2010

Managing High-Biomass Sorghum
as a Dedicated Energy Crop

BLADE®
ENERGY CROPS

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Blade has established the largest trial network of energy crops in the world, including leading universities and institutes.

FOREWORD

This guide was developed to provide agricultural producers and biomass procurers with the most current information on the establishment, management and harvest of high-biomass sorghum as a dedicated energy crop for biopower and biofuels. While sorghum has been widely planted for grain and forage production, and even syrup, its use as a biomass crop is still evolving.

Due to the broad geographical range and environments where sorghum can be planted for bioenergy, we will address more general recommendations as well as considerations unique to managing high-biomass sorghum types as a raw material for power generation and cellulosic biofuels. Management practices for the use of sweet sorghum as an energy crop will be discussed separately in a future guide.

In preparing this publication, we have drawn from our collective experience with sorghum as well as our collaborative partners at Texas AgriLife of the Texas A&M University System, among others. Because we foresee upcoming innovations in genetics, seed technology and farm equipment – as well as developments in the biomass markets – we expect to update this guide frequently, as these forces necessitate changes to crop management practices.

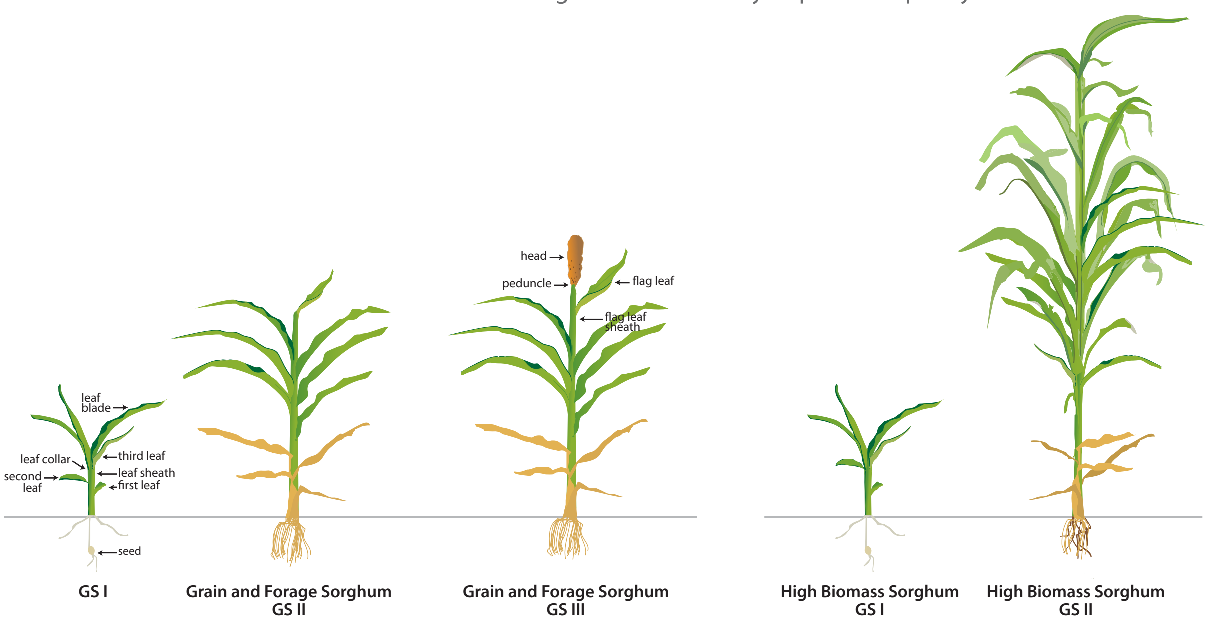
SORGHUM AS A DEDICATED ENERGY CROP

As a quick-growing annual, high-biomass sorghum fits well into the mix of dedicated energy crops. It adds flexibility to feedstock production and can be rotated as part of an annual cropping system using existing production equipment.

Like other energy grasses, sorghum uses water and other inputs very efficiently, and thus tends to perform well on lands or in conditions considered marginal for other crops. And unlike perennial energy grasses, which are generally not harvested during the first season, sorghum has robust establishment characteristics and can produce high yields of biomass in as few as 90 to 100 days in many areas.

Agronomic practices for growing sorghum as a forage or grain crop are relatively well defined—and many of these practices can be employed when planting and establishing high-biomass sorghum—however, managing sorghum as a bioenergy crop requires distinct considerations:

- Availability: Extension of the harvest/supply window—through the use of single harvest, multi-cut harvests and staggered plantings—minimizes storage requirements for bioenergy facilities, which need year-round supplies.
- Moisture content: Optimal feedstock moisture content ranges will vary according to bioenergy conversion technologies and storage systems.
- Biomass composition and quality: Relative amounts of carbohydrates, compounds including ash or sulfur and debris collected during harvest will likely impact the quality of biomass.



GROWTH STAGES

Sorghum development is typically divided into three growth stages (GS): GS I, GS II and GS III. GS I refers to the vegetative stage between emergence and initiation of the reproductive stage, and is characterized by the development of structures such as leaves and tillers. GS II refers to the plant's reproductive phase, which includes panicle initiation, booting and heading. GS III refers to the grain-filling stage, beginning with flowering and continuing through grain development and final maturity.

