UNITED SORGHUM CHECKOFF PROGRAM

West Texas Production Guide

Welcome to the United Sorghum Checkoff Program's West Texas 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.

Chair, United Sorghum Checkoff Program Board
Sorghum Farmer, Prairie View, Kansas

Produced and Edited by:

Dr. Jeff Dahlberg, USCP Research Director

Earl Roemer, USCP Research Committee Chair

Jeff Casten, USCP Research Committee

Gary Kilgore, USCP Research Committee

James Vorderstrasse, USCP Research Committee

Authored by:

Dr. Calvin Trostle

Agronomist, Texas AgriLife Extension Service

Dr. Brent Bean

Agronomist & Weed scientist,
Texas AgriLife Extension Service

Nicholas Kenny

Irrigation Specialist, Texas AgriLife Extension Service

Dr. Tom Isakeit

Plant Pathologist, Texas AgriLife Extension Service

Dr. Pat Porter

Entomologist, Texas AgriLife Extension Service

Dr. Roy Parker

Entomologist, Texas AgriLife Extension Service

Dr. David Drake

Agronomist, Texas AgriLife Extension Service

Dr. Todd Baughman

Agronomist & Weed scientist,
Texas AgriLife Extension Service

Funded By:

SORGHUM CHECKOFF

4201 N. Interstate 27
Lubbock, TX 79403
806-687-8727
www.sorghumcheckoff.com

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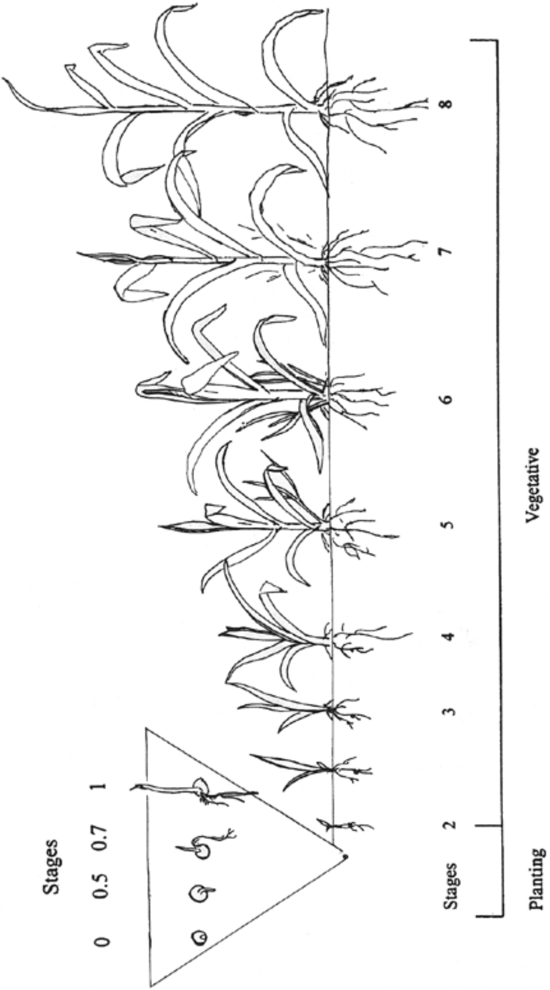
Growth Stages

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 (vegetative) would equate to stages 0-5 in this system. GS2 (floral initiation to bloom) would represent from stages 5-10, and finally, GS3 (bloom to maximum dry weight) 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 167, for more information about the sorghum plant.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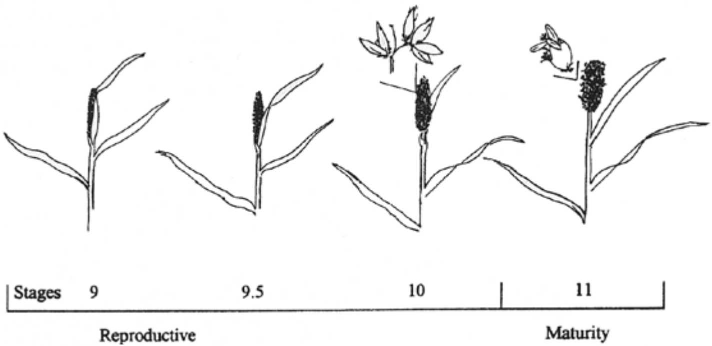


Fig. 1. Stages of sorghum growth: Stage 0: 0.0 planting; 0.1 start of imbibition; 0.5 radicle emergence from seed (caryopsis); 0.7 coleoptile emergence from seed (caryopsis); 0.9 leaf at coleoptile tip; Stage 1: emergence; Stage 2: first leaf visible; Stage 3: third leaf sheath visible; Stage 4: fifth 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.
5-Leaf	Collar of fifth leaf is visible approximately 20 days after emergence. May have lost 1st leaf (coleoptile) by this time. Plant is approxiamtely 8 to 10 inches tall. Cool soil and air temperatures coupled with sunny days to this point may trigger more tillering especially for stands less than 3 plants per row-foot.

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 midseason 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, 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, 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. The final N should be applied pre-boot.
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 (first appears as light brown) 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: 1) number of heads, 2) head size, which includes the number of seed and seed size, and 3) 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. Pre-harvest freeze can affect test weight. 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 additional grain sorghum production information resources for the South and Rolling Plains, consult online resources:
http://amarillo.tamu.edu
http://lubbock.tamu.edu/sorghum
http://varitytesting.tamu.edu
http://www.sorghumproducers.com
http://www.sorghumcheckoff.com

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

The initial criteria most producers make in choosing a grain sorghum hybrid in West Texas is maturity. Once an appropriate maturity range is decided upon, yield is paramount. Long maturity hybrids on dryland in this region will exhaust available moisture before maturity, and thus have reduced yields and even crop failure. This happens even in dry years for medium maturity hybrids. Extension does not recommend any sorghum hybrid maturity longer than medium maturity anywhere in West Texas; however, seed company and producer choices may differ. Just as important, grain sorghum production in the High Plains faces the task of reaching adequate maturity prior to the onset of cold nighttime temperatures, which are often more detrimental to a sorghum crop than when an actual killing frost occurs. This reverses the potential yield benefit of longer maturity hybrids.

Sources for Hybrid Yield Data

The Texas AgriLife Research Crop Testing Program conducts performance tests in West Texas, and, when combined with additional sites begun in 2009 funded by United Sorghum Checkoff Program, trials are conducted at three irrigated and up to seven dryland test sites in West Texas. In most cases, companies enter the hybrids they think will perform best at each site. These independent tests collect a variety of data including days to half bloom, lodging, test weight, and yield. Trial results are published at http://varietytesting.tamu.edu, and producers may choose test sites and then review several years of results, looking for hybrids that have good consistent results over years and locations. Caution, test results with CV's above 15% should be questioned.

Producers should also consult individual companies for their recommendations. Company data is not considered independent in the manner that public tests are conducted; however, these tests can still be an excellent source of information, particularly when comparing yields among hybrids from the same company.

Additional Hybrid Selection Criteria

In addition to maturity and yield, the following hybrid parameters have a potentially major impact on sorghum performance in West Texas.

Tillering

Hybrids express differences in tillering. Early planting and low populations foster increased tillering. Although tillering enables sorghum hybrids to adapt to their environment, Extension recommends producers emphasize low-tillering hybrids for dryland cropping where drought stress is expected. This reduces the possibility that early favorable conditions lead to increased tillering, which leads to drought and heat increase.

<u>Lodging</u>

Standability is important for grain sorghum. Companies rate their own hybrids for lodging resistance, but significant lodging only occasionally shows up in Texas AgriLife hybrid trials. Though it is often not even reported. Dryland sorghum producers should be concerned about lodging potential in drought conditions.

Lesser sorghum hybrid considerations include the following:

<u>Stay-green</u>

Grain sorghum hybrids maintain prolonged leaf and stalk integrity after flowering and are associated with post-flowering drought resistance. This trait can assist grain fill, take better advantage of late rains, and maintain stalk health later in the season ,which may reduce lodging, especially from stalk rots.

<u>Greenbug Tolerance</u>

Many hybrids note resistance to Biotype C and E greenbugs, but these biotypes have been gone from West Texas for many years. Biotype I is now predominant, but only a few hybrids offer resistance. A small amount of Biotype K is also present. With the advent of numerous insecticide treatments, there is little emphasis placed on greenbug resistance.

<u>Grain Color and Plant Color</u>

Red, bronze, crème, yellow, even white grain hybrids are marketed. Unless you are pursuing a specialty market (food sorghum, chicken feeding, etc.) where white grain is desired, there is little reason to choose a hybrid based on seed coat color. Yield considerations generally override any considerations of grain or plant color (purple, red, tan).

Panicle (head) Type

Loose panicle hybrids (in contrast to tight, compact heads) that are fast growing and dry down rapidly may be preferred in areas with higher humidity and greater panicle feeding pressure from insects.

Plant Disease Resistance

Though some hybrids may have tolerance of certain diseases, this consideration is largely ignored by producers. If you have a particular disease that has affected your crop in many years, consult your Texas AgriLife Extension plant pathology experts or your seed dealer for possible suggested hybrids that may reduce disease injury potential.

Herbicide Tolerance

Although these technologies are now in the testing phase with seed companies and are not currently available, two major non-GMO herbicide tolerant traits will likely become important selection criteria once the traits are bred into competitively yielding commercial hybrids. These include ALS-herbicide or sulfonylurea tolerance (metsulfuron, nicosulfuron, rimsulfuron, e.g., Ally) and ACC-ase herbicide tolerance (quizalofop, e.g. Assure II).

Duration of Hybrid Bloom and Physiological Maturity

Hybrid ratings of the same hybrid may vary among companies. Days to half bloom and physiological maturity will depend greatly on weather since maturation is driven by heat accumulation. Texas High Plains Crop Testing results, mostly representing planting dates from late May to late June, demonstrate that medium maturity hybrids advance more quickly (often a week or more) to half bloom under dryland vs. irrigated production. This is just one example of the complexities of projecting the days to maturity as planting date and climate affect growth and development.

Guideline for late planting grain sorghum:
A typical sorghum planting date should allow the sorghum to reach black layer 1 to 2 weeks before your area's average killing frost (or since that data is harder to find, 2 to 3 weeks prior to the average first freeze). This allows for sorghum maturation without significant risk to yield or test weight if a frost/freeze occurs up to 10 days earlier than average.

Maturity ratings may vary by several days among companies. Knowing maturity range and days to half bloom are key to effective sorghum management strategies in terms of late planting dates or split-pivot irrigation scenarios.

The average range of days to half bloom and physiological maturity. In contrast to harvest maturity, which can be up to several weeks later depending on weather conditions and drying.

Table 1. Expected and observed days to half bloom and expected days to physiological maturity for the Texas High Plains.

General Company Maturity Rating	Production System	Expected mid-range half bloom	Expected physiological matutiy◄	High Plains half bloom (2006-2009)◁
Early (~15)	Dryland	≤58	80-95	50-55
Medium-early	Dryland	59-63	90-100	53-60
Medium (~17)	Dryland	64-68	95-105	56-64
	Irrigated	64-68	100-110	65-70
Medium-long	Irrigated	69-73	105-115	68-74
Long (~19)	Irrigated	≥74	110-120	71-80

†Expected maturity is highly dependent on planting date, heat accumulation, and the onset of cool fall weather.

††Planting dates typically mid-May to late June.

Cheap Seed

Because cost of seed when prorated per acre is relatively low for grain sorghum, particularly compared to just about all other crops, selecting seed based on price alone is a poor choice. Low-priced seed probably does not represent the best yield potential and proven genetics you would like to have for your farm. Shop hybrid maturity and yield potential, scour the yield trial data, narrow your choices, and find your best price for those hybrids on your short-list. Do not fret paying $2 per acre more in dryland to plant the hybrid of your choice.

The Bottom Line of Hybrid Selection

When extension staff surveys the means by which many producers choose their hybrids for planting grain sorghum, for irrigated and dryland West Texas producers could improve their yields 10% or more overnight by planting hybrids that have a track record of better performance. Depending on your production area, extension has compiled informal 'Picks' lists based on Texas AgriLife Research's Crop Testing Program. Consult your county agent or regional specialist for hybrid suggestions.

Early maturity hybrids are frequently criticized for their lower yield potential and higher lodging potential. Yet these hybrids have their place when time is short. Some producers accept the increased risk of planting a medium-maturity hybrid in exchange for greater yield potential knowing that late planting dates in some years will encounter cold and frost that may reduce yields. Early maturing hybrid require a different management approach.

Planting

Site and Seedbed Selection

Sorghum often benefits by being planted low in the landscape profile. Most sorghum was planted with buster style planters into the 1980s. Buster planting patterns fit sorghum well because the plants were low in the landscape, brace roots were easily covered, and sorghum stood well. The possible drawbacks were the two-fold risk of a large rain either burying the sorghum or washing and concentrating atrazine in and around the plant.

Today, most of the dryland sorghum in South Plains and much of the Rolling Plains and Concho Valley is planted on top of the bed. This is essentially the reverse of historical plantings. The listing of fields, particularly dryland, controls wind erosion and blowing soil. Furthermore, these raised beds give the producer the opportunity to knock off the top of the bed to get to planting moisture, and the raised position may also offer warmer soil temperatures; however, raised beds are likely to be detrimental for sorghum production. Sorghum brace roots and standability are compromised by planting on top of the bed:

- Soil is drier on top of the bed, and this limits brace roots' ability to penetrate the soil—roots will not move into or through dry soil (soil at the bottom of a furrow, even if a shallow furrow, is more moist).

- Soil is warmer on top of the bed and limits the ability of brace root tips to grow into the soil.
- It is more difficult to cultivate soil to the elevated base of the sorghum plants, because soil must be moved uphill.

Sorghum does not have to be planted as deeply as the traditional buster planters will place seed, and most planters today can do a modest job of placing sorghum below the average level of the field to still benefit in the manner of buster planting. The key for producers is they need to reconsider how they manage the field to take advantage of sorghum's potential when planted lower in the landscape. If this is done, then subsequent cotton planting is a good bet between the sorghum rows (still elevated) with the stalks providing wind protection.

Skip-Row Sorghum

Some fields are planted in a 2-in/1-out skip-row pattern for cotton, which is thought to enhance yield in dry years by giving individual plants more rooting area to procure moisture. Small savings might be realized in crop insurance or the application of insecticides if using a ground rig.

A similar approach to grain sorghum production also views skip row planting as potentially favorable. However, research conducted by Texas AgriLife shows that long-term yields for grain sorghum are higher in solid planted fields vs. skip-row provided that the per acre populations are not increased from the skip-row pattern. For example, if you plant three sorghum seeds per foot on 40-inch rows (26,000 seeds per acre) in skip-row, then a solid planted field should reduce to two seeds per foot and maintain the same 26,000 seed drop per acre. This spaces the plants out, provides more shading for weed suppression, and reduces potential moisture evaporation.

The combined results of two multi-year Rolling Plains studies found that solid planted grain sorghum yields averaged 3,195 lbs. per acre, but the skip-row pattern yielded 2,709 lbs. per acre, a yield decrease of 15%. Similar results have been reported in the distant past for the South Plains, as well.

Is furrow diking still a good idea for dryland or irrigated sorghum?
Yes, in both cases, but if you have greatly reduced tillage, moved to no-till, or now maintain a residue cover as much as possible, then furrow diking may be difficult to implement and have reduced potential benefit. Research results from furrow diking in conventional tillage systems have long showed distinct yield advantages.

- **Dryland**—Rolling Plains results found that in multi-year tests, conventionally tilled grain sorghum averaged 1,979 lbs. per acre, but with furrow dikes, the yields increased to 2,619 lbs. per acre (+32%). Other studies have shown similar benefits though not quite as much increase. Furrow dikes implemented long before planting provided the most benefit.

- **Irrigated**—Furrow dikes are an essential component of alternate furrow LEPA irrigation using drag hoses with socks. Water is ponded in the diked furrow and remains in place wetting only 40% of the soil surface, which allows deeper downward moisture percolation. Although dikes in sandy loam and loamy sands may not last the season or survive well with slopes greater than 2%, they are still beneficial as long as they last.

Although many producers have moved to less tillage and residue, it is more difficult to dike, because it adds to soil disturbance and may mean another pass over the field. Furthermore, the presence of stubble on the surface may diminish the expected benefit. If dikes can readily be installed, extension recommends that producers implement this time-proven practice.

Seed Treatments.

Many companies now treat all their seed with Concep III, which enables a producer to use the preferred method of grass control in grain sorghum, s-metolachlor (e.g., Dual Magnum) herbicides, This usually costs $10 to $15 per bag.

Insecticides and fungicides

Gaucho and Poncho for insects may cost about $30 per bag, but generics are inexpensive and may enable some greenbug control for cents per acre. Advanced combination insecticide/

fungicide treatments like CruiserMaxx, etc. may double the cost of a bag of seed. Most seed is treated with a simple fungicide like metalaxyl as standard practice.

Due to low seeding rates used in dryland, even the cost of an expensive seed treatment, particularly for insecticide, is still a relatively small per-acre cost. A producer might actually be able to justify the cost better on dryland, where you may be reluctant to apply an insecticide versus irrigated, where if a problem develops, you are more willing to undertake control measures.

Having said this, the majority of Texas AgriLife studies in West Texas have not documented a consistent benefit among insecticide treatments. However, there is some peace of mind knowing that you may have some protection.

Planting Date

Grain sorghum's practical planting date throughout the region is three months wide in southern regions to about two months in the northwest South Plains. Possible outcomes are provided for what we can expect from sorghum if planted early or planted late.

