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Switchgrass as a Biofuel for Michigan

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Switchgrass in establishment year.

Biofuels are carbon-based energy sources taken ultimately from solar energy captured through photosynthesis and stored in plant tissue. It is renewable because the plants grow back after harvest, and it can be regenerative when sustainable methods are employed to manage, harvest and process the crops. Ethanol, used in gasoline (spark-plug) engines, is produced through the fermentation of plant sugars and distillation of the mash to produce fuel alcohol. Ethanol can be produced from crops such as corn and sugarcane, which are high in the sugars needed for fermentation, or from cellulosic materials, such as wood byproducts and high-fiber grasses. The Bioenergy Feedstock Development Program (BFDP) screened more than 30 herbaceous crops species, and a decision was made to focus on the high-yielding perennial grass species switchgrass (*Panicum virgatum* L.), which combines excellent conservation attributes and good compatibility with conventional farming practices.

Switchgrass in the form of pellets can also be directly combusted or co-fired with coal, resulting in lower emissions associated with the burning of that fuel. For switchgrass to become practical as a directly combusted fuel in coal plants, retrofitting current boilers from coal or co-fired applications is required. Switchgrass can be used as a fuel source to power ethanol plants, which results in reduced use of fossil fuels and contributes to a more positive energy balance for cellulosic ethanol. Although recent news has been full of exciting reports about ethanol and switchgrass, producers need to be aware that a market for switchgrass as an energy crop is now — in 2007 — scarce to nonexistent. There is intense speculation about how, when and whether these potential markets will materialize. In the meantime, corn ethanol is becoming more popular in the marketplace. In fact, 14 percent of the 2005 U.S. corn crop was used to produce ethanol, and the percentage is expected to grow. Cellulosic ethanol production is still in a research and development phase. As further research into cellulosic ethanol production and processing is completed, perhaps switchgrass can become a cost-effective, viable alternative energy source.

Description, Range and Adaptation

Switchgrass is a native warm-season perennial grass indigenous to Central and North American tall-grass prairies. It is found in Canada, and ecotypes have been identified in regions from the Atlantic coast to the eastern side of the Rocky Mountains. Switchgrass is historically found in association with several other important native tall-grass prairie plants such as big bluestem, Indiangrass, little bluestem, sideoats grama, eastern gamagrass and various forbs (sunflowers, gayfeather, prairie clover, prairie coneflower). These widely adapted species once occupied millions of acres. Now they are rarely seen, usually on land that cannot be utilized for annual cropping. Look for native plants like these in protected areas along fence lines, in riparian buffers, and especially in old cemeteries and churchyards across the prairie states.

Switchgrass grows well in fine- to coarse-textured soils and in regions with annual precipitation of 15 to 30 inches or more per year. It is an immense biomass producer and can reach heights of 10 feet or more in wetter areas of the country. In general, ecotypical differences are related to local soil and climatic characteristics, with eastern and southern varieties adapted to higher moisture conditions, and western and northern varieties adapted to drier conditions.

Switchgrass Ecotypes and Cultivars

As switchgrass evolved across North America, various ecotypes emerged with genetic and morphological characteristics that provide a good fit to a particular place. Thus ecotypes in the South typify Southern characteristics, such as long-season growth and subsequent high dry matter yield, given favorable growing conditions. Two major types have emerged through natural selection. The upland types favor drier soils and fare better in semi-arid climates. The lowland varieties grow better in heavier soils and are found where water availability is more reliable. The lowland cultivars have the genetic capability to produce more dry matter than the upland cultivars.

Plant breeders at various agricultural research stations in Texas, Oklahoma and Nebraska have collected seeds from local switchgrass colonies and released them to form relatively uniform strains adapted to particular locales. These strains, often with some bit of uniformity achieved through artificial selection, are then registered as cultivars. This simple selection program has created the many switchgrass cultivars available today.

