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Establishing and managing perennial grasses for bioenergy

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Switchgrass (Panicum virgatum) is native to every U.S. state east of the Rocky Mountains, is the most advanced herbaceous perennial bioenergy feedstock, and best management practices (BMPs) have been developed for bioenergy production in most agro-ecoregions. Additionally, big bluestem (Andropogon gerardii), indiangrass (Sorghastrum nutans), and sideoats grama (Bouteloua curtipendula) are native perennial warm-season grasses and are promising bioenergy feedstocks, especially when planted in low-diversity mixtures. BMPs have been developed for big bluestem, indiangrass, and sideoats grama specifically for the Great Plains and Midwest. Perennial grasses likely will be grown on cropland that is marginally productive for row crops, similar to land enrolled in the Conservation Reserve Program (CRP).

Establishment

Native warm-season grasses like switchgrass, big bluestem, and indiangrass have a reputation for being difficult to establish. Historically, these grasses often required 2 or 3 years to establish an acceptable stand. However, advancements in herbicides, cultivar development, and planting equipment have improved establishment dramatically. Today, it is feasible to harvest 50% of the cultivar's yield potential after frost in the seeding year. By the end of the first full growing season after seeding, it is feasible to produce and harvest 75% to 100% of the cultivar's yield potential (Mitchell et al., 2012), with many fields in the central Great Plains approaching full production (Mitchell et al., 2010). If precipitation is adequate, warm-season grasses are readily established when quality seed of adapted cultivars are used in conjunction with the proper planting date, seeding rate, seeding method, and weed control.

In the central Great Plains and Midwest, plant warm-season grasses 2 or 3 weeks before to 2 or 3 weeks after the recommended planting dates for corn, typically from mid-April to early June. Warm-season grasses should be seeded at 30 pure live seed (PLS) per ft$^2$. Excellent results are obtained by planting after a soybean crop using a properly-calibrated no-till drill with depth bands that plant seeds 1/4” to 1/2” deep in 6 to 10-inch rows (Mitchell et al., 2012). Big bluestem and indiangrass seeds are fluffy and require a seed box equipped with an active seed flow mechanism. If warm-season grasses are planted after crops that leave heavy residue such as corn, it may be necessary to remove the residue prior to planting. If the field is tilled, the seedbed needs to be packed to firm the soil as would be done for alfalfa.

The cultural practices are similar for establishing all native warm-season grasses. However, grasses have different herbicide tolerances, so weed control needs to be specifically tailored to the species being planted. Weed competition is the major reason warm-season grasses are slow to establish. For big bluestem, indiangrass, and sideoats grama, applying 4 ounces of imazapic (Plateau) per acre plus glyphosate immediately after planting and prior to warm-season grass seedling emergence provides good grassy and broadleaf weed control. For switchgrass, applying 8 ounces of quinclorac (Paramount) plus 1 quart of atrazine per acre immediately after planting provided the best weed control and most rapid establishment for upland and lowland switchgrass ecotypes in Nebraska, South Dakota, and North Dakota, USA (Mitchell et al., 2010). Indiangrass seedlings do not tolerate atrazine and switchgrass seedlings do not tolerate Plateau, so use care when applying herbicides to mixtures containing both indiangrass and switchgrass. For mixtures of switchgrass, big bluestem, indiangrass, and sideoats grama, apply 8 ounces of quinclorac (Paramount) followed by applications of 2,4-D as needed for broadleaf weed control. During the establishment year, a cost-effective method to control broadleaf weeds is to apply 2,4-D at 1 qt/acre after grass seedlings have four leaves. Weed control is inexpensive and will account for only 5-10% of total establishment costs. After the establishment year, a successfully established warm-season grass stand requires limited herbicide applications. Although some herbicides labelled for corn work well for managing weeds in perennial warm-season grasses, not all herbicides are labelled for application in all states. Always read and follow label instructions.
Managing Established Stands

Biomass yield in a given location is dictated by management decisions such as cultivar selected, fertilization, and harvest timing. Most yields data is for warm-season grass cultivars released for grazing or conservation in the 1980’s or 1990’s. However, ‘Liberty’, a high-yielding bioenergy switchgrass cultivar was released by USDA-ARS and the University of Nebraska in 2013 for the Great Plains and Midwest. Liberty has a 3-year average yield of 8.1 tons/acre, 2.4 tons/acre greater than Shawnee, a switchgrass cultivar developed for grazing. In field-scale trials planted in 2012 in eastern Nebraska, Liberty produced 3.4 tons/acre in the seeding year during one of the most severe droughts on record. By the end of 2013, the first full production year, Liberty yield exceeded 8 tons/acre. Additionally, mature stands of Liberty will be harvested after frost and will produce more than 500 pounds of seed/acre, which will provide an important food source for wildlife. Liberty seed should be commercially available by 2015.