Early-Season Planting

Planting early in the South Plains, particularly for dryland, is questionable unless ample deep soil moisture is available and soil temperatures are up. For dryland in the South Plains and

Rolling Plains, if deep soil moisture in the spring is 3 inches or less, consider delaying planting until mid- or late June in hopes of storing deep moisture from May and June rains. This delay, however, is questionable for Concho Valley dryland sorghum and possibly the lower Rolling Plains due to sorghum midge potential on later planted fields. In general, yields in the South Plains and northern Rolling Plains are higher for later planting.

Rules for early grain sorghum planting:

1. Target grain sorghum no earlier than a minimum of two weeks after your last average spring freeze (see Table 2).
2. Delay Rule No. 1, especially in the South Plains, if the average soil temperature has not reached a five-day average of at least 60°F at a 2-inch depth although an ideal temperature for quick germination and establishment of grain sorghum is a 10-day average minimum of 62 to 65°F at the 4-inch depth. If you plant early contact your seed dealer for any hybrids that may have better cool soil germination and vigor. You can view local soil temperatures at http://txhighplainset.tamu.edu, http://www.mesonet.ttu.edu or your nearest National Weather Service regional website
3. If Nos. 1 and 2 are satisfied, but there is a major cold front predicted in a few days then consider delaying planting.

Table 2. Average last spring freeze and first fall freeze for selected locations in West Texas (Texas Almanac, 2008-2009)

Location	Last Average Spring Freeze	Earliest Planting Based on Spring Freeze	First Average Fall Freeze
Muleshoe	April 17	May 1	October 21
Tulia	April 14	April 28	October 24
Floydada	April 8	April 22	October 30
Plains	April 6	April 20	October 29
Lubbock	April 5	April 19	November 1
Lamesa	April 3	April 17	November 5
Snyder	April 1	April 14	November 7
Vernon	April 2	April 16	November 6
Haskell	March 31	April 14	November 8
Ballinger/San Angelo	March 28	April 12	November 11

Last Recommended Planting Dates
South Plains

In general, extension suggests the following guidelines as criteria for the last recommended planting dates for sorghum maturity classes in the South Plains region. These dates reflect a combination of slowing heat unit accumulation in the fall, first freeze dates, elevation, etc. If your county is on the north and west edge of a planting date zone (e.g., for example the northwest portion of Parmer, Yoakum, Hockley Counties), you should take this into account and perhaps move planting forward a few days.

Table 3. Last recommeneded planting dates for different maturites of grain sorghum hybrids in the Texas South Plains. Dates ensure provide a likelihood of adequate crop maturity and minimal risk from fall temperaturres or early freeze.

Texas Counties	Hybrid Mturity Classification Long	Med. Long	Med.	Med. Early	Early
Parmer Castro Swisher Briscoe Bailey Lamb Cochran	June 10	June 18	June 25	June 30	July 5
Hale Floyd Hockley Lubbock Crosby Yoakum Terry	June 15	June 23	June 30	July 5	July 10
Lynn Garza Gaines Dawson Borden Scrurry Andrews Martin Howard Mitchell	June 20	June 28	July 5	July 10	July 15

Planting Dates and Late-Season Risk

Planting hybrids a week after its LRPD for your county will provide satisfactory results most years, but extension recommendations protect against unnecessary risk and complacency. In all cases, if you can plant a few days earlier than the LRPD, there is an occasional year that would make a nice difference.

Planting Date for the Rolling Plains

(Summarized from Dr. Ed Clark, deceased)
Sorghum can be planted from early April through early July in the Rolling Plains. Based on 16 years of tests, it should be planted from April 1 through April 20 or from June 20 through around July 7. There was a significant advantage for late plantings versus early plantings in yield tests conducted at Chillicothe. Although mid-season plantings can sometimes produce higher yields than early plantings, they rarely, if ever, produce higher yields than late plantings at Chillicothe. It is generally recommended to plant in the late window for yield, but in practical terms, the subsequent late season sorghum harvest poses some problems:

- Cotton harvest and wheat planting are in full force.
- Sorghum is difficult to dry down, leading to long harvest delays and increased lodging potential, feral hog damage, etc.

This harvest issue may favor early planted sorghum for a farmer planting any number of acres. Early planting also fits better with your other spring cropping work. Sorghum is planted before cotton planting and wheat harvest, and likewise, sorghum harvest occurs before fall wheat planting and cotton harvest.

We recommend irrigated production. Follow Dr. Clark's suggestions on planting dates to avoid the worst of potentially damaging summer heat during peak water use, flowering, and early grain development.

Planting Dates for the Concho Valley

In contrast to the South Plains region where low spring stored soil moisture merits delaying planting until mid-June, high sorghum midge potential makes Concho Valley grain sorghum risky for fields which have not completed bloom around June 30. By this date research suggests about five percent midge damage increasing with delayed flowering. In this case we recommend that a medium maturity grain sorghum hybrid on dryland should be seeded by about April 20-25 (earlier for longer maturity hybrids under irrigation; earlier hybrid maturities planted by approximately May 5). Otherwise, similar to the Rolling Plains, sorghum likely should not be seeded again until late June to minimize the effect of summer heat on the crop. Any late plantings—primarily in the case of cotton hailout—will face

substantial sorghum midge activity even if flowering occurs after early September.
Late planted sorghum in the Concho Valley otherwise should follow the LRPD guidelines for the lower South Plains in Table 3.

Restricting Sorghum Plantings to Avoid Bloom in July and August Heat

This is a particular consideration for dryland in the Rolling Plains and Concho Valley, but also for the South Plains. Temperatures consistently near 100°F or more may lead to sterility during flowering. Water in the whorl or on the head at 113°F for 10 mins. will kill male pollen. The heat alone also makes for reduced efficiency of limited water. Planting a medium maturity hybrid by approxiamtely April 20 through the 25 in the Rolling Plains and Concho Valley should avoid significant flowering in July, whereas later planting near the end of June will reduce the potential for hot conditions that remain in August. This is also a consideration in the South Plains for any late planting, a rain and ideal planting conditions may move June planting forward to take advantage of the moisture. This is less of a concern for irrigated production in the South Plains where absolute heat is less of an issue if irrigation can be provided.

Consider these TIPS to ensure successful seeding of sorghum hybrids:

- Ensure that sorghum seed sits on good moisture.

- Typical sorghum seeding depth is near 1.5 inches. Sorghum can emerge in a hurry in a couple of days from 1-inch depth if conditions are warm. Depths greater than two inches can lead to emergence problems and a spindly seedling.
- There is no substitute for local producer experience; if you've had trouble getting sorghum to emerge ask your neighbors.
- Particularly in dryland, minimize soil crusts by dragging dry soil back over the seed row to reduce drying and baking of the soil if hot weather prevails This will enhance seedling emergence.

Sorghum is the most common option after failed cotton in West Texas. Note these general guidelines:

- Follow the same guidelines for planting date noted above.
- In this rushed situation, producers may cut corners in an effort to plant as soon as possible, and the secondary attitude takes over for too may growers.
- In spite of this catch crop situation, we should expect no less from our grain sorghum, keep seeding rate low (unless you expect an emergence issue due to cotton herbicides), and still manage the crop.

Ensure that you adequately address cotton herbicide concerns—do not plant sorghum if Staple herbicide has been applied and consider the needed degree of buster planting to protect from trifluralin and other yellow injury. For further information on planting grain sorghum after cotton hail out, consult the annually updated "Alternative Crop Options after Failed Cotton & Late-Season Crop Planting for the Texas South Plains."

Plant Population

Planting

Seeds per Acre vs. Pounds per Acre

Texas AgriLife has long recommended that sorghum producers base planting on seeds per acre rather than pounds per acre. Grain sorghum seed can vary widely in seed size, often 12,000 to 18,000 seeds per pound, with 13,000 to 16,000 being most common. If you have to assume a seed number per pound, choose about 14,500 or 15,000. If you assume 14,500 seeds per pound, but the seed was actually 16,500, you have effectively increased the seeding rate 14% (germination and emergence will probably be similar).

Calculating seed rates can be done two ways.

Seeding rate

$$\frac{43560\ \text{ft}^2}{\text{acre}} \times \frac{12\text{in}\cdot}{\text{row spacing(in)}} \times \frac{\text{seeds}}{\text{foot of row}} = \frac{\text{seeds per}}{\text{acre}}$$

Seeds (or plants) per foot

$$\frac{\text{target seeding rate}}{43{,}560\ \text{ft}^2} \times \frac{\text{row spacing (in.)}}{12\ \text{in.}} = \frac{\text{seeds per}}{\text{foot or row}}$$

TIP: Texas AgriLife found that grain sorghum seeding rate varied by roughly 20% on individual rows of an air-vacuum planter. Even a new planter had significant differences in seed drop that needed correction. Before planting season, check your seed drop at both low and high rates to ensure you are planting your target seeding rate. Use the above table to help determine an approximate seed drop for each row over a predetermined length such as 50 feet.

Table 4. Approximate final plants per acre at standard seed germination and emergence:

85%	Too low	22,100	27,200	34,000	42,500	51,000	59,500	68,000	85,000

(Common when irrigation is used to establish the crop and soil temperature is favorable.)

70%	14,000	18,200	22,400	28,000	Too high for W. Texas dryland seeding rate.

(Typical of dryland when soil moisture and temperatures are adequate.)

Table 5. Summarizes row spacing, seeds per acre, and the resulting seeds per foot.

Planter Row Width (in.)	Linear Row (ft./acre)	Target Seeding Rate per Acre for West Texas								
		20,000	26,000	32,000	40,000	50,000	60,000	70,000	80,000	100,000
		Seeds per Foot of Row								
40	13,068	1.5	2.0	2.4	3.1	3.8	4.6	5.4	6.1	7.7
38	13,756	1.5	1.9	2.3	2.9	3.6	4.4	5.1	5.8	7.3
36	14,520	1.4	1.8	2.2	2.8	3.4	4.1	4.8	5.5	6.9
30	17,424	1.1	1.5	1.8	2.3	2.9	3.4	4.0	4.6	5.7
20	26,136	0.8	1.0	1.2	1.5	1.9	2.3	2.7	3.1	3.8
15	34,848	0.6	0.7	0.9	1.1	1.4	1.7	2.0	2.3	2.9
10	52,272	0.4	0.5	0.6	0.8	1.0	1.1	1.3	1.5	1.9

Texas South Plains Seeding Rate General Guidelines

Benefit: Less is more! This principle has long guided grain sorghum seeding rates, especially for dryland. Lower seeding rates can produce higher yield when droughty conditions prevail and you're begging for a rain. Lower plant populations are suited to these drought conditions, preserving more moisture per individual plant, thus reducing the plant's stress level. Moisture and yield potential are conserved as less moisture is used to produce unneeded steams and leaves while the crop is better able to wait extra days until that next rain you are hoping for.

Dryland

For most dryland sorghum production in the Texas South Plains, when soil profile moisture is high (5 or more inches of available soil moisture), a good target is 30,000 to 35,000 seeds per acre. A seed drop of 32,000 seed per acre is commonly cited for a wide range of production conditions because it is two and a half seeds per foot on a 40-inch row. Likewise 26,000 seeds per acre is commonly cited as well (two seeds per foot) when soil moisture is reduced. These seed drops have been shown to provide the best results under a wide range of conditions. This is a high enough seeding rate and resulting population to not limit yield, while, under extreme dry conditions, the sorghum will be less likely to burn up compared to a higher population.

If soil moisture is lower (2 to 3 inches), a seed drop of 24,000 to 28,000 per acre is advised. For any dryland situation with poor soil moisture, especially as plantings approach July 1, consider as little as 20,000 seeds per acre.

A common mistake often made by producers is applying an excessively high seeding rate. Keeping seeding rated down enables the crop to handle drought, retain modest yield potential, and still take advantage of a good year.

Irrigated

Producers in the South Plains who plan limited irrigation on grain sorghum frequently cite a target irrigation level of 6 to 8 inches. In this scenario:

- Low soil profile moisture conditions of around 2 inches, target 40,000 to 45,000 seeds per acre.
- Very good soil moisture profile conditions of 5 to 6 inches, target 50,000 to 55,000 seeds per acre.

For full irrigation levels of 15 inches or more, cap target seeding rates at no more than 80,000 seeds per acre by early June, but by July (which requires a reduction in hybrid maturity) consider 100,000 seeds per acre for non-tillering hybrids and 80,000 to 90,000 seeds per acre for tillering hybrids. Several producers report, however, that even 60,000 seeds per acre is adequate to achieve grain sorghum yield potential of 10,000 lbs. per acre if planting long and medium-long maturity hybrids by June 1.

CAUTION: Low sorghum prices and high irrigation pumping costs cause some irrigated sorghum growers to cut back on irrigation after they plant a longer-season hybrid at a higher seeding rate. This hurts the crop and will diminish yield through no fault of the hybrid. If you are uncertain how much you might irrigate, be conservative with your seeding rate and cautious about long-season hybrids.

Table 6. Texas South Plains seeding rate guidelines for irrigated grain sorghum production based on soil moisture and projected pivot irrigation. Basic calculations for projected yield are presented—results will be variable—as well as the target N level for that level of production.

†The amount of available soil moisture is a factor in gauging suggested seeding rates, and depends on soil type.
‡Irrigation is based on timely irrigation using a center pivot.
§Calculations are based on a general formula that attempts to fit seeding rate to projected moisture (soil, irrigation, and an assumption of about 6 inches median rainfall for any three-month period; full season hybrids will likely benefit from additional rainfall).
#Yield projections assume the first 5-8 inches are needed to produce grain depending on the plant population then assumes 400 lbs. of grain yield per subsequent inch of incremental moisture.
^Two lbs. of N per 100 lbs. of calculated yield goal.

Table 6.

Available stored soil water† (inches in top 3-4')	Projected irrigation level‡ (inches)	Suggested seeding rate target§ (seeds/A)	Projected potential yield (lbs./A)	Projected N fertilizer target^ (lbs. N/A)
<1	0	20,000	400	8
	4	28,000	1,800	36
	8	37,000	3,200	64
	12	47,000	4,600	92
	16	57,000	6,000	120
2	0	24,000	1,200	24
	4	32,000	2,600	52
	8	42,000	4,000	80
	12	52,000	5,400	108
	16	62,000	6,800	136

Available stored soil water† (inches in top 3-4')	Projected irrigation level‡ (inches)	Suggested seeding rate target§ (seeds/acre)	Projected potential yield (lbs./acre)	Projected N fertilizer target^ (lbs. N/A)
4	0	28,000	2,000	40
	4	37,000	3,400	68
	8	47,000	4,800	96
	12	57,000	6,200	124
	16	67,000	7,600	152
≥6	0	32,000	2,600	52
	4	42,000	4,000	80
	8	52,000	5,400	108
	12	62,000	6,800	136
	16	72,000	8,200	164

TIP: Wherever you farm in West Texas, if you are having doubts about whether you need to increase your seeding rate, do not. It is rare to see a South Plains sorghum field that is too thin for its production environment.

<u>Rolling Plains Seeding Rate Guidelines</u>
Although the higher rainfall in the northern Rolling Plains supports the idea of higher seeding rates, the excessive heat—the worst of which is avoided by April or late June/early July plantings—suggests we remain conservative in our recommendations. In lieu of any recent grain sorghum seeding rate trials with current hybrids, we suggest the following:

For April plantings with potentially lower establishment due to cool conditions.

- Excellent stored soil moisture, 36,000 to 42,000 seeds per acre
- Moderate stored soil moisture, 32,000 to 36,000 seeds per acre
- Low stored soil moisture, 26,000 to 32,000 seeds per acre

For late June/early July plantings with moderate establishment.

- Excellent stored soil moisture, 32,000 to 36,000 seeds per acre
- Moderate stored soil moisture, 26,000 to 32,000 seeds per acre
- Low stored soil moisture, 20,000 to 26,000 seeds per acre

These suggested seeding rate targets reduce the 1980s Rolling Plains recommendations by about half. If you have used the older higher seeding rates but have doubts about dropping the seeding rate this much, at least plant pass through the field at one or two lower seeding rates and watch the performance. For irrigated grain sorghum in the area, we suggest you start with the above then follow the relative recommendations for the South Plains based on projected irrigation level. These recommendations generally increase seeding rates by approximately 2,500 seeds per acre per inch of projected irrigation.

Concho Valley Seeding Rate Guidelines

This production area faces more pronounced heat than the South Plains but with 1 to 2 inches higher median rainfall during the growing season for any three-month period. Hence, heat and moisture balance each other out. We recommend that producers follow the above seeding rate guidelines for the South Plains. The southwest South Plains has sandier soil and less water holding capacity. As a result, there is a strong probability that grain sorghum seeding rates established populations well above the carrying capacity of sandy soil (and its lower inherent fertility), irrigation, and climate.

BENEFIT—Dryland Seeding Rate Summary: Seeding to obtain a modest plant population is agronomically and economically less risky than seeding a higher plant population under droughty conditions.

Row Spacing

Historically, sorghum and cotton producers in the Southern Great Plains considered 40-inch row widths as standard which in fact traced back to animal power. With hybrid sorghum becoming commonplace new and more efficient planting patterns were tested by experiment stations and put into practice by creative and progressive producers across the sorghum belt. Using twin rows and narrow rows (30 inches or less) these top growers quickly added 10% or more to their yields. To the contrary increasing seeding rates rarely had an advantage and could often be deleterious,especially with limited moisture. Most of the region is on 40-inch rows, with some on 30-inch rows especially in the northern South Plains. We recommend you do not make significant changes in seeding rate if on narrower rows. If using a drill follow these guidelines:

- Consider plugging one of two or two of three holes to ensure that you can lower the seeding rate, especially if drilling on dryland. (The value of good seed placement with a planter under adverse conditions to ensure a stand at low seeding rates may make drilling undesirable).
- Increase seeding rate no more than 10 to 20% over what you would use with a planter only if you expect reduced stand establishment due to decreased desirability of seed placement with a drill.
- Avoid over-seeding on narrow rows. If you bump the seeding rate up substantially, think-

ing you might have trouble getting a stand, but all the seed comes up due to a good rain, you irreversibly have too many plants per acre in a crop and will have higher susceptibility to drought.