Due to photoperiod sensitivity or long maturities, many high-biomass sorghums reach GS II very late in the season, if at all. Most never complete the GS III stage.

HIGH-BIOMASS CHARACTERISTICS

High-biomass sorghums are typically late or nonheading, photoperiod-sensitive (delayed flowering) hybrids. They are similar to forage types, but with greatly enhanced biomass yield potential. When planted in nontropical latitudes and during periods with appropriate day length, high-biomass types are highly productive and can reach upwards of 20 feet in height under favorable conditions. This is due to the plant's prolonged vegetative growth stage. (See Growth Stages sidebar.)

Growth stage I (GS I) lengths for these types of sorghums vary greatly from typical grain sorghums. Many high-biomass hybrids are able to grow continually for more than 200 days in southern areas such as Texas. By comparison, a typical grain sorghum plant remains relatively small and completes its lifecycle in 60 to 90 days.

ES 5200 and ES 5201 from Blade should be planted after day lengths exceed 12 hours and 20 minutes — early April in most latitudes of North America.

Many of the photoperiod-sensitive sorghums grown in North America today have photoperiod triggers of about 12 hours and 20 minutes of daylight, meaning that a day length of 12 hours and 20 minutes or less is required to induce flowering. As such, these sorghums should be sown after daylight hours exceed this duration. For most areas of North America, this dictates an early April planting date – or later, depending on the specific latitude. Planting before the day length has reached a sufficient photoperiod will trigger early flowering, premature crop "cutout," and result in a very low biomass yield. For varieties that ratoon (regrow) well, this issue can be mitigated by a cut and subsequent regrowth during a period of appropriate day length.

Due to photoperiod sensitivity, high-biomass hybrids generally do not produce grain heads until very late in the season, if at all. Therefore, if provided sufficient inputs, they continue growing and producing more biomass (i.e., stems, stalks and leaves) until the fall, when shorter day lengths trigger flowering, or plants experience the first killing frost.

(Note: Since high-biomass sorghum hybrids were selected for bioenergy production, and not for consumption by livestock, they may not have the same nutritive value as forage types. Contact your local cooperative extension agent or veterinarian prior to feeding to ensure the fitness of biomass as a feedstuff for a particular livestock species.)

HYBRID TYPES

Producers have a number of different hybrid types and traits to choose from:

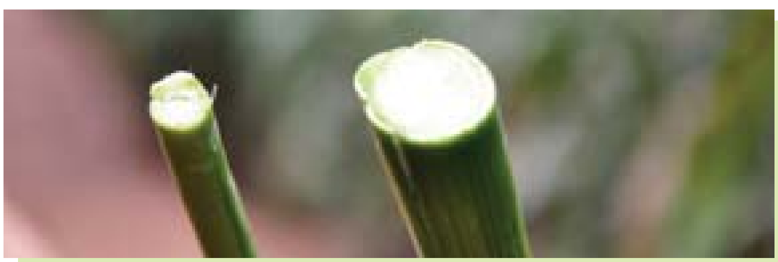
Sorghum x sorghum – These hybrids result from the cross of two sorghum parents. They show the highest biomass yield potential and represent the latest in high-biomass plant breeding and trait development. Sorghum x sorghum hybrids are designed for single-harvest production systems that endeavor to maximize per-acre yields while minimizing crop input and management expenditures. Moreover, currently available hybrids were generally not selected for ratooning, and are therefore not suited to multi-cut harvest systems. Two of the newest hybrids in this class are ES 5200 and ES 5201, from Blade.

Sorghum x sudangrass hybrids – Sorghum x sudangrass hybrids result from the cross of a grain sorghum female parent and a sudangrass male parent. These hybrids have been used for many years in the livestock industry for grazing and hay production, but also have application in bioenergy, since their finer stems and enhanced ratooning quality allows for multiple cuts throughout the season. For end-use processes requiring dry biomass material, the thinner stems of these hybrids have been shown to dry down more easily than sorghum x sorghum hybrids. ES 5140 and ES 5150, available from Blade, are two sorghum x sudan hybrids suited to bioenergy production.

Sudangrass – Although not a sorghum, sudangrass has been proposed as a potential biomass source, and has historically been used in forage and hay operations alongside forage sorghums. The very thin stems of sudangrasses lend to easy drydown and baling. Straight sudans also tend to ratoon well and can be cut for biomass throughout the season. However, most sudangrasses have been developed for feed applications and tend to have quite low biomass yields when compared to high-biomass sorghums. For this reason, pure sudangrass varieties are not generally recommended for bioenergy production.

HYBRID SELECTION CONSIDERATIONS

As with other crops, appropriate hybrid selection is one of the most important elements of successful sorghum biomass production. Key considerations for evaluating sorghums include adaptation, maturity, harvest timing, drydown ability and end-use requirements.



Thick-stemmed hybrids (right) offer comparative yield advantages and other assets. They can benefit from stem-crushing harvest systems to speed drydown.

