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# Switchgrass for Biomass Production in Kentucky

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Switchgrass (*Panicum virgatum* L.) is a warm-season, perennial bunch-type grass native to the North American Tallgrass Prairie that has been investigated as a bioenergy crop due to its adaptation to a wide range of environmental conditions and soil types as well as its high stable yields. Switchgrass is recommended for soil conservation and wildlife habitat in both monoculture and in mixed stands of native warm-season grasses and forbs as well as for summer grazing in pasture systems and as a hay crop for cattle. Switchgrass is not recommended for use by horses due to the saponin presence within the plant, which may cause liver damage.

Due to the extensive root system and perennial growth habit of warm-season grasses, switchgrass provides positive environmental benefits, including low nutrient use, low pesticide requirements, erosion control, decreased water runoff (which reduces agricultural chemical loss), and increased soil organic matter. Switchgrass begins to green up in the spring when soil temperatures reach 55°F and matures in June and July, with the highest productivity in June, July, and August. Proper management of a biomass switchgrass stand is essential. A poorly managed stand will not produce optimum yields, and the longevity of the stand will be reduced. A well-managed stand can live for decades (e.g., the University of Tennessee is maintaining a stand more than 25 years old on a research farm near Knoxville).

During the establishment year, switchgrass is not expected to produce much aboveground biomass, due to plants primarily establishing the extensive root system. As a result, a successful first-year stand may often appear irregular and weedy compared to other crops. It is common for leaf and stem growth to reach no more than 2 feet in height by the end of the first growing season. By the second growing season, stands produce noticeably more aboveground biomass and should reach optimum yields by the third growing season.

## Types of Switchgrass

There are two main types of switchgrass, upland and lowland, with many varieties within each type. Choosing the correct switchgrass varieties for your farm is essential for maximum production and stand longevity.

### Keys to No-Till Switchgrass Establishment Success

**Prior to Seeding**

- Soil test site prior to establishment.
- If soil tests are below pH 5.5, P 30 lb/acre, K 200 lb/acre, apply at least 40 lb/acre $P_2O_5$ and 60 lb/acre of $K_2O$ and adjust soil pH appropriately.
- If existing plant material is 6 to 12 inches, mow with a rotary mower to a 3-inch height.
- If existing plant material is >12 inches, harvest material at a 3-inch height and remove from site.
- Apply herbicide treatment with glyphosate at 1.5 to 3 qt/acre* in the late summer or fall of the year before seeding when plants such as tall fescue have at least 6 inches of new growth.
- Apply a second application of the glyphosate four to six weeks prior to the spring seeding. Excess weed/grass growth should be harvested and removed from the site.

**Seeding**

- Choose a variety adapted to your area.
- Choose an appropriate variety for the intended land use.
- Seed 7-10 lb Pure Live Seed/acre from mid-May through mid-June.
- Plant at a depth of ¼ inch.
- Do not apply nitrogen during the establishment year.

**Post-Seeding**

- Control post-emergent weeds as needed with the appropriate herbicide labeled for switchgrass use after switchgrass is well established (at least a three-leaf growth stage).
- Harvest after a killing frost at a cutting height of 6 to 8 inches.
- Store in a clean, dry area (shed or under a secure tarp) before delivery.
- Beginning in year 2, apply 60 lb/acre of nitrogen each spring at initial switchgrass green-up.
- Apply at least 40 lb/acre $P_2O_5$ and 60 lb/acre of $K_2O$ if soil tests are below P 30 lb/acre, K 200 lb/acre

**Application rate will depend on specific glyphosate product used and the presence of other grasses or weeds to be controlled.*

## Phases of Switchgrass Establishment

**Figure 1.** Establishment of switchgrass using a no-till seeder into a killed sod.

**Figure 2.** Weed control is often necessary in the establishment year due to slow aboveground growth.

**Figure 3.** Second-year aboveground growth outcompetes most weeds.

**Figure 4.** Switchgrass can be harvested in large round or square bales.

### Upland Varieties

Upland varieties have finer stems and a higher percentage of leaf production, which results in a better forage compared to lowland varieties. These varieties originate in the colder areas of North America and perform better in semi-arid climates and drier soils. Upland varieties planted in Kentucky include Cave-in-Rock, Trailblazer, and Shelter, with most researchers agreeing that Cave-in-Rock and Cave-in-Rock-derived varieties are the most well-adapted and highest-yielding upland varieties in Kentucky.