Switchgrass cultivars should therefore be chosen on the basis of ecotype (whether an upland or lowland variety) and the latitude of origin. Check with your local Michigan State University Extension office for varieties adapted to your area. Our limited research in Michigan has found Carthage and Cave-in-Rock to be the highest yielding cultivars in a two-year test in East Lansing with total two-year dry matter yields of 18 and 17 tons/acre, respectively. Because switchgrass seed varies greatly in purity and germination, it is often sold on the basis of its "pure live seed" (PLS) percentage. Seed lots with equal amounts of PLS may differ in their volume of bulk seed. Consider this when calibrating seeding equipment. Seed from newly harvested switchgrass can have a high percent dormancy. Acceptable germination levels are often achieved after one year of storage.

Switchgrass Cultivars

Trailblazer	**Upland**
Blackwell	**Upland**
Cave-in-Rock	**Upland**
Pathfinder	**Upland**
Carthage	**Upland**
Alamo	**Lowland**
Kanlow	**Lowland**
Summer	**Lowland**

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Switchgrass in third year of production at East Lansing, Mich.

Establishment, Management and Harvest

Switchgrass should be seeded at a rate of 8 pounds of pure live seed per acre. Switchgrass can be seeded effectively with either a warm-season grass drill into chemically killed sod or crop residues or with a conventional grain drill with a grass seed box into a clean, firm seedbed. Though conservation techniques work well, more important factors in establishment success are planting date, cultivar used, seeding depth and weed control. For conventional field preparation, there are six important characteristics of an ideal seedbed: soil firmness below the seedbed, well pulverized soil on the surface, the absence of clods and puddles, the absence of live resident weed competition, the absence of seeds from competitive species and a moderate amount of mulch/residue on the surface.

Planting switchgrass into cool soils can be problematic. Cool-season weeds germinate first and can choke out switchgrass seedlings when the soil warms. If cool-season weeds are a concern, consider no-till planting the switchgrass into a warmed soil with non-dormant seed. Switchgrass seedlings can compete better in warmer soils with warm-season weeds. A producer should expect slow switchgrass establishment even with non-dormant seed and good planting management similar to that of other native perennial grasses. Switchgrass should be seeded between May and mid-June. If the seedbed is prepared too early, the cool-season grasses and weeds will be strong and competitive by the time the warm-season grasses emerge. If warm-season grasses are planted too late and the weather is hot and dry, the seedlings may not establish quickly. Seeding near these dates allows seedlings to take advantage of the usually moist spring/early summer growing conditions, establish early and thus take advantage of the longer growing season and better growing conditions. Switchgrass seed is smooth and will flow through a conventional drill. The broadly accepted optimal seeding depth for switchgrass is between ¼ and ½ inch. Planting seeds excessively deep will likely result in stand failures.

Fertility

Switchgrass, like any other North American tall-grass prairie species, evolved among ecological factors including grazing, fire, nitrogen-fixing legumes and other forbs, and soil microorganisms including bacteria and fungi. Many scientists now believe that soil microbes play a major role in nutrient uptake. For example, microfungi (mycorrhizae) are thought to play an important role in phosphorus uptake. These microbes are a natural constituent in native grassland soils.

Fertility management is essential to establishing successful stands of switchgrass. Proper soil testing and amendment are necessary to allow addition of corrective quantities of potassium and phosphorus, and careful timing is required for addition of any needed nitrogen. A minimum pH of 6.0 should be maintained for hay and pasture production, though these grasses will tolerate a pH as low as 4.5. Because switchgrass seedlings are not as vigorous as cool-season grass or weed seedlings, addition of nitrogen at planting or near planting time can be advantageous to the cool-season grasses and weeds and detrimental to the warm-season grass stand. Therefore, addition of nitrogen fertilizer is not recommended until the stand is established. Fertilizing in late spring, after the weeds have completed their spring growth and when the warm-season grasses are initiating their vigorous summer growth, will increase warm-season grass yield and maintain desirable composition. The amount of nitrogen fertilizer applied should just meet crop needs so there will be no carryover to the following spring. This will help avoid future weed competition.

If the protein composition at harvest is 2 percent and yield is 6 tons per acre, approximately 38 pounds of nitrogen are harvested per acre. This nitrogen must somehow be replaced or recycled to maintain productivity. Nitrogen can be added into the switchgrass agroecosystem by either:

- Maintaining a legume component of at least 30 percent in the stand.
- Adding 2 to 3 tons of manure per acre broadcast after harvest.
- Incorporating manure in the fall prior to planting.
- Using synthetic fertilizers judiciously.