TIP: Older plate planters have difficulty achieving the low seeding rates needed for dryland production You may use an old worn out buster planter to plant deep in the landscape, but it is still necessary to try to get the seed drop reduced. Short of getting a new planter, possible fixes include:

- Hammer a .22 caliber bullet lead or similar soft metal to fill every third planter plate cell, then file smooth.
- Purchase large sorghum seed (less than or equal to 13,000 seeds per pound) to fill cells with fewer seeds.

TIP: Watch for crusting and especially baking conditions that brick moist soils, especially sandy loams and loamy sands prevent emergence or trap roots inside the hard seed furrow sidewall from the disk opener. Having a rotary hoe available to enable good sorghum emergence is much better than changing a seeding rate.

Irrigation

Sorghum's water use characteristics make it an excellent crop for a wide range of irrigation scenarios in the Southern Great Plains. Sorghum yields reliably under dryland conditions in many semi-arid environments (greater than 15 inches annual precipitation) can be managed to reach significant yield potential under full irrigation. Because of sorghum's water use versatility, it fits well into many cropping and irrigation patterns, a valuable trait considering current trends of declining groundwater and pending regulatory water use limitations.

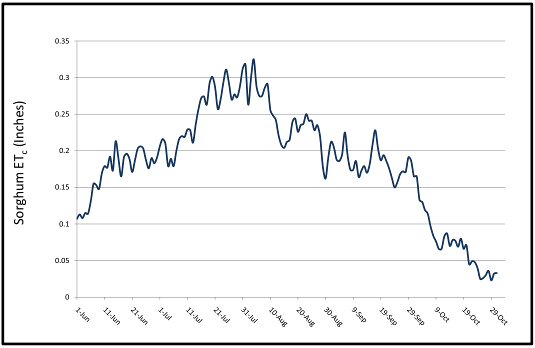
As with all grain crops, sorghum yield is most directly related to available water during the cropping season. The total available moisture (TAM) a sorghum crop uses is a combination of applied irrigation water, stored soil water and in-season precipitation. Individual TAM inputs can be managed to optimize the grain yield return per unit of water available.

Evapotranspiration

Identifying the amount of water to be applied to a crop is one of the most important management contributions that a sorghum producer can make. Evapotranspiration (ET) is the preferred method for measuring and estimating the total crop water use and the irrigation demand of a crop. ET is a comprehensive measure of crop water use in a production setting, because it measures water evaporated from the soil, plant surface, and plant's leaves during photosynthesis. Irrigation demand is the difference between the ET value and the water available from precipitation and/or the soil storage. ET values for sorghum can be obtained locally through extension services and, in most agricultural regions, online through weather station networks such as http://txhighplainset.tamu.edu/ and http://texaset.tamu.edu/ Also, the northern Rolling Plains may use nearby weather information in Oklahoma at http://agweather.mesonet.org

Over the 10-year period from 2000 to 2009, the peak daily grain sorghum ET was approximately 0.33 inches at the USDA Conservation and Production Research Laboratory at Bushland, Texas. This value will slowly increase the further you move south into the South Plains, Rolling Plains, and Concho Valley. For May through June plantings, water use commences at planting, peaks during late July and early August, and continues through harvest. Early or late planted sorghum can avoid these peak ET times and shift the sorghum's peak water use away from the hottest time of year. Under fully irrigated conditions, seasonal sorghum ET is approximately 27 inches.

Figure 2. 10-year average sorghum Daily Evapotranspiration at Bushland, Texas



Irrigation

In the Southern Great Plains, an irrigated sorghum crop will receive approximately half of its water through irrigation. Irrigation water is the one controllable crop water source and, when managed properly, can optimize the quality and yield returns of all crop inputs, including soil water and in-season precipitation.

Pre-Irrigation

Irrigation immediately following planting is generally recommended for sorghum rather than pre-irrigation. Research has shown that up to 60% of water applied as pre-irrigation is not available in the soil at the time of planting, especially close to the soil surface near sown seeds. In dry conditions, sorghum establishment nearly always improves with an inch irrigation applied at planting.

Growth Stages & Optimum Irrigation Timing

Following plant establishment, key water use periods occur 30 to 35 days after emergence during the formation of the seed head, during the boot stage, and during early grain fill. Sorghum reaches its maximum daily water use requirement during heading and early grain fill. The most significant sorghum yield response from irrigation occurs during sorghum's rapid growth stage, or the 40- to 50-day period encompassing the 4-leaf stage through the boot stage. The more visible process of sorghum seed set occurs at flowering after the end of this rapid growth stage based primarily on climatic factors and, to some extent, nutrient and water availability as the sorghum plant is transitioning from reproductive growth to grain filling. The unseen process of defining potential seed number, however, is determined many weeks earlier than seed set, usually about 5 to 6 weeks after germination when the growing point differentiates. The sorghum plant is also establishing leaf mass and area throughout the rapid growth stage in preparation for nutrient transfer that will occur during grain fill. A producer targeting maximum yield should be prepared to irrigate 6 to 8 inches during this period, depending on seasonal rainfall.

In deficit or low capacity irrigation scenarios, which are likely in the South Plains, Rolling Plains, and Concho Valley, preference should be given to irrigation applications just prior to the boot stage. Stresses caused by lack of water prior to and during the boot stage will define lower yield capacity that cannot be overcome with adequate or excess water later in the growing season.

The reproductive stage, a 40-day period following the boot stage, is critical in actually harvesting the potential yield established during the rapid growth stage. A producer targeting maximum yield should be prepared to irrigate 5 to 6 inches during this period. Adequate water should be available completely through the soft dough stage. Since sorghum water consumption declines as the plant reaches physiological maturity, preference should be given to earlier water applications.

Grain Sorghum Water/Irrigation Requirements in Relation to Heat Unit Accumulation

When a deficit irrigation strategy is implemented, either due to limited water or as part of a producer's overall agronomic approach, irrigation water should be applied during the priority periods of rapid growth and reproduction. Smaller, timely applications are recommended for sorghum under deficit irrigation to encourage uniform growth conditions. As little as 6 inches of timely irrigation water on sorghum in the Southern Great Plains has shown to greatly increase yields and profitability.

Table 7. **Sorghum ET and recommended Irrigation at typical dates and growth stages.**

Date	Crop Stage	Days after Planting	Heat Units after planting	ET per stage (in.)	Irrigation per stage (in.)
1-Jun	Seeded	0	0	1.1	1.0
9-Jun	Emerged	8	200	2.2	0.0
Rapid Growth Stage					
21-Jun	3 Leaf	20	500	0.6	1.0
24-Jun	4 Leaf	23	575	0.8	0.0
28-Jun	5 Leaf	27	660	1.6	2.0
6-Jul	GPD	35	925	3.3	3.0
20-Jul	Flag	49	1,290	2.8	2.0
30-Jul	Boot	59	1,550	1.8	1.0
Reproductive Stage					
7-Aug	Heading	67	1,710	1.4	1.0
10-Aug	Flower	70	1,850	3.5	2.0
25-Aug	Soft Dough	85	2,210	2.7	2.0
7-Sep	Hard Dough	98	2,510	1.8	None
17-Sep	Black Layer	108	2,700	3.9	None
15-Oct	Grain Harvest	136	3,100		None

Water and Grain Sorghum Productivity

These two considerations involving water affect the potential yield that can be produced in a particular field given its soil, water, and climatic conditions:

1. The amount of water needed for initial grain production. An approximate amount, a minimum of water—stored soil moisture, rainfall, or irrigation—is required for a grain sorghum crop to achieve initial grain production. For a low plant population field (likely lass than 20,000 plants per acre, and furthermore a crop with few tillers) with a hybrid maturity of medium or less, crop water use may be as little as 5 inches of equivalent moisture. In contrast, a typical field in the South Plains planted for modest irrigation levels resulting in 40,000 to 50,000 plants per acre might require 7 to 8 inches of moisture before initial grain yield, and plant populations of 70,000 or more plants per acre might require as much as 10 inches of moisture before any significant yield is produced. This readily demonstrates why we emphasize modest seed drop in West Texas. When population is modest, less water is wasted on unneeded stems and leaves, but instead, can go toward making grain.

2. The amount of sorghum grain yield per one incremental inch of water. Texas AgriLife Research and Texas Tech University data from the South Plains suggests that once the above threshold is met that each incremental inch of

rainfall or irrigation is generally worth about 350 to 425 lbs. of grain yield. In hot, dry weather, expect the lower end of the range. As one moves toward the Texas Panhandle, we more likely expect the incremental yield to surpass 425 lbs. per acre. In the South Plains, some field tests on drip irrigation suggest incremental yields over 500 lbs. per acre per inch.

Ceasing Irrigation

Irrigation cut-out will most likely occur no later than hard dough stage. The sorghum seed will proceed through grain development from watery ripe to milky ripe to mealy ripe then begins to firm at soft dough on to hard dough. If good soil moisture is still available to the plant (at least 2 inches) terminate irrigation as sorghum moves past soft dough. It is not reliable to base irrigation termination on grain color. A final irrigation may be applied during hard dough only if soil moisture storage is completely depleted or drought conditions are severe enough to hinder stalk quality at harvest.

When examining the head for seed maturation, be sure to check many heads and the whole head. Some difference in maturity will be observed on each head as seeds at the tip could easily be seven days older than seeds at the bottom of the head or primary tillers.

The color of the grain sorghum head can not be reliable to be used to determine irrigation termination. You still need to hand-check the heads and seeds. Furthermore, turnrow observations of sorghum fields do not tell you how much soil moisture is still available. Head coloration varies depending on hybrid. Some red sorghums are not as red as others, and many hybrids have grain color of orange, yellow, crème and white that never do give the sharp impression of distinct color change.

In general, when the seed in the head begins to take on an orange or reddish tint, the seed is most likely at the milk stage. As a field turns color, do not base the decision to irrigate again on the changing sorghum heads. Check for available soil moisture and the stage of seed maturity. Extension staff notes that little to no increase in yield is likely after a general red color appears over the field but an additional late season irrigation might help maintain stalk quality for harvest.

Does Sprinkler Irrigation Diminish Seed Set on Blooming Grain Sorghum? This question occurs among producers in West Texas. When a grain sorghum producer looks at the blasting effect of sprinkler irrigation under pressure and it is possibly knocking anthers off the head, there is concern that sprinkler irrigation on blooming sorghum could be detrimental. Texas AgriLife sorghum breeders and physiologists do not believe this is likely. Sorghum is largely self pollinated, which means that by the time you see the anther protruding from the floret the seed embryo is likely already fertilized. Farmers may be inclined to associate possible blanking in the heads with the timing of sprinkler irrigation, and admittedly, there may not appear to be any other plausible explanation if the weather conditions at bloom were not hot and dry. If producers remain worried about this issue, consider using LEPA irrigation with drag hoses and take advantage of the increase in irrigation water use efficiency for sorghum.

Irrigation System Efficiency

Irrigation efficiency is defined as the percentage of water delivered to the field that is beneficially utilized by the crop. Factors such as wind drift, leaching, evaporation, and run-off all lead to decreased irrigation efficiency. To determine the depth of water to be applied during an irrigation event, irrigation system efficiency should be accounted for by using the following equation:

$$\text{Irr. Depth} = \frac{\text{Irr. Demand}}{\text{Irr. System Eff.}}$$

With rising energy and water costs and declining water levels, wasted or underutilized water has the potential to directly impact sorghum profitability. To maximize the return on water and pumping cost inputs, it is recommended that irrigated producers make use of high efficiency irrigation systems such as subsurface drip (SDI) and low elevation center pivot sprinklers (LESA and LEPA) wherever feasible. To reach sorghum yield potential, an SDI, LESA, or LEPA irrigation system should be designed or nozzled at four gallons per minute per acre (GPM/acre) or higher. At lower system capacities, irrigation should begin earlier in each crop stage to ensure that soil moisture reserves are present to buffer sorghum water needs during the rapid growth and reproductive stages.

Table 8. Depth of irrigation water applied at various irrigation system capacities.

GPM/ Acre	Daily	Weekly	30 Days	45 Days	60 Days	90 Days
	inches applied					
2.0	0.11	0.74	3.2	4.8	6.4	9.5
2.5	0.13	0.93	4.0	6.0	8.0	11.9
3.0	0.16	1.11	4.8	7.2	9.5	14.3
3.5	0.19	1.30	5.6	8.4	11.1	16.7
4.0	0.21	1.48	6.4	9.5	12.7	19.1
4.5	0.24	1.67	7.2	10.7	14.3	21.5
5.0	0.27	1.86	8.0	11.9	15.9	23.9
6.0	0.32	2.23	9.5	14.3	19.1	28.6
7.0	0.37	2.60	11.1	16.7	22.3	33.4
8.0	0.42	2.97	12.7	19.1	25.5	38.2
9.0	0.48	3.34	14.3	21.5	28.6	43.0
10.0	0.53	3.71	15.9	23.9	31.8	47.7

Table 9. Efficiencies for agricultural irrigation systems under *optimal field conditions*.

Irrigation Method	Potential Application Efficiency
Surface	**50 - 80%**
Common Flood	50%
Land Leveled	60%
Row	65%
Alternate Furrow	70%
Surge	80%
Center Pivot	**70-92%**
LESA	85%
LEPA	90%
Drag Hoses	92%
Drip	**90-95%**
Above Ground	92%
Subsurface (SDI)	95%

Irrigation Costs

In most sorghum regions, the most significant portion of irrigation cost is related to the energy consumed during pumping. Historically, natural gas and electric pumping plants offer the lowest cost per unit of water pumped, typically by a significant margin. Where natural gas pipelines or electrical service are not available, diesel is the lowest cost pumping option. Although gasoline and propane engines offer the same thermal efficiency as the natural gas engines, they are traditionally more expensive to operate due to the higher cost of fuel on an energy basis (BTU) and should be avoided except in very specific situations. Regardless of energy source, the following operational practices universally promote lower irrigation water costs:

- Irrigate to crop needs, not irrigation system capacity.
- Regularly maintain and/or replace irrigation motors and pumps.
- Properly size irrigation motors and pumps.
- Use properly sized pipelines with smooth transition fittings.
- Operate at lower pressures.
- Make use of continuous acting air relief valves to eliminate false head and pressure surges.
- Utilize flow meters and pressure gauges to monitor irrigation system conditions.

Pump Costs for One Inch of Water

Unfortunately, most producers do not have an approximate answer to this question. This is particularly important when grain prices are low. If grain sorghum is $5 per cwt, and you figure your production at 400 lbs. per acre-inch, the gross return is $20 per acre-inch. Grain sorghum has both lower input costs per unit of return and better suitability to limited, timely irrigation.

Soil Water

In addition to providing necessary structure and nutrients to crops, soil serves as a holding reserve for water. Each soil has a certain holding capacity for plant available water (PAW), or water that a plant can successfully extract from the soil. Coarse soils with rapid infiltration rates hold a minimal amount of water within the plant root zone, but nearly all of the water is available for plant use. Conversely, fine textured soils hold a significant amount of water within the root zone, but a lesser percentage of the stored water is available for plant use.

Table 10. Available soil moisture by soil texture class. Soils with higher clay content hold a great amount of total water, but is increasingly ***less*** available to plants.

Soil Texture	Inches of Water (3' Root Zone)
Coarse Sand	1.50
Fine Sand	2.75
Loamy Sand	3.50
Sandy Loam	4.00
Fine Sandy Loam	5.25
Silt Loam	6.75
Silty Clay Loam	5.75
Silty Clay	5.00
Clay	4.00

Soil moisture is generally considered most valuable to a sorghum crop when it has been captured prior to planting. Field preparation following the crop previous to sorghum is vitally important in capturing off-season precipitation in preparation for the coming sorghum crop. Low impact, minimum tillage operations are recommended to minimize evaporation and surface run-off while maximizing soil water infiltration and sub-surface organic matter to assist in water holding capacity.

Capturing off-season precipitation through soil storage is a recommended agronomical strategy that helps early season plant growth, buffers drought stresses throughout the season, and saves costs associated with pumping and delivering irrigation water. Ideally, water from soil storage should be exhausted at the end of the season during grain drying.

In-Season Precipitation

Depending on location and weather patterns, in-season precipitation is typically a part of the water budget of irrigated sorghum, despite seasonal variations in quantity and timing. Although difficult to manage, the return on in-season precipitation can be optimized. In areas where in-season precipitation is probable, a portion of soil water capacity should be maintained to provide sufficient room to capture and contain water from small to moderate rainfall events. In addition to increased seasonal water and reduced pumping costs from holding and utilizing in-season precipitation, run-off and erosion are reduced, leaching effectiveness is increased, and in many cases, nitrogen is supplemented.

In regards to irrigation scheduling, in-season precipitation should be evaluated on an "effective rainfall" basis. Research has shown only a portion of the water received during a precipitation event will actually become useful to the sorghum crop. To avoid overestimating water received from precipitation, a producer should only credit precipitation events greater than 0.30 inch, or the peak daily sorghum ET. Consideration should be given to forgoing or delaying irrigation only if a precipitation event is larger than the scheduled irrigation depth or exceeds soil holding capacity. The benefit of in-season precipitation can often be redeemed at the end of growing season by terminating irrigation earlier with sufficient water stored in the soil profile.

Summary of "Top Tips" for Grain Sorghum Irrigation

- Begin the sorghum season with significant water reserves in the soil profile. This is best accomplished by maximizing off-season precipitation capture with minimum tillage and residue management practices. Pre-plant irrigation is not generally recommended for sorghum.
- In the arid and droughty conditions of the South Plains, Rolling Plains, and Concho Valley, LEPA irrigation coupled with furrow diking and drag hoses is an excellent practice to conserve water and maximize economic return on grain sorghum.
- Irrigate immediately following planting to improve germination, plant stand and soil-water reserves.
- Critical in-season irrigation periods are near growing point differentiation (if dry), early to mid-boot stage and early in the grain fill stage. In limited water conditions, any amount of water during these periods will be beneficial.