Adaptation – While biomass sorghums are generally broadly adapted, it is essential that a given hybrid has appropriate tolerances to disease, temperature, soil conditions and other environmental factors likely present at your planting site. Choosing an ill-adapted hybrid may result in a substantial reduction in performance and yield.

Maturity – Sorghum maturity can be regulated by photoperiod (day length), as described previously, or thermal time (heat units). Thermal-time regulated hybrids will reach maturity following exposure to a specified accumulation of heat units, as calculated by average daytime and nighttime temperatures. Hybrids that are regulated entirely by thermal time are referred to as photoperiod insensitive. Many sorghum hybrids have a combination of maturity-determining mechanisms, and are regulated to varying degrees by both thermal time and by photoperiod.

Harvest timing – Selecting hybrids according to their appropriate harvest time is the key to influencing both biomass availability and quality.

- For once-over harvest systems, full-season hybrids that maximize biomass production are preferred.
- For multi-cut harvest systems, hybrids that show strong ratooning ability should be selected. Note that hybrids intended for single-cut systems should not be used for multi-cut systems unless regrowth potential is specified in the product description.

Producers may consider using a combination of sorghum maturity types to extend the supply window for a particular bioenergy process.

- Harvest can be extended by planting blocks of photoperiod-insensitive hybrids (such as ES 5140 and ES 5150) early in the season, followed by blocks of photoperiod-sensitive varieties (such as ES 5200 and ES 5201) later in the season.
- Staggered planting, as part of a rotation with other crops, is another method to optimize biomass supply.

Drydown ability – Full-season maturities maximize biomass production potential. However, they also increase the likelihood that sorghum biomass will be green at harvest time. Moisture content and levels of extractives (e.g., starch and sugars) in the harvested biomass can be higher later-maturing varieties than in lower-yielding and typically earlier maturing hybrids that senesce (dry) before harvest. Longer maturity times also tend to produce a crop with larger and thicker stems that may require different drydown steps. (See Harvest section.)

Selecting sorghum varieties that will flower and mature in your region prior to harvest time can help lower the moisture content of the biomass. This benefit comes at a cost, however. Flowering, production of grain and crop senescence before the end of the growing season will potentially reduce total biomass yield, as well as alter the compositional makeup of the biomass harvested.

If delaying harvest for drydown purposes, it is important to note that newer sorghum x sorghum hybrids have been bred for late-season standability. In contrast, many forage sorghums used historically for biomass production were developed for harvest earlier in their growth cycles — a trait that may lead to a greater risk of lodging with later harvest dates.

Biomass composition and quality – Distinct compositional differences among sorghum varieties influence the efficiency by which sorghum biomass is converted to biofuel or biopower. This is an area of intense study, and significant improvements are expected as "lock-and-key" systems are developed between customized seed varieties and bioenergy conversion processes.

TRAITS

Several traits exist for biomass sorghums that can influence hybrid selection.

High-biomass traits – The latest high-biomass hybrids offer growers a new trait named Skyscraper, which provides a significant boost to overall biomass yield potential. Since it was developed through genomics-based plant breeding, there are no additional stewardship requirements. Hybrids ES 5200 and 5201 both feature the Skyscraper trait.

Brown midrib traits – Many forage sorghums in use today contain traits for altered lignin, a tough, fibrous compound that plants use to build their cell walls. Referred to as brown midrib (BMR), for the characteristic brown color in the plant's leaf ribs and the pith of the stalk, this trait has been shown to improve the digestibility of feed. Biofuel process developers have speculated that BMR traits may be similarly beneficial to conversion processes that employ enzymes to break down and convert biomass to liquid fuels. However, current research shows that lignin content and enzymatic digestibility are not necessarily linked. Furthermore, sorghums with BMR traits tend to have a higher risk of lodging due to weakened cell walls, which leads to reduced yield—particularly under adverse weather conditions. Additional research is necessary to determine if the brown midrib trait conveys enough added value to offset its potential for harvest losses due to lodging.

Biotech traits – Currently, there are no commercially available sorghum hybrids with traits developed through biotechnology. However, greater resources have been applied to improving sorghum, and rapid advances are expected. Initial advances will be realized through marker-assisted plant breeding, where important characteristics are tracked at the DNA level. Biotech traits are expected to follow soon after.

SEED TREATMENTS

A wide range of seed treatments are marketed to bolster performance and stand establishment. Maxim and Apron are newer fungicides; longstanding options include the fungicide Captan and Lorsban, an insecticide. Systemic seed treatments that protect sorghum from certain insects during establishment and herbicide safeners, which allow a wider range of preplant herbicides to be used, are also available.

Many of these products are standard treatments provided when seed is commercially prepared and sold, while others are provided upon request. Consult your seed supplier about available treatments, and always follow the manufacturer's directions.

Common Seed Treatments for Sorghum

Captan – Fungicide
Lorsban® – Insecticide
Maxim® – Fungicide
Apron® – Fungicide
Concep® – Herbicide safener
Poncho® – Systemic insecticide

STAND ESTABLISHMENT

Successful stand establishment involves several critical considerations. As discussed previously, the agronomic practices required vary greatly by region, local cultural practices, equipment and existing cropping systems. While the following guidance will help with general planting requirements, consultation with an agronomist or crop consultant who has location-relevant expertise is critical for successful stand establishment and maximum biomass production potential.