Incorporating legumes into a switchgrass stand can be problematic if the crop is intended to be ethanol feedstock but not if the biomass is to be dried and used in direct combustion. If synthetics are used, the producer should remember that low rates will provide excellent biomass yields. Our studies have shown that yearly applications of no more than 50 pounds per acre should be appropriate. One can expect a yield increase of 2 to 3 tons per acre with this amount of nitrogen applied. Applying more nitrogen will result in severe lodging and lower dry matter yields.

Seed Sources

There are several sources for switchgrass seed in Michigan. Switchgrass becomes fully productive the third year after planting, but one can expect about 75 percent of potential yield in the second year of production.

Seed Dormancy

Warm-season grasses have varying degrees of seed dormancy. Switchgrass naturally drops its seed during the fall and winter. In northern regions, overwintering naturally cold stratifies the seed, thereby reducing existing dormancy. Cold stratification can also be done by allowing the seeds to imbibe water and then chilling them at 4 degrees C for 2 to 4 weeks. However, stratification may be avoided by aging the seeds for a year. Seed that is more than 1 or 2 years old could have reduced viability.

Because seed dormancy is common in switchgrass, seeding rates are standardized using a convention referred to as pure live seed (PLS). Switchgrass seed sold by seed companies should be sold by percent PLS in addition to the percent purity, germination and hard (dormant) seed. When determining the pounds of bulk seed needed per acre, the purity and germination percentages must first be changed to respective decimals (e.g., 95 percent purity would be 0.95). The PLS calculation is made by multiplying the purity decimal by the germination decimal, excluding dormant seed that may germinate later but would not generally germinate within 2 to 4 weeks. The desired number of pounds of pure live seed (PLS) is then divided by the product of the purity X germination calculation. For example, if the target planting rate of switchgrass seed is 9 pounds PLS/acre and the tag indicated that seed purity = 90 percent, germination = 75 percent and hard seed (will not germinate) = 15 percent, the following calculation would be made: 0.90 X 0.75 = 0.675 = PLS decimal. Target rate ÷ PLS decimal = 9.0 ÷ 0.675 = 13.3 bulk pounds.

Therefore, 13.3 bulk pounds of switchgrass seed per acre would be needed to obtain the target rate of 9 pounds PLS per acre. Variables affecting optimal rates include method of seeding, precipitation patterns, temperature patterns, seed predation and anticipated weed competition.

Weed Control

Managing weed competition is essential to successful establishment. This is accomplished by timely application of fertilizers, mechanical or chemical control of weeds before and after planting, correct seeding depth and rate, and appropriate seeding date. Annual grasses such as barnyardgrass, crabgrass, fall panicum, green foxtail and yellow foxtail are frequently the species that are most competitive with warm-season grasses in the establishment phase. Though few herbicides are labeled for use with warm-season grasses, particularly in livestock operations, some herbicides are helpful in managing weed competition. The Michigan Department of Natural Resources Warm Season Grass Planting Guide (2001) recommends preplant weed control by flail mowing or early to mid-May application of glyphosate (Roundup) and/or imazapic (Plateau) for control of annual or perennial weeds.

Daniel Hudson

Switchgrass no-till establishment using a Truax drill.

Plateau should *not* be used for weed control in establishing switchgrass stands. The planting guide also suggests spraying 2,4-D in summer or late fall for control of broadleaf weeds. To prevent seedling damage, 2,4-D should be applied to establishing stands of warm-season grasses only when the seedlings are at or beyond the five-leaf stage.

Plateau (imazapic, BASF) herbicide is effective as a pre- or postemergent herbicide and is labeled for use with big bluestem, but it damages or kills switchgrass seedlings. Pursuit (imazethapyr, BASF) herbicide is labeled for pre- and postemergent application for both switchgrass and big bluestem in CRP and Agricultural Reserve Program.

