



Guidebook for the Sustainable Production Practices of Switchgrass in the Southeastern U.S.

THE UNIVERSITY of TENNESSEE LI

INSTITUTE of AGRICULTURE

IBSS: An Introduction

The Southeastern Partnership for Integrated Biomass Supply Systems (The IBSS Partnership) is working to deploy the infrastructure-compatible biofuels industry in the southeastern United States. Selected by the U.S. Department of Agriculture, National Institute for Food and Agriculture through a highly competitive process as a Coordinated Agricultural Project, the IBSS Partnership leverages extensive prior investment in research infrastructure to further advance the vision of reduced reliance on fossil fuels. The program organizes a powerful, multidisciplinary team of skilled scientists, outreach specialists, and educators to address its three primary goals:

- Demonstrate real-world solutions to barriers limiting deployment of advanced biofuels in the Southeastern region.
- Create, validate and use new metrics for improved decision-making for regional biorefinery development.
- Provide credible and relevant programs to dispense new knowledge for the workforce and stakeholders.

The IBSS Partnership is working closely with key industry interests to create a sustainable feedstock supply system to reduce risk and accelerate investment in this new industry.

Guidebook for the Sustainable Production Practices of Switchgrass in the Southeastern U.S.

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Switchgrass: An Introduction

Why Switchgrass?

Why switchgrass as a biomass feedstock for advanced biofuels and bioproducts? Switchgrass is favorable feedstock for biomass production because of the plant's great yield potential and high cellulosic content.

Switchgrass 101

Switchgrass is a warm-season grass native to the tallgrass prairies of the United States. Its native range covers most of the continental U.S. east of the Rocky Mountains and extends into both Mexico and Canada. It is often said that when Louis and Clark were in awe viewing the buffalo herds on the plains, they were standing in switchgrass. Switchgrass has been identified by the U.S. Department of Energy as a leading dedicated energy crop because it tolerates a wide range of environmental conditions and offers high biomass yield compared to many other perennial grasses and conventional crop plants.

Switchgrass is a perennial, meaning it does not need to be replanted each year as with annual crops like corn and soybeans. It generates new regrowth from the same root crown each growing season; however, switchgrass is not rhizominous and is noninvasive. The plant can be established successfully from the planting of seeds in either a tillage or no-till situation. The planting of seeds is a much more cost-efficient means of establishing a crop as opposed to vegetative propagation (planting seedling plants). Once established, switchgrass that is well-managed for biomass production should have a productive lifespan of 10-20 years.



Once the plant reaches maturity (which is the third growing season after successful establishment) it can reach heights of 10 feet, producing greater than 7 dry tons per acre. Switchgrass, being a native warm-season perennial, has an extensive fibrous root system, which can reach depths greater than that of the plant's height — 10-plus feet. This extensive root system seeks soil moisture during dry periods and prevents soil erosion during long or intensive rain events, thus giving the plant its drought-tolerant nature. There are other attractive sustainable attributes stemming from the switchgrass root system: improving soil health, increasing soil content of organic matter and carbon sequestration.

Switchgrass adapts well to a variety of soil and climatic conditions. It is most productive on moderately well to welldrained soils of medium fertility and a soil pH at 5.0 or above. This avoids the food versus fuel debate and prevents competition with row crops, allowing for more of what is referred to as "marginal" land to be brought into production. This adaptability, coupled with the climate and amount of rainfall in the Southeast, gives switchgrass a competitive advantage in the region.

For example: during the five-year University of Tennessee BioFuels Initiative Program, some very poor soils (sites that were cleared of young pine trees, sweetgum sprouts and brambles) were successfully planted in switchgrass. Certainly switchgrass, like other crops, will produce higher yields in higher quality soils; however, economically feasible yields can be harvested from soils that normally do not contribute to a farming operation's cash flow.

Switchgrass is considered to be a relatively low input crop and is less demanding from the managerial aspect, especially when compared to row crops like corn, soybeans and cotton. A



producer is able to plant once, and after successful establishment the only operations needed in the field are an application of fertilizer in the spring and harvest operations in the fall. The fertility requirements are low compared to other crops such as corn. Once it is established, switchgrass will outcompete most weeds during the growing season thereby reducing, and in most cases eliminating, the need for an herbicide application. There is less of a burden on the managerial aspect of the operation because of the reduced number of field operations required for switchgrass production. It also should be noted that the planting or harvesting of switchgrass does not require specialized equipment. Existing planters, no-till drills, and hay and forage equipment can be readily utilized for establishing and harvesting switchgrass.

Switchgrass Varieties

The two main types of switchgrass include both upland and lowland varieties. Blackwell, Cave-in-Rock and Carthage are a few examples of upland varieties, while Alamo and Kanlow are examples of lowland varieties. The upland varieties are typically finer stemmed, shorter in stature and thus lower yielding when compared to lowland eco-types. With these growth characteristics, upland types are adapted and better suited to the environmental conditions of the Midwest and Northern Plains regions of the United States. They are shorter, growing usually 5 to 6 feet tall, and therefore yield less. However, upland varieties are more winter hardy and cold tolerant when compared to the lowland varieties.

Lowland varieties are taller growing, reaching heights in excess of 9 and 10 feet. The taller-growing material produces more biomass per acre, resulting in greater yields on a per-acre basis



than the upland varieties. However, lowland types are not as cold tolerant or winter hardy and are more suited to the southern regions of the United States, especially those of the southeastern U.S.

