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Improving Switchgrass Yields for Bioenergy Production

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What Is Switchgrass?

Switchgrass (Fig. 1) is a warm-season prairie grass that is native to North America and grew in the Great Plains for centuries. It is a perennial grass, meaning that, once planted, it will regrow each year and can maintain this ability for at least 15 years. It is a nutrient- and water-efficient grass that produces a massive root system up to 10 feet deep with plant heights of 3.5 to greater than 6.5 feet tall.

Switchgrass has numerous benefits. It has been identified for its use in riparian buffer strips to prevent excess nutrients from entering natural water systems, for its ability to remove harmful substances from the soil and to provide wildlife habitat. The perennial nature of switchgrass reduces erosion rates as much as 95 percent relative to annual tilled row crops like corn and soybean. It is used in many areas, including Tennessee, as a forage crop, due to its capacity to grow during the summer when temperatures are high and moisture is limited. Switchgrass generally produces up to 90 percent of total yields during this period (between June and August).



Fig. 1. Switchgrass production at Tennessee State University Research and Education Center.

Planting, managing and harvesting switchgrass uses conventional farming equipment. Seed drills with attachments (boxes) for small seeds are recommended for planting and disc mower conditioners are recommended for harvesting switchgrass.

Switchgrass and Bioenergy

Bioenergy involves the use of plant biomass (plant material) to produce energy. Biomass currently makes up 3 percent of U.S. energy production and is the second largest renewable energy source after hydropower. Bioenergy is playing an important role in meeting the renewable fuel standards that have been mandated by the U.S. government, requiring that total transportation fuel usage must be made up of at least 38 billion gallons of biofuels by 2022 (currently less than 2 billion gallons of biofuels are used). (Fig. 2) Switchgrass, as with many bioenergy crops, can be converted to ethanol for fuel use or it can be burned to create electricity in traditional

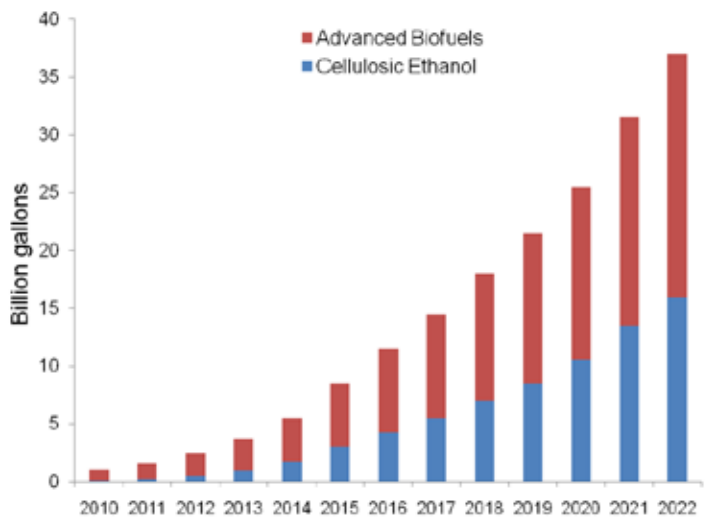


Fig. 2. Current U.S. renewable fuels standards for total transportation fuel usage.

coal-fired power plants. There is currently a pilot plant in operation in Vonore, TN for converting switchgrass to ethanol.

In 1991, switchgrass was selected as a model bioenergy crop by the Biofuels Feedstock Development Program, largely due to its consistently high productivity, large range of adaptability and low water and nutrient requirements. These lower requirements allow switchgrass to be grown on marginal lands, such as those in the Conservation Reserve Program (CRP) without taking away land that is currently being used to grow food or fiber products. Numerous scientific studies have been performed to identify certain factors that improve switchgrass yields, which can be as high as 15 tons/acre. These factors include cultivar type, fertilizer inputs, location, stand age and harvest frequency.

Cultivar Types

Switchgrass cultivars differ based on where they are naturally found. There are four main cultivar types: southern lowland, southern upland, northern lowland and northern upland. The southern varieties originated in more southern latitudes than the northern and generally produce biomass for a longer period of time. The northern varieties are generally more cold-tolerant. Lowland varieties are more adapted to floodplains with wetter soil conditions than the upland, which are more adapted to moderate moisture environments. Lowland varieties also grow more slowly, while upland varieties are shorter plants with thinner stems that accumulate all of their biomass earlier in the season. Lowland cultivars have also been shown to outperform upland cultivars in biomass yields in flooded conditions and perform the same as upland cultivars under drought conditions. Most research has identified lowland varieties to be the best cultivars to grow in areas like Tennessee due to their higher yields. One study in Tennessee identified numerically higher yields for lowland cultivars (called Alamo and Kanlow) in Jackson and Knoxville for a single-cut harvest system (Fig. 3).