Sprayed crops should not be grazed or harvested for forage. Depending on which herbicides are labeled for use with warm-season grasses at a given time, the only option for weed control may be clipping. The key to successful switchgrass establishment is paying close attention to seedbed preparation, weed control, seeding depth, seeding date, seed dormancy, planting rate, soil type and soil pH. Germination and emergence of warm-season grasses tend to be slower than that of cool-season grasses. It can be powerfully tempting to assume that a seeding failed when all that is needed is patience. The producer should not expect to harvest the crop during the establishment year, but if established and managed properly, the crop should be ready to harvest the following fall as in the photo below of switchgrass in the second year of production.

Richard Leep

Switchgrass in second year of production after being established in grain sorghum nurse crop.

Companion Crops

Some farmers use companion or nurse crops in establishing perennial crops such as alfalfa and grass pastures and hayfields. An ideal nurse crop will grow more quickly than the crop it accompanies and will provide plant cover for the soil. Nurse crops must be removed early enough to allow the protected crop to grow unhindered. Nurse crops are often used on slopes to prevent water erosion and on level ground to prevent wind erosion and seedling desiccation. A nurse crop that has been used successfully in establishing switchgrass is sorghum-Sudangrass or grain sorghum.

Richard Leep

Switchgrass establishment in a grain sorghum nurse crop.

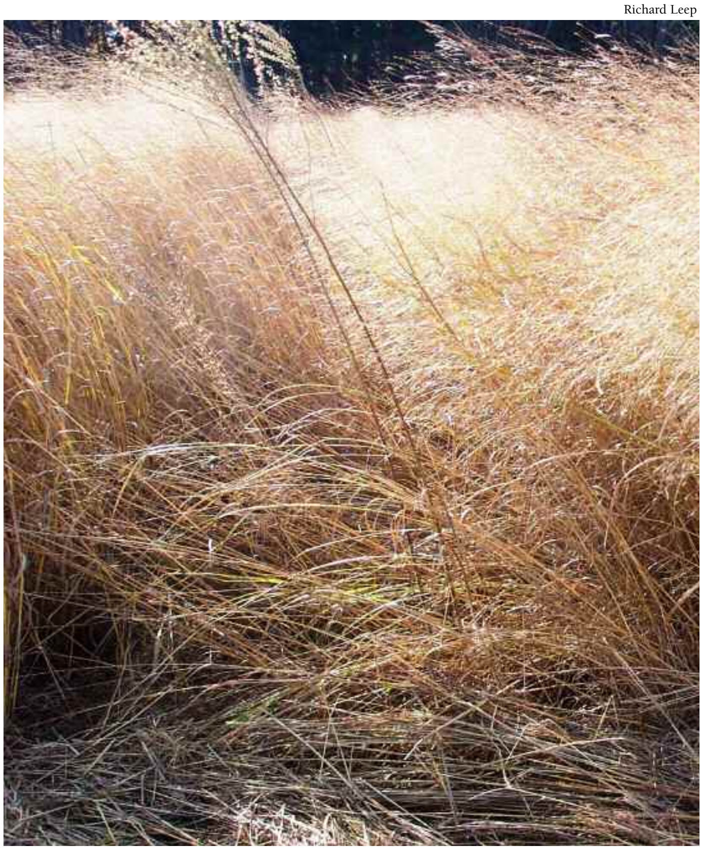
Sorghum-Sudangrass is a warm-season annual grass that is used for grazing, hay or silage. It is fast-growing in warm regions, broadleaved and of excellent forage quality when harvested at the right time — just around panicle emergence. In addition, researchers in Iowa using atrazine herbicide when planting switchgrass with corn found corn to be an excellent nurse crop when it was removed either as silage or as grain. This would allow better use of land for establishment because a crop would be harvested during the establishment year without hurting the switchgrass establishment.

Harvesting

Switchgrass for biomass should be harvested once per year, after the top growth has completely died, using conventional haying equipment in the late fall or early winter. Under good management, a producer can expect a yield up to 10 tons per acre. Michigan State University yields in East Lansing ranged from 7 to 10 tons per acre.

Studies in other states have found that a single harvest of switchgrass in late fall or early winter results in the highest sustainable biomass yields and good stand persistence from year to year. Moisture should be 15 percent or less to facilitate quick baling and transport. Many research programs have successfully utilized large rectangular bales (3 by 4 by 8 feet), finding them easier to transport than small squares or round bales. Be sure to leave about a 6-inch stubble after harvest. Forage research has shown that leaving stubble helps to trap snow that protects the root crowns from winterkill.