- Effort to apply water early during critical crop stages should be taken, especially in limited water conditions. Stresses caused by lack of water prior to and during the boot stage and grain fill stages will define lower yield capacity that cannot be overcome with adequate or excess water during subsequent plant growth stages.
- Smaller, timely applications are recommended for sorghum under deficit irrigation to encourage uniform growth conditions. As little as 6 inches of timely irrigation water on sorghum in the Southern Great Plains has shown to greatly increase yields and profitability.
- Irrigation termination should occur following the soft dough stage under typical seasonal conditions.
- On an on-going basis, know how much it costs you to pump one acre-inch of irrigation.
- Avoiding excessive plant populations above what is appropriate for the environment and the projected irrigation level ensures better, more efficient use of irrigation.

Sorghum Production Scenarios with Shared Irrigation on Split Pivots

In the past several years as irrigation capacities have continued their decline, numerous South Plains farmers have become more interested in scenarios where grain sorghum shares pivot irrigation space and water with another crop, particularly cotton. By managing the planting date of grain sorghum as well as choosing the sorghum hybrid maturity producers can minimize, if not eliminate, the overlap of significant water requirements for either crop ultimately reducing the number of acres to be irrigated at one time.

Which crop has main emphasis? That is assumed to be cotton (unless you signed a pounds contract for grain) then the decision becomes regarding cotton (or corn or peanuts) to give it all you can in contrast to trying to grow a full circle of crop that needs irrigation all at once. Grain sorghum's positive role in this scenario with cotton, however, is growing a crop that can fit to lower input conditions while also providing all-important rotational advantages.

The dual crop/dual planting date scenarios for split pivot irrigation in different regions of the South Plains include several possibilities with grain sorghum:

- Early cotton, late sorghum
- Early sorghum, delayed cotton
- Early corn, late sorghum
- Early sorghum, normal runner peanut; early Valencia peanut, late sorghum
- Early sorghum, late sorghum same pivot

<u>Planting Dates and Physiological Growth</u>

A particular planting date for either cotton or grain sorghum does not mean cotton cut-out or sorghum flowering will occur on a certain day or even within a few days. Heat and its accumulation drives physiological growth. For grain sorghum, cotton, or other crops these differences include:

- The same sorghum hybrid planted in late April will probably take five to seven days longer to reach half bloom versus plantings in June.
- Grain filling and maturation will likely be quicker for the early planted grain sorghum as it occurs in the summer rather than early fall.
- Delays in planting may be needed to allow for early season cool conditions. It is not worth slow emergence or sickly seedlings on cotton or sorghum if it means you need to wait another five days to plant. And if there is a major cold front coming you may decide to let it pass before planting. The potential damage to a crop from too-cold early conditions is likely a greater risk than if a bit more drought stress or heat during flowering hit crop later.
- Cool fall temperatures can greatly slow growth.

Split Pivot Scenarios Counties

Scurry/Howard/Dawson/Gaines/Lynn/Terry

Early cotton, late grain sorghum

- Half pivot with cotton, planted around May 5
- Peak water use early July to mid-August
- Physiological cut out (five nodes above white flower, NAWF) by about Aug. 10
- Greatly reduce irrigation around Aug. 20 if soil moisture is available. Texas AgriLife data suggests little additional irrigation benefit

especially if some rain is received.

- Consider medium maturity sorghum.
  - -"Schedule" flowering about Sept. 5
  - -Back up 65 to 67 days (from Sept. 5)-plant around July 1

Result—Early cotton, late grain sorghum: Early cotton is up to three weeks past cut out prior to sorghum flowering (around Sept. 5), and now has much lower moisture requirement. Sorghum enters peak water demand about 7 days after cotton cut out when cotton irrigation is greatly reduced. Sorghum maturity is near Oct. 10-15 with added potential of September rainfall assisting yield. Concentrate water to cotton early with one to two possible key waterings to sorghum (growing point differentiation, early boot) prior to flowering.

Early grain sorghum, delayed cotton

- Half pivot with medium-early sorghum, planted about April 25
- Flower by June 25-30—peak water use in sorghum is declining as cotton water needs rise rapidly
- Maturity about first week of August with harvest mid/late-August
- Cotton planting delayed to May 15th
  - -Physiological cut out about Aug. 20th
  - -Little overlap in peak irrigation needs

Hockley/Lubbock/Crosby/Floyd/Hale

Early cotton, late grain sorghum

- Half pivot with cotton, planted around May 5
- Peak water use early July to mid-late August
- Physiological cut out (5 NAWF) around Aug. 15
- Reduce irrigation around Aug. 25 if moisture is available, Texas AgriLife data suggests little additional irrigation benefit especially if some rain is received
- Consider medium-early maturity sorghum
  - -"Schedule" flowering about Sept. 1
  - -Back up 60 to 62 days (from Sept. 1)—plant around July 1.

Result—Early cotton, late grain sorghum: Cotton is up to two weeks past cut out and higher moisture requirement prior to sorghum flowering. Sorghum enters peak water demand about the time of cotton cut out but before end of cotton irrigation. Sorghum maturity is near Oct. 5 to the 10 with the potential of September rainfall assisting yield. Concentrate water to cotton early with one to two possible key waterings to sorghum (growing point differentiation, early boot) prior to flowering.

Early grain sorghum, delayed cotton

- Half pivot with medium-early sorghum, planted about April 25 (watch soil temps. if cool)
- Medium-early hybrid, flower by about July 1—peak water use is declining as cotton water needs rise rapidly

- Maturity about Aug. 5 and harvest begins about Aug. 20
- Cotton planting delayed to May 15
    - -Physiological cut out about Aug. 25th
    - -Little overlap in peak irrigation needs

Parmer/Castro/Bailey/Lamb/Cochran

May 10 cotton, late grain sorghum—this scenario is harder to separate irrigation of the two crops than to the south and east

- Half pivot cotton, planted around May 10
- Plant cotton earlier if you safely can due to soil temp.
- Peak water use early July to late August
- Cut out (5 NAWF) about Aug. 20-25
- Consider medium-early maturity sorghum
    - -"Schedule" flowering by Sept. 1st
    - -Back up 60 to 62 days (from Sept. 1)—plant about June 30th

Result—May 10 cotton, late grain sorghum: Cotton is about 1 week past cut out before sorghum flowering (around Sept. 1) and cut-out is about 0 to 7 days after peak sorghum water demand begins. Sorghum maturity near Oct. 5-10 (this is close to early frosts) with potential of September rainfall assisting yield. Concentrate water to cotton early with 1 to 2 possible key waterings to sorghum (growing point differentiation, early boot) prior to flowering.

Early grain sorghum, May 10 cotton (can't advocate delaying cotton in the NW South Plains)

- More separation in water use than late sorghum?
- Half pivot with sorghum, planted about May 1
- Medium-early hybrid, flower by about July 4
- Peak sorghum water demand reduces after July 10
- Half pivot cotton, planted about May 10
    -Peak water use early July to late August
    -Cut out (5 NAWF) around Aug. 20-25

Parmer/Castro/Bailey/Lamb

Early corn, late grain sorghum

- Half pivot 108- to 115-day relative maturity corn, planted approximately April 15
- Compare heat units requirements for specific hybrids
- Peak water use ~V10 and especially from silking to past milk (through about July 25); maintain good soil water to near ½ starch line
- Don't cut the corn short
- Consider medium maturity sorghum, about 5,000 lbs. per acre yield goal
    -"Schedule" flowering by about Sept. 1
    -Back up 65 to 67 days (from Sept. 1)—plant about June 20 to the 25

Result—early corn, late grain sorghum: The half circle of corn is essentially fully irrigated, but for grain sorghum one watering to establish stand (late June). Before corn is finished, a possible second water about four weeks after planting in advance of growing point differentiation (increase spikelet and seeds per spikelet set). Grain sorghum maturity Oct. 5 to 10 (this is close to early freezes) with potential of Sept. rainfall assisting yield. Modest population for grain sorghum to better prepare the crop to wait until after corn irrigation is completed.

Gaines/Terry/Yoakum

Runner peanuts (late April to May 1), early grain sorghum

- You can not diminish water to peanuts!
- Peak peanut water use early July to early/mid September
- Consider medium-early maturity sorghum, and planting late April
- Flowering by end of June and peak water use declining in early July—if you even decide to water any in July (choose lower seed drop for the sorghum crop)
- Some sorghum water sharing with peanut needed

Result: Sorghum is at or past flowering (about June 30) before peanut enters peak water demand. Concentrate water to peanut after July 1 with only one possible additional watering to sorghum, especially if soil water is banked. Sorghum maturity by approximately Aug. 5.

Early Valencia peanut, late grain sorghum

- Valencia peanuts usually dig 4 to 5 weeks earlier than runner peanuts
- Approximately May 1 Valencia peanut maturing in about 130 days to digging
- Must dig to avoid loss of large pods

- Most remaining irrigation could go to sorghum by about Sept. 1
- Consider medium-early maturity sorghum
  -"Schedule" flowering about Sept. 10
  -Back up 60 to 62 days (from Sept. 10)—
plant by end of first week of July

Fertilization

Grain sorghum production in West Texas ranges from unfertilized dryland to high-input full irrigation. Needless to say, the soil nutrient status is highly variable. Crop rotation and the frequent producer practice to fertilize only when a certain crop is in rotation means that residual fertility may be more important. Tillage and fertilizer placement practices will affect the nutrient use efficiency of grain sorghum.

Soil Testing

Many producers do not realize the extent of research and testing that is behind the process of analyzing soil samples for nutrients and the subsequent recommendations they generate. A realistic goal for many producers is to soil sample every three years.

Different Philosophies of Soil Test Recommendations

There are two common approaches to soil fertility recommendations for the same crop and production conditions. Each has its own merits and can be used successfully although these approaches can generate recommendations that seemingly are at odds with each other.

1. Provide what the crop needs for current-year production. Based on your yield goal, your current soil nutrient status and that nutrient's

projected availability to your crop, add the level of nutrients needed to fertilize your crop for the year. This approach in terms of out-of-pocket expenses costs less and may reduce potential nutrient losses due to leaching or other means.

2. Build-and-maintain soil nutrient status. Most likely this means fertilizing to maintain a higher long-term residual level of nutrients in the soil. Nutrient levels may be in excess of the crop's requirement, but also not at a luxury or wasteful level that squanders money. This approach, provided there are ample nutrients available, may guard against unexpected limitations in nutrient availability or higher crop demand if yields are higher than expected. This philosophy is more likely to be found among private labs.

TIP: If you have a fertilizer dealer, crop consultant, or other third party collect and submit soil samples for you, be sure to obtain a sample of the soil test report. Understand what the report is saying, and keep it in your records for the farm or field for up to 15 years so that you may track changes in the soil over time.

Different fertilizer recommendations

There are differences in the philosophy of soil testing. Provided the soil test value for a particular nutrient is the same, then build-and-maintain would likely have a higher fertilizer recommendation. This philosophy may be the normal approach to recommendations by a test lab. Apart from differences in philosophy, the calibration curves plotting nutrient requirement for a unit of yield are not necessarily the same. One lab may recommend 2 lbs. of N per cwt. of sorghum yield goal, whereas another recommends 2.5. Or a particular lab's recommendations might include additions or deductions to their calculation that are not factored in by a different lab.

TIP: When your soil test lab, fertilizer dealer, crop consultant, or other third party provides fertilizer recommendations, do the following:

- Ask about their philosophy of soil test recommendations.
- If you are receiving fertilizer application recommendations without the benefit of soil test results, ask about the guidelines used in arriving at those recommendations.
- Finally, if you receive recommendations without having even provided a yield goal, you need to question the recommendations closely to ensure that at least a minimum agronomic basis and not a pure sales motive alone is guiding fertilizer plans.

TIP: When choosing a soil test lab, inquire if the lab is accredited by a state agency/certification board, a participant in the North American Proficiency Testing program, or some other testing standard guidelines.

Texas A&M University Soil Testing Lab

The College Station lab provides complete fee-based services for soil, plant tissue, and water analyses. Texas AgriLife testing across Texas on grain sorghum forms the basis for soil test recommendations for samples. For more information on services, submittal forms, and how to collect and submit representative samples visit http://soiltesting.tamu.edu/

Table 11. Approximate nutrient uptake and removal by grain sorghum per acre for major nutrients.

Yield per acre	Nutrient Uptake (cwt.)†			Nutrient Removal (cwt.)‡		
(lbs.)	N	P2O5	K2O	N	P2O5	K2O
2,000	60	21	55	30	15	8
4,000	120	42	110	60	30	16
6,000	180	63	165	90	45	24
8,000	240	84	220	120	60	32
10,000	300	105	275	150	75	40

†Nutrient uptake at the rate (per cwt.) of 3.0 N, 1.1 P2O5, 2.75 K2O

‡Nutrient removal at the rate (per cwt.) of 1.5 N, 0.75 P2O5, 0.4 K2O

Nutrient uptake is the total taken up by the crop grain and above ground vegetation. These numbers should be used only a general guideline (Source: Potash & Phosphate Institute).

Nitrogen

It is common in West Texas, particularly on dryland, do not fertilize grain sorghum at all, even for nitrogen. To some extent this 'just-get-by' attitude resulted from low grain sorghum prices, but may also reflect poor attitudes and the lack of success on the part of many producers due to too-high seeding rates and little thought in hybrid selection. Sorghum indeed responds to nitrogen. The Texas AgriLife Research Crop Testing program for dryland sorghum performance tests in West Texas routinely adds 40 lbs. N per acre, then producers have difficulty believing our yields in some years that top 3,000 lbs. per acre. The N was available when conditions were favorable for hybrids to take advantage of it.

Nitrogen is by far the most important nutrient for sorghum to maximize production. For maximum yields relative to the available water, N should not be lacking or grain development will be reduced. The long-standing general nitrogen (N) nutrient requirement for Texas grain sorghum is:

N requirement:
2 lbs. actual N (soil or fertilizer) per acre per 100 lbs. of yield goal
Thus a 5,000-pound grain yield would need about 100 lbs. of N per acre. In Texas this has generally been presented to producers as the amount of N fertilizer to add. The Texas A&M University soil test lab recommendations, however, use the

above rule but deduct nitrate-N from a soil test in the top 6 inches.

Texas A&M recommendation:
(Fertilize 2 lbs. actual N per acre per 100 lbs. of yield goal) - (soil N at 0-6 inches)

Hence for the same yield goal noted above, but with a soil test report showing 9 ppm NO_3—N for a 6-inch deep sample (which is about 2 million lbs. of soil), the calculated N fertilizer addition is:

Fertilizer N to add:
(2 lbs. N per acre) X (50 cwts. per acre yield goal) – (2 X 9 ppm) = 82 lbs. N per acre

This N recommendation, particularly when the profile N is deducted, is more conservative (lower) that what is normally generated in other states, such as Kansas or Oklahoma, which use a more complicated formula or include other adjustments. When soil test information is not available this rule will help producers at a minimum to be in the range of meeting the sorghum's N requirement for good yield.

Crop rotations may affect residual N, and ideally soil testing for N would use a 24-inch depth sample.

Nitrogen Applications after Sorghum Emergence

Side-dress N applications with knives or coulters should be made approximately 20 to 25 days after germination (4 to 5 leaf stage) to ensure good N fertility in advance of initial growing point differentiation (30 to 35 days after germination) while minimizing any root pruning. Later applications may excessively prune feeder roots and miss the potential benefits to GPD.

Under center pivot irrigation, N fertilizer may be applied several times during the early part of the growing season. Due to the convenience of pivot-applying N, up to 20% of N might be held back until after GPD, but extension recommends that the final N be applied no later than boot stage, which is about 60 days after germination for a full-season hybrid and no later than about 50 days for a medium maturity hybrid. About 70% of the needed N for a grain sorghum crop is already in the plant at boot stage.

Because N is relatively mobile in the soil, fertilizer placement is not as critical for N as it is for most other nutrients. Nitrate-nitrogen, NO_3—N, the form most available to grain sorghum, will move with water and can be readily brought into contact with crop roots for quick absorption.

Ammonium-nitrogen (NH_4, also available to plants) is positively charged and is held by negatively-charged clay and organic matter particles in the soil until converted by soil bacterial action into the nitrate form. Nitrification, the conversion from ammonium to NO_3—N in the soil, is most likely to occur when fields are arable. When fields are water-logged, nitrate can be converted to nitrogen gas, a process known as denitrification, and lost from the soil by volatilization.

<u>Guidelines for Surface Applied N Fertilizer</u>

Ammonium-based fertilizers are more susceptible to volatilization losses when applied to the soil surface if no rain or irrigation occurs. Three key factors reduce the effectiveness of the surface-applied N leading to volatilization losses, particularly when acting together:

- Moist or wet soil
- pH level greater than 7
- Increased temperature
- Windy conditions

Extension always recommends that producers using broadcast N fertilizer apply to dry soil when possible. Also, applying N prior to a predicted rain or scheduled irrigation is particularly advantageous.

Table 12. Recommended Nitrogen Application Rates (lb/acre) for Grain Sorghum based on grain sorghum price and N fertilizer price.

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

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

Starter Fertilizer & Salt Injury Potential

Starter fertilizer applications for sorghum are a sound practice in the Texas High Plains. Even if soil tests like phosphorus (P) are in the "medium" range, one of the purposes of "starter" fertilizer for N and P is to "kick-start" or stimulate growth right after emergence. Starter fertilizer research, especially in Kansas has shown that rooting and early growth is promoted by starter fertilizer applications in the 2 in. x 2 in. configuration (from the seed, 2 inches to the side and 2 inches below). Starter fertilizer can be applied with the seed, known as "pop-up" fertilization, but at rates much less than the 2 in. x 2 in. placement. A common concern is potential salt and ammonia damage if the rate of starter fertilizer is too high.