Fertilizer Inputs

Perennial grasses like switchgrass are nutrient-efficient, because they recycle nutrients from standing plant material back to the roots before a killing frost occurs. Therefore, when the plant goes dormant during the winter, the nutrients are kept in

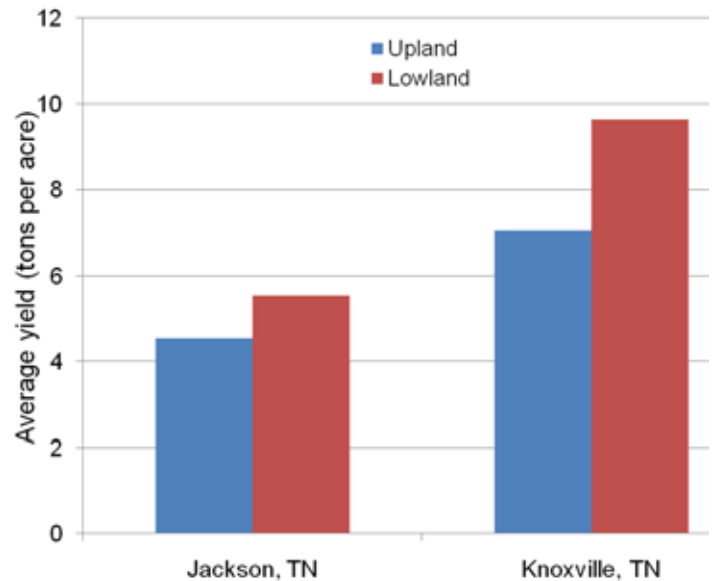


Fig. 3. Average yield of upland vs. lowland switchgrass cultivars in eastern and western Tennessee under a single-cut harvest system (adapted from Fike et al., 2006)

the root system until they are used to produce new shoot growth in the spring.

As with most plants, nitrogen (N) is the most important input for increasing biomass yields in switchgrass. Phosphorus (P) and potassium (K) applications generally result in little or no addition in plant matter accumulation. Though switchgrass is highly nutrient-efficient, higher yields have been achieved with greater levels of nitrogen (N) fertilizer. These levels are usually between 60 and 90 lbs/acre and are one-third to one-half the levels required by traditional row crops like corn. Upland switchgrass cultivars generally produce lower yields than lowland cultivars at the same N rate. In Tennessee, a switchgrass stand containing lowland cultivars (Alamo or Kanlow) that yielded 9 tons/acre/yr would require an estimated annual N fertilizer application of 55 lbs N/acre. Annual applications of 60 lbs N/acre are recommended for established switchgrass stands in Tennessee. Fertilizer recommendations for switchgrass grown for biofuels are available based on soil sample analyses at the UT Soil, Plant and Pest Center in Nashville, TN.

The optimum level of fertilizer application can depend on the type of soil. A lowland switchgrass, Alamo, grown on a well-drained soil in Tennessee reached maximum yields of 8 tons/acre at rates of 60 lbs N/acre, while the same switchgrass grown on a poorly drained floodplain in Tennessee required

180 lbs N/acre to achieve the greatest yields (4 tons/acre). This additional nitrogen requirement was due in part to the need for enhanced tillering from the nitrogen and to overcome potential losses due to less nitrogen under the wet conditions. It is important to identify optimal N application rates, because N applied at rates higher than required may cause detrimental effects to switchgrass through lodging, reduced root development and decreased yields due to stand thinning with possible weed development.