Richard Leep



Switchgrass ready to be harvested in East Lansing, Mich., in late October.

Feedstock Quality

Producers who are experienced at growing grasses for livestock forage will find that producing switchgrass as an ethanol feedstock necessitates a management regime unlike that utilized to produce quality forages. High-quality ethanol feedstock is low in nitrogen content and high in cellulose. Cellulose is broken down by either an acid or enzymes into fermentable sugars prior to fermentation. Nitrogen reduces the conversion efficiency of fuels into energy and can become an air pollutant after combustion. Therefore, zero or low nitrogen fertilizer applications and a single yearly harvest after the plants have died back fully in the winter produce the best feedstock as well as the highest amount of aboveground biomass for ethanol production.

Cost Variables in Switchgrass Production

A short list of items to consider in calculating the cost of producing switchgrass:

- Land—rent, land payments, taxes, opportunity cost.
- Establishment—fuel, seeds, tillage and planting equipment, weed control, fertility, labor.
- Crop maintenance—weed control, equipment repair, fertility, labor, etc.
- Harvest—equipment, fuel, baling materials, labor.
- Transport—fuel, equipment, custom hauling, storage loss, labor.

Other Cellulosic Feedstocks

Switchgrass is not the only or possibly even the best biomass species for cellulosic ethanol production, but it does possess some ecological characteristics that make it a very good candidate. Among its positive qualities, switchgrass offers:

- Pest and disease resistance.
- High yields of cellulose.
- Low fertility needs.
- Cultivars that are locally adapted and relatively available.
- Excellent wildlife habitat.
- Carbon sequestration in its extensive and very deep root system.

- Tolerance of poor soils and wide variations of soil pH.
- Drought and flood tolerance (depending on the ecotype and variety).
- Efficient water use in grassland ecosystems.

But many other perennial warm-season grasses may possess these same characteristics and more. What makes switchgrass particularly suitable as an ethanol feedstock? In research trials beginning in the mid-1980s, the Department of Energy began to seek plant species that would yield high-quality and high-quantity biofuel feedstocks. Among the plants considered were reed canarygrass and switchgrass, as well as other grasses and legumes. In the trials, switchgrass had the highest yields, and breeding work subsequently focused on switchgrass to the exclusion of the others.

In summary, switchgrass is very likely the best candidate for producing biofuel in Michigan because of its inherent high yield potential and adaptation to the region. We have discussed production practices necessary to achieve high yields of switchgrass using known technology. If these practices are followed, one could expect to achieve yields up to 10 tons of dry matter per acre. With additional research on genetics and release of improved switchgrass cultivars specifically adapted for Michigan and with proper management, one could expect to see a 50 percent increase in dry matter yields, which would make it even more attractive as a biofuel crop.

Sources of Seed

The following list of seed companies is included to help the reader who may not be able to find sources of some varieties of seed — it is not intended as a recommendation of these companies, or as an inclusive/exclusive listing.

CSI/GEOTURF INC.
1225 76th Street
Byron Center, MI 49315
Phone: 888-208-5772

J. MOLLEMA & SONS
4660 E. Paris, S.E.
Grand Rapids, MI 49512
Phone: 800-234-4769

MICHIGAN STATE SEED SOLUTIONS
717 N. Clinton
Grand Ledge, MI 48837
Phone: 800-647-8873, 517-627-2164

RHINO SEED AND LANDSCAPE SUPPLY
850 Old US-23
Brighton, MI 48114
Phone: 810-632-5640

SOUTHERN MICHIGAN SEED
48580 County Road 352
Decatur, MI 49045
Phone: 269-423-7051

STANDISH MILLING COMPANY INC.
1331 West Cedar Street
Standish, MI 48658
Phone: 989-846-6911

SWEENEY SEED COMPANY
110 South Washington Street
Mount Pleasant, MI 48858
Phone: 800-344-2482

TRI TURF
3751 Blair Townhall Road
Traverse City, MI 49684
Phone: 800-636-7039

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