Switchgrass for Forage and Bioenergy

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This note combines an eXtension article titled "Switchgrass for biofuel production" available at http://www.extension.org/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production with a UNL NebGuide titled "Switchgrasss, big bluestem, and indiangrass for grazing and hay" available at http://www.ianrpubs.unl.edu/pages/publicationD.jsp?publicationId=1132.
Always read and follow herbicide label directions.

Switchgrass is a native warm-season grass that has been used for hay, forage, and conservation purposes for decades and switchgrass research in Nebraska has been ongoing since 1936. Recently, switchgrass has been identified as a model perennial grass for bioenergy in the Great Plains and Midwest. Since 1990, research in Nebraska on marginally productive cropland has demonstrated that best management practices (BMPs) will maintain productive, profitable, and sustainable switchgrass stands for more than 15 years on marginally productive cropland in the eastern half of Nebraska.

Switchgrass has distinct lowland and upland ecotypes. Upland ecotypes occur in upland areas that are not subject to flooding and are represented by most of the forage-type cultivars such as 'Trailblazer' and 'Shawnee.' Lowland ecotypes are found on flood plains and other wetter areas and typically have a later heading date, are taller with larger and thicker stems, and are best-suited for bioenergy production. The only lowland switchgrass cultivar adapted to this region is 'Liberty' switchgrass, released in 2013 as the first biomass-specific cultivar for the Great Plains and Midwest.

Switchgrass produces 70% to 80% of its annual yield after June 1 in Nebraska, and can provide quality forage for grazing after cool-season pastures have been utilized. Warm-season grasses must be properly managed to maintain productive stands and quality forage. Poor management will cause productivity and stand persistence to decline, and forage quality will be poor. Proper grazing management and cultural practices will optimize production, maintain a healthy stand, and provide adequate forage quality.

Adaptation and Yield

Switchgrass is adapted to most soils throughout the eastern half of Nebraska. Switchgrass can be grown in mixtures, but is grazed more efficiently in monocultures than in mixtures. Switchgrass yield depends on factors like precipitation, fertility, soil, location, and genetics. Most switchgrass research has been conducted on forage-type cultivars, which, in the Great Plains and Midwest, are entirely represented by upland ecotypes with lower yield than lowland ecotypes. Yields for forage-type cultivars like 'Shawnee' and 'Trailblazer' are low relative to bioenergy-specific cultivars. In a three-year trial in eastern Nebraska, the bioenergy-specific cultivar 'Liberty' had dryland yields of 8.1 tons acre^{-1} year^{-1}, which was 2.4 tons acre^{-1} year^{-1} greater than 'Shawnee.' For more specific information on areas of adaptation and available cultivars, consult Extension Circular *EC120, Certified Perennial Grass Varieties Recommended for Nebraska.*

Managing for Forage

Grazing: Proper grazing management is crucial to maintain dense switchgrass stands. Switchgrass pastures can be stocked continuously or rotationally. Continuous stocking may result in poor utilization, with some plants overgrazed while other plants are under used. Rotational stocking generally is a better grazing method for more fully utilizing switchgrass. Average daily gains of yearling steers typically range from 1.4 to 2.2 pounds per day when switchgrass pastures are stocked continuously with the proper number of animals grazing during the summer. Well-managed grazing research on class 1 and 2 land near Mead in eastern Nebraska produced as much gain as 2.2 pounds per head per day and 500 pounds per acre from 'Trailblazer' switchgrass. Average daily gains with rotational stocking may be slightly lower than with continuous stocking unless grazing is well managed. Rotationally-stocked pastures usually provide 10% to 60% more animal days of grazing than continuous-use pastures, depending on the number of pastures available for rotation and the effectiveness of grazing management.

Switchgrass must be grazed before seedheads emerge. Before seedheads emerge, forage quality is high and palatability good. After seedheads emerge, nutrient levels become low and switchgrass becomes less acceptable as pasture. Animals are reluctant to eat mature switchgrass and may refuse it entirely if other feed is available. Begin grazing switchgrass when it becomes ready to graze, regardless of how much grazing potential remains on cool-season pastures. Switchgrass matures earlier than most warm-season grasses, so grazing often needs to begin while cool-season grasses still provide good forage. It is better to graze switchgrass when it is ready and then graze the remaining cool-season grass later in the summer, than to finish grazing the cool-season grass first and let the switchgrass become stemmy. If switchgrass becomes stemmy before grazing begins, cut it for hay and graze the regrowth about 45 days later.

