

# Management Guide

## for Biomass Feedstock Production

### from Switchgrass in the Northern Great Plains



## Contents

<b>1. Introduction</b> .....	<b>4</b>
<b>2. Establishment</b> .....	<b>4</b>
2.1. Planting Methods .....	<b>4</b>
2.2. Seeding Rate .....	<b>5</b>
2.3. Seeding Depth .....	<b>5</b>
2.4. Time of Planting .....	<b>5</b>
<b>3. Cultivar Selection</b> .....	<b>6</b>
3.1. Pests and Diseases .....	<b>8</b>
3.2. Diseases .....	<b>8</b>
3.3. Insects .....	<b>8</b>
<b>4. Management</b> .....	<b>8</b>
4.1. Harvest Timing .....	<b>8</b>
4.2. Cutting Height .....	<b>8</b>
4.3. Fertilization and Soil Fertility .....	<b>8</b>
4.4. Weed Control Options .....	<b>9</b>
4.5. Persistence .....	<b>10</b>
<b>5. Other Benefits of Switchgrass</b> .....	<b>10</b>
5.1. Biodiversity .....	<b>10</b>
5.2. Carbon Sequestration .....	<b>10</b>
5.3. Revegetation and Soil Erosion Control .....	<b>10</b>
5.4. Farmer Friendly .....	<b>10</b>
<b>References</b> .....	<b>12</b>



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## 1. Introduction

Warm-season grasses such as switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* Vitman), and indiangrass (*Sorghastrum nutans* L.) have considerable potential as sources of biofuel. They have high net energy yield per acre, low cost of production, low nutrient requirement, relatively low ash content, and high water use efficiency. Many warm-season grasses can be established from seed and are adapted to a wide range of environments including marginal soils and arid climates. Warm-season grasses also have great potential to protect the environment through carbon sequestration and erosion control.

The Northern Great Plains (NGP) region has the environmental conditions conducive to production of biomass feedstock from switchgrass and other warm-season grasses. Table 1 shows the estimated potential land area and production amounts for warm-season grasses grown as dedicated energy crops in the NGP. This production guide focuses on the production of switchgrass.

Table 1: Estimated area for warm-season grasses (WSG) and biomass potential of the Northern Great Plains

State	Potential area for WSG species (million acres)	Mean biomass yields (tons/acre)	WSG biomass (million tons)
North Dakota	19.97	4.39	87.7
South Dakota	12.64	5.09	64.3
Nebraska	13.71	5.41	74.2

Source: Graham and Walsh 1999

Switchgrass is a native, warm-season, sod forming grass whose natural range stretches from Mexico into Canada. Switchgrass is a major component of the tall-grass prairie, which once was the dominant vegetation of the central U.S. Uplands types are adapted to drier habitats and are most common in the NGP.

Switchgrass develops rhizomes and has a deep rooting system, often deeper than 6 ft. Switchgrass grows up to 8 ft tall, depending on the variety and climatic conditions, and possesses excellent nitrogen and water use efficiency. Biomass production varies from 1.5 to 6 tons/acre, depending on soil and environmental conditions. If properly managed for biomass, we expect switchgrass to be productive for 10 or more years.

## 2. Establishment

### 2.1 Planting methods

#### Conventional

The ideal condition for conventional seeding should be a smooth, firm, clod-free soil for optimum seed placement with drills or culti-packer seeders. The seedbed should be firm enough at planting to ensure good seed-soil contact and a consistent seeding depth. Fertilizers, particularly N, should not be applied at planting as they encourage vigorous growth from annual weeds, increasing the competition for sunlight and moisture.

#### No-till

No-till helps to conserve soil moisture and eliminate the soil crusting frequently encountered in conventional seedbeds. Other advantages of no-till include savings on fuel, labor, and time. No-till planting has been used to produce good stands of perennial grasses in central and eastern South Dakota.

With no-till seeding, fields should first be cleared of perennial weeds. A nonselective herbicide such as glyphosate should be applied prior to or at the time of planting to eliminate weed competition. Seed is planted with drills that are able to penetrate the soil surface and residue from the previous crop or vegetation.

#### Broadcasting

Broadcasting is done on tilled seedbeds that are rolled or cultipacked before or during planting. Cultipacking or rolling the seedbed after broadcasting is recommended to ensure that seed is sufficiently covered by soil and to improve seed-to-soil contact.



Switchgrass growing in Brookings County, July 2005. Photo by Vance Owens.

#