Location

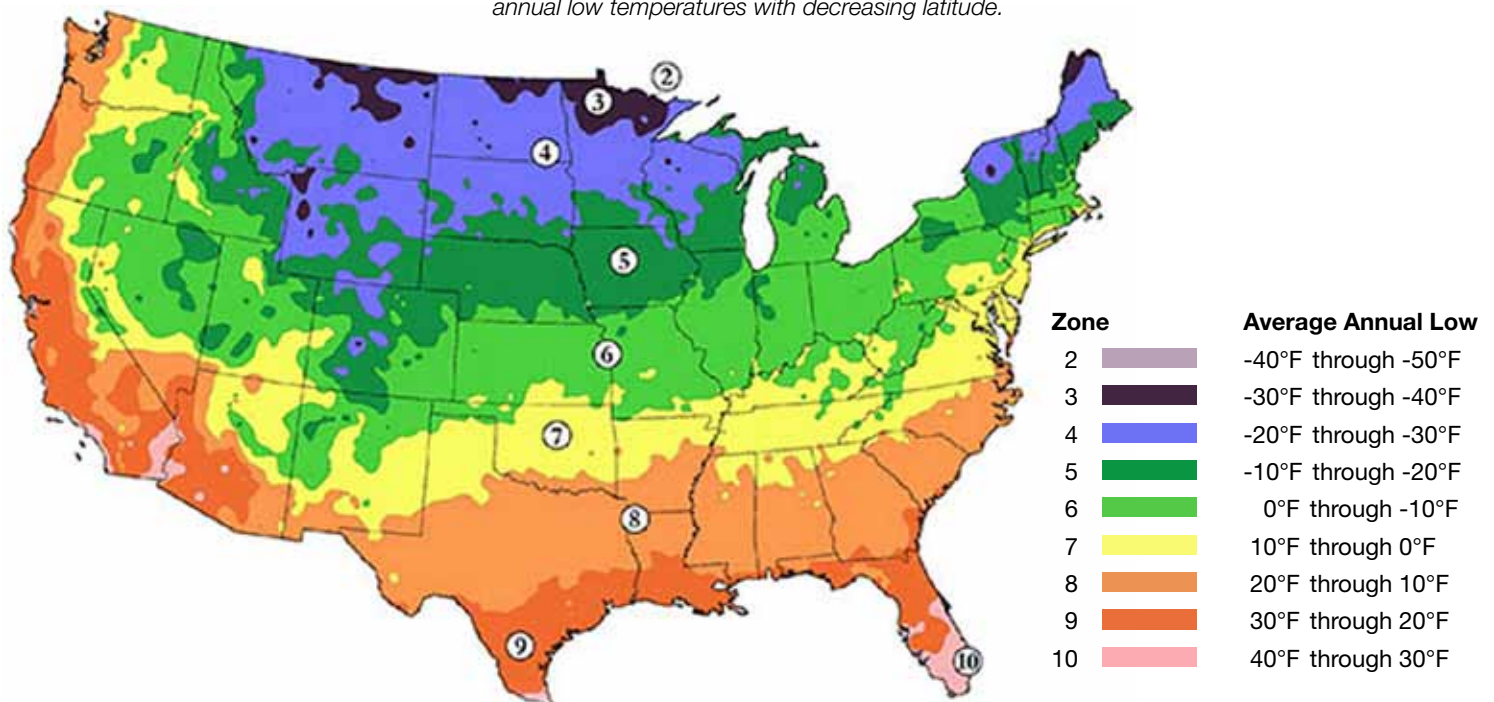
Switchgrass yields can differ depending on where the plants are located on either a large-scale or small-scale basis. On a large scale, changes in longitude do not make a difference in switchgrass yields, but variations in latitude affect temperatures and photoperiod (day length), which can influence switchgrass growth (Fig. 4). For lowland cultivars, like Alamo, yields may increase with higher latitude (movement northward) and photoperiod from 30 to 34 degrees latitude, and may decrease as latitude and photoperiod increase from 36 to 46 degrees latitude. Tennessee is located between 35 and 37 degrees latitude, and therefore should produce the highest yields for these lowland cultivars.

On the small scale, landscape differences within an agricultural field can also affect switchgrass yields. A study in Minnesota observed greater yields of switchgrass when grown on the summit of a hill or on west-facing slopes.

Stand Age

When switchgrass is first planted, it can take a couple of years to become established and reach its full yield potential. This is because switchgrass initially devotes more time to establishing its significant root system. Fertilizers are generally not applied during the first year of establishment because they will enhance weed development more than switchgrass growth. During the establishment period, yields are usually lower than maximum expected yields. In a recent study in Milan, TN, Alamo switchgrass planted on different soil types exhibited the same general trend, with greater yields observed during the second and third season after planting in a single-cut harvest system. During the first year, yields ranged from 0.7 to 1.3 tons/acre, but increased by the second season to between 3 and 5 tons/acre, and to 5-10 tons/acre by the third season (Fig. 5).

Fig. 4. **USDA Hardiness Zone Map** depicting the increase in average annual low temperatures with decreasing latitude.