Establishment

The establishment of switchgrass takes time, preparation and planning to ensure success. Regardless of the preferred method of planting (no-till vs. tillage), knowledge from the evaluation of the chosen field, its previous production history and a recent soil test are all imperative to the successful establishment for each specific location. Soil tests are crucial to the successful establishment of switchgrass because there are varying degrees of change between neighboring farms and even within the same farm field. Ten different soil types may exist within the same field.



(Fig. 1) Switchgrass seed.



Switchgrass is a very small, fine seed totaling more than 400,000 seeds per pound. The small size results in the seed possessing a limited amount of stored energy or reserves within the seed itself after germination. This is where the soil type and related planting depth and the timeliness of moisture play a critical role in seedling success.

Switchgrass may be established using either no-till or conventional tillage practices. Each practice requires thorough planning and preparation to ensure successful stand establishment.



(Fig. 2) No-till drill.

No-till

Drills designed for no-till are essential for no-till planting. In order to place seed into a soil environment that provides good germination (underneath a killed sod or underneath previous crop residue), the drill should be equipped with offset double disc openers or a lead coulter to slice into the soil. The drill should weigh enough to slice through compact clay soils at the desired depth throughout the width of the drill.

The press wheels should be adjusted with adequate downpressure to assure good and consistent seed-to-soil contact. A small seed hopper will generally adjust more easily and accurately meter the small switchgrass seed. The larger seed hoppers can be used; however, proper seeding rates are more difficult to achieve.

Soil scientists throughout the Southeast will agree that no-till is the preferred method for planting switchgrass.

Benefits of No-till Establishment:

- Conserves soil moisture.
- Prevents erosion.
- Increases water.
- Improves infiltration.
- Reduces run-off.
- Saves time and labor.



(Fig. 3) Example of field that was planted with a no-till drill.



No-till will allow production of switchgrass on land that otherwise could not be row-cropped due to slope or soil conditions. These are lands that are deemed unsuitable for rowcrop production and are often referred to as "marginal."

Switchgrass may be established using no-till methods when adequate preparation has taken place to manage competition. When establishing switchgrass into a fescue sod such as a pasture or hayfield, chemical control of tall fescue should start with a fall application of glyphosate prior to spring planting. This application would be followed by a second application of glyphosate after green-up in the spring and a third application as close to planting as possible. When establishing switchgrass into cropland following corn, soybeans, etc., the weeds present should be inventoried early in the season and addressed with one or more burn-down applications prior to planting. This method will prevent weed biomass from becoming large enough to inhibit the effectiveness of planting equipment in accurately placing seed.



Conventional Tillage

(Fig. 4) Conventional tillage.

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Switchgrass established using conventional tillage practices requires thorough planning and preparation to minimize weed competition. In the event that an established fescue sod (pasture or hay field) will be tilled prior to planting switchgrass, an application of glyphosate the fall prior to tilling and planting will increase the effectiveness of the initial tillage pass. This fall application will decrease the potential for fescue to survive the tillage process, then regrow and compete with seedling switchgrass. Spreading tillage passes over a rain and drying cycle will help ensure that the sod is detached and killed prior to final seedbed preparation.

A firm seedbed is a must for successful germination following conventional tillage. Use a cultipacker or a culti-mulcher to adequately firm the soil prior to planting. Proper tillage is achieved when all sod or crop residue is detached and thoroughly mixed into the tillage profile. To accomplish this, many farmers will disc, chisel, disc, disc, culti-pack and plant. The field appearance will resemble a field properly prepared for planting corn.



(Fig. 5) Prepared seed bed.

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The following are two approaches to weed control in a tilled seedbed prior to planting:

- Stale Seedbed (preferable): In this approach the seedbed is adequately tilled and firmed and left fallow for a period of time prior to planting. During this fallow period, weed seed will germinate. Immediately prior to planting, a burn-down application of nonselective herbicide (glyphosate or Gramoxone Super) is used to eliminate weed competition.
- 2. Prepare Seedbed and Plant Immediately: This approach relies on the final tillage pass to eliminate any germinated weed seeds prior to planting. A potential weakness of this approach is the difference in rates of seedling growth between switchgrass and weeds. (Remember to firm the seedbed prior to planting.)

Planting Window

Plant early.

Preferred planting dates for Tennessee are from mid-March to mid-June. Always plant early when adequate soil moisture is available.

For many states, planting dates for switchgrass will range from three weeks prior to the earliest planting date for corn until the latest planting date for soybeans.

Can I plant switchgrass at times other than Spring?

Switchgrass seedlings with a 4-inch root system should survive normal winter conditions.



Seeding Rate

Switchgrass, as with any native warm-season grass, is seeded based on percent Pure Live Seed (PLS). If percent PLS is not calculated on the label use the top formula (below) to make calculations (use the actual numbers without moving the decimal). Calculate the seed to be planted per acre by dividing the desired seeding rate by the PLS and multiply by 100.

Formula:

- Percent Purity x Percent Total Germination = Percent Pure Live Seed (PLS)
- Desired seeding rate / Percent PLS = Actual Amount of Seed Planted

The suggested seeding rate for switchgrass is 6 pounds of PLS per acre.

:41	1897 CR 1018; Muleshoe, TX 79347; 806-272-5508 Permite: TXD0905						
	ALAMO SWITCHGRASS						
	Lot #: 27052 Pure Seed Inert Other Crop Weed Seed	98.68% 1.29% 0.01% 0.02%	Germination: Dormant: Hard: Total Germination:	Test Date: Origin: 92.00% 3.00% 0.00% 95.00%	2/08 TX		
		Pure Live Seed	93.75%	Net Wt	50.0 lbs		

(Fig. 6) Example seed tag.



