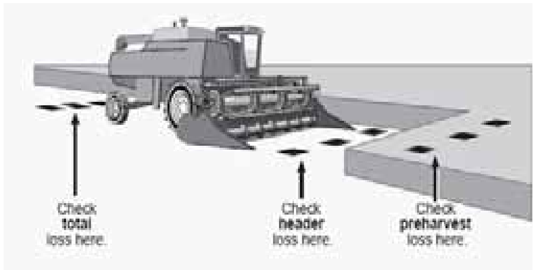
Header loss can be determined by backing the combine a few feet and taking ground counts between the header and the uncut sorghum. The difference between the header count and pre-harvest count is the net header loss.

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.

Determining harvest losses



Sorghum Economics

Two questions each producer must answer when selecting crops and the acreage of each crop to produce are: (1) Will the crop be profitable? and (2) Will the crop add more to farm profitability than other crops? Information needed to answer these questions include crop yield, crop price, government payments, crop insurance proceeds and production costs.

Production costs are typically broken down into variable and fixed costs. Variable costs vary with the level of production and include seed, fertilizer, herbicide, insecticide, fuel and utilities, repairs, insurance and miscellaneous items such as storage and marketing. Fixed costs do not vary with the level of production and include depreciation, interest on noncurrent assets, taxes and land charges.

Historical revenue and production costs are shown for non-irrigated grain sorghum in eastern, central, and western production regions (Table 13). The northwest production region information represents no-till production. Data for the other regions represent mixed tillage operations. The historical revenue and production costs illustrated represent the operator's share of revenue and costs. Gross income per acre includes revenue from grain sorghum production and other revenue such as patronage dividends, government payments and crop insurance proceeds. Production cost per acre includes cash costs, depreciation and opportunity costs on owned assets, but excludes hired labor and unpaid operator and family labor. Thus, the bottom line number represents a residual return accruing to labor and management. An individual that owns their ground would have higher per acre revenue and cost than that shown.

More information pertaining to whole-farm and enterprise profitability can be obtaining by clicking on "KFMA" on the following web site: www.agmanager.info/kfma.

Table 13. Net Return to Labor and Management for Non-Irrigated Grain Sorghum for the Eastern and Central Plains Sorghum Growing Regions.

	North-east	South-east	North Central	South Central
Yield per acre	95	75	90	82
Revenue from Corn Production	254.39	157.06	204.22	169.29
Other Revenue	48.33	33.98	26.21	42.17
GROSS INCOME PER ACRE	$302.72	$191.04	$230.43	$211.46
Seed	11.01	12.04	11.89	15.32
Fertilizer and Limes	43.68	40.53	39.88	35.86
Herbicide and Insecticide	23.15	19.43	27.29	21.72
Fuel and Utilities	19.81	16.94	15.81	16.99
Repairs and Machine Hire	32.9	19.39	20.65	20.49
Crop Insurance	6.92	5.60	7.84	5.04
General Farm Insurance	5.22	2.77	3.03	2.61
Miscellaneous	3.64	6.37	2.99	4.01
Depreciation	19.84	19.24	16.53	18.27
Interest	19.24	14.22	14.02	14.16
Taxes	5.85	2.88	3.52	3.66
Land Charges	70.03	18.65	30.29	20.29
PRODUCTION COST PER ACRE	$261.08	$174.98	$193.74	$178.42
NET RETURN TO LABOR AND MANAGEMENT	$41.64	$16.07	$36.70	$33.04

Note: Table above shows revenue and cost items based on Kansas Farm Management Association enterprise data for the 2004-2008 period and include only the operator's share of revenue and costs.

References

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2. U.S. Grains Council. 2008. Sorghum. Online. *http://www.grains.org/sorghum*

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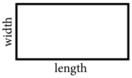
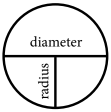
5. U.S. EPA. 2009. Crop Production. Online. *http://www.epa.gov/oecaagct/ag101/printcrop.html*

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

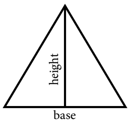
Calculations & Conversions



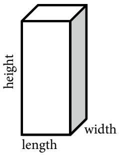
Area of a rectangle or square = length x width



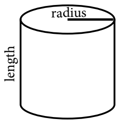
Area of a circle = 3.1416 x radius squared; or 0.7854 x diameter squared
Circumference of a circle = 3.1416 x diameter; or 6.2832 x radius



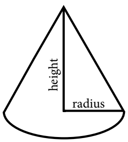
Area of triangle = base x height ÷ 2



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

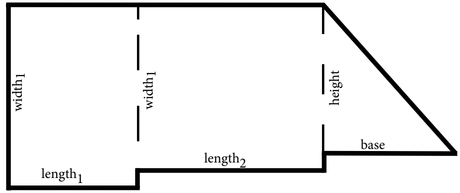


Volume of a cylinder = 3.1416 x radius squared x length



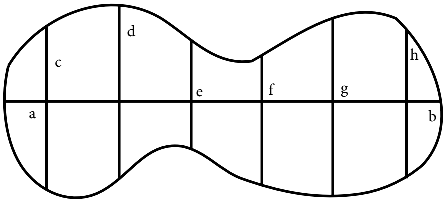
Volume of cone = 1.0472 x radius squared x height

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



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

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



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

Conversion Factors

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

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

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

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

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

Appendices

a. The Sorghum Plant

Sorghum grain is found on the panicle, commonly referred to as the head. The panicle consists of a central axis with whorls of main branches, each of which contains secondary and at times, tertiary branching. The length of the branches allows for a wide range of shapes and sizes in sorghum and for sorghums with very open panicles or sorghums with very compact panicles. The branches carry the racemes of the spikelets where the grain is found (see Figure 9). The panicle emerges at boot from the flag leaf sheath.