### Lowland Varieties

Lowland varieties are tall, coarser stemmed plants with greater yield potential and higher disease resistance than upland varieties in the southern United States. They are native to areas that have higher rainfall and mild winter temperatures (i.e., those with a climate similar to Kentucky's).

They grow better in heavier soils and are found where water availability is reliable. Examples of lowland varieties planted in Kentucky include Alamo, Kanlow, EG1101, and EG1102, with Kanlow-derived varieties showing the most dependable winter survival in Kentucky.

### Varieties for Biomass

Research studying switchgrass for biomass has focused on lowland varieties due to their high yield potential of 4 to 9 tons per acre in the Southeast (Table 1). Lowland varieties are also better adapted to the soils and conditions of this region. Lowland varieties produce similar yields when managed as a one- and two-cut system; therefore, a one-cut harvest system is recommended for lowland varieties grown for biomass. However, upland varieties are desirable if producers are interested in utilizing the stand for forage and biomass. Table 1 provides biomass yields from selected varieties in both a one- and two-cut harvest system.

## Site Preparation and Establishment

Prior to seeding, a soil test should be taken of the intended site, and the soil pH and fertility adjusted for optimum growth based on the University of Kentucky recommendations (pH $\geq$ 5.5, P>30 lb/acre, and K>200 lb/acre). If soil tests indicate medium to high phosphorous (P) and potassium (K) levels, no additional fertilizer is needed at planting. Contact your county extension agent for agriculture and natural resources for assistance with soil testing.

**Table 1.** Switchgrass yields (tons/acre) of a one- and two-cut system (one cut: June and November; two-cut: November harvest) at Princeton, KY.

| | 1994 | | 1995 | | 1996 | | 1997 | | 1998 | | 1999 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | One-cut | Two-cut | One-cut | Two-cut | One-cut | Two-cut | One-cut | Two-cut | One-cut | Two-cut | One-cut | Two-cut |
| Alamo | 4.3 | 7.1 | 9.2 | 8.7 | 7.3 | 6.5 | 5.0 | 6.0 | 5.2 | 7.1 | 7.3 | 6.1 |
| Kanlow | 4.3 | 7.1 | 8.6 | 7.6 | 7.3 | 6.2 | 4.9 | 5.6 | 6.5 | 7.0 | 6.8 | 5.1 |
| Cave-in-Rock | 3.8 | 7.0 | 5.4 | 6.4 | 5.0 | 5.7 | 4.5 | 4.9 | 5.4 | 6.6 | 5.8 | 5.1 |
| Shelter | 3.4 | 4.9 | 5.4 | 5.8 | 4.1 | 4.5 | 3.6 | 3.7 | 5.3 | 5.8 | 5.4 | 4.1 |
| NC-1 | 3.4 | 4.1 | 8.7 | 6.8 | 6.5 | 5.5 | 5.0 | 5.8 | 6.0 | 6.8 | 6.0 | 6.1 |
| NC-2 | 3.5 | 5.2 | 8.3 | 7.2 | 7.2 | 5.7 | 5.2 | 5.2 | 7.2 | 6.8 | 6.6 | 6.2 |
| LSD | 0.6 | | 1.1 | | 0.7 | | 1.0 | | 0.9 | | 1.5 | |
| Average | 3.8 | 5.9 | 7.6 | 7.1 | 6.2 | 5.7 | 4.7 | 5.2 | 5.9 | 6.7 | 6.3 | 5.5 |

Note: The one-cut system received one application of 45 lb/acre nitrogen (late April), and the two-cut system received two applications of 45 lb/acre nitrogen (late April and after first harvest) (Fike et al. 2006).