- Salt injury comes from N, potassium (K), and sulfur (S).
- Pounds per acre of N+K+S applied will determine injury potential, but K and S fertilization is rare on the High Plains due to our high K and S native soil fertility.
- N fertilizers that contain or readily form ammonia, NH_3, can be toxic to seed (see below).
- Phosphorus fertilizer does not cause injury to seedlings, but most P fertilizers used in West Texas contain N, so follow the below guidelines for N.

Table 13. Suggested maximum fertilizer salt amounts (lbs. N-K2O-S/acre) for seed row fertilizer placement, row spacing, and soil type.

Fertilizer	row spacing (inches)					
Placement	20	30	40	20	30	40
Pop-up (with seed)	8-12	5-8	6	8	5	4
2"X2" pattern	60	40	30	40	20	15

More salt-forming N and K fertilizers can be applied to loamy and clayey soils than to sandy soils or on narrower rows spacings. Pop-up starter fertilizer rates are much lower than starter fertilizer 2 inches from the seed. If the total amount of N fertilizer applied to your sorghum is 60 lbs. N per acre, and you are on 20-inch rows, then the entire dose could be applied as a 2 in. x 2 in. starter on loamy and clayey soils. However, in most cases, the balance of the N fertilizer will have to be sidedressed. This can be as 32-0-0 either dribbled or knifed in 6 to 10 inches off the row without the threat of injury, applied through a pivot, or using a broadcast spreader.

Some starter N fertilizers have potential for injury from ammonia (NH3). This is mainly a concern with pop-up fertilization. For pop-up applications with the seed, the safest bet is to avoid altogether urea ammonium nitrate (32-0-0 or 28-0-0), mixtures of 32-0-0 and ammonium thiosulfate (28-0-0-5S), solid urea (46-0-0), mono-ammonium phosphate, or MAP (11-52-0), and diammonium phosphate DAP (18-46-0).

Phosphorus (P_2O_5)

It is difficult to gauge P requirements for grain sorghum without soil test information. Complicating matters, soil test P is best determined for a six inch depth sample in contrast to the suggested N sampling up to 24 inches. Furthermore, once soil test P levels rise above 'very low' and 'low' P response is inconsistent. When growing conditions are cool or wet early in the season, especially where producers might be planting early to minimize sorghum midge potential, seedlings may show temporary P-deficiency symptoms. This particular situation lends itself well to either banded or in-furrow application of P.

Since soil P is relatively immobile, or "fixed" in soils, placement in a concentrated form is particularly important in low to medium testing soils. Research has shown that plants obtain a higher proportion of their needed P from soil reserves. Only about 30% of applied P is used by the crop following fertilization in the current year, even though it may have been banded.

TIP: If you don't know your soil P status, don't have a soil test, but are willing to band P then consider a P_2O_5 rate that is about one-fourth to one-third of the N rate.

Potassium (K2O, or Potash)

Soil K levels in West Texas are generally high and unless soil K levels have been diminished greatly, it is likely that only top end grain sorghum yields would consider K additions. Texas A&M University soil test guidelines project the K requirement at 2 lbs. K_2O/A per cwt. However, the soil test levels are normally sufficient (if not well in excess) to preclude fertilizing with potassium.

Iron (Fe) and Zinc (Zn)

Two other important nutrients for grain sorghum production in West Texas are iron and zinc. Zinc is not commonly an issue in sorghum in this region, but iron deficiency related to caliche soils and outcroppings in West Texas is a particular concern for sorghum. Chalky soils that appear whitish across the field should probably never have grain sorghum, and it is prohibitively expensive to correct it. Many fields, however, simply experience some degree of iron deficiency. The classical condition of interveinal chlorosis where the veins of the younger leaves remain green and the leaves are yellow between the veins (Figure 'Fe' for young sorghum that was also rained on). In the worst of cases, the leaves are almost completely bleached out and the plants do not grow. Fe deficiency can be induced temporarily due to water-logged conditions.

Iron Deficiency Compared to N Deficiency.

Fe deficiency is normally expressed on the newest leaves, and Fe is immobile within the plant.

When Fe becomes available again, newly emerging leaves will again be dark green. Older chlorotic leaves will not green up unless they receive a direct foliar feed. In contrast, N is mobile in the plant, and will move to the youngest leaves from older plant tissues (which may express N deficiency) and shows no striping symptoms.

Most soil tests will flag Fe less than 4 parts per million (ppm) as deficient. Currently, there are no economical sources of soil-applied Fe available. Therefore, the only options for correcting Fe deficiencies are to apply foliar Fe sprays in-season or to apply manure for long-term correction. If iron chlorosis has been observed during previous years in a field, Fe fertilizer materials may be applied preemptively to the foliage through multiple sprayings early in the season. Table X gives suggested foliar treatments to correct iron as well as Zn deficiencies.

Table 14. Suggested sources, rates and timing of iron and zinc foliar sprays.

Product*	Product/100 gals water	Product/ Acre	Timing
Iron sulfate (20% Fe)	20 lbs (2.5% solution)	1 lb. then 2-3 lbs.	10-14 days after emergence - 5 gals/A over crop row. Follow with 2 apps. @ 10-14 day interval @ 10-15 gals/A
Iron chelate (10% Fe)	8 lbs. (1%)	0.4-0.5 lbs	Same as above
Zinc sulfate (30% Zn)	2 lbs. (0.5%)	0.2 - 0.4 lbs	10-20 gals/A in first 30 days
Zinc chelate (9% Zn)	2 qts (0.1%)	1 pint	10-20 gals/A in first 30 days

Zinc

Where soil P is 'very high' or 'high' and zinc levels are low then further P application may induce zinc deficiency particularly when soil pH is high. If soil test results indicate a possible zinc deficiency (less than 1 ppm Zn), zinc fertilizer may be broadcast and incorporated preplant with other fertilizers or ideally banded near the seed at planting. Chelates are up to five times more effective than inorganic sources, but price will determine which product is a better choice.

Other Nutrients in Texas Sorghum

Unless you have had a particular problem in the past with sulfur, calcium (all West Texas soils are high), manganese, etc. there is no fertility correction likely needed. Noting other nutrients and their levels in soil test reports is probably sufficient for keeping an eye on possible imbalances.

Foliar Feeding Major and Minor Nutrients

In general foliar feeding is expensive. Extension does not recommend that producers rely on foliar feeding for N due to the far higher per unit cost of N. Foliar feeding of micronutrients is more common, and many products will have a package of micronutrients and simply may be the most convenient means to use if you have a known deficiency with an individual nutrient. Otherwise, significant amounts of micronutrient sprays are used that probably provide little if any benefit ('feel good' or 'catch all' treatments?). Micronutrient deficiencies other than iron are hard to diagnose without experience and/or a tissue test. Non-chelated sources if available and applied with a good sticking agent can be quite effective and perhaps a better buy.

Weed Control

Weeds compete with grain sorghum for light, nutrients, and soil water thus reducing yield and grain quality. In addition, they harbor insects and diseases that further impact yield and increase costs. Effective sorghum weed control first begins with identifying problem weeds in a given field and developing a control strategy. If there is any doubt about a particular weed take it to your county agent or extension specialist for identification. Implement control strategies to first control those weeds that most affect yield.

Weed control in sorghum must begin in the months prior to planting. Weeds left uncontrolled during any fallow period will use up valuable soil moisture that could otherwise be used by the sorghum crop. Control these weeds either by tillage or with herbicide application. The use of soil residual herbicides like atrazine can be particularly valuable prior to planting, reducing tillage and herbicide applications that might otherwise be necessary to control multiple flushes of weeds. However, make certain that any soil residual herbicide used is safe for planting sorghum.

The yield loss associated with sorghum due to weed competition is greater than that of most grain crops. Typical losses range from 30 to 50% but in extreme cases can result in complete crop failure. In the Southern High Plains, pigweed species and kochia are cited most often as the weeds that infest the largest number of sorghum acres. Studies have shown that even one pigweed within 24 inches of grain sorghum can reduce yield nearly 40%. Kochia can be even more competitive than pigweed using 1 inch of soil moisture by the time it reaches 6 inches in height. One inch of soil moisture can be worth 500 lbs. per acre of grain sorghum yield.

Annual grasses generally do not reduce yield as much as broadleaf weeds, but are more difficult to control. Yield loss will be the greatest when weeds emerge with the crop or soon afterwards. The most critical period for weed control is the first four weeks after planting. If weeds are controlled during this time, and control is maintained through the remainder of the season, little reduction in grain sorghum yield will occur. Yield reduction from weeds that emerge four weeks after planting is usually minimal.

Broadleaf Weed Control

Most weed control strategies should consider the use of atrazine (also propazine if rotating to cotton) either applied prior to planting, at planting, prior to crop emergence or applied soon after crop emergence. Atrazine is relatively inexpensive and will control most broadleaf weeds. Restrictions and rates of atrazine use vary considerably depending on state/local requirements. Closely examine the label for use in any particular field. Generally, atrazine should only be applied prior to sorghum emergence in medium or fine textured soils at reduced rates, or crop injury can occur. The safest way to use atrazine is to apply the herbicide soon after the crop has emerged but before it reaches 12 inches in height. To control emerged weeds, atrazine should always be applied with crop oil. The smaller the weeds, the better the control will be. If atrazine cannot be used or is ineffective on the weeds present, other herbicides should then be considered.

Other commonly used herbicides applied prior to sorghum and weed emergence are propazine, metolachlor, alachlor and dimethenamid (Table 15). These are sold under a host of trade names. Propazine is very effective on many broadleaf weeds and is safer on the sorghum crop than atrazine. The other three herbicides are more specific on which broadleaf weeds they will control and generally do not control the weeds for as long. Combining atrazine with any of the three improves overall control of broadleaf weeds.

Herbicide labels are constantly being updated. Before using any herbicide check the label for specific use under your conditions. Most state extension services provide updated herbicide lists and specific weed control recommendations.

Table 15. Popular pre-emergent herbicides by active ingredient name (common trade names).

Atrazine (AAtrex, atrazine)	Primarily broadleaf weed control. Long residual.
Propazine (Milo-Pro)	
Metolachlor (Dual II Magnum, Cinch, Parallel, Me-Too-lachlor)	Good annual grass control with some broadleaf activity. Must use Concep III treated sorghum seed.
Dimethenamid (Outlook)	
Alachlor (Micro-Tech)	
Atrazine + Metolachlor (Bicep II Magnum, Cinch ATZ)	Broadleaf weed and grass control. Must use Concep III treated sorghum seed.
Atrazine + dimethenamid (Guardsman Max. G-Max Lite)	
Atrazine + alachlor (Bullet, Lariat)	
Others	See state and local Extension service recommendations for other pre emergent herbicides.

Herbicides commonly used after crop and weed emergence are listed in Table 16 along with a brief description of their strengths and weaknesses. Check label for rates, application timing and other restrictions. All of these can be used in combination with each other. However, 2,4-D and dicamba have been used for decades for broadleaf weed control. These must be applied correctly or severe crop injury can occur. These should only be applied to sorghum that has not exceeded eight inches in height. Drop nozzles that keep the herbicides out of the whorl of the sorghum can be used up to 15-inch sorghum. Care should be taken to minimize drift of 2,4-D and dicamba or damage to other broadleaf crops and ornamentals can occur.

Table 16. Popular broadleaf post emergent herbicides by active ingredient name (common trade names).

Atrazine (AAtrex, atrazine)	Effective on most broadleaf weeds and will provide soil residual control. Apply with crop oil.
2,4-D (2,4-D, Unison, Barrage, others)	Will control most broadleaf weeds, crop injury can be significant and drift to cotton fields is a concern.
Dicamba (Banvel, Clarity, Vision)	Will control most broadleaf weeds, crop injury can be significant and drift to cotton fields is a concern but safer than 2,4-D.
Prosulfuron (Peak)	Must be applied to small weeds. Best to use with dicamba, 2,4-D or atrazine.

Fluroxypyr (Starane)	Weak on pigweed. Good on kochia, morningglory, and devilsclaw.
Carfentrazone (Aim)	Fast burn down. Effective only on small weeds (<2 inches).
Halosulfuron (Permit)	Best product to use for nutsedge (nutgrass) control. Ineffective when used alone on most broadleaf weeds.
Others	See state and local Extension service recommendations for other post emergent herbicides.

<u>Grass Control</u>

There are no effective herbicides that can be used after the crop and grass has emerged in grain sorghum. Either metolachlor (Dual, Cinch, Parallel, Me-Too-lachlor), alachlor (Micro-Tech), or dimethenamid (Outlook) must be applied prior to crop and weed emergence. The sorghum seed must be treated with a herbicide seed safener (Concep III) or crop injury will occur. The effectiveness of control of annual grasses will depend on the specific grass species as well as other factors. However, these are the best products currently available for annual grass control. These three products are often sold in combination with atrazine. All herbicides applied pre emergence require a minimum of 0.5 inches of rain or irrigation to move them into the soil. An alternative to rain or irrigation is to incorporate the herbicides with a rolling cultivator prior to grass emergence. However, care must be taken to avoid damaging the sorghum.

Perennial Weeds

Johnsongrass and bindweed are the two perennial weeds that cause the most problems in sorghum with both weeds having the potential to completely eliminate any significant grain sorghum yield. Prevention is the best method of control with these weeds. As soon as either weed is detected, producers should do everything possible to prevent their spread. Do not run tillage equipment through isolated spots of these weeds as this will tend to spread them to other parts of the field. Diligent spot treating with glyphosate (Roundup) for Johnsongrass and dicamba, 2,4-D, glyphosate, and even some soil sterilants for bindweed will be required to eradicate these two weeds. For Johnsongrass that is already widespread, the best control method is to allow the Johnsongrass to emerge prior to sorghum planting. Once the Johnsongrass has about 6 inches of growth treat it with glyphosate. Sorghum should then be immediately planted with as little disturbance of the treated Johnsongrass as possible. Although this will not provide season-long control it will allow the grain sorghum to grow with very little Johnsongrass competition during the critical four weeks after planting. Grain yield will be considerably better than if no control was attempted.

The glyphosate treatment procedure outlined above can also be effective on bindweed. In addition, early in-season treatment of 2,4-D or dicamba should be considered. Another herbicide, quinclorac (Paramount), can be used alone or in combination with 2,4-D or dicamba. Quinclorac is safe on sorghum and can be very effective.

Table 17. A Closer Look at Propazine and Atrazine for West Texas Sorghum-Cotton Rotations

Propazine and Atrazine Herbicide Label(*) and Miscellaneous Notes for Grain Sorghum

Parameter	**Propazine**	**Atrazine, 24(c) label**
Cost	~2X of atrazine	
Soil pH*	No restriction	<8.5, no caliche, cuts, etc.
Organic matter*	No restriction	Minimum, 1.0%
Soil texture exclusions	Loamy sand, sand (incorporate shallow on sandy loam soils)	Sandy loam, loamy sand, sand
Application timing*	Not labeled for post-emerge	Pre-plant, pre-emerge, post-emerge?

Rotation to cotton*	None	Yes, depending on application timing, rain + irrigation
Tank mixes*	Many (see label)	Many (see full label)
Parameter	**Propazine**	**Atrazine, 24(c) label**
Minimum carrier volume:		
aerial	3 gal/A	Not listed on 24(c)
ground	10 gal/A	10 gal/A
Additional info.*	50 mesh screens	50 mesh screens
	min. 30-40 psi	35-40 psi
	agitate well	agitate well

Texas AgriLife Weed Scientist Comments on Propazine vs. Atrazine

Wayne Keeling, Research weed scientist, Lubbock, (806) 746-6101, wkeeling@ag.tamu.edu

Brent Bean, Extension Agronomist, Amarillo, (806) 677-5600, bbean@ag.tamu.edu

The following reflect research observations, an analysis of producer experience, and potential limitations for propazine in grain sorghum weed control.

- Be careful with both herbicides especially on sandy soils and/or less than 1% O.M.
- Both herbicides have similar activity on broadleaves when used pre-emerge, but atrazine has better post-emerge activity.

Atrazine

- Atrazine rates less than or equal to 1 lb. per acre should be ok to minimize sorghum injury potential and rotating back to cotton.
- For sandy loam, reduce rates to about 0.75 lb. per acre or even slightly less if you expect potential carry over.
- For sandy soils, early POST may be slightly better then PRE, but weeds must be small.
- POST safer but still potential carryover issues
- Atrazine on sandy soils does, however, present risks due to possible injury to current-year sorghum and cotton or wheat rotation.

Propazine

- Preplant and pre-emerge applications (not labeled post-emerge), excellent on pigweed, with some help on troublesome broadleaf weeds
- Propazine must be pre-emerge to any weed; application to young sorghum probably not injurious.
- Propazine is safer than atrazine on grain sorghum and for rotating to cotton.
- Rotation flexibility for wheat (120 days) or cotton
- Tank mix with metolachlor, alachlor, dimethenamid, glyphosate
- 0.75 to 1.0 qts. per acre can be rotated to cotton though rates above 0.75 qt. per acre are not for sandy loam soils.
- 1.2 qts. per acre probably no problem on heavier soils and irrigated sorghum.

- Has minimal to poor activity on grasses at the labeled rates hence not recommended for grass control.
- Mixing with s-metolachlor is a good idea, especially for irrigated sorghum, heavy pigweed pressure, and a wet year.
- Propazine alone is suitable for dryland.