Location selection – Sorghum is relatively drought tolerant compared to many other row crops, and performs well on a wide range of soils, from clay to sandy types. It prefers well-drained soils, as excessive moisture or waterlogging leads to reduced germination or plant death. Sorghum also fares best in deeper soils that support its extensive root system.

Land preparation – Land preparation options vary greatly by location, condition of the field and equipment available. For conservation purposes, the following tillage practices are recommended for high-biomass sorghum, when appropriate:

- No till (on suitable soils)
- Strip till
- Conservation tillage

Conventional tillage should be carefully considered for bioenergy crops. Excessive tillage can result in topsoil erosion, additional weed pressure and the release of greenhouse gases.

20-inch or 30-inch row spacings are most commonly used for bioenergy crop production.

Agronomists generally advise that high-biomass hybrids be planted on a 20-inch or 30-inch row spacing to maintain compatibility with most production systems. Narrower row spacing is being evaluated, since denser stubble tends to keep windrowed biomass off the ground. This may facilitate drying and reduce ash content

Reducing or eliminating weed pressure before planting is essential.

of the harvested biomass. It is important to note that optimal row and plant spacing is dependent upon both plant variety and the agronomic systems employed. Regardless of the preparation techniques, good seed spacing (singulation) and seed-to-soil contact are essential.

Weed control – Herbicide options for establishing and managing sorghum are somewhat limited compared to other crops. Thus, it is essential to eliminate or reduce weed pressure before planting. If sown into weed-free soil under good conditions, high-biomass sorghum hybrids will typically outcompete most weeds because of their rapid germination and growth. Excessive weed pressure can create stand-establishment problems and subsequently reduce final biomass yield. Controlling weeds as early as possible can help soil retain fertility and moisture, an important factor in water-constrained areas.

The optimal weed management program for a given location must factor in planting history, previous crop rotations, soil type and climate conditions. While weed pressures can potentially be managed through repeated tillage prior to planting, consideration should be given to reducing soil erosion and input costs associated with land preparation, as well as potential bioenergy qualification requirements.

If sowing into fallow cropland, or if weed pressures are expected to be high, one or several preplant burndowns, using a broad-spectrum herbicide, should be considered.

A few examples of herbicides labeled for sorghum include Bicep, Dual and Expert. Always check with your local extension agent or the herbicide manufacturer before use. Care must be taken during herbicide application to prevent damage to the crop.

Agronomists often recommend the use of pre-emergent herbicides during planting and establishment, as the pre-emergent herbicide provides a window of opportunity for sorghums to grow in a period of reduced weed pressure. Consult an agronomist or crop consultant to determine whether a seed safener is necessary for your intended herbicide program.

One example week management strategy that has been effective for many growers establishing forage sorghum involves a preplanting weed burndown using a glyphosate-based herbicide. Seed is then treated with an appropriate seed safener before planting, followed by a pre-emergent application of atrazine and s-metalochlor herbicides.

With regard to labeled herbicide and pesticide use, sorghum grown for bioenergy is generally considered the same as sorghum grown for forage, although some ambiguity still exists. Always consult your local extension office for optimal herbicide application regimes for sorghum in your area. Always read and follow all label directions for herbicides.

Rotation – As with all crops, growing multiple crops of sorghum back to back in the same location is not recommended due to crop-specific nutrient depletion and the buildup of disease and pest pressures. Sorghum crops should be rotated with alternate winter crops and/or summer crops to

mitigate these risks. Several good choices for rotation exist (including soybean, cotton and corn), depending on your geographic location.

Nutrient requirements – Removal of green plant material depletes nitrogen (N), phosphate (P) and potassium (K). Soils should be tested for pH, P, K and N before planting, and pH should be adjusted to between 6.0 and 6.5, if possible.

A typical fertilizer starting recommendation for a sorghum crop is 120 pounds of N, 65 pounds of P_20_5 and 120 pounds of K_2O. Required levels for these nutrients vary by soil type and local environmental conditions. Consultation with an agronomist or crop consultant familiar with the biomass production area will be important. If deficiencies of P and K exist, these nutrients can be applied to the soil before planting.

Nitrogen deficiency is the most common soil issue faced by growers who produce sorghum for biomass yield. A standard recommendation frequently cited for biomass production is 10 pounds of nitrogen per dry ton of biomass removed. The optimal rate is highly influenced by sorghum variety, environment and management practices. For example, sorghum yields in good soils under favorable conditions have shown high performance with nitrogen application rates of less than 10 pounds per dry ton of material removed per acre. Conversely, sandy soils and/or fields that receive excessive rainfall early in the season can exhibit diminished levels of available nitrogen, regardless of initial application rate. This results in an apparent increase in the nitrogen needs per unit ton of biomass harvested. Other examples include the use of leafier forage sorghums or multi-cut systems, where the removal of higher leaf-to-stem ratio material can increase the nitrogen removed from the fields, resulting in nitrogen requirements reported to exceed 15 pounds per ton.