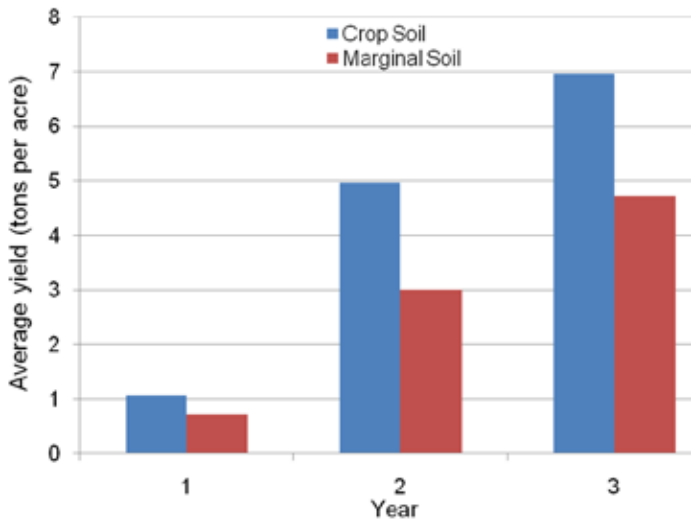


Fig. 5. Changes in Alamo switchgrass yield during establishment period on typical crop and marginal soils in Milan, TN under a single-cut harvest system (adapted from Mooney et al., 2009).

Harvest Frequency

Under most forage systems, multiple harvests are taken each season. When switchgrass is grown solely for bioenergy, however, yields are more important than nutritive contents. In general, multiple harvests of switchgrass can reduce future yields. For example, multiple annual harvests, even with applications of 60-120 lbs N/acre, have been found to reduce yields in the southern U.S. In Jackson, TN, a twice-cut annual harvest with N applications of 90 lbs N/acre was generally able to produce greater yields of the lowland switchgrass cultivars Alamo and Kanlow than under a one-cut system fertilized with 45 lbs N/acre. Under the same conditions in Knoxville, TN, however, the twice-cut harvest produced lower yields than the single-cut system. Possible reductions in yields observed in multiple harvest systems may be due to the loss of nutrients that are removed with the spring or summer harvests. This is because the nutrients within the aboveground plant tissue are not allowed



Fig. 6. December harvest of switchgrass at Tennessee State University Research and Education Center.

to relocate to the roots, which usually occurs in the later stages of maturity. If harvests are taken before this occurs, then the nutrients cannot be recycled. Lower yields may be observed in future years if adequate fertilization is not applied. It is also usually recommended that switchgrass be harvested after a killing frost or later (Fig. 6). This allows for the greatest biomass quality for bioenergy production and prevents yield reductions in the following years. Using a one-cut system can also enhance wildlife by providing important habitat for grassland birds during the breeding season.

Summary

In addition to erosion control and forage utilization, switchgrass could also be a vital bioenergy crop in Tennessee, due to its ability to produce high yields in this area of the U.S. and its ability to grow in marginal soils not devoted to row crops. Several factors, including cultivar and soil type, fertilizer inputs and harvest frequency, must be taken into consideration when trying to maximize switchgrass production in Tennessee.

Further Information

To learn more about switchgrass production for bioenergy, see the following resources:

Bates, G., and J. Walton. Adjusting and calibrating a drill for planting switchgrass for biofuels. UT Extension #SP701-C, <https://utextension.tennessee.edu/publications/Documents/SP701-C.pdf>

Garland, C.D. Growing and harvesting switchgrass for ethanol production in Tennessee. UT Extension #SP701-A, <https://utextension.tennessee.edu/publications/Documents/SP701-A.pdf>

Harper, C.A., and P.D. Keyser. Potential impacts on wildlife of switchgrass grown for biofuels. UT Extension #SP704-A, <https://utextension.tennessee.edu/publications/Documents/SP704-A.pdf>

Visit the TSU and UT Extension publication websites to find out more information on a number of important topics:

<http://www.tnstate.edu/agriculture/publications.aspx>

<https://utextension.tennessee.edu/publications/Pages/default.aspx>

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Fike, J.H., D.J. Parrish, D.D. Wolf, J.A. Balasko, J.T. Green, Jr., M. Rasnake and J.H. Reynolds. 2006. Switchgrass production for the upper southeastern USA: influence of cultivar and cutting frequency on biomass yields. *Biomass and Bioenergy* 30:207-213.

Mooney, D.F., R.K. Roberts, B.C. English, D.D. Tyler and J.A. Larson. 2009. Yield and breakeven price of 'Alamo' switchgrass for biofuels in Tennessee. *Agron. J.* 101:1234-1242.

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