- (98.68 percent / 100) Purity x (95 percent / 100) Germination = 0.9375 x 100 = 93.75 percent PLS
- 6 pounds per acre (desired seeding rate) / (93.75/100) =
 6.4 pounds / acre planted seed

*Note: When calibrating a drill, round up planted seed to nearest whole number (achieving accuracy in less than whole numbers is difficult).

Seed Placement and Depth

The preferred seeding depth for switchgrass is 1/8 to 1/4 inch. It is acceptable if a small amount of seed is visible on the soil surface. In conventionally tilled seedbeds, a best practice is to distribute seed on the soil surface with the drill opener discs adjusted for no soil contact. Follow the drill with a cultipacker pass to incorporate seed. Cultipacker-seeder combinations are also acceptable. Drills that are set to slightly cover most of the seed have worked much better in Tennessee than seed planted 1/2 inch or deeper.

Some drill makes and models will disturb more field residue than others. Make certain, however, that the seed is not covered too deep even if it is placed within a cut made by an aggressive double-disc opener.

The biggest problem farmers have trying to establish a good stand of switchgrass is planting too deep. Remember, these are very small seeds and thus possess little energy reserves. Therefore, they need to break through and reach sunlight soon after germination.



Effect of Seed Treatments for Seed-borne and Soilborne Switchgrass Pathogens

Research from IBSS and the University of Tennessee examined the effects of soilborne and seed-borne pathogens on switchgrass seed and seedlings. The study sampled 9,000 seeds where the overall infection rate was 25.3 percent; infection rate of seed lots and cultivars ranged from 1 percent to 87 percent. As seen below, infected plants have initial stunted growth and are slower to establish. This research shows that a seed certification program, effective seed treatments or both are needed.

It was determined that switchgrass seed is more vulnerable to *Bipolaris* spp. than larger plants. This finding supports an observation by Ken Goddard that fungicide/ insecticide seed treatments have improved stands and the establishment of switchgrass in Tennessee. A state label was approved for Gaucho XT as a seed treatment for switchgrass seed following randomizedreplicated studies.



(Fig. 7) Left: Control plant. Right: Infected plant.





(Fig. 8) Treating switchgrass seed with fungicide/insecticide.

Properly labeled seed treatments have improved stands and seedling vigor.



(Fig. 9) Test plot of treated and nontreated seed.



Gaucho XT provides a visible stand improvement compared to the untreated check. Gaucho XT provided a degree of both disease and soil insect protection.

Switchgrass has resistance to a number of diseases and insects. Researchers and farmers have not experienced significant insects and disease problems in switchgrass produced in Tennessee. As switchgrass acreage expands into a monoculture setting, it is not unreasonable to expect problems to develop over time.

Fertilization

Tennessee fertilizer recommendations are based on crop removal rates. Phosphorus and potash are not recommended unless the soil test level falls into the low category. When tests are low for these two major nutrients, add 40 pounds phosphorus (P) per acre and 80 pounds potassium (K) per acre. Nitrogen is not suggested until year two since weed competition will become too severe if it is added during the establishment year. Some agri-suppliers only stock Diammonium phosphate (DAP) as their source for phosphorous. DAP contains 18 percent nitrogen. If P is needed before planting and DAP is the available source of P, then the small amount of nitrogen applied in the P source will not cause significant problems. It will be important to add the needed P and K for each particular field.

Note: Lime is not recommended for switchgrass unless soil pH is below 5.0.



Soil Test Recommendations for Establishment and										
Maintenance of Switchgrass for Biomass (SWBIO)										
	Nitrogen	Pho	sphate (P2	205)	Potash (K2O)					
	Practice									
	(NT)	L	М	н	L	М	Н			
1. Establishment Year	0	40	0	0	80	0	0			
2. Maintenance Year	60	40	0	0	80	0	0			
*NT = Not Tested L = Low M = Medium H = High										

(Fig. 10) Soil Test Recommendations for Establishment and Maintenance of Switchgrass for Biomass (SWBIO).

Generally, nitrogen applied during the establishment period will create excessive competition from annual grasses and broadleaf weeds. In the first year, **do not** apply nitrogen. It increases competition from annual grasses and broadleaf weeds. Beginning in the spring of the second year, 60 pounds of nitrogen per acre are recommended.

There are exceptions to the "No nitrogen during year one" rule. Note: Use good agronomic practices if weeds are not problematic and switchgrass is growing in poor soils that do not provide adequate natural fertility.





(Fig. 11) Emerging first-year switchgrass in poor soil conditions with no weed competition will benefit from nitrogen fertilizer.

Actively growing switchgrass should be fertilized with 60 pounds nitrogen per acre beginning in year two. The appropriate time to apply fertilizers is about April 1 in Tennessee. Active growth will begin earlier in more southern locations. Also, blend any recommended P and K during this same time period.



(Fig. 12) Second-year switchgrass.



Successful Production Systems

Several production systems have been identified for successful switchgrass establishment. The preferred system will be the system that best matches the field conditions and the time remaining for adequate planning and implementing the proper production steps.



(Fig. 13) Switchgrass established behind soybeans.



(Fig. 14) Switchgrass planted into wheat stubble.

The two systems shown in Fig. 13 and 14, switchgrass established behind soybeans and planted into wheat stubble, have worked particularly well. Grassy weed competition is not as severe behind previous years of chemical weed control (as shown in Fig. 13) behind soybeans. Also, grassy weeds have not been severe planting into wheat stubble following wheat baleage or wheat hay crops. Adequate soil moisture may be a problem when planting behind wheat as a forage; however, when moisture is available excellent stands can be anticipated.