Purchasing seed by count rather than by weight will help growers avoid overbuying to cover variations among seed varieties and lots.

(Note: Nitrogen recommendations for sorghum silage production range from 10 to 20 pounds of nitrogen per ton of dry matter removed. High biomass sorghums are not developed or evaluated for their feed value. They are grown on lower nitrogen input levels per ton of biomass harvested than have typically been used for sorghum in forage applications. Further research is being conducted in this area.)

Planting time – Sorghum seed germination requires a minimum soil temperature of 60°F – 65°F (16°C – 18°C). Optimal soil temperatures for germination and growth are between 70 and 75°F (21 to 74°C). Planting should commence only after any risk of freezing temperatures has passed, as sorghums are highly frost sensitive.

Photoperiod-sensitive hybrids should be planted after day lengths exceed 12 hours and 20 minutes. Planting before the day length has reached a sufficient photoperiod will trigger early flowering and premature crop cutout, resulting in a very low biomass yield.

Planting method – Energy sorghum is generally planted in rows, using either a row-crop planter or a conventional or no-till drill. Planters should be equipped with press wheels for good singulation and seed-to-soil contact. It is important to note that average sorghum seed sizes are in the 16,000- to 18,000-seed-per-pound range. However, sorghums can have seed as large as 12,000 seeds per pound, and as small as 35,000 seeds per pound.

A proper match between planting equipment (plates and/or air settings) and seed size is important for successful stand establishment. Preferred planting depth is typically ¾ to 1¼ inches for heaver to medium soils. Lighter, sandy soils permit planting to depths of up to 2 inches (5 cm). Planting into moisture is encouraged, and care must be taken to ensure enough moisture is present to allow for imbibition (absorption of water), germination and growth. Sufficient moisture reduces the risk of stand failure due to drying out and subsequent seed/seedling death. Avoid soil crusting and planter disk opener sidewall compaction, since both can reduce the plant's ability to emerge.

Seeding rate – Experience has shown that sorghum biomass yields vary across a range of seeding rates, and yield potential can be maximized with optimum plant density. The average seeding rate for sorghum grown for biomass is 100,000 seeds per acre. Seeding rates influence space availability for plants to grow and directly influence stem thickness and ratooning properties.

Seeding rates in locations with better resource availability can be higher as the inputs are more likely to support the stand. Planting density can be as high as 120,000 seeds per acre or as low as 75,000 seeds per acre, depending on input and management scenarios.

Irrigation during establishment – Sorghum is generally a drought-tolerant crop traditionally grown in hot, dry conditions. However, the crop is most vulnerable to drought stress during establishment. Limited irrigation at this time can be useful to ensure good stand establishment and improve flexibility in planting time, if sufficient moisture is not available through rainfall.

STAND MANAGEMENT

Insect pests and diseases – Sorghum can be affected by a number of different insect pests throughout its life cycle. Insect pressure depends on location, weather and the growth stage of the crop. Common examples of pests that can severely damage a sorghum crop include cutworms on seedlings, nematodes on roots, greenbugs or fall armyworm on leaves and panicles and sugarcane borers in the stalks.

Fungal diseases can limit biomass yields. The impact on conversion has yet to be determined.

Sorghum may also be affected by a number of diseases that are geographically and management-system dependent. Examples include anthracnose, downy mildew and Fusarium. Sorghum diseases commonly encountered in a given growing location should be identified prior to planting so that appropriate management practices can be employed.

Several standard agricultural practices exist for mitigating disease and insect pressures in a sorghum crop, including seed treatments, crop rotation and the application of crop protection products. Consult your local agronomist, crop consultant or extension service before planting for information on mitigating pest and disease risks in your area.

Rainfall, irrigation and yield – Sorghum typically does not require irrigation in most environments. However, there is a strong correlation between water availability and yield. Sorghum will do best in areas with at least 30 inches of rainfall per year. While sufficient soil moisture is critical at establishment and in the early stages of growth, overall water use by the crop is low in the early stages of development.

Water use increases later in the crop cycle, as the sorghum enters its rapid, or logarithmic, growth phase —typically 80 to 90 days after emergence. This is the time when substantial biomass accumulation occurs. Water needs taper off substantially when the plant initiates its reproductive phase (GS II) as biomass accumulation declines rapidly and eventually stops.

Top: Existing equipment is capable of harvesting high-biomass types. However, equipment manufacturers are studying optimizations. **Middle:** Swather systems with built-in single or double conditioning systems have been used successfully. *Photo courtesy of Dave Jordan, MacDon, Inc.* **Bottom:** Large, square bales are a storage option when moisture content is below 20%. *Photo courtesy of Brian Olander, AGCO.*

During periods of drought, well-established sorghum stands tend to enter a dormant phase while waiting for additional moisture. Once conditions improve, the sorghum stand will rapidly recover and continue growing. However, prolonged periods of drought can adversely affect sorghum yields. In periods of prolonged drought, supplemental irrigation—even in small amounts—may minimize crop loss and maintain high yield potential.