Several options are available for managing switchgrass for forage. One option is to begin grazing when switchgrass is 8-10 inches tall (late May to early June). Stock the pasture so livestock will consume switchgrass at the same rate that it grows. Livestock will graze off the tops of switchgrass plants rather uniformly if coarse stems have not started to form. Keep plant height between 8 and 16 inches for six weeks, and then remove livestock for 30 to 45 days. Any regrowth then can be grazed to a stubble height no shorter than 8 inches. Usually it is better to stock switchgrass too heavily and move animals to other pastures sooner than planned than to stock lightly and have abundant seed-head development.

Switchgrass is not good as the only summer forage source. It is better to use switchgrass during just two of the three summer months. Either graze switchgrass uniformly in June and July or graze completely in June and graze regrowth in August. Avoid stemmy, mature growth. Do not over-utilize switchgrass late in the summer, and do not graze short between September 1 and the first killing frost. Leave at least 6 to 8 inches of growth when plants go dormant for the winter. Severe defoliation in late summer will result in poor regrowth, reduced plant vigor, and potential stand thinning and weed encroachment the following spring.

Top growth of dormant switchgrass can be grazed with little effect on survival, plant vigor, and subsequent-year growth. Allow 4 to 6 inches of stubble to remain until spring to help catch snow, insulate plant roots, and provide wildlife cover. Forage quality will be very low, so feed appropriate supplements, since nutrient content of winter pasture usually is below animal requirements for crude protein, energy, phosphorus, and vitamin A.

Haying: Harvest switchgrass hay based on the stage of plant growth and intended use of the hay. Proper hay management balances hay quality and quantity with livestock nutrient requirements, while maintaining vigorous stands. Switchgrass hay is very palatable if it is harvested before or just as the first seedheads appear. But as plants become more mature and stemmy, switchgrass hay can become unacceptable unless it is ground. Regrowth is influenced by initial harvest date and weather conditions. Harvest prior to the boot stage for best regrowth (*Figure 1*). Very little regrowth will occur following a harvest after heading. Cut switchgrass pastures for hay if forage production exceeds livestock consumption to avoid overly mature forage.

Fertilization: Fertilizing often is profitable on haylands, since extra growth is harvested easily. Fertilize pastures, especially with nitrogen, only when livestock numbers exceed the growth potential of unfertilized pastures and when grazing can be managed properly. Otherwise, growth might become stemmy, less palatable, and lower quality. Animal performance will be poorer than expected and much of the extra growth stimulated by the nitrogen will be wasted. With sufficient moisture, switchgrass produces higher yields when fertilized with nitrogen and/or phosphorus (soil tests are needed to determine rate). Fertilizing is economical only when extra growth can be harvested efficiently. Typically, good growing conditions will produce about 20 to 30 pounds of additional switchgrass, or 1 pound of additional animal gain for every 1 pound of nitrogen applied. Consequently, if a pound of nitrogen is cheaper than a pound of animal gain, it is generally profitable to fertilize warm-season grass pastures.

Apply nitrogen in May after warm-season grasses have 6 to 8 inches of growth. Do not apply nitrogen in early spring; it will stimulate growth of cool-season grasses and weeds rather than the warm-season grasses. Also, only apply as much nitrogen as the warm-season grasses will use during one growing season, typically no more than 120 pounds of nitrogen per acre. Nitrogen carryover into fall promotes growth of weeds and cool-season grasses, and may also contaminate water sources.

Managing for Bioenergy

Although switchgrass survives on low fertility soils, it does respond to fertilizer, especially N. The amount of N required by switchgrass is a function of the yield potential of the site and cultivar. Yield and stands will decline over years if inadequate N is applied, since harvesting removes large quantities of N. For example, harvesting 5 tons acre^{-1} of switchgrass DM after frost with a crude protein concentration of 4% (0.64% N) will remove 64 pounds of N acre^{-1}. Not all removed N has to be replaced with fertilizer N because of atmospheric deposition and soil mineralization, but this will vary with location and soil. In general, for post-frost harvests, about 50 to 65 lbs of N acre^{-1} yr^{-1} should be applied to meet expected yield goals. In Nebraska and Iowa, 'Cave-In-Rock' switchgrass yields increased as N rate increased from 0 to 270 pounds of N acre^{-1}, but residual soil N increased if more than 100 pounds of N acre^{-1} was applied. Soil testing should be conducted periodically to monitor soil N levels. Apply N in May to minimize cool-season weed competition.