In compacted soils, a single vertical tillage pass prior to planting with a no-till drill will loosen soil particles and improve seed placement and germination.



Research has proven tall fescue, orchardgrass, and other coolseason grass types can be successfully controlled during late fall periods with lower glyphosate rates as compared to spring applications. These grasses are difficult to kill in the spring even with sequential applications of the higher approved application rates.

If dallisgrass is present among these cool-season grass fields and no-till is the production system of choice, a fall spraying is a must. Otherwise (when dallisgrass is identified) extensive tillage will be the only spring establishment option.

The conventional tillage option works well on more level slopes where soil erosion is not problematic. Again, early planting is important to establish switchgrass prior to severe weed problems.



(Figs. 15a) No-till planting into tall fescue pasture



(Figs. 15b) Conventional planting following a culti-mulcher, which provides a firm, smooth-surfaced seed bed.

Avoid planting when soil conditions are too wet for proper coverage of seed and good seed-to-soil contact cannot be achieved. A sample of soil rubbed between your thumb and pointing finger should flake apart when a field is dry enough to plant.





(Fig. 16) Notice furrows from drill were not closed, a result of planting when conditions were too wet.

Plant Emergence

During year two, new aboveground tillers will become visible in February or early March. Short rhizomes are visible throughout the winter and can be seen any time a root crown is dug and soil particles are shaken from the roots. Switchgrass tillers or shoots will begin active growth in March.



(Fig. 17) Emergence of switchgrass tillers in year two.





(Figs. 18 and 19) The ability to delineate planted rows is a rule of thumb indicator of a successful establishment of switchgrass.

Yield Expectations

It takes three years for switchgrass to produce optimum yields. The first year should be dedicated to successful stand establishment and proper weed control. Even though research indicates a 30 percent yield expectation the first year, actual yields will range from zero to as much as 5 tons per acre.

Yield Expectations

- 1st year 30% yield (Milan 1 to 2 tons DM)
- 2nd year 70% yield (Milan 4 to 5 tons DM)
- 3rd year 100% yield (Milan 7-12 tons DM)

*University of Tennessee, Milan AgResearch and Education Center

(Fig. 20) Switchgrass yield expectations.



Weeds

When considering the production of switchgrass as a biomass crop, a number of challenges and opportunities in the area of weed control should be noted. The primary challenge is the disparity in competitiveness during the establishment phase of production. Switchgrass is slow to establish and will take several weeks to develop a root system. Many of the weeds that are commonly present in switchgrass fields grow quickly and will significantly damage or eliminate a stand of switchgrass seedlings if not addressed in a timely and appropriate manner. After the switchgrass is fully established, this issue of competitiveness is reversed in the favor of the switchgrass plant, eliminating the need for active weed control except in the cases of encroachment by winter annuals during the inactive period of growth. The following are weed control considerations for various establishment and post-establishment periods of switchgrass biomass management.

Weed Control After Planting

Frequent monitoring is an essential part of a successful weed control strategy after planting switchgrass. Failure to identify problems early will diminish the effectiveness of control methods as well as decrease or eliminate the stand of switchgrass seedlings. Proper identification of weed species is also essential in creating a plan for control.

Very limited herbicide control options are currently available for control of grass weeds in switchgrass during the establishment period. The grass-type weeds that provide the greatest competition to switchgrass seedlings are large crabgrass, barnyardgrass, goosegrass, broadleaf signalgrass, and johnsongrass. The presence of these weeds requires the use of mechanical control through mowing to decrease competition for sunlight. In instances where mowing alone will produce a level of biomass capable of smothering seedlings, removal of this biomass as hay may be preferable.

A larger range of chemical control options are available for broadleaf weeds in switchgrass. A number of products labeled for use in pasture and rangeland are effective.

Before considering chemical control options for grass or broadleaf types of weeds, note the size of switchgrass seedlings. Smaller seedlings can be damaged by herbicides. When damage is a concern, control through mowing may be necessary to allow time for the seedling root system to develop. Always consult herbicide labels prior to use.

Weed Control Post-establishment

After successful establishment of switchgrass for biomass production, it is necessary to monitor fields during midwinter for the presence of winter annual weeds. These weeds germinate after the biomass harvest and when left uncontrolled will compete with switchgrass in the spring for nutrients. Application of broadleaf herbicides, such as 2,4-D will control winter annual weeds such as tall buttercup, carolina geranium, curly dock, etc. If winter annual grasses such as ryegrass and bluegrass are present, along with broadleafs not controlled by 2,4-D (henbit, chickweed, deadnettle) an application of a nonselective contact herbicide (Gramoxone Super) may be necessary. Again, prior to use of any herbicide consult the Tennessee Weed Control Manual available at http://utextention.tennessee.edu/publications and follow all label guidelines and restrictions.

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(Fig. 21) Broadleaf weed competition.

This field of switchgrass (Fig. 21) was infested with a variety of broadleaf weeds. Close observation of this photo will reveal the presence of common ragweed along with amaranth types, etc. Consider the chemical weed control options with the broadest spectrum of control.

Note: State labels for weed control products must be in place and followed precisely. Use of proper PPE and accurate sprayer calibration are required.





(Fig. 22) Grass weed competition.

Clip fast-growing johnsongrass above seedling switchgrass. Begin chemical control of johnsongrass with nicosulfuron (if labeled) when switchgrass secondary roots are present. (Switchgrass seedlings should be 20 inches tall or about knee-high).

Excellent rows of switchgrass are visible in the field seen in Fig. 22 even though johnsongrass has become a problem. The young seedlings of switchgrass are not mature enough to avoid injury from Tennessee labeled nicosulfuron (Accent) and products such as Pastora. A rotary mower will provide enough sunlight and growing time for switchgrass to grow large enough for chemical weed control.