Herbicides, Grain Sorghum, and Crop Rotation Restrictions

Cotton Herbicides and Rotation to Grain Sorghum

- Staple—Do not plant grain sorghum in a cotton hailout/replant situation after Staple has been applied. Even banded applications present a major concern. Though high irrigation or rainfall may diminish Staple residues, significant sorghum injury can still be expected the year after Staple was applied.
- Valor—In a cotton crop failure situation do not plant grain sorghum for one month.
- Other cotton pre-emerge herbicides—Should be OK the next year. For example, the rotation restriction for diuron and Layby Pro is 8 months.

Table 18. Rotation Restrictions Herbicide and Related Formulations (Months)		
Wheat & Small Grains	**Corn**	**Peanut or Soybean**
Amber 75 DF {triasulfuron}, 14	Nicosulfuron (Accent & Steadfast), 10 or 18	
Stinger {clopy-ralid}, 10.5		Cadre, 18
Maverick Pro {sulfosulfuron}, 22	Pursuit (Clearfield), 18	Pursuit, 18
Beyond (imazamox) (Clearfield), 9	Corvus, 9 or 17	Raptor, 9
Ally XP {metsul-furon methyl}, 10		
Glean {chlorsulfuron}, 14-25		
Finesse (Glean + Ally) {chlorsulfu-ron + metsulfuron methyl}, 14-26		
Olympus {pro-poxycarbazone-sodium}, 12		
Olympus Flex, 9		
Rave 59 WDG {triasulfuron + dicamba}, 14		

Grain Sorghum Herbicides and Rotation to Cotton

Peak (prosulfuron)—22-month restriction

Atrazine and the many products that contain atrazine—The main labels for atrazine products state:

- If applied after June 10, do not rotate with crops other than corn or sorghum the next year, or injury may occur.
- In the High Plains and Intermountain areas of the West where rainfall is sparse and erratic or where irrigation is required, use only when corn or sorghum is to follow.
- Cotton can be planted the following year but as noted elsewhere there are specific restrictions on use rates and soil types for use in sorghum which may affect rotational cotton.

Propazine—The label states that in West Texas cotton may be planted after a broadcast application of 1.2 qts., however, that high an application rate would possibly be found only in the Texas Panhandle (0.50 to 0.75 qts. per acre on sandy loams in the South Plains; 0.75 to 1.20 qts. per acre on loams).

Controlling Volunteer Wheat

Controlling volunteer wheat is not easy. The best bet particularly for dryland may be to not till and leave the wheat on the surface with minimal soil contact and drying conditions. Tillage helps if the wheat is buried, but most land is rarely tilled. Dual Magnum is the best grass herbicide in sorghum, but does not efficiently control wheat. Hoods are risky, sweeps do not get wheat in the row.

For irrigated production considering watering once to trigger germination of first flush of volunteer wheat, then kill with Roundup or burndown in about two weeks, then plant.

The potential problems with these chemicals are chemical applications place too much of the herbicides on the plant or in the whorl, causing injury and errors with both hooded sprayers and mis-directed drop nozzles, which may be due to defective equipment, ground speed too fast, drift within the row, and operator error. None of these potential errors are without a solution; attention to detail can solve many of the concerns.

If you are frequently relying on 2,4-D, dicamba, paraquat, or glyphosate mid-season to deal with weed problems, then we need to back up and re-evaluate our comprehensive weed control program to prepare for and attack potential weed issues earlier in the season.

CAUTION: Sprayer equipment, applicators and labels aren't perfect. We may be inclined to push the limit on:

- Herbicide rate (a little more per acre, especially on that sandy soil),
- Timing (a few days or a week later won't hurt, this leads to increased crop injury OR weeds that germinate or grow larger and become harder to control),
- Permitting too much herbicide/crop contact.

Glyphosate Drift from Cotton to Grain Sorghum

An increasing problem throughout West Texas is glyphosate drift. Grain sorghum can tolerate low levels of glyphosate drift without long-term impacts but is susceptible to injury.

Improving Your Weed Control Team

The manner in which you train, supervise and verify your employees understanding and their herbicide application methods can pay large dividends. Require your permanent employees and/or sprayer operators to obtain a pesticide applicator's license.

How you verify your staff's mixing and spraying of herbicides can reduce the possibility of a mistake leading to crop injury or worse. Consider these suggestions:

- Confirm and cross-check which chemicals are being used.
- Ask questions to double check.
- Ride the rig with your staff. There are things you see as an experienced operator that can ensure proper application or recognize

something that is not right.
- Stress the important of fixing plugged nozzles and other equipment issues promptly.
- Maintain consistent communication between your employees when problems arise.

Keys & Concerns for Weed Control in Southern and Rolling Plains Grain Sorghum

The following weed scientists offer these suggestions regarding weed control tips, concerns, and common mistakes in West Texas grain sorghum.

South Plains

Wayne Keeling, Research Agronomist, Lubbock, (806) 746-6101, wkeeling@ag.tamu.edu

- Palmer amaranth/pigweed control—it is a necessity for profitable yields.
- Ensuring crop safety both from herbicide applications as well the potential injury from residual activity to your rotation crop, especially in sandy soils.
- Post-emergence weed control—grain sorghum becomes too advanced for dicamba (e.g., Banvel, Clarity, etc.) use limited post-emerge options.
- When grain sorghum follows wheat—volunteer wheat control is not readily accomplished.
- Mistake: no pre-emerge herbicide is used—and it gets weedy—then what do you do?
- Mistake: dicamba—applied too late leads to crop injury (as well as reduced weed control effectiveness on larger weeds).

South Plains and Panhandle

Brent Bean, Extension Agronomist, Amarillo, (806) 677-5600, bbean@ag.tamu.edu

- Applying 2,4-D or dicamba past the labeled stage. Once the growing point is above ground, sorghum injury is more likely. Reduced yield may or may not occur. Somewhat dependent on hybrid. Sometimes injury, including reduced yield, will occur even if these products are applied according to the label.
- Expecting 100% control of large broadleaf weeds with post emergence herbicides. The smaller the weed the better the control.
- Expecting atrazine or propazine to control grass. If you get any significant control of grass with these products, consider yourself fortunate.
- Thinking you have atrazine or propazine tolerant weeds. Most of the time herbicide failures with these two products are a result of either poor application timing, or an environmental issue. For example, if weeds germinate and emerge prior to rainfall or irrigation to incorporate the herbicide, weed control failure will occur.

Rolling Plains

Todd Baughman, Extension Agronomist, Vernon, (940) 552-9941, tbaughma@ag.tamu.edu

- Few herbicide options (2,4-D or dicamba options cannot always be used, and if planning on double cropping wheat behind sorghum then atrazine is out).

- Pre-emergence applications:
  - Problem—lack of rainfall behind pre-emergence applications to activate the herbicide (some labels may then recommend light incorporation if rain is not received). Mistake—lack of pre-emerge application at all.
  - Weather conditions before and after herbicide application (hot and dry) reduce weed control effectiveness.
- Weeds
  - Timing—applying herbicides at the right time for optimum control.
  - Size (mistake)—the smaller sized weeds are more easily controlled, but too often control efforts come later
  - Weed condition (mistake)—weeds that are stressed are hardened thus more difficult to control, and waiting until drought conditions to effect control reduces success.
- Timing weed control options to the appropriate grain sorghum stage of growth (common mistake is waiting until sorghum is too large thus more susceptible to herbicide injury).
- Mistake—Unwillingness to run hooded sprayer: this tool indeed is an effective option to protect grain sorghum but still get many weeds knocked back.
- Windmillgrass and marestail are becoming bigger issues on no-till ground

Most Common Weed Issues—Rolling Plains

- Pigweed
- Crabgrass
- Texas Panicum (Colorado grass)
- Barnyard grass
- Morningglory
- Kochia
- Russian thistle

For further information and online access to chemical labels view:

- *Chemical Data Management Systems, http://www.cdms.net (click on 'Services,' then Labels/MSDS, then type in chemical brand name*
- *Greenbook, http://www.greenbook.net, may need to register for use. Allows searches by product or active ingredient. Often database is incomplete as a major chemical label is not found.*

Insect Management

An integrated approach to managing insect and mite pests can help Texas sorghum growers and crop protection specialists:

- prevent damaging insect pest infestations;
- diagnose the presence and severity of an insect pest infestation; and
- control an infestation with insecticides when preventive methods are not fully effective and sampling justifies the need for insecticide.

Some insect and mite pests can reach damaging levels throughout the growing season. Others are occasional pests, meaning they cause economic damage in localized areas or only during specific stages of plant growth. Often only one or two key insect pests are likely active at any given time in any sorghum-growing area in Texas. Figure 3 illustrates the probability of various insect and mite pests occurring at each plant development stage.

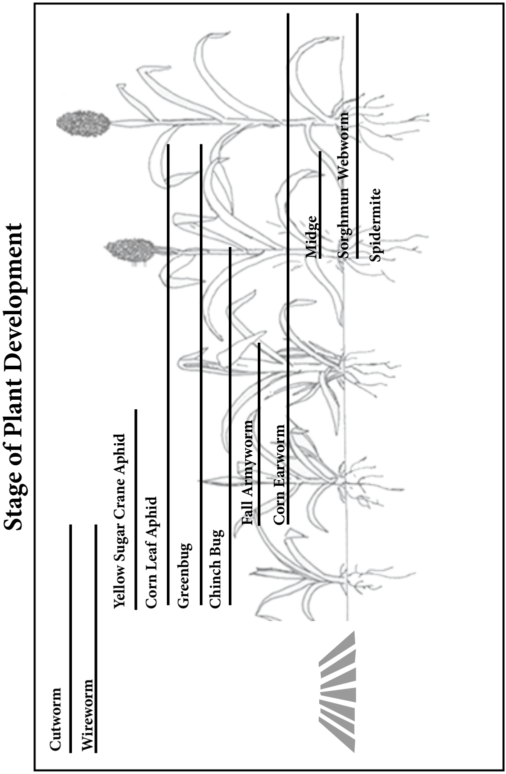


Fig. 3. Consists of data compiled by the University of Arkansas Extension Service which outlines the time-frame (shown in darkened line) when common insect pests are more likely to occur during the sorghum growing season.

Table 19. According to AgriLife Extension entomologists, the pests that can potentially cause the most serious economic damage in Texas grain sorghum are:

Major Pests	High Plains Rolling Plains Concho Valley	Central Texas Coastal Bend South Texas
Southern corn rootworm	No	Yes
Greenbugs	Yes	Yes
Yellow sugarcane aphid	Yes	Yes
Corn leaf aphid	Minor	Common, not severe
Spider mites	Yes	
Sorghum head-worms— corn earworm and fall army worm	Yes	Yes
Rice stink bug	No	Yes
Sorghum midge	Yes	Yes

Methods of Preventing Insect Pest Infestations

Managing insect and mite pests of sorghum involves actions that prevent pests from increasing to high enough numbers to cause economic damage. These practices help avoid pests, reduce their abundance, slow their rate of increase, lengthen the time it takes them to reach damaging levels, and/or increase the plant's tolerance to the insect pest.

These actions include:

- Crop rotation
- Destroying the previous crop (helpful in reducing southern corn rootworm, sorghum midge, etc.), volunteer, and alternate plant hosts (e.g., Johnsongrass)
- Hybrid selection, seedbed preparation, and seed treatment
- Planting time
- Fertilizer and irrigation
- Biological management methods, including protecting beneficials

Sampling and Determining Economic Injury Levels

Because sorghum insect pest levels can change quickly, it is beneficial to scout insects once a week, unless otherwise noted. The major exception is sorghum midge, which may require scouting daily during flowering so as not to miss a sudden increase in their number in the field. The full Texas AgriLife Extension sorghum insect guide contains further details on scouting and sampling techniques.

Economic injury levels will vary based on the projected or contracted price of the grain as well as insecticide and application costs. Economic injury levels, however, should be regarded as in making decisions about pest insect control.

Seed Treatments

Seed treated with Gaucho® (imidacloprid), Poncho® (clothianidin), or Cruiser® (thiamethoxam) can be purchased to manage southern corn rootworm, greenbug, yellow sugarcane aphid, chinch bug, stink bug, wireworms, false wireworms, and grubs. Recently Extension has suggested the efficacy of these treatments may extend to about 45 days from planting. Texas AgriLife trials with many of these seed treatment products has produced varied results in part depending greatly on the insect and a particular region in Texas.

Bottom Line: Consult your local IPM agents of regional Extension staff for trial results and observations in your area. Many of these insecticide active ingredients are now often packaged with seed fungicides as well (e.g., CruiserMaxx). See the hybrid selection section for comments about price considerations when purchased on your planting seed.

Major Soil Insect Pests of Texas Grain Sorghum

Wireworms and False Wireworms

Description: True and false wireworms are immature stages of click and darkling beetles. Wireworms generally are shiny, slender, cylindrical, and hard-bodied. Color ranges from yellow to brown.

Time of attack: Primarily planting to a few days after germination.

Damage: Wireworms feed on planted sorghum seed, preventing germination. To a lesser degree, they feed on seedling plant roots.
Sampling: Two to three weeks before planting. Sift soil for wireworms or set up bait stations for examination before planting.
Economic threshold: One wireworm larva per square foot (4 inches deep) or two or more larvae per bait trap.
Major suggested insecticides: Seed treatments- imidacloprid, clothianidin, thiamethoxam; at planting - terbufos.

Southern Corn Rootworm
Description: Southern corn rootworm is the larval stage of the spotted cucumber beetle. Rootworms are small, brown-headed and creamy white with wrinkled skin.
Time of attack: Planting to mid-vegetative stage prior to boot.
Damage: Larvae burrow into germinating seeds, roots and crowns of sorghum plants. Symptoms of rootworm damage include reduced stands, lower plant vigor, and the occurrence of "dead heart" in young plants. Plants may be more susceptible to lodging later in the season. Damage by southern corn rootworm is most likely to occur in the Texas Coastal Bend area.
Major suggested insecticides: Seed treatment—clothianidin, thiamethoxam; at planting—chlorpyrifos, terbufos.

Yellow Sugarcane Aphid (Photo 4)*
Description: Usually lemon-yellow, but under some conditions are pale green. They are covered with small spines and have two double rows of dark spots on the back. Both winged and wingless forms live in the colony. They often feed on nearby Johnsongrass or dallisgrass.
Time of attack: Seedlings and older plants to near whorl stage in Southern Texas. Yellow sugarcane aphid tends to be a later season pest on the High Plains; high numbers on seedling and whorl stage plants are seldom observed.
Damage: Yellow sugarcane aphids feed on sorghum and inject toxin into leaves of seedlings and older plants. Aphids feeding on seedling plants turn the leaves purple and stunt growth. On more mature plants, leaves turn yellow. By the time discoloration symptoms are visible, plants have been injured significantly. Damage often leads to delayed maturity and plant lodging that may be worsened by associated stalk rots.
Sampling: Determine presence soon after sorghum plants emerge. Purple-colored seedling plants are an indication of infestation. Scout sorghum by inspecting plants beginning the first week of plant emergence, then twice weekly until plants have at least five true leaves. As plants grow larger, they become more tolerant of aphid feeding. Very small seedling sorghum plants (one to three true leaves) often are significantly damaged after being infested for a week or less. Discoloration symptoms may be useful in assess-

ing yield losses, and may be used in a decision to replant.

Economic threshold: See Texas AgriLife sorghum insect guide for tables. Decision is based on the percentage of yellow sugarcane aphid-infested plants at 1, 2, or 3 true-leaf stage. There are no established thresholds for later infestations.

Major suggested insecticides: Seed treatment—clothianidin, imidacloprid, thiamethoxam; foliar—dimethoate.

Corn Leaf Aphid (Photo 3)*

Description: This dark bluish-green aphid is oval-shaped, with black legs, cornicles and antennae. There are winged and wingless forms. Corn leaf aphids are found most frequently deep in the whorl of the middle leaf of pre-boot sorghum, but also found on the undersides of leaves, on stems or in grain heads.

Time of attack: Most likely active from pre-boot sorghum to head exsertion.

Damage: This insect rarely causes economic loss to sorghum and in fact may be considered helpful as they attract beneficial arthropods to grain sorghum, many of which feed on greenbugs and yellow sugarcane aphids. Corn leaf aphids often infest the whorl and undersides of sorghum leaves in great numbers. When feeding, corn leaf aphids suck plant juices but do not inject toxin as do greenbugs and yellow sugarcane aphids. These aphids are common, but their presence does not necessarily mean significant damage is expected. The most apparent feeding damage is yellow mottling of leaves that unfold from the whorl.

Economic threshold: None. Often present, but rarely a pest.
Major suggested insecticides: Rarely justified. Seed treatment—imidacloprid, thiamethoxam; at planting—phorate, terbufos; post-emerge/foliar rescue, several products.

Greenbug (Photo 2)*
Description: Adult greenbugs are light green, approximately 1/16 inch long, with a characteristic darker green stripe down the back. Usually, the tips of the cornicles and leg segments farthest from the body are black. Winged and wingless forms may be present in the same colony. Females produce living young (nymphs) without mating. Under optimum conditions, the life cycle is completed in seven days. Each female produces about 80 offspring during a 25-day period.
Time of attack: Greenbugs are active throughout the life of the plant. The greenbug may be a pest during the seedling, the boot, and the heading stages.
Damage: The greenbug is an aphid that sucks plant juices and injects toxin into sorghum plants. Greenbugs usually feed in colonies on the undersides of leaves and produce honeydew. Infestations may be detected by the appearance of reddish leaf spots caused by the toxin greenbugs inject into the plant. The reddened areas enlarge

as the number of greenbugs and injury increase. Damaged leaves begin to die, turning yellow then brown. Damage at the seedling stage may result in stand loss. Larger sorghum plants tolerate more greenbugs. Yield reductions during boot, flowering and grain-development stages depend on greenbug numbers, length of time greenbugs have infested the plants, and general plant health

Sampling: Scout seedling sorghum, examining the entire plant and the soil around the base of the plant. Note the presence or absence of greenbugs and any damage to plants (yellowing, death of tissue). Usually only the undersides of lower leaves need to be examined, although in some cases greenbug colonies may be found first on the undersides of upper leaves. Greenbugs in a field can increase 20-fold per week, but the seasonal average is a five- to six-fold increase each week. Examine a minimum of 40 randomly selected plants per field each week. Greenbugs are seldomly distributed evenly in a field, so examine plants from all parts of the field; avoid examining only field borders. In fields larger than 80 acres, or if making a control decision is difficult, examine more than 40 plants.

Economic threshold: When deciding whether to control greenbugs, consider the amount of leaf damage, number of greenbugs per plant, percentage of parasitized greenbugs (mummies), numbers of greenbug predators (lady beetles) per plant, moisture conditions, plant size, stage of plant growth and overall condition of the crop. It is important to know from week to week whether greenbug numbers are increasing or decreasing. Insecticide treatment is not justified if the recommended treatment level (based on leaf damage) has been reached but greenbug numbers have declined substantially from previous observations. (See Table 20.)

Major suggested insecticides: Seed treatment—clothianidin, imidacloprid, thiamethoxam; at planting—aldicarb, chlorpyrifos, phorate, terbufos; post-emerge—chlorpyrifos, dimethoate, malathion, phorate.

Table 20. Economic threshold levels for greenbug on sorghum at different plant growth stages.

Plant size	When to treat
Emergence to about 6 inches	20% of plants visibly damaged (beginning to yellow), with greenbugs on plants
Larger plant to boot	Greenbug colonies causing red spotting or yellowing of leaves and before any entire leaves on 20% of plants are killed
Boot to heading	At death of one functional leaf on 20% of plants
Heading to	When greenbug numbers are sufficient to cause
Hard dough	death of two normal-sized leaves on 20% of plants

Whorlworms and Headworms—Corn Earworm and Fall Armyworm (Photo 5 and 6)*

Description: Corn earworm and fall armyworm comprise the sorghum headworm complex. They infest the whorls and grain heads of sorghum plants. Larvae hatching from eggs laid on sorghum leaves before grain heads are available migrate to and feed on tender, folded leaves in the whorl.

Newly hatched corn earworm larvae are pale in color and only 1/16 inch long. They grow rapidly and become variously colored, ranging from pink, green or yellow to almost black. Many are conspicuously striped. Down the side is a pale stripe edged above with a dark stripe. Down the middle of the back is a dark stripe divided by a narrow white line that makes the dark stripe appear doubled. Corn earworm larvae have small hairs (microspines) over much of the body. Fall armyworms and true armyworms do not, so the presence of microspines is one way to differentiate between corn earworm and fall armyworm or true armyworm. Fully grown larvae are robust and 1.5 to 2 inches long.

Young fall armyworm larvae are greenish and have black heads. Mature larvae vary from greenish to grayish brown and have a light-colored, inverted, Y-shaped suture on the front of the head and dorsal lines lengthwise on the body. An important management tactic is to use sorghum hybrids with loose (open) grain heads.

Time of attack: Whorl stage and then again from flowering into kernel development as late as hard dough. Infestations occur less often in early- than late-planted sorghum.

Damage: Whorl—Damaged leaves unfolding from the whorl are ragged with "shot holes." Although this may look dramatic, leaf damage usually does not reduce yields greatly. The fall armyworm is more likely to cause significant damage since many more are often found on individual plants. Heads—corn earworm and fall armyworm larvae feed on developing grain. Small larvae feed on flowering parts of the grain head at first, then hollow out kernels. Larger larvae consume more kernels and cause the most damage. The last two larval stages cause about 80% of the damage.

Sampling: Whorl stage—Pull the whorl leaf from the plant and unfold it. Frass, or larval excrement, is present where larvae feed within the whorl. Heads—Begin sampling for head-worms soon after the field finishes flowering and continue at five-day intervals until the hard dough stage. Scouting should also determine the percentage of corn earworm larvae separately from the percentage of fall armyworm larvae. Fall armyworms are often more difficult to kill with pyrethroid insecticides, and a treatable population that is mostly fall armyworm might require a different insecticide than one which is predominately corn earworm. This may be especially important if control is to be directed at a population that is composed of larger larvae.

Economic threshold: Whorl—Larvae within the whorl are somewhat protected from insec-

ticide. Control of larvae during the whorl stage is seldom economically justified, but insecticide application may be necessary if larval feeding reduces leaf area by more than 30% or is damaging the developing grain head or growing point within the whorl. It is very difficult to achieve good control of caterpillars in whorl stage sorghum because the larvae are sheltered from the insecticide while in the whorl. If control is needed, chemigation will provide better results than ground application, which in turn will provide better results than aerial application.
Head—Determining the threshold will depend on the number of larvae per head and the size of the larvae. Consult the Texas AgriLife grain sorghum pest guide for instructions, calculations, and tables to help determine spray thresholds.
Major suggested insecticides: Carbaryl, cyfluthrin, cyhalothrin, esfenvalerate, methomyl, zeta-cypermethrin. (Note: It is more difficult to kill fall armyworms with the pyrethroid class of insecticides.)

Banks Grass Mite
Description: Large numbers of Banks grass sometime occur on sorghum, especially in more arid areas of Texas. After feeding, these very small mites turn deep green, except for the mouthparts and first two pairs of legs that remain light salmon colored. Eggs, laid in webbing on the undersides of sorghum leaves, are pearly white, spherical, one-fourth the size of the adults, and hatch in three to four days. The life cycle

requires about 11 days under favorable conditions.

Hot, dry weather may lead to a rapid increase in mites. Also, mites in sorghum may respond as induced (secondary) pests after an insecticide application for a key insect pest such as greenbug. A rapid increase in spider mites after insecticide application may be due to tolerance of mites to some insecticides, the destruction of beneficial insects, and the dispersal of mites from colonies. Spider mites increase more rapidly on moisture stressed plants. Irrigation reduces the potential of mite population reaching damaging levels, but once mites are present, resuming irrigation will not diminish the injury potential from the mites.

Time of attack: Present at low to moderate levels, but worst potential damage occurs after heading to early grain fill.

Damage: Spider mites suck juices from the undersides of sorghum leaves, initially along the midribs of the lower leaves. Infested areas become pale yellow and reddish on the top surface, and the leaf may turn brown. As spider mites increase on lower leaves, infestation spreads upward through the plant. The undersides of heavily infested leaves may have a dense deposit of fine webbing. Increases in spider mite abundance generally occur after sorghum grain heads emerge. Large numbers of spider mites occurring early in kernel development can reduce the ability of sorghum plants to make and fill grain. After kernels reach hard dough, grain is not affected.

Sampling: Inspect the undersides of lower leaves carefully. Mites occur in colonies, first along midribs of leaves. Later, they spread away from the midrib and up the plant to higher leaves. Webbing indicates the presence of mites. Mite infestations commonly begin along field borders and may spread quickly throughout a field.
Economic threshold: Miticides produce varying degrees of success. Historically, insecticidal control of mites in sorghum has been erratic. Thorough leaf coverage is essential, especially since the mites live on the lower sides of the leaves. Ground application equipment with high gallons of water per acre is preferred. Insecticide application may be justified when 30% of the leaf area of most sorghum plants in a field shows some damage symptoms from mite feeding.
Major suggested insecticides: Dimethoate, phorate, propargite.

Sorghum Midge (Photo 8)*
Description: The sorghum midge is one of the most damaging insects to sorghum in Texas, especially in the southern half of the state. The adult sorghum midge is a small, fragile-looking, orange-red fly with a yellow head, brown antennae and legs and gray, membranous wings.

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

A generation is completed in 14 to 16 days under favorable conditions. Sorghum midge numbers increase rapidly because of multiple generations during a season and when sorghum flowering times are extended by a range of planting dates or sorghum maturities.

Sorghum midges overwinter as larvae in cocoons in spikelets of sorghum or Johnsongrass. When sorghum is shredded, spikelets containing larvae fall to the ground and are disked into the soil. Sorghum midges emerging in spring do so before flowering sorghum is available, and these adults infest Johnsongrass. Sorghum midges developing in Johnsongrass disperse to fields of sorghum when it flowers.
<u>Time of Attack:</u> Early-season infestations in sorghum are usually below damaging levels. As the season progresses, sorghum midge abundance increases, especially when flowering sorghum is available in the area. Numbers often drop late in the season.

* *Photos found in Appendix B, page 163*

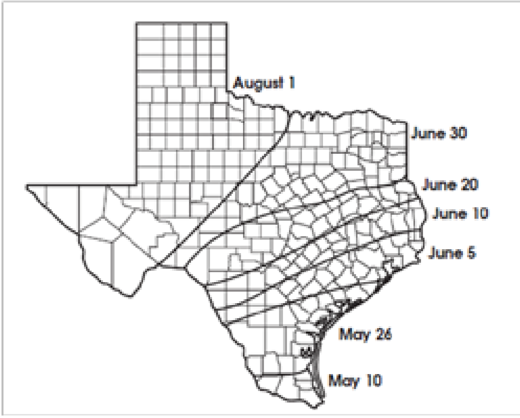


Figure 4. Estimated latest sorghum flowering dates most likely to escape significant damage by sorghum midge.

Damage: A sorghum midge damages sorghum when the larva feeds on a newly fertilized ovary, preventing normal kernel development. Grain loss can be extremely high. Glumes of a sorghum midge-infested spikelet fit tightly together because no kernel develops. Typically, a sorghum grain head infested by sorghum midge has various proportions of normal kernels scattered among non-kernel-bearing spikelets, depending on the degree of damage.

Effective control of sorghum midge requires the integration of several practices that reduce sorghum midge abundance and their potential to cause crop damage. The most effective cultural management method for avoiding damage is early, uniform planting of sorghum in an area so flowering occurs before sorghum midges reach damaging levels. Planting hybrids of uniform maturity early enough to avoid late flowering of grain heads is extremely important. This practice allows sorghum to complete flowering before sorghum midge increases to damaging levels.

Cultural practices that promote uniform heading and flowering in a field are also important in deciding treatment methods and in achieving acceptable levels of insecticidal control. To reduce sorghum midge abundance, use cultivation and/or herbicides to eliminate Johnsongrass inside and outside the field. Where practical, disk and deep plow the previous year's sorghum crop to destroy overwintering sorghum midges.

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

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

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

Because they are relatively weak fliers and rely on wind currents to aid their dispersal, adult sorghum midges usually are most abundant along edges of sorghum fields. For this reason, inspect plants along field borders first, particularly those downwind of earlier flowering sorghum or Johnsongrass. If few sorghum midges are found on sorghum grain heads along field edges, there should be little need to sample the entire field.

However, if you find more than one sorghum midge per flowering grain head in border areas of a sorghum field, inspect the rest of the field. Sample at least 20 flowering grain heads for every 20 acres in a field. Flowering heads are those with yellow blooms. Record the number of sorghum midges for each flowering head sampled and then calculate the average number of midges per flowering head. Almost all of the sorghum midges seen on flowering sorghum heads are female.

Economic Threshold: The economic injury level for sorghum midge can be calculated from the following equation:

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

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

Economic injury levels, as determined from the above equation, are shown in Table X for a range of typical treatment costs per acre, market values per 100 lbs. of grain, and numbers of flowering heads per acre. Use the equation for estimating injury levels for your actual control costs, crop value and number of flowering heads per acre. Insecticide residues should effectively suppress sorghum midge egg laying one to two days after treatment. However, if adults still are present three to five days after the first application of insecticide, immediately apply a second insecticide treatment. Several insecticide applications at three-day intervals may be justified if yield potential is high and sorghum midges exceed the economic injury level.

Table 21. Estimated economic injury levels for sorghum midge for a range of factors. (This table is only a guide. Use the equation in the text to estimate the economic injury level in your field.)

		Economic injury level-mean no. of midges/flowering heads		
Control cost, $/acre	**Crop value $100 lbs.**	**Flowering heads = 18,000/ acre**	**Flowering heads = 45,000/ acre**	**Flowering head = 67,500/ acre**
5	6	1.5	0.62	0.41
5	7	1.3	0.53	0.35
5	8	1.2	0.46	0.31
6	6	1.8	0.74	0.49
6	7	1.6	0.63	0.42
6	8	1.4	0.55	0.37
7	6	2.2	0.86	0.57
7	7	1.8	0.74	0.49
7	8	1.6	0.65	0.43

Table 22. Suggested insecticides for controlling sorghum midge.

Insecticide	Application rate	Harvest	Graze
Chlorpyrifos (Lorsban 4E)	8 oz	30	30
Cyfluthrin (Baythroid® 2E)	1.0-1.3 oz	See Remarks	14
Cyhalothrin (Karate® 1E) (Warrior 1E)	1.92-2.56 oz	See remarks	
Esfenvalerate (Asana® XL)	2.9-5.8 oz	21	–
Malathion (Fyfanon® ULV)	8-12 oz	7	7
Methomyl (Lannate®) (2.4LV) (90WSP)	12-24 oz 4-8 oz	14 14	14 14
Zeta-cypermethrin (Mustang Max®)	1.28-4.0 oz	14	45

Remarks:

Cyfluthrin. If one or two applications are made, green forage may be fed or grazed on the day of treatment. If three applications are made, allow at least 14 days between last application and grazing.
Cyhalothrin. Do not graze livestock in treated area or harvest for fodder, silage or hay.

Rice Stink Bug and Related Insects

Rice stink bug is a pest of grain sorghum in South Texas and the Coastal Bend. It is one of several species of true bugs, primarily stink bugs, which may move in relatively large numbers from alternate host plants into sorghum during kernel development. Bugs infesting sorghum in Texas include rice stink bug, southern green stink bug, conchuela stink bug, brown stink bug, red-shouldered stink bug, leaf-footed bug and false chinch bug.

Description: The rice stink bug is straw-colored, shield-shaped, and a half inch long. Females lay about 10 to 47 short, cylindrical, light-green eggs in a cluster of two rows.
Time of attack: During sorghum kernel development.
Damage: Rice stink bugs suck juices from developing sorghum kernels and, to a lesser extent, from other grain head parts. Damage depends on the number of bugs per grain head, the duration of infestation, and the stage of kernel development. Damaged kernels rarely develop fully and may be lost during harvest.
Sampling: Grain head-feeding bugs tend to congregate on sorghum grain heads and sometimes within areas of a field. Using the beat-bucket method, count all bugs including fliers as well as those on leaves. Sample at least 30 plants from a field. Take at least one sample per acre in fields larger than 40 acres.

Economic threshold: Determine the average number of bugs per sorghum head. Then multiply the average number of bugs per head by the plant density per acre to calculate the number of bugs per acre.
Major suggested insecticides: Carbaryl, cyfluthrin, cyhalothrin.

Tips and Concerns for Insects in Grain Sorghum Insects

West Texas

Pat Porter, Extension entomologist, Lubbock
(806) 746-6101, pporter@ag.tamu.edu

- Spending the money trying to control worms in the whorl—the insecticide does not get to the insects.
- Though midge in the South Plains is sporadic on late-blooming grain sorghum, failure to check for this insect is a major mistake. Once midge comes it is a potentially huge threat. Prior to your own late sorghum reaching bloom (around Aug. 1 and later in the High Plains) inquire with extension, local crop scouts, chemical dealers if there are reports of midge in the region.
- Failure to adjust to new lower, more accurate thresholds for treating headworms.
- Using or mis-timing pyrethroids in seed and grain production, thus triggering a mite problem.

Kerry Siders, Extension IPM agent, Hockley-Cochran Counties, (806) 894-2406, ksiders@ag.tamu.edu

- Not utilizing a seed treatment insecticide to control for yellow sugarcane aphid.
- Attempting to treat larvae in whorl stage.
- Triggering secondary pests like mites after a pyrethroid application.
- Blaming lodging problems on insects when it could have very well been water management or the lack thereof.
- Not scouting correctly if at all for midge.

Central & South Texas

Roy Parker, Extension entomologist, Corpus Christi, (361) 265-9203, rd-parker@tamu.edu

- Failure to use a systematic insecticide seed treatment or in-furrow insecticide.
- Lack of timely scouting for yellow sugarcane aphid.
- Planting sorghum late resulting in high sorghum midge numbers and failure to adequately scout and treat for the midge.
- Use of the incorrect insecticide for rice stink bug.
- Failure to scout properly for rice stink bug and headworms.

Policy Statement for Making Pest Management and Insecticide Suggestions

Labels list product uses for grain sorghum grown for grain. When using products it is impossible to eliminate all risks and conditions or circumstances that are unforeseen or unexpected that could result in less than satisfactory results. Such responsibility shall be assumed by the user of this publication. Pesticides must be labeled for use by the Environmental Protection Agency. The status of pesticide label clearances is subject to change and may be changed since this guide was printed. The USER is always responsible for the effects of pesticide residues on his livestock and crops as well as problems that could arise from drift or movement of the pesticide. Always read and follow carefully the instructions on the container label. Pay particular attention to those practices that ensure worker safety. For information about the registration status of a product and product use, contact a local chemical company representative, a dealer representative, and/or your county extension staff.

The primary Texas AgriLife Extension Service resource for grain sorghum insects was updated in 2007 for insects, new treatment thresholds, and labeled insecticides. "Managing Insect and Mites Pests of Texas Sorghum" B-1220 and "Field Guide to Pests & Beneficials in Texas Grain Sorghum," B-6094 is available at *http://agrilifebookstore.org or through your local county Extension office.*

Texas AgriLife Extension Entomology Staff

Texas AgriLife has Extension entomologists with responsibility in grain sorghum located in Lubbock, Amarillo, San Angelo, Ft. Stockton, Stephenville, Dallas, Corpus Christi, Uvalde, and Weslaco. In addition, most of the sorghum acreage in the South Plains and Concho Valley as well as key production areas in Central Texas, the Coastal Bend, and the Rio Grande Valley are covered by county-based integrated pest management (IPM) extension agents.

Identifying Insects

Contact your local county office or your nearest Texas AgriLife Research & Extension Center for assistance. If the insect still can't be identified then county or regional extension staff can send a digital image or actual specimen to the Texas A&M University Department of Entomology for identification (instructions and submittal form at http://insects.tamu.edu/insectquestions/index.cfm; we recommend further ID be conducted through extension staff rather than submitting directly yourself).

Diseases

Diagnosis and Management of Texas Grain Sorghum Diseases
Tom Isakeit, Extension plant pathologist, College Station, (979) 862-1340, tisakeit@ag.tamu.edu
The following are the common and secondary plant disease pests of Texas grain sorghum. Many are influenced by certain environmental conditions that trigger increased diseased potential. Texas AgriLife has research and extension plant disease specialists covering grain sorghum based at Amarillo, College Station, and Corpus Christi.

Disease	**Seedling Disease**
Symptoms	Seedling root rot may result in sparse or irregular stands. Roots are rotted, with a brown to black appearance, or missing all together.
Management	The disease is favored by wet to saturated soils, or soils with cool soil temperatures that are unfavorable for plant growth. Under these conditions, fungicides normally applied to seed have limited effectiveness, particularly if poor quality seed is planted. Plants are vulnerable to seedling disease before emergence and only in the first two to three weeks after emergence.

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

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

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

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

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

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

Disease:	**Stalk Rot**
Cause:	Macrophomina phaseolina (Charcoal Rot), Colletotrichum graminicola (Stalk Red Rot/Anthracnose)
Symptoms:	Stalk is spongy, and internal tissue (pith) is shredded and often discolored. Plants sometimes turn grayish-green after jointing.
Key Features of Disease Cycle:	Fungi survive on crop residue. High plant population, high nitrogen and low potash can aggravate the diseases. Charcoal Rot is prevalent in hot, dry weather. Stalk Red Rot is prevalent during warm weather with alternating wet and dry periods.

Management:	Use hybrids resistant to Stalk Red Rot and tolerant to Charcoal Rot. Avoid excessive plant populations. Maintain proper soil fertility. Rotate away from sorghum for two or more years following a severe outbreak of either disease. Avoid soybeans and corn for two or more years following severe outbreaks of Charcoal Rot.

Disease	**Charcoal Rot**
Cause	A fungus, Macrophomina phaseolina
Symptoms	External symptoms of charcoal rot are lodging and poor grain filling. The lower stalks of infected plants disintegrate internally and the small, black resting structures (microsclerotia) of the fungus are found in the rotted area of the stem.
Management	The disease develops only when temperatures are hot and plants are under drought stress. A high plant density or previous cropping with cotton with adequate to excess N. may predispose plants to charcoal rot. Sorghum grown under rain fed conditions rarely develops charcoal rot if plant density is low. Plants that develop a good root system in response to dry conditions early in the season and then exposed to a prolonged dry period are less likely to become diseased.

Disease	Fusarium
Symptoms	Lesion may vary in size from small spots to elongated streaks which can be either red or dark purple. These may be appear on the interior and exterior of infected tissue. Typically the lower part of the stem will contain large areas of reddish pith, while the upper internodes will be discolored. Tis my cause premature death if the plant and lodging. Charcoal field observation of rot and fusarium look very similar to the untrained eye.
Management	Cold wet weather after planting may require replanting to replace damaged plants, which are highly susceptible. Selection of hybrids with good stalk strength can help reduce lodging. Reducing or limiting stress during flowering will also help.

Disease	Anthracnose
Cause	A fungus, Colletotrichum sublineolum

Symptoms	This fungus causes both leaf spots and stalk rot. The leaf spots are oval to circular and red, orange, blackish purple, or tan, with small black spots in the centers. Numerous leaf spots can coalesce, killing all or large portions of a leaf. Growth may be reduced or the plants may die before maturity. Stalk rot starts with water soaked, discolored elliptical areas on the panicle, which later become tan to blackish purple. When infected stalks are split open with a marbled, discolored appearance and embedded, small, black fungal structures.
Management	This disease may be a problem in the coastal areas of Texas, particularly in warm, wet years. If the disease occurs, the field should not be cropped to sorghum for two years, to eliminate the fungus, which survives in soil. Resistant sor ghum hybrids can also be planted.
Disease	**Zonate Leaf Spot**
Symptoms	Leaf spots are circular, reddish purple bands alternating with light brown or tan areas, forming a concentric, or zonate, pattern with irregular borders

Management	The disease is prevalent in the coastal areas of Texas, particularly in warm, wet years.
Disease	**Rust**
Symptoms	Small, purple, red, or tan, slightly-raised flecks appear on both surfaces of leaves, which may coalesce. Powdery, reddish-brown spores are produced from these flecks.
Management	This disease is not a problem in West Texas. It is prevalent in the coastal areas of Texas, particularly in cool, wet years.
Disease	**Target Leaf Spot**
Symptoms	This disease is not a problem in west Texas. It is prevalent in the coastal areas of Texas, particularly in cool, wet years.
Management	This disease is prevalent in the coastal areas of Texas, particularly in warm, wet years.

Disease	Sooty Stripe
Symptoms	Elongated spots appear with light brown centers and reddish purple or tan margins. The interior of spots become grayish, then black or sooty. Later, small, black, raised resting structures of the fungus will form
Management	This disease has been observed in the coastal areas of Texas and may be a potential problem in wet years. Because the pathogen survives on leaves, affected fields should be rotated out of sorghum. Resistance is avadible.

Disease	Ergot
Symptoms	Infection occurs only in the ovary of the flower and only prior to its fertilization. The initial symptom is a white, swollen fungal structure that is formed between the glumes, where the seed normally develops. This structure, the sphacelium, exudes a sweet, sticky liquid that contains sugars and spores.
Management	Fall-grown hybrids in the Lower Rio Grande Valley have the highest risk of ergot because they have the greatest chances of encountering cool, rainy weather conditions that interferes with pollen production or pollination.

Disease	Grain Mold
Symptoms	Fungal growth is seen on the surface of the grain. The growth can be pink, orange, gray, white or black, depending upon the fungal species involved. Seed size and weight are reduced, as well as seed quality and germination.
Management	Prolonged humid weather favors grain mold and commonly occurs when sorghum kernels are maturing. Sorghum grown in the Gulf Coast region is more likely to encounter these conditions. Little can be done to prevent this disease unless sorghum is grown when conditions do not favor the development of grain mold. Hybrids differ in their resistance.

Disease	Grain Weathering
Symptoms	Fungal growth occurs on the surface of the grain after maturation of the seed, under conditions of high humidity and extended dew periods. Many species of saprophytic fungi can cause grain weathering.
Management	A timely harvest is important to minimize the length of time that the mature crop is exposed to high humidity. Hybrids differ in their resistance.

Harvesting

Producers should consider harvest aids to provide for easier threshing or to hasten harvest to meet a delivery/pricing deadline, make fields more uniform for harvest or dry out the late-emerging non-productive sucker-head tillers. Extension believes there is questionable economic benefit of sorghum harvest aids particularly when maturity is occurring during summer and early fall when days are still quite warm.

Currently, sodium chlorate and glyphosate are labeled for application in grain sorghum. Paraquat is not labeled for use in sorghum drydown. Glyphosate is a preferred option among many producers, as additional late-season weed control benefits may be achieved, particularly in fields that have significant Johnsongrass. Both chemicals generally state that applications should be made once the field is generally mature (black layer) and seed moisture is below 30%. The Rolling Plains region, however, struggles to get late planted sorghum harvested because once maturity is achieved foggy, moist weather prevails and long delays are common. So, harvest aids may still be a consideration although earlier planting (late June rather than early July) may be just as effective for fall drydown. Once a harvest aid is applied, it is imperative that timely sorghum harvest occurs.

Harvesting & Drying

Grain sorghum can be harvested once seed moisture drops below 20%, however, few elevators have significant capacity to dry grain. Thus, grain needs to be delivered at 14% moisture or less. When drying conditions are favorable (temperatures greater than 75° F, breezy, low humidity) grain may lose 1% moisture per day. The standard test weight for grain sorghum is 56 lbs./bu. Nevertheless, there are a couple of key points that guide grain sorghum harvest:

- Timely harvest—Availability of combines: Most sorghum producers do not have a combine.
- Timely harvest—Lodging and standability: The longer grain sorghum stands in the field, the more lodging potential increases. This is most likely when grain sorghum has smaller stalks, or in particular, has been stressed by drought which leads to weakening of the stalk and drought-induced stalk rots weaken the stalk. Some hybrids may be more prone to lodging, as well.
- Timely harvest—Pricing based on delivery or market conditions: The ethanol plants using grain sorghum in the High Plains may offer favorable contract pricing based on delivery by a certain date. This may require closer attention to timely combining and the possible use of harvest aids to hasten drydown if the lost pricing potential is somewhat more than the cost of harvest aids.
- Low test weight grain—Late maturing grain

may not achieve maturity leading to low test weights, which may be significantly discounted below 55 lbs./bu. When setting the combine ensure that much of this light low test grain is blown out the back with the trash. Some buyers may refuse to accept grain below 51 lbs./bu. Grain that has a test weight in the 40s can be used for cattle feed as the pound-per-pound feed value is about the same as mature grain. Cattle feeders, however, must still grind the grain and will have to set the hammer mill closer hence the grain will be heavily discounted, perhaps 50%.

Economic "Loss" from Selling Low Moisture Grain Due to Excessive Harvest Delay

Producers understand the need for timely harvest to minimize potential lodging and the reduction in yield. A hidden loss of gross income, however, comes from delaying harvest well beyond when sorghum can be cut and sold at 14% moisture. Your pay weight is not adjusted up for low moisture, so you don't get to sell water. Any moisture in the seed up to 14% adds to your pay weight.

Possible Sorghum Failure

When grain sorghum fails due to drought, grazing and baling are options to recapture some value from the crop. Nitrate accumulation in sorghum crops tends to occur only when drought stresses the crop to the point where little growth is occurring, particularly when significant N fertilizer has been applied. Even though the sorghum is not growing, nitrate accumulation is still occurring in the plants. Prussic acid normally would only be a possible issue for grain sorghum for a very late maturing crop that will not reach sufficient grain yield for harvest. Once a killing frost occurs the crop should be left ungrazed for a minimum of one week before grazing.

After Harvest : Preserving Grain Sorghum Stubble

A few producers may bale the hay and sell it for profit. Keep in mind, however, that the sorghum has value in terms of soil tilth, erosion control, the protection of future cotton seedlings, and the fertilizer replacement cost of the nutrients that leave the field in the hay.

For each ton of stubble removed from a field you are also selling nitrogen and other nutrients in the forage, which has a replacement cost when you purchase fertilizer. Nitrogen content of grain sorghum stubble is about 0.4 to 0.6% (or about 2.5 to 3.5% crude protein), so a ton of baled stubble removes about 8 to 12 lbs. per N. At a fertilizer replacement cost of $0.50 per lb. of N, then each ton contains $4 to $6 worth of N, as well as values of P and K. This must be factored in to the price of the hay. If a hay harvester offers to buy your standing grain sorghum stubble 'as is' in the field, it is still not 'free money.' The nutrient losses let alone the intangible value of the stubble for soil and erosion protection.

Erosion Protection & Reduced Tillage

If you are committed to no-till or strip tillage, the opportunity to manage the stubble to optimize erosion protection and possibly replace cover crop small grains for cotton seedling protection should be carefully considered. Many more producers are now inclined to leave the stubble on the surface. Extension believes sorghum crops that produce a minimum of about 1,500 lbs. of grain provide sufficient ground cover to express benefits for erosion control. Furthermore, particularly with the advent of GPS guidance systems, producers are programming their planting pattern to offset the planting of cotton and sorghum rows in rotation to minimize the need to disturb the sorghum stubble.

Leaving the sorghum stubble stand as long as possible offers the best soil protection in the long run. To our knowledge, producers have never had a problem with sorghum stubble interfering with cotton harvest. Standing stubble does, however, catch tumbleweeds and contain nutrients you might wish to have available to a future crop.

Plowing sorghum stubble does not increase organic matter. In dry West Texas soils which are often quite sandy, there is little stability for organic matter due to heat and lack of moisture. Any tillage operation compounds this as it destabilizes the organic matter you have. Research conducted by USDA on a sandy loam in Wellman, Texas, demonstrated that one tillage pass after five or more years of no-till was enough to undo all the gains in organic matter that had been achieved. Tillage and deep breaking sorghum stubble may improve the condition of your land for a time, but it does not increase organic matter after you have completely disturbed the root system.

Grain Sorghum and Conservation Tillage

Properly managed sorghum residues can greatly reduce water and especially wind erosion particularly on the sandy soils of West Texas. Producers are encouraged to experiment with tillage options that grain sorghum rotation affords, especially in retaining much or most of the stubble above the surface. Stubble can reduce the amount of light and wind at the soil surface which leads to moisture loss. Much of West Texas relies far too much on tillage or cover crops to control wind erosion and damage to cotton seedlings. Both options lead to moisture losses, and dedicated cover crops are not viable for dryland. Keep in mind that achieving the benefits of the ultimate conservation tillage program—no-till—requires patience in both learning how to make the system work and having the patience to await for coarse soils to develop aggregation.

Grain Sorghum Crop Budgets & Regional Custom Rates

Texas AgriLife Extension Service agricultural economics staff have prepared templates for an extensive list of crops including grain sorghum.

Specific budgets are available for the South Plains (D-2), Rolling Plains (D-3), and the Concho Valley (D-7) at http://agecoext.tamu.edu, then click on "Crop & Livestock Budgets" and select 'District' or 'Commodity' to access the information for your region. In addition, extension compiles custom rates for a variety of field and transportation operations which are summarized by USDA at the above website, then click on "Custom Rates Statistics." Finally, comparative crop budgeting is available for the Texas South Plains region at *http://southplainsprofit.tamu.edu* This document is an interactive Microsoft Excel spreadsheet in which you may enter your own numbers and compare them with other crops.

Table 23. Sorghum Grades and Grade Requirements, from the United States Standards for Sorghum, effective June 2008

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

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

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

References

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

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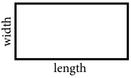
4. Kansas Grain Sorghum Producers Association. 2008. Kansas Ethanol Production. Online. *http://www.ksgrains.com/ethanol/kseth.html*

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

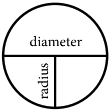
6. Figure 2. Pocket Guide to Crop Development: Illustrated Growth Timelines for Corn, Sorghum, Soybean, and Wheat. 2003. University of Illinois Extension Publication #C1389.

Table References

Calculations & Conversions

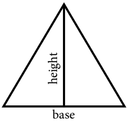


Area of a rectangle or square = length x width

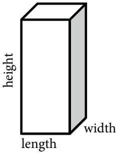


Area of a circle = 3.1416 x radius squared; or 0.7854 x diameter squared

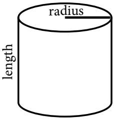
Circumference of a circle = 3.1416 x diameter; or 6.2832 x radius



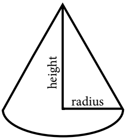
Area of triangle = base x height ÷ 2



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

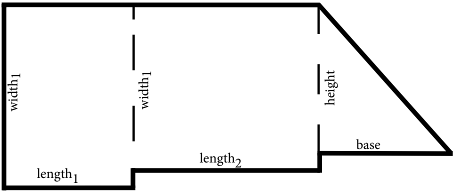


Volume of a cylinder = 3.1416 x radius squared x length



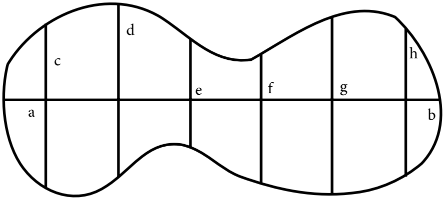
Volume of cone = 1.0472 x radius squared x height

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



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

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



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

Conversion Factors

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

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

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

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

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

Appendices

a. The Sorghum Plant

Sorghum grain is found on the panicle, commonly referred to as the head. The panicle consists of a central axis with whorls of main branches, each of which contains secondary and at times, tertiary branching. The length of the branches allows for a wide range of shapes and sizes in sorghum and for sorghums with very open panicles or sorghums with very compact panicles. The branches carry the racemes of the spikelets where the grain is found (see Figure 5). The panicle emerges at boot from the flag leaf sheath.

Fig. 5. 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% 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 6). 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.

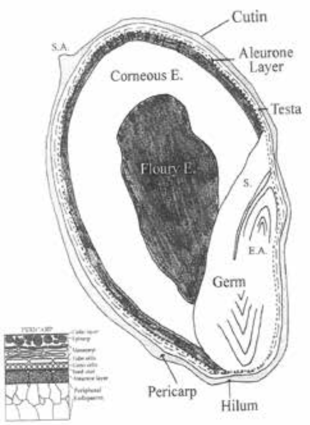


Fig. 6. Sorghum grain, showing the pericarp (cutin, epicarp, mesocarp, cross cells, tube cells, testa, pedicel, and stylar area (SA)), endosperm (aleurone layer, corneous and floury), and the germ (scutellum (S) and embryonic axis (EA). Adapted from L. W. Rooney and Miller, 1982).

b. Photos

Photo 1. *Iron Deficiency*

Courtesy of International Plant Nutrition Institute

Photo 2. *Greenbug*

Photo 3. *Corn Leaf Aphid*

Photo 4. *Yellow Sugarcane Aphid**

Photo 5**. Corn Earworm

***Photo 6**. Fall Armyworm**

***Used with permission of USDA-ARS*

Photo 7. *Sorghum Webworm**

Photo 8. *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.

United Sorghum Checkoff Program

SORGHUM CHECKOFF SM

DISCLAIMER

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