Switchgrass has been successfully established in Kentucky using a variety of methods including conventional tillage and no-till drilling. No-till establishment is most common due to the lower cost, reduced erosion potential, and reduced weed pressure as a result of not disturbing additional weed seeds in the soil seed bank.

### No-till

When seeding into existing pasture and hay fields, multiple applications of a broad-spectrum herbicide may be needed. The most common recommendation is to apply an herbicide containing glyphosate (e.g. Roundup® or other glyphosate-containing product) at 1.5 to 3 qt/acre during the late summer or fall the year prior to seeding. Consult the label for specific application rates, which varies depending on the product formulation. Before applying the herbicide, the existing plant material needs to be mowed to stimulate regrowth, which will result in a more effective kill. If existing plant material is 6 to 12 inches in height, mow using a rotary mower to 3 inches. If >12 inches, harvest material at a 3-inch height and remove it from the site. The glyphosate herbicide treatment should be applied once the existing material regrows to a 6-inch height. A second application of glyphosate should be applied four to six weeks before seeding the following spring to control any remaining vegetation. An additional spring application may be needed in some fields prior to seeding. Control of existing vegetation is often not as effective when the initial glyphosate application is applied in the spring instead of the previous fall. No-till plantings are generally more successful than conventional tillage due to less weed pressure.

Crop stubble provides an ideal seedbed for no-till establishment of switchgrass as long as crop residues are minimal. In Kentucky, some of the most successful first-year stands have been seeded into soybean stubble. Although small grain stubble, like rye and wheat crops, can also be used, excessive drying of the soil can result and inhibit germination when the cover crop is grown to maturity. Ideally, small grains should only be used for winter cover and then killed at least one month before seeding.

### Conventional Tillage

When using conventional tillage methods, use equipment such as a moldboard plow, chisel plow, or a heavy disk that buries much of the surface residue, leaving mostly bare soil. For establishment in existing pastures and hay fields, a glyphosate-containing herbicide treatment should also be applied prior to seeding. Apply glyphosate at least seven to 14 days before plowing, disking, harrowing, and culti-packing the site. Application should be performed at least one month prior to planting. After weeds have germinated and emerged in the worked soil, apply a second application of the glyphosate three days prior to planting. The herbicide application prior to planting is especially important in fields with a known history of crabgrass or foxtail. In a prepared seedbed, it is very easy to plant switchgrass seed too deeply, exceeding the recommended 1/4 -inch depth. Culti-packing the soil to create a firm seedbed and carefully calibrating planting equipment is essential to prevent seeding too deeply.

## Seeding

### Date, Depth, and Rate

When establishing switchgrass for biomass, three of the most important factors are seeding date, depth, and rate. For optimum success in Kentucky, switchgrass stands should be planted in the spring once the soil temperature is consistently above 65°F. Switchgrass can successfully be seeded in mid-June, but earlier dates are recommended. The standard recommended seeding rate is 7 to 10 lb Pure Live Seed (PLS) per acre at a depth of a

1/4 inch, but in biomass stands, some prefer 5-7 lb PLS per acre, since larger stemmed plants result. Since switchgrass seeds are very small, they do not have enough stored energy reserves to dependably emerge when planted more than 1/2 inch deep. The most common reasons for poor establishment are drilling seed too deeply, inadequate weed control, and planting too late in the growing season. Some seed should be apparent on the soil surface when it is drilled at the correct depth. In Kentucky, most farmers have planted switchgrass biomass stands with a 6- to 12- inch row spacing. However, some research suggests wider spacing may result in higher yields.