Adjust the cutting height to the top of the switchgrass seedlings. This setting will allow sunlight into the young switchgrass and keep it actively growing. Two clippings may be needed prior to spraying for johnsongrass control.





(Fig. 23) Clipping – mechanical weed control.

A pure, high-yielding stand of switchgrass resulted following mechanical suppression of goosegrass (Fig. 24). Two trips with a rotary mower, spaced three weeks apart, allowed the switchgrass to outperform the competition by providing sunlight for the switchgrass seedlings.

Note: Reminder for clipping — raise the mower to the top of the switchgrass seedlings so as not to make heavy windrows of clipped material.



(Fig. 24) Example of mechanical weed control success resulting from switchgrass' need for sunlight.



Here is yet another example of switchgrass' ability to outcompete other grasses and weeds. Figs. 25a-c are three photos of the same field. Notice the canopy of Kentucky bluegrass (Fig. 25a), then how the field looked immediately after clipping (Fig. 25b). Fig. 25c was taken two weeks later from the same location.



(Fig. 25a) Kentucky bluegrass canopies switchgrass.



(Fig. 25b) Kentucky bluegrass after clipping.



(Fig. 25c) Two weeks after clipping.

Once established, switchgrass grows quickly and aggressively. The plant's dense growth provides shading, resulting in very little need for weed control inputs in established stands.

Adequate weed control is the most important factor in successful switchgrass stand establishment.

Note: Herbicide Reminder – **Always** follow labeled directions.

Small switchgrass seedlings are vulnerable to competition from annual and perennial grass weeds. Seedlings grow slowly and cannot tolerate shading from fast-growing weed competition. A total loss of an acceptable stand of switchgrass can occur if weeds are not kept in check. A combination of mechanical and chemical weed control may be needed on a timely basis.





(Fig. 26) Switchgrass emerges unevenly and grows slowly; whereas, most weeds emerge and grow quickly. Begin scouting for weeds one week after planting.

Weed Situations to avoid:

- Bermudagrass (tillage doesn't remove, just spreads).
- Crabgrass.
- Broadleaf signalgrass.
- Dallisgrass.
- Broomsedge.



Weed Identification Gallery



(Fig. 27a) Common Bermudagrass.



(Fig. 27b) Large crabgrass.



(Fig. 27c) Broadleaf signalgrass.



(Fig. 27d) Dallisgrass.





(Fig. 27e) Broomsedge.



(Fig. 27f) Johnsongrass.



Other Weed Situations (experienced during establishment)

It is much easier to establish switchgrass into fescue sod than annual and perennial grass weeds such as dallisgrass and broadleaf signalgrass. It is also easier to kill fescue in the fall than in the spring. For this reason, it is suggested to begin making preparations in the fall.



(Fig. 28) Planting into killed fescue sod.

Switchgrass Establishment Management Reminders:

- No nitrogen application; keep weeds from having a competitive advantage.
- Switchgrass emerges unevenly and grows slowly, opposite of most weeds (and corn and beans).
- Scout field no later than one week after planning.
- Broadleaf weeds not an issue.
- Competitive grasses are an issue.
 - Avoid broadleaf signalgrass (annual) if possible.



Switchgrass Herbicide Reminders:

- Metsulfuron (Cimarron Plus) provides a wide range of broadleaf weeds, but it will not control common ragweed. If common ragweed is present, consider 2,4-D. Take precautions to avoid 2,4-D amine spray drift.
- Aminopyralid (GrazonNext HL or ForeFront HL) application should not be made until switchgrass plants have begun to tiller and have developed good secondary root systems. Switchgrass stage of development is critical when using aminopyralid.
- PastureGard controls woody plants locust, briars, etc., and switchgrass must have tillered.
- Nicosulfuron (Pastora) can cause injury to young switchgrass.



(Fig. 29) Emergence of "new ground" switchgrass

Saplings of locusts and other trees, brambles, and other brush species can be a problem during establishment of switchgrass on "new ground," or fields where timber has been harvested. Spot sprays of PastureGard HL, a premix of triclopyr and fluroxypyr, have worked well in these situations. As is the case with aminopyralid, do not apply PastureGard HL to switchgrass before it has developed a good secondary root system and has begun to tiller.



Grasses are more challenging, more competitive and have fewer herbicide control options. As mentioned earlier, grass weeds present a much greater challenge to the successful establishment of switchgrass than do broadleaf weeds. They are more competitive, due to shading, than most broadleaf weeds, and leave producers with fewer herbicide options. Unfortunately, research trials have not yet identified an effective option for crabgrass, which is one of the most commonly encountered weeds in switchgrass. This reason is why early planting is encouraged.

According to G. Neil Rhodes Jr., UT Extension weed specialist and professor in the UT Department of Plant Sciences:

It became evident in our early work that broadleaf signalgrass, an annual, and johnsongrass, a perennial, presented problems during switchgrass establishment. From our previous experience with no-till corn in the 1990s, we knew that nicosulfuron (trade named Accent) was effective on these two weeds if applications were properly timed. Our evaluations in switchgrass showed that although nicosulfuron was effective on seedling signalgrass and rhizome johnsongrass, injury to young switchgrass was often unacceptable. As a result, we are recommending that fields heavily infested with broadleaf signalgrass should be avoided if possible.