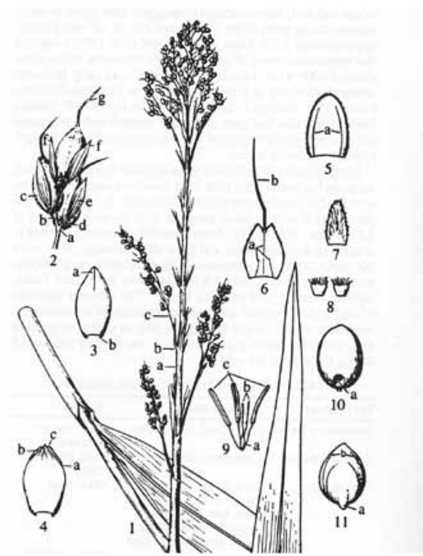


Fig. 9. The panicle of *Sorghum bicolor* subsp. *bicolor* which consists of the inflorescence and spikelets. 1. Part of panicle: a = internode of rachis; b = node with branches; c = branch with several racemes. 2. Raceme: a = node; b = internode; c = sessile spikelet; d = pedicel; e = pedicelled spikelet; f = terminal pedicelled spikelets; g = awn. 3. Upper glume: a = keel; b = incurved margin. 4. Lower glume: a = keel; b = keel wing; c = minute tooth terminating keel. 5 Lower lemma: a = nerves. 6. Upper lemma: a = nerves; b = awn. 7. Palea. 8. Lodicules. 9. Flower: a = ovary; b = stigma; c = anthers. 10. Grain: a = hilum. 11. Grain: a = embryon-mark; b = lateral lines. (Drawing by G. Atkinson. Reprinted, with permission, from J. D. Snowden, 1936, The Cultivated Races of sorghum, Adlard and Son, London. Copyright Bentham - Moxon Trust - Royal Botanical Gardens, Kew, England.

Seeds begin developing shortly after flowering and reach physiological maturity when the

black layer is formed between the germ and the endosperm, some 25 to 40 days after flowering. Seeds are normally harvested 10 to 20 days after black layer when moisture content is generally 15 percent or less. Black layer can be seen at the base of the grain where it attaches to the rachis branch and indicates that the grain is physiologically mature. Seeds are made up of three major components, the endosperm, embryo, and pericarp (Figure 14). All sorghums contain a testa, which separates the pericarp from the endosperm. If the testa is pigmented, sorghum will contain tannins, if not, the grain is free of tannins. None of the commercial U.S. grain sorghums have a pigmented testa and all are said to be free of tannins.

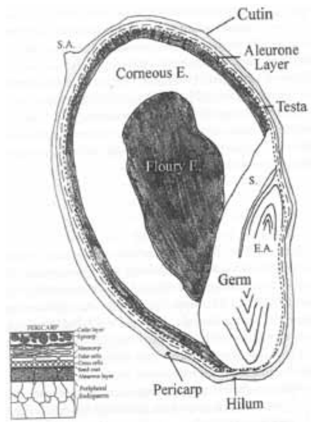


Fig. 10. Sorghum grain, showing the pericarp (cutin, epicarp, mesocarp, cross cells, tube cells, testa, pedicel, and stylar area (SA)), endosperm (aleurone layer, corneous and floury), and the germ (scutellum (S) and embryonic axis (EA). Adapted from L. W. Rooney and Miller, 1982).

b. Photos

Photos 1-3 above. *Sorghum at top had no herbicides applied and yielded 20 bushels per acre. Sorghum in the center had post-emergence broadleaf weed control only and yielded 82 bushels per acre. The sorghum on the right received pre-emergance broadleaf and grass weed control and yielded 130 bushels per acre.*

Photos 4-6 above. *Sorghum photos above are from a last post-emergence application of herbicides and showing evidence of crop injury. Sorghum on the left treated with one pint of 2,4-D Ester. Note the growth regulator response, leaning sorghum etc. Sorghum in the center was with 0.5 fl oz of Aim EC + nonionic surfactant. Note the leaf burn to sorghum leaves. Sorghum on the right was treated with 0.005 oz of Ally + 8 fl oz of 2,4-D amine, Slight chlorosis to some leaves and slight 2,4-D injury are visible.*

Photo 7. *Iron Deficiency*

Courtesy of International Plant Nutrition Institute

Photo 8. *Greenbug*

Photo 9. *Corn Leaf Aphid*

Photo 10. *Yellow Sugarcane Aphid**

Photo 11**. Corn Earworm

***Photo 12**. Fall Armyworm**

***Used with permission of USDA-ARS*

***Photo 13.** Sorghum Webworm**

***Photo 14.** Sorghum Midge**

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

Sorghum Facts

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

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