### Stand Assessment

In order to properly manage a stand, it is necessary to evaluate the stand health shortly after establishment. According to the USDA National Resource Conservation Service recommendations, initial assessment should be conducted six to 10 weeks after planting. This assessment can be accomplished by counting the number of switchgrass plants in a 1 square foot area multiple times. Samples should be taken randomly throughout the stand to ensure accuracy. The average of the sampled areas is the average stand density. During the establishment year, average stand density should be at least three to six plants per square foot. By the end of the second growing season, a density of two plants per square foot is considered acceptable to produce a long-term productive stand. If density is less than the recommended values, you should consider reseeding or over-seeding the stand the following spring. If the stand meets the recommended values in some areas of the field but not others, reseed the poorly established sections of the stand.

However, care should be taken before reseeding to determine and address the reason(s) for poor establishment. According to the NRCS, switchgrass stands fail to establish for numerous reasons, including poor seedbed preparation, improper seed depth, insect damage, high seed dormancy, poor weed control, insufficient rain after planting, frost heaving, improper herbicide use, poor mowing, and wildlife damage.

**Herbicides at a Glance**

| Application Time | Targeted Weeds | Herbicide Recommendation |
|---|---|---|
| Before spring green-up | All weeds | glyphosate |
| After three-leaf stage | Broadleaf weeds | 2,4-D, 2,4-D plus dicamba |
| After three-leaf stage | Grassy weeds | Outrider® |

## Weed Control

### Mowing in the Establishment Year

There are a number of techniques that can be used for weed control in switchgrass stands, but the most common is simply periodic mowing. When weeds reach a height of 18 to 24 inches and before the development of flowers and seed heads, the entire stand should be mowed to a height no lower than 8 to 10 inches. This mowing opens the canopy and allows light to reach switchgrass seedlings while reducing weed competition. When mowing, use extreme caution to ensure that seedlings are not damaged, because close mowing can remove plant growth points and significantly stunt further growth. Mow as needed until September 1, after which the stand should be rested to allow the proper development of root nutrient reserves necessary for winter survival. Implementing a strategy that includes both herbicide use and mowing will significantly reduce weed pressure and improve chances of stand establishment and survival.

### Using Herbicides after Planting

Due to the modest aboveground growth during the establishment year, weed competition may be strong. Two year-old stands are also vulnerable to weed competition; therefore, understanding how to reduce weed pressure is necessary for proper stand establishment and management.

In general, weed control with herbicides is necessary during the establishment year and in the spring of the second growing season. At the end of the second growing season, the switchgrass stand canopy will close and reduce the amount of light that reaches weed seeds, effectively eliminating weed competition. The herbicide recommendations for the establishment year and the second growing season are the same. To control broadleaf weeds, apply an herbicide containing 2,4-D or 2,4-D plus dicamba. To control grassy weeds like johnsongrass, apply Outrider®; however, Outrider® cannot be sprayed on switchgrass intended for use by cattle. Post-emergent herbicides should not be applied before plants reach a three- to four-leaf stage.

Herbicide application timing is important, since switchgrass can be damaged if herbicides are applied at the wrong time. Herbicides containing glyphosate will kill switchgrass if sprayed after green-up, and broadleaf herbicides (e.g., 2,4-D, 2,4-D plus dicamba) and Outrider® can damage switchgrass seedlings if sprayed before plants reach a three- to four-leaf stage. Contact your county extension agent for agriculture and natural resources for information on herbicide registration for use on switchgrass in Kentucky. Always read and properly follow herbicide labels.

| Soil Fertilization at a Glance | | | |
|---|---|---|---|
| **Nutrient (Symbol)** | **Minimum levels** | **One-cut System** | **Multiple-cut System** |
| Nitrogen (N) | -- | 60lb/A at 6-8 inch height in spring | 60 lb/A at 6-8 inch growth in spring and after regrowth of 6-8 inches |
| Phosphorous (P) | 30 lb/A | 40 lb/A $P_2O_5$ minimum at 6-8 inch height in spring | 60 lb/A $P_2O_5$ minimum at 6-8 inch height in spring |
| Potassium (K) | 200 lb/A | 60 lb/A $K_2O$ at 6-8 inch height in spring | 120 lb/A $K_2O$ at 6-8 inch height in spring |

## Insect and Disease Control

Few insects are known to threaten switchgrass stands in Kentucky. Some research has found grasshoppers, stem-boring moths, nematodes, crickets, and corn flea beetles to cause some minimal damage. However, some publications suggest that insect problems may increase as switchgrass stands become more widespread.

Research has shown that switchgrass can be susceptible to rust, spot, barley yellow dwarf virus, and *Panicum* mosaic virus. If disease and/or insect damage are suspected, simply contact your county extension agent for agriculture and natural resources for appropriate control strategies. As previously mentioned, lowland switchgrass varieties are more disease-resistant compared to upland varieties.

## Fertilization

A proper switchgrass management program involves soil testing every three years to ensure that soil fertility requirements are met to obtain maximum biomass production.

### Nitrogen

Typically, no nitrogen (N) should be applied during the establishment year, which helps prevent weed species from smothering the emerging switchgrass. If stands are yellowing in mid-summer, 30 to 40 lb per acre of nitrogen can be applied.

Beginning the second growing season, 60 lb per acre of N should be applied each spring once plants are 6 to 8 inches tall. Even though switchgrass can survive in nutrient-poor soils, N can significantly improve biomass yields. In a multiple harvest system, additional fertilizer can be applied once post-harvest regrowth reaches 6 to 8 inches. Applying nitrogen too late in the season can prolong the dry-down process in the fall, which may lead to greater frost damage and possibly winter kill.

### pH, P, and K

Soil pH should be maintained at ≥ 5.5; adjust pH when necessary. Soil P and K levels should be maintained at K > 200 lb per acre and P > 30 lb per acre. If P and K are less than recommended levels, apply at least 40 lb per acre $P_2O_5$ and 60 lb per acre $K_2O$ in the spring once plants are 6 to 8 inches tall and continue to test the soil every year until levels are within the recommended range.

## Prescribed Burns

Conducting prescribed, controlled burns is a common management practice in perennial warm-season grass stands. Burning removes residual biomass, destroys cool-season weeds, improves nutrient availability, improves light penetration, and promotes faster and earlier growth. Reducing stand stubble helps improve the amount of light reaching the soil surface, which warms the soil faster, allowing the switchgrass to emerge earlier. Stands should be burned in the early spring before spring emergence, not in the fall. Stand stubble and residue provides insulation for plant roots during winter and winter cover for some wildlife. Proper safety precautions should be taken, including contacting, prior to burning, your local NRCS agent, county extension agent for agriculture and natural resources, and fire department. For more information about conducting a controlled burn, see the Kansas State University publication *Prescribed Burning: Planning and Conducting* (http://www.ksre.ksu.edu/library/crpsl2/L664.pdf).

## Harvest

### In the Fall

According to most research, the optimal harvest management for switchgrass managed for biomass production is a one-cut system harvested at least one month after the first killing frost. This system promotes stand persistence, removes fewer nutrients from the soil, and produces high, consistent yields. Harvesting after the material has dried allows the plant time to translocate nutrients back into the root system. In contrast, a two-cut system harvests the material in the midsummer, removing nutrients from the system, which then requires more agricultural inputs. Switchgrass grown for biomass should be harvested at a cutting height of 6 to 8 inches with conventional hay equipment. The higher cutting height improves stand survival and longevity, reduces the risk of winter kill, and reduces the risk of puncturing tires by allowing the sharp cut stems to lay down as tractor tires roll over them. Switchgrass should be baled at 13 to

15% moisture in large round or square bales and stored in a clean, dry area, such as inside a shed or under a secured tarp.

### In the Spring

Plant material can also be harvested the following spring to allow the material to further dry over winter. This system removes even less nutrients, which further improves stand persistence, lowers agricultural inputs, improves material quality for biomass combustion, and provides winter habitat for wildlife. Research has shown that switchgrass harvested in spring has lower mineral concentrations (e.g., potassium and chlorine) than switchgrass harvested in the fall (Table 2). Nitrogen, P, and K removal is also lower in a spring harvest, which will result in lower production costs for producers by reducing agricultural inputs (Table 2). Material with high mineral concentrations is undesirable for companies burning switchgrass to produce electricity, due to emission regulations and risk of damage to equipment. However, reduced yield due to leaf and seed head loss over winter, as high as 1/3 loss, has been reported as a drawback of spring harvest.

## Dual-use Switchgrass Stands

Since switchgrass can be used as both a forage and biomass crop, it is possible to manage a stand for both uses; however, the management plan will have to be altered to allow producers to take advantage of high-quality early switchgrass growth and the stimulation of regrowth by cutting.

Stand persistence should be considered before transferring to a dual-purpose management system. Multiple harvests lead to fewer recycled/stored nutrients and reduce stand persistence. However, good harvesting practices and a good nutrient management plan can reduce these negative consequences.

### Harvesting

The first hay harvest can be taken in June, cut at a stubble height of 8 to 10 inches. The regrowth can then be harvested for subsequent hay harvests or left for a biomass harvest. If a manager intends to graze the stand, the best time to begin grazing is in late May, when growth reaches approximately 18 inches. Cattle should not be allowed to graze switchgrass below an average stand height of 12 inches. Again, the regrowth can be harvested at the end of the year for biomass. Regrowth may be significantly reduced if stands are cut or grazed lower than recommended heights.

### Fertilization

When managing switchgrass as a dual-purpose crop, maintaining soil fertility is even more important. Harvesting switchgrass for hay removes more nutrients than a biomass crop. Therefore, additional fertilization will be required for a dual-purpose system. Stands should receive 60 lb per acre of N when initial growth reaches 8 to 10 inches and additional treatments of 60 lb per acre of N applied after each hay harvest (except the last one). Potassium and phosphorous levels should also be monitored more closely in this system. If managing for grazing, 30 to 40 lb per acre of N should be applied after each grazing (except the last one). Nitrogen should not be applied after the last hay harvest or grazing period, because this will prolong the dry-down process in the fall.

**Table 2.** Change in elemental concentration between fall and spring harvested switchgrass averaged over years (Adler et al. 2006).

| | Ash | N | P | K | Ca | Mg | S | Cl |
|---|---|---|---|---|---|---|---|---|
| **Harvest season** | g/kg | | | | | | | |
| Plot-scale, Rock Springs, PA | | | | | | | | |
| Fall | 34.15a* | 6.21a | 0.89a | 3.33a | 4.36a | 1.73a | 0.68a | 0.99a |
| Spring | 24.71b | 5.40b | 0.52b | 0.59b | 3.49b | 0.71b | 0.59b | 0.27b |
| Residual (%)** | 72.36 | 86.90 | 58.62 | 17.60 | 80.10 | 41.00 | 85.77 | 27.37 |
| Field-scale, Rock Springs, PA | | | | | | | | |
| Fall | 34.61a | 4.29a | 0.89a | 3.36a | 3.58a | 1.22a | 0.64a | 0.60a |
| Spring | 24.62b | 4.05a | 0.43b | 0.69b | 2.77b | 0.60b | 0.46b | 0.15b |
| Residual (%) | 65.35 | 94.36 | 47.93 | 20.66 | 77.35 | 49.35 | 71.90 | 25.44 |
| Field-scale conservation lands, Ligonier, PA | | | | | | | | |
| Fall | 33.85a | 3.28a | 0.80a | 3.45a | 5.05a | 0.98a | 0.50a | 0.73a |
| Spring | 23.95b | 2.92a | 0.40a | 0.60b | 3.75b | 0.33b | 0.48a | 0.45a |
| Residual (%) | 70.75 | 89.02 | 50.00 | 17.39 | 74.26 | 33.33 | 95.00 | 62.07 |

*Least square means within columns were separated by Tukey's HSD ($P \leq 0.05$).
**Percentage of fall element content remaining in spring.

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