The nicosulfuron product that is labeled for switchgrass is called Pastora, and it is actually a premix of nicosulfuron and metsulfuron. The product gives control of johnsongrass, broadleaf signalgrass and several other grasses, but not crabgrass. And, because it contains metsulfuron, it also controls a number of broadleaf weeds. Similar to Accent, it also causes substantial injury to young switchgrass. A system of clipping, followed by application of Pastora, has worked well and lessened the severity of injury.



Winter Weed Competition



(Fig. 30) Winter annual weed competition.

Most winter annuals will die naturally in late spring to early summer and switchgrass will grow. However, these winter weeds can rob your switchgrass of needed nutrients and slow early growth. Gramoxone Super at 2 pints per acre plus 0.5 percent nonionic surfactant (NIS) per 100 gallons of water applied prior to mid-March will clean up the competition. The resulting pure stand of switchgrass will better utilize the fertilizer recommended by the soil test.

Note: During February and early March check your year-two fields for winter weeds.

Winter Weeds:

- Tall Buttercup
- Deadnettle
- Common and mouse-eared chickweed
- Annual bluegrass
- Musk thistle
- Annual ryegrass



Five Steps for Success

1. Select fields wisely

From the standpoint of weed challenges during switchgrass establishment, a field that has been in a corn-soybean rotation using Roundup Ready technology is less challenging. Knowledge of the weed history of the field is important information to have during the selection process.

Avoid heavy bermudagrass and broadleaf signalgrass. Bermudagrass cannot be controlled either in no-till or conventional tillage. Broadleaf signalgrass grows aggressively and is difficult to control without causing substantial injury to seedling switchgrass.

2. Properly prepare and plant the field.



(Figs. 31a) Haybuster drill is shown in use for no-till planting into a tall fescue pasture.



(Figs. 31b) Good soil moisture and the killed sod provide excellent germination conditions and delay weed competition.

• If possible, begin the transition the fall before planting switchgrass. Fescue sod is much easier to kill then, and fall spray applications are required for broomsedge and dallisgrass.



- In no-till or conventional, it is imperative that no green vegetation whether it is composed of weeds, sod (as in the case of a pasture), or a combination of both is present at planting.
- Remember, switchgrass seedlings are slow to emerge and grow initially; therefore, planting into a clean field reduces early competition.

3. Closely monitor recently planted fields.

• Identify weeds and be ready to make informed management decisions.

4. Make timely herbicide applications if needed.

• Base your decisions on information you learned from scouting. Match the optimum herbicide, or combination of herbicides, to the weeds present.

5. Monitor fields the remainder of the first year and the second year.

• Spot sprays may be needed for johnsongrass and other weeds in areas where switchgrass stand is thin. Also, persistent woody saplings may need attention the second year in new ground.



(Fig. 32) Example of switchgrass failure due to weed competition.





(Fig. 33) And this is what successful establishment looks like! In early November, this year-two Alamo switchgrass averaged 7.5 feet tall.

Harvest

The suggested harvest window for switchgrass is after the first killing frost or Nov. 1 through mid-February. During the first part of the harvest window, the typical forage haying process of mowing then letting the material "cure" or dry-down to a desirable moisture content conducive to baling is achieved. The curing time frame is the time from when the material is mowed until it is baled (or chopped). The preferred moisture content for baled material is 18 percent or less. While the suggested harvest window begins Nov. 1; an October harvest may be appropriate for fields with drainage issues or poorly drained soils. This option has proven to hold potential due to the amount of daylight and heat units still available to adequately cure the material in a windrow. In addition, October historically holds the rank as being the driest month throughout the year for most states in the southeastern U.S.



Managing Moisture

Why is moisture management important when baling switchgrass? Material that is baled at a higher moisture content will experience mold growth during storage, creating inhibitors to the conversion process. Also, material baled at higher moistures has the potential to self-ignite after experiencing heat respiration (burning of plant sugars to produce energy.) Most all baled material will experience this "heating" effect; however, material harvested at a higher moisture (above 25 percent) creates an ideal environment for warm temperature bacteria, potentially resulting in combustion of the bale.

Later in the harvest window, once the standing material has experienced several freeze-thaw cycles, the material can reach a standing moisture content of less than 18 percent, eliminating the need for curing and permitting a single-pass harvest system where the material is mowed and then directly baled.

Mowing

A disc mower conditioner is recommended for use in cutting switchgrass. Rotary or disc cutterbars are essential. Sicklebar cutting systems are not adequate to efficiently cut dense, largediameter switchgrass stems. The conditioner crimps or crushes the switchgrass stems and reduces the time needed for curing or drying prior to baling. An equally important function of the conditioner is to assist the large volume of material to move through the machine. The conditioning system is desired in order to operate most efficiently by clearing the cutter bar of material debris, further increasing throughput of the machine. However, the conditioning system also helps to speed curing through stem destruction when moisture is greater than 18



percent. A mower conditioner also allows windrow formation, thus eliminating the need for raking. Windrow formation is achieved by setting and adjusting the forming shields on the mower conditioner to the width of the pick-up of the baler.

Note: Removing the task of raking eliminates an infield operation resulting in a reduction in cost.

Stubble Height

The recommended cutting height of switchgrass is a minimum of 6 inches. A stubble height of 6-10 inches prevents damage to the crown and aids in maintaining stand density and longevity. The energy remaining in the stubble will help the plant recover following harvest. It also reduces the potential for tire damage by increasing the angle at which the tire hits the stem, thus allowing the tire to push over the stubble as opposed to "riding" on top of it. Another benefit of an increased stubble height is that after mowing, the windrow is held off the ground allowing for air flow underneath, which also will help facilitate the curing process and greatly reduce soil contact ensuring a cleaner product with a lower ash content.