Controlling broadleaf weeds with herbicides typically is needed only once every three or four years in established, well-managed stands. For broadleaf weeds, the most effective and economical approach is with 2,4-D applied when weeds are less than 3 inches tall early in the growing season to reduce the impact of weed interference on switchgrass yield. In some cases, cool-season grasses may invade switchgrass stands and reduce yield. Harvesting after senescence

in autumn but while cool-season grasses are growing, then applying glyphosate, is an effective method to reduce cool-season grasses and winter annuals. Make certain switchgrass is dormant when glyphosate is applied or stands could be damaged.

Maximizing biomass recovery, matching feedstock quality to the conversion platform, and maintaining productive stands are the primary harvesting objectives. Productive stands are maintained indefinitely with proper harvest timing, cutting height, and adequate N fertility. In the first 9 years of a long-term study, switchgrass biomass was greatest in plots fertilized with 100 pounds of N $acre^{-1}$ and harvested at a 4" stubble height after frost. A single harvest after frost to a 4" stubble height has maintained stand productivity and persistence, even during drought, and is the harvest BMP for the Great Plains and Midwest.

Switchgrass can be harvested and baled with commercially-available haying equipment. Self-propelled harvesters equipped with a rotary head (disc mowers) are best for harvesting high-yielding ($\geq$6-ton per acre) switchgrass fields. Round bales tend to have less storage losses than large square bales (>800 lbs) when stored outside, but square bales tend to be easier to handle and load a truck for transport without road width restrictions. After harvest, poor switchgrass storage conditions can result in storage losses of 25% or greater in a single year. In addition to storage losses in weight, biomass quality may degrade to the point of being in unacceptable condition for a biorefinery. Switchgrass grown for biomass may have to be stored for a full year or longer, since biorefineries will operate 365 days a year. Some type of covered storage is needed to protect the biomass.

Production Cost

An economic study based on the five-year average of 10 farms in Nebraska, South Dakota, and North Dakota using 2010 production costs indicated farmers can grow switchgrass at a farm-gate cost of $60/ton. However, farmers with experience growing switchgrass had five-year average costs of $43/ton, and one farmer grew switchgrass for $38/ton. These costs include all expenses plus land costs and labor at $10/hour. Each big round bale represents 50 gallons of ethanol assuming 80 gallons per ton of switchgrass, with a farm-gate cost of $0.75/gallon at $60/ton. This research from 50 production environments indicates that growing switchgrass for cellulosic ethanol is economically feasible in the central and northern Great Plains. Fuel and land prices have increased since this study; adjusting for 2014 prices indicates switchgrass can be delivered to the farm gate for $70/ton including land and labor costs.

When Will Switchgrass for Bioenergy Become a Reality?

Switchgrass for bioenergy has several challenges. A stable and consistent feedstock supply must be provided year-round to the ethanol or power plant. For the producer, switchgrass must be profitable, it must fit into existing farming operations, it must be easy to store and deliver to the plant, and extension efforts must be provided to inform farmers on the BMPs. However, switchgrass has potential for improvement, and presents unique opportunities on the agricultural landscape. There are numerous environmental benefits to switchgrass that can improve agricultural land use practices such as stabilizing soils and reducing soil erosion, improved water quality, increased and improved wildlife habitat, and storing C to mitigate greenhouse gas emissions. All of these benefits can be achieved, provided that switchgrass cropping systems are fully developed and accepted by farmers. Switchgrass and other perennial grasses may be used in conjunction with corn stover and wheat straw to meet feedstock demands.

Growing seed to meet potential bioenergy demand will not be an issue. Switchgrass has

many desirable seed characteristics and can produce viable seed during the seeding year, especially under irrigation. Established seed fields can grow 500 to 1,000 pounds of seed per acre with irrigation, and the seed is easily threshed, cleaned, and planted with commercial planting equipment. Seed production systems are well-established and a commercial industry for switchgrass seed has existed for more than 50 years.