HARVEST

Harvest timing is dependent on when biomass is needed, variety type, season length, time of planting and desired moisture parameters. Several options exist for harvesting sorghum using currently available equipment. While many of the high-biomass sorghum hybrids favor a single cut in the later stages of the season to achieve maximum biomass production, hybrids specifically developed with ratooning qualities may be cut repeatedly throughout the season to ensure continuous biomass supply.

The issue of harvest frequency and timing for dedicated energy crops depends on the agronomic system used to deliver the most continuous supply of biomass possible to a biorefinery or biopower facility. Thus, management practices must be optimized to achieve maximum sustainable yields, while recognizing the needs of end users at the biorefinery or biopower facility.

Common harvest methods – The two most common methods for harvesting sorghums for biomass are 1) swathing followed by baling or chopping of windrows, and 2) direct forage chopping of the standing crop. A key consideration in choosing between the two methods is the optimum final moisture content of biomass for the desired end use, as well as what level of subsequent drying is needed to achieve it.

Arguably, the most convenient method for harvesting sorghum is to direct chop the standing material into a truck as it passes through the field. This method minimizes dirt in the harvested material. However, it also requires rapid processing of the harvested biomass because the sugars present in the freshly chopped material will contribute to its degradation.

Using a swather to cut and windrow for later pickup is another way to harvest and dry sorghum for biomass. This method also allows the biomass to be field dried before final pickup, when drier material is required or field storage is preferred.

While existing swather technology is able to handle the harvest of biomass sorghums, several well-known companies are developing customized swather technology that can more efficiently handle the higher yields associated with biomass sorghums. Once ready for pickup, the windrow can be baled directly or run through a forage chopper and put into a trailer. Care should be taken to avoid picking up soil when collecting the windrow, as excess dirt can have a negative effect on biomass quality and end-use processes.

Lodging – Like many crops, high-biomass sorghum can experience lodging. Sorghum's susceptibility to lodging may increase at later stages of its growth cycle, particularly in locations prone to high wind or heavy rain. In many cases, the large amount of material produced in a given field results in the crop leaning against itself, rather than completely falling over.

Despite some of these challenges, it is usually possible to get beneath the crop and successfully harvest the material. Certain types of harvesting heads are known to be more successful in collecting lodged crops. While optimal harvest time for sorghum in the Southeastern U.S. is typically July through October, high-biomass sorghum has been harvested from stands in North America as late as March, despite the lodging issues associated with the crop at that time of year. It is important to note that soil contact during lodging can increase grit and potentially reduce biomass quality.

Managing moisture – Sorghum's moisture content at harvest can be as high as 80%, and is directly related to hybrid variety, growing conditions, harvest timing and harvest method. However, with proper management, and in the right environment, moisture can be reduced to the maximum 15 to 20% range required for baling. When moisture content is immaterial to the end-use, then forage chopping is likely the most convenient means of harvest.

When end uses (storage, handling or conversion processes) require dry biomass, several techniques can be used to enhance drydown of the material.

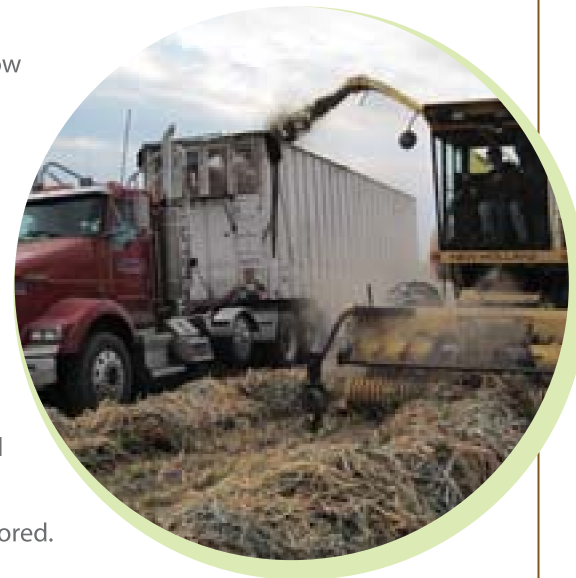
In some environments, sorghum stands can be left in the field to allow natural senescing or exposure to a killing frost, which will also aid drying.

Research is under way to determine if broad-spectrum herbicides can be applied to the stand to terminate growth and encourage drydown in advance of desired harvest time. This method would be best suited for situations where a harvest time is desired before field senescence can occur, or the length of the season prohibits waiting. Early results of this research are encouraging. However, regardless of the preharvest drying method used, it is important to note that later harvests increase the likelihood of complications caused by lodging.

Following preharvest drying, motorized swather systems with built-in single or double conditioning systems can break apart the stalks and allow further field drying in windrows. Additional drying can be achieved through the use of raking or tedder systems to turn or spread out the windrow and allow sun

Moisture content at harvest can be as high as 80%. However, with proper management, levels can be reduced to the 15-20% range for bioenergy uses requiring drier biomass.

and wind to evenly reduce moisture content. Moisture contents below 10% have been achieved with these methods, though the minimum achievable moisture is highly dependent on relative moisture (rain and humidity) in the production area. For example, 30 – 40% moisture content would be typical in the high rain and humidity of the Southeast U.S. Achievable moisture levels will vary significantly based on harvest time and weather conditions during the drying process. Adverse weather conditions, such as rain during the drying process, will also reduce overall biomass yields because the extractives present in the biomass will be washed out as the material lies in the field. Bales stored in the field may also see weathering effects, such as the loss of extractives, depending on how they are stored.