Three methods exist to obtain the desired cutting height:

 Place stroke limiting collars on the lift cylinders of the mower conditioner. This process may be trial and error in order to achieve the desired stubble height. Note: Make sure collars are snapped on securely.





(Fig. 34a) Stroke limiting collars.

2. Modify skid shoes for mower conditioner. This method would require the time and skill necessary to modify (cut and weld) the existing skid shoes.



(Fig. 34b) Modified skid shoes.

3. Add adjustable skid shoes for the mower conditioner.





(Fig. 34c) Adjustable skid shoes.

Windrow Formation

Adjusting shields on rear of mower conditioner:

- 1. Eliminates the need for the raking operation.
- 2. Eliminates the need to "weave" over the windrow to produce a uniform bale when size is set to match baler pickup.



(Fig. 35a) Mower conditioner (windrow) forming shields.





(Fig. 35b) Mower conditioner in operation.



(Fig. 35c) Windrows formed by forming shields on mower conditioner.

Conditioner Options: Rollers vs. Flail-Impeller

Two types of conditioning systems are available for mower conditioners: roller and flail-impeller.

Roller conditioning consists of a set of two rollers that have an interlocking chevron design. Depending on the type, rollers can be rubber on rubber, steel on steel, or rubber on steel.



Note: The clearance between the conditioning rolls will determine the severity and thoroughness of the stem conditioning.



(Fig. 36a) Rubber rollers on mower conditioner

As seen in Fig. 36a, there is a clearance between the two conditioning rolls. You should be familiar with your particular machine as to the methods of adjustment of the clearance.

Flail Type: There is a shaft behind the cutter bar that has a set of swinging hammers (pieces of metal) attached to it. These hammers grab the material and force it against an adjustable shield in the back of the mower, which will break or bend the stems in a number of locations. The advantage of the flailimpeller machine is that it will have a higher throughput in very high-yielding crops.





(Fig. 36b) Hammers on flail type mower conditioner.

As you can see in Fig. 36b, the V-shaped hammers are hanging when the machine is not in operation. However, when the machine is in operation, centrifugal force will swing the hammers out allowing them to pick up the material off of the cutter bar as mentioned earlier. The shield is adjustable, allowing the user to achieve the amount and severity of conditioning desired.

As with any operation, the user should put the mower in gear and mow a patch, shut the mower off, get off the tractor, and pull samples from the windrow and judge how well the chosen conditioning system is working. This is critically important earlier in the harvest season when moisture in the stems is higher.

Note: The more severe the conditioning, the faster the "cure" or dry-down time, and the quicker producers can get in the field to bale.



Package Type

Round Bales

Round bales may be wrapped with either twine or net wrap. However, net wrap has shown to possess certain advantages over twine for round bales.



(Fig. 37) Net-wrapped round bale of switchgrass.

Net wrap significantly improves field efficiency during the baling operation when compared to twine-wrapped bales. The wrapping operation itself takes about a third of the time that a twine tying operation would take to complete the same task. There are also storage advantages of new wrap over twine: net wrap will shed water better than twine-wrapped bales, resulting in reduced spoilage on the outer rind of the bale. A minimum two wraps per bale is sufficient, and an even number of wraps is recommended because half wraps are not advantageous.



As for the twine-wrapped bales (Note: Nylon, not sisal twine), these bales need to be triple wrapped in order to keep and hold their integrity during the multiple handlings the bales will experience from the field to the end user.

Square Bales

Large, square bales provide several logistical advantages. First, they are easier to stack on a truck. Second, more bales can be added per load resulting in the ability to more closely achieve truckload axle weights.

However, there are also significant on-farm disadvantages to large square bales.

Square bales can only be secured with twine, and they must be protected from rain as they are unable to shed water. The best management practices for square bales are for them to be moved, stacked and protected from the rain as soon as the bales are made in the field. Given the requirement for immediate stacking, moisture management at baling is critical to prevent heating, mold growth and potential fire.



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(Fig. 38a) Placing square bales under a tarp.



(Fig. 38b) Square bales under covered structure.

Square bales are more sensitive to rough handling. Moving large square bales requires a different set of handling equipment than that required for round bale handling.

Regardless of bale type, the density of the bale is important. The greater the pounds per cubic foot, the greater the ability to more closely attain axle weights — the maximum efficiency for truckload transportation — resulting in lower transport cost.

Other Potential Harvest Methods

Another option for the harvest package type is an in-field chopping system. This operation utilizes either a self-propelled or pull-type forage harvester and the accompanying pieces of equipment used in harvesting silage as a feed crop. It achieves a significant amount of size reduction in the field, which moves some of the preprocessing to the farm. This method allows the producer to deliver near spec, or in some cases, spec material to the end user, creating a potentially higher value product by reducing the end user's material processing.

A downside of the in-field chopping is that it significantly lowers bulk density in transport (The bulk density of baled switchgrass is 12-13 pounds per cubic foot, whereas chopped material is about 5 pounds per cubic foot.). Also, chopping requires potential greater capital outlay and labor costs for harvesting due to the number of people and equipment simultaneously in the field. Someone must be there collecting material that is coming off of the chopper; whereas in a baling set-up one person can accomplish all given right conditions.





(Fig. 39a) Pull-type chopper and tip wagon (switchgrass harvest).



(Fig. 39b) Self-propelled forage harvester (switchgrass harvest).

Another option in the baling format is to achieve material size reduction in baled form. This method involves balers that have a chopper or some kind of sizing mechanism, usually a set of stationary knives incorporated behind the pickup. These knives are located in the baler and will generally size the material before it enters the bale chamber. The size of the material here is typically greater in length and variability than one would find from a forage harvester. But in a package, these bales have a greater density than from a standard baler. The advantages for pre-chopped bales are greater bale densities and increased efficiency of downstream size reduction equipment (breaking down 6- to 10-inch material instead of 8- to 10-foot stems).