Fertility

Biomass production fields will require fertilization. Site productivity, expected biomass yield, and time of harvest dictate switchgrass fertilizer needs (Vogel et al., 2002). Although warm-season grasses growing in native grasslands and CRP tolerate low fertility soils, fertilization is required to optimize biomass, maintain stands, and replace nutrients in bioenergy production fields where large quantities of biomass are removed annually. The primary limiting nutrient for warm-season grass biomass is N. Biomass increases as N rate increases, but excessive fertilizer can result in N leaching or runoff and cause groundwater and surface water contamination (Vogel et al., 2002), so N rate must be carefully managed.

Soil tests are recommended before planting. Since switchgrass, big bluestem, and indiangrass are deep rooted, soil samples should be taken from each 1-foot increment to a depth of 5 feet. Nitrogen is not recommended during the planting year since N encourages weeds, increases competition for establishing seedlings, and increases establishment costs (Mitchell et al., 2008) and residual N is present in land cropped with soybeans. Harvesting biomass removes N from the system which must be replaced to meet plant growth demands. Harvesting at anthesis removes more N from the system than harvesting after frost, which is when we recommend harvesting biomass. For example, harvesting 5 tons/acre of switchgrass DM after frost with a crude protein concentration of 4% (0.64% N) will remove 64 pounds of N/acre. 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/year should be applied to meet expected yield goals (Vogel et al., 2002; Mitchell et al., 2012). In Nebraska and Iowa, ‘Cave-In-Rock’ switchgrass yields increased as N rate increased from 0 to 270 pounds of N/acre, but residual soil N increased if more than 100 pounds of N/acre was applied (Vogel et al., 2002). Soil testing should be conducted periodically to monitor soil N levels. Adequate levels of phosphorus (P) and potassium (K) will be available in most agricultural fields. If warranted by soil tests, P and K can be applied before seeding to encourage root growth and promote rapid establishment. If soils test medium, low, or very low for P, apply 10, 20, or 40 pounds of P per acre, respectively. Quantifying the response of bioenergy-specific cultivars to N, P, and K is a major research need.

Harvest and storage

Maximizing biomass recovery, matching feedstock quality to the conversion platform, and maintaining productive stands are the primary harvesting objectives (Mitchell et al., 2012). Productive stands can be maintained indefinitely with proper harvest timing, cutting height, and adequate N fertility (Mitchell et al., 2012). For example, in the first 9 years of a long-term study managed for biomass production, Follett et al. (2012) reported switchgrass biomass was greatest in plots fertilized with 100 pounds of N/acre and harvested at a 4-inch stubble height after frost. The combination of these management practices ensures carbohydrate translocation to the plant crowns for setting new tiller buds and maintaining stand productivity and persistence, even during drought (Mitchell et al., 2012). Additionally, harvest timing is a major cultural practice affecting feedstock composition. Harvesting after frost provides biomass with higher structural carbohydrates and lignin as well as lower protein and ash compared to earlier-harvested biomass.

Switchgrass bioenergy BMPs and extension guidelines have been developed for most agro-ecoregions (Mitchell et al., 2012), but most BMPs for other native warm-season grasses have been developed primarily for grazing, haying, and conservation (Mitchell and Anderson, 2008; Moser and Vogel, 1994). In the Great Plains and Midwest, a single annual harvest to a 4” stubble height optimizes biomass and energy inputs and maintains stands (Vogel et al., 2002). A cutting height of 4” maintains stands and keeps the windrows elevated to facilitate air movement and more rapid drying before baling (Vogel et al., 2011).
The goal for the storage process is to maintain biomass and quality, which requires the biomass to enter storage at low moisture levels (generally less than 18% is preferable) and to be protected from moisture during storage (Mitchell and Schmer, 2012). Research is limited on DM losses during switchgrass storage, but in general bales stored inside can be stored indefinitely with minimal DM losses (0 to 2%), regardless of bale type. However, when bales are stored outside, large round bales generally have less storage losses than large rectangular bales. Tarped and untarped large rectangular bales had DM losses of 7% and up to 25%, respectively, after 6 months of storage in Nebraska (Mitchell et al., 2012). Large rectangular bales can spoil from the top and bottom and lose DM rapidly. Wrapping big round bales with at least three wraps of net-wrap maintains the structure of the bale and reduces bale contact with the ground and tarping reduces DM loss to less than 3% in 6 months. Improper storage not only results in DM losses, but can change the compositional characteristics of the biomass. For a detailed review on harvest and storage management, see Mitchell and Schmer (2012).

**Conclusions**

Rapid establishment of perennial warm-season grasses is repeatable in the Great Plains and Midwest. Growing perennial grasses on marginally productive cropland for biomass production will minimize land use competition with annual row crops, reduce erosion, and provide perennial grassland habitat for wildlife. Research demonstrates that switchgrass for bioenergy is productive, profitable for the farmer, and protective of the environment.

Fact sheets and videos on seeding, managing, and harvesting switchgrass and other warm-season grasses can be found on the CenUSA website at www.cenusa.iastate.edu.

**References**