Currently available plant materials and production practices can reliably produce 6-8 tons per acre in the central Great Plains and Midwest. New cultivars and management practices could significantly increase yields further. The availability of adequate acres of cropland and the relative profit potential will determine the feasibility of growing switchgrass. BMPs and plant materials are available to achieve sustainable and profitable biomass production, for both farmers and bio-refineries, to help meet the energy requirements of the nation and reduce our dependence on foreign oil. There are four commercial-scale cellulosic ethanol plants under construction in the Great Plains and Midwest that are scheduled to become operational in 2014 or 2015: one in Kansas and three in Iowa. They will use corn stover as the primary feedstock. These facilities represent a step forward in bioenergy and will be critical to commercializing switchgrass for bioenergy.

Potential Problems

Switchgrass contains diosgenin, a chemical that is toxic to horses and other non-ruminants. Consequently, do not feed switchgrass hay to horses, or graze switchgrass monocultures with horses. Current research is underway to determine if the concentrations of diosgenin decline with increased plant height, or if concentrations differ among cultivars.

There are potential difficulties with large-scale switchgrass monocultures for bioenergy. Concerns arise for potential disease and insect pests, and the escape of switchgrass as an invasive species. Most pathogen issues will not be fully realized until large areas are planted to switchgrass. However, the broad genetic diversity available to switchgrass breeders, the initial pathogen screening conducted during cultivar development, and the fact switchgrass has been a native component of central U.S. grasslands for centuries will likely limit the negative pest issues. Switchgrass has been used for decades in the Great Plains and Midwest for pasture and conservation purposes, with no identified invasive problems.

Conclusions

Growing switchgrass for forage or bioenergy must be profitable for farmers, it must fit into existing farming operations, it must be easy to store and deliver to the ethanol plant, and extension efforts must be provided to inform farmers on BMPs – all of which have been addressed for switchgrass. Harvesting after frost for bioenergy is a time when most farmers have completed corn and soybean harvests, and handling switchgrass as a hay crop is not foreign to most producers. The economic opportunities of switchgrass for small, difficult-to-farm, or poorly-productive fields will be attractive to many farmers.

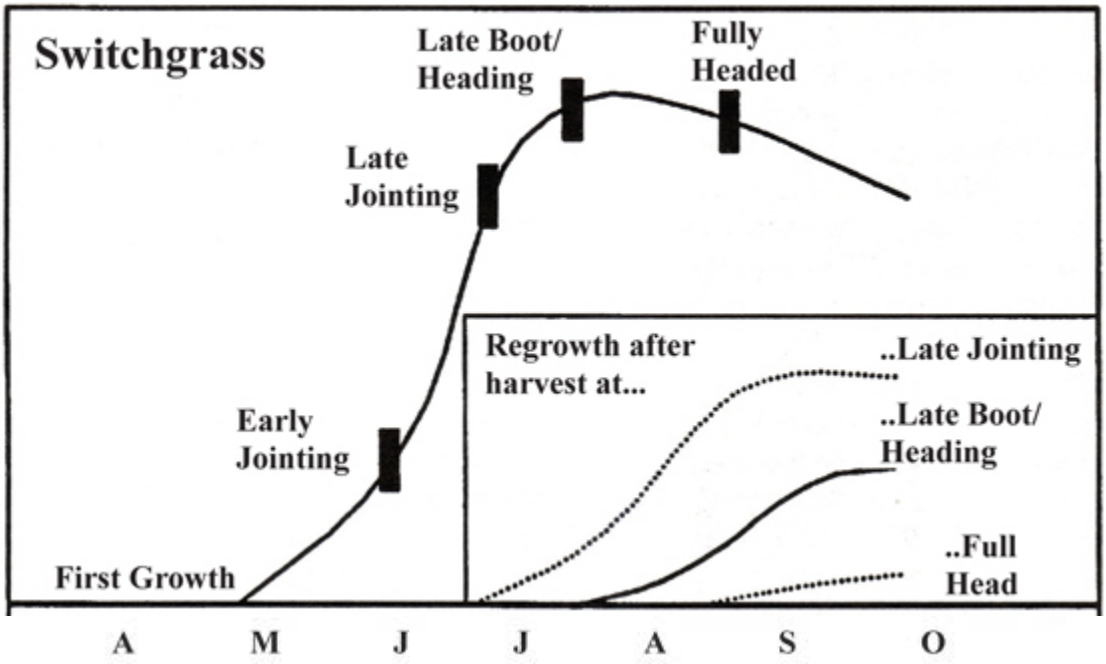

Figure 1. Forage accumulation of first growth and regrowth of switchgrass. If switchgrass is harvested for hay at anthesis (~August 1), a good management strategy is to graze the regrowth after dormancy.