(Fig. 40) Example of material from a "pre-chopped" round bale.



(Fig. 41) Field of baled switchgrass.

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Bale Handling: Staging and Storage

Once the baling operation has concluded, if that is the preferred method of harvest, there is still more work to do. A producer may have as many as 15 bales to the acre depending on yield and bale size. Producers say it takes more time energy and effort to move bales off of the field than for them to mow and bale combined. A significant amount of time, consideration and planning should take place regarding the handling, staging and storage of bales before the harvest begins.

Moving the bales to staging areas near an all-weather road will, many times, take longer than the baling process. Also, if large square bales are produced, all the square bales stacked at the staging area should be covered prior to rain. Square bales will readily absorb rainfall and tarps will add to the time involved as well as production and labor costs.

Round bales will better shield rainfall and switchgrass may be stored for short periods without being covered. Placing a cover over stacked bales is important for long-term storage.

Postharvest Considerations: Logistics

Bale transport to pick-up location is not an insignificant operation. The methods and equipment vary depending on the specific farm situation while taking capital and labor tradeoffs into consideration.



It is important to remember that cellulosic biofuels require:

- Adequate, sustainable feedstock supply.
- Consistent feedstock quality.
- Economical supply chain expenses.

Considerations for supplying desirable, consistent material to the end-user:

- Feedstock composition and quality is driven by genetics and production systems.
- However, feedstock composition and quality can be significantly impacted by proper logistics, storage and handling of material.
- Careful management of supply chains can address many feedstock quality concerns.

Steps for quality control throughout the supply chain (harvest, storage, delivery):

- Maintain material quality throughout harvesting, handling and storage by using Best Management Practices.
- Material moisture control is critical and will be managed with quality control sampling at the field, in storage and at delivery.

Staging materials:

- Staging after harvest is critical for moisture management.
- Bales (squares especially) must be collected, staged and covered soon after harvest.
- Staging is utilized when bales will be moved from the farm site to a central storage location.
- Highest efficiency systems will collect and directly deposit bales into appropriate storage location.



Storage:

- Proper storage is critical for quality management.
 - Moisture management.
 - Large footprint required.
 - Dry matter loss does occur.
- Dry matter loss can be significant (greater than 6 percent per year).
- Research underway in bale storage to evaluate storage losses and best practices.
- Storage types include:
 - Structures (barns, huts, etc.).
 - Tarps (polyethylene-coated nylon).
- Storage site must be properly prepared.
 - Site graded to allow moisture drainage.
 - Stone or other hard surface bed for stacking.
 - Access by semis (tractor-trailer trucks).

Successful switchgrass transport systems:

- Maximize bulk handling. Current systems are labor intensive; more automation reduces costs.
- Increase bulk density. The most significant hurdle to overcome is low bulk density material out of field. Improve to reduce costs.
- Achieve maximum legal axle weight per truck in a safe manner. This achievement is critical to cost reduction.
- Maximize efficiencies in bale transport.
 - Maximize individual bale densities.
 - Reduce transport densities.
- Involve significant labor when moving bales.
 - Staging.
 - Loading.
 - Unloading.
- Put safety first.
 - Secure loads appropriately.
 - Back road safety.

Sustainability

The market for energy crops has been enabled, in part, by policies and incentives that encourage practices believed to improve the environment. As such, cropping systems that further these goals, such as no-till, will likely garner greater support from policymakers and the general public, and in many cases, provide other rewards.

Environmental Benefits

An exhaustive treatment of the sustainability topic is beyond the scope of this management guide, but highlighting a few of the ways that switchgrass meets or exceeds this standard may be useful background for cropping decisions.

Net Energy

Detailed studies have shown that switchgrass can be cultivated in a manner that yields 540 percent more energy than is used in cultivation and harvest. Indeed, new seed varieties and traits are expected to increase net energy and sustainability through higher yields and lower inputs. Likewise, cropping practices that minimize the use of diesel and fossil fuel-derived fertilizers could increase net energy.

Carbon Sequestration

Switchgrass plants grow as much underground as they do aboveground. Their deep root systems have been estimated to sequester as much as 5 tons of carbon dioxide-eqivalents per acre per year. Certain cropping systems may be able to increase these benefits. Furthermore, a U.S. government study found that perennial grasses like switchgrass can sequester more CO2 from the atmosphere than is released in the life cycle of producing and burning the fuel derived from them, making "carbon negative" transportation a real possibility. Carbon sequestration may become an attractive source of income should government policy more sharply restrict carbon emissions and carbon trading markets mature. Furthermore, increasing soil carbon improves the quality and productivity of the soil, making all agricultural activities on the land more sustainable.

Marginal Land

Perhaps the most important characteristic of switchgrass is its ability to thrive on acres that do not produce economically viable yields for other crops. A Sandia National Labs study concluded that there are 48 million acres or more of idle or low-yielding cropland in the U.S. that could be used for energy crops.

Wildlife Habitat

Switchgrass provides habitat for up to five times more bird species than other crops. Limiting the movement of equipment during nesting season is recommended for landowners interested in increasing bird populations. High stubble may also be useful for conservation and other purposes.

Ecosytem Services

Switchgrass has shown as much as one-eighth the nitrogen runoff of corn and one hundredth of the soil erosion. It is often used as a buffer along waterways and for erosion control, among other so-called ecosystem services.



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Integrated Biomass Supply Systems





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