Windrowed sorghum is blown directly into a semitrailer for immediate shipment to a nearby power generation facility, which co-fires the sorghum biomass for electricity production.

Stubble height – For multi-cut hybrids, a stubble height of 4 to 6 inches (10 to 15 cm) is generally recommended to promote regrowth. A clean cut can be equally or even more important than stubble height. Cutting too quickly (ground speed) or using a dull cutting mechanism (e.g., rotating blade or sickle) can shatter the base of the stalk, resulting in greater open area for disease entry, drying out from ambient temperature and other damage. Be especially careful of ground speed in stands with heavier stalks.

Storage – Although just-in-time harvest and delivery to a biorefinery is preferred, there are very few locations where this will be feasible year round.

Storage of biomass will be necessary for two reasons: 1) to provide for year round operation, and 2) to ensure operation during inclement times (when using just-in-time harvest).

Several different storage options are being developed by equipment manufacturers and university programs such as Texas AgriLife Research (Texas A&M System).

One option is large, square bales, which can be used when moisture content is below 20% (some research has shown that moisture levels approaching 40% may be acceptable). Note that higher moisture content, depending on the conversion technology, may not be as concerning as it is for hay because forage quality may not be as important. Storage of biomass at elevated moisture levels should only be undertaken with suitable facilities and equipment to prevent overheating and spontaneous combustion.

Large, round bales are also a possibility. However, they are less efficient to transport and store.

Another option under evaluation is using the cotton module builder to receive cured, chopped sorghum in module form.

Lastly, ensiling processes are also being considered.

GOVERNMENT INCENTIVES

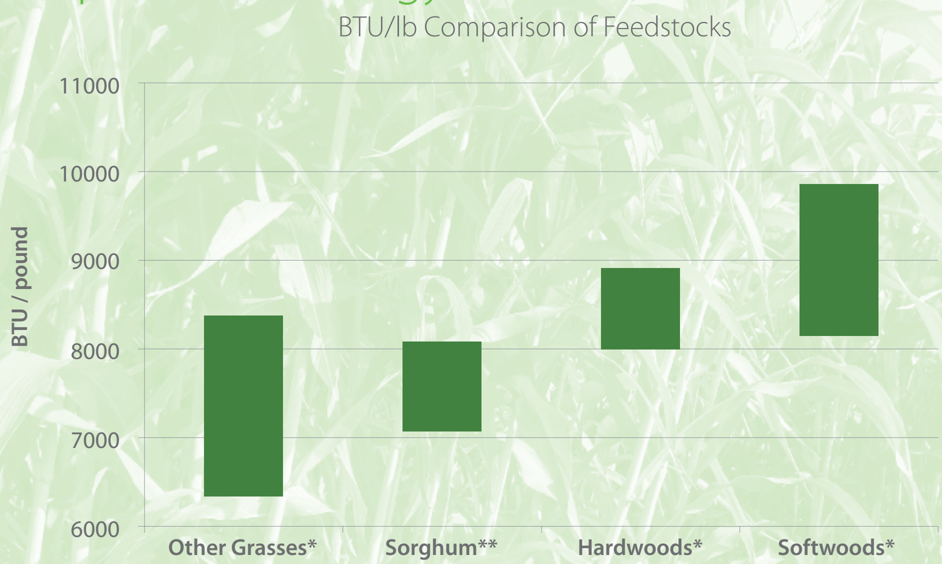
The U.S. departments of energy and agriculture as well as many state governments are supporting demonstration and commercial-scale activities for energy crops. The 2008 Farm Bill contains a program known as the Biomass Crop Assistance Program (BCAP) to help growers seeking experience with nonfood, low-carbon crops, such as high-biomass sorghum.

The first phase of the program provides dollar-for-dollar matching payments for collection, harvest, storage and transportation of qualified biomass, up to $45 per dry ton. More than 400 facilities have qualified for the program to date. Phase 2 of the BCAP program will support the establishment and production of certain biomass crops for conversion to bioenergy. Final rules and funding for Phase 2 are expected in 2010. Contact your local Farm Service Agency office for more information about BCAP. A reference guide on BCAP may also be downloaded at www.BladeEnergy.com.

ENERGY CONVERSION

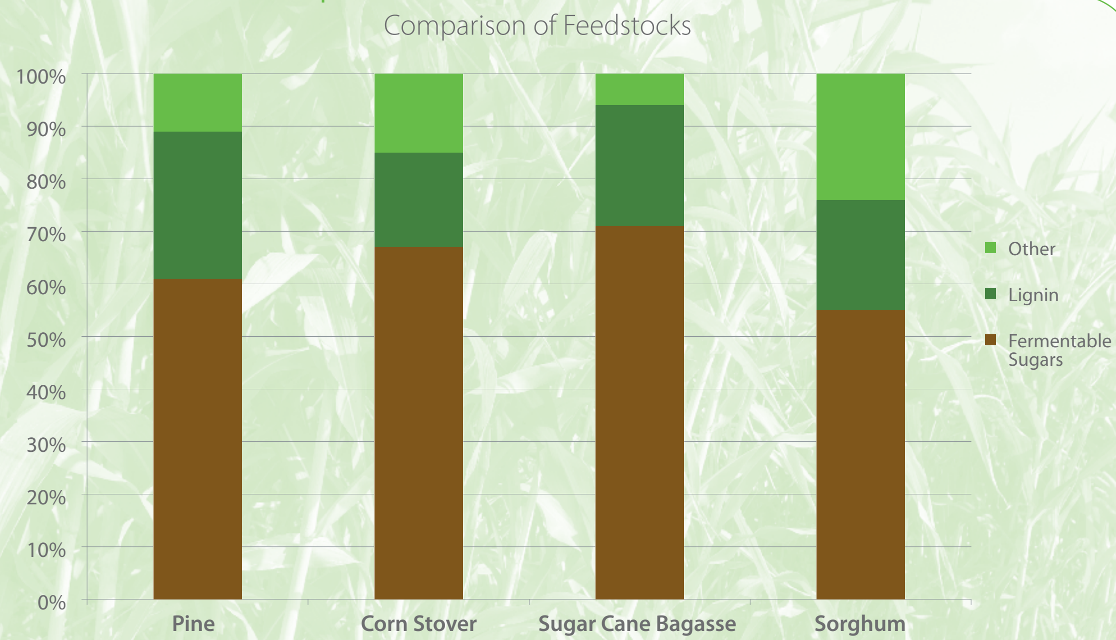
There are three major types of biomass conversion processes: combustion, thermochemical and biochemical. These processes can be used to produce energy in the form of liquid transportation fuels (e.g., ethanol, butanol, gasoline, diesel and jet fuel), heat and power (electricity), as well as provide the chemical building blocks for industrial processes.

Comparison of Energy Content



The average BTUs per pound for sorghum compares very favorably with grasses and also overlaps the range of values for woody feedstocks.

Chemical Composition of Biomass Feedstocks



The content and accessibility of sorghum sugars compare well with corn stover and other grasses as well as woody crops.

For combustion and thermochemical conversion, a key measure of expected performance is BTU (British Thermal Units) per pound. At an average 7,750 BTU/lb., sorghum compares very favorably with grasses, and also overlaps the range of values for woody feedstocks. By comparison, Powder River Basin coal, a common fuel for electricity generation, averages 8,800 BTU/lb.

As with many other features of biomass, many of the key compositional features that influence the performance of herbaceous crops in biopower applications—including energy (HHV) and ash content—are influenced by both agronomic practices and genetics. It is generally accepted that biomass can be cofired in coal-fired facilities at up to 15% without requiring significant boiler retrofit. Sorghum has shown to compare favorably against multiple other biomass feedstocks in these areas, and projects are currently underway to conduct larger-scale evaluations.

Biochemical conversion of biomass to biofuel utilizes a process that involves a thermochemical pretreatment of the biomass, which is usually followed by enzymatic treatment to break down the complex of structural carbohydrate chains found there. The resulting sugars can then be fermented to biofuels. Some of the challenges of this technology involve the complexity of converting the biomass into a form that is efficient for conversion, as well as the diversity of compounds present in biomass.

The efficiency of this conversion process is dependent on a host of factors that can make the sugar chains more or less accessible to enzymes and/or fermenting organisms. Understanding those factors and modifying them to increase the accessibility of convertible sugars is an active area of research. However, it is generally understood that higher content and easier accessibility of these complex chains of sugars are important, since they establish the maximum theoretical biofuel yield. In this regard, sorghum compares well with corn stover and other herbaceous and woody species.

FURTHER READING

Sorghum Growth and Development, Gerik, Bean and Vanderlip.

Grain Sorghum Production Handbook, Kansas State University, February 1998.

Forage Sorghum, Roth G. and Harper J., 1995

LEGAL NOTICES

This guide is intended to serve as an informational tool for growers to use in the production of high-biomass sorghum as an energy crop. The information contained in this guide is based on public and private research that is currently available. Successful farming of any crop requires a high degree of skill. Seed and crop performance are heavily dependent on environmental conditions such as sunlight, moisture, temperature and soil composition, all of which are beyond the control of any individual. The authors and collaborators who prepared this guide do not guarantee crop yield or performance. In order to maximize a crop's potential, growers must actively manage the crop according to environmental conditions, pests and diseases as they occur. While no farming guide can predict or address every farming situation, this guide will provide a strong foundation on which to build techniques for producing a high-biomass energy crop.

This guide is not part of the labeling of any seed or pesticide. Growers must always read and follow all instructions in the product labels of seed and pesticide products. Contact the pesticide product manufacturers or local extension agents to confirm that pesticide products are labeled for an intended use. Contact the seed producers to confirm instructions and intended uses on seed. Always read and follow all labels and instructions for pesticide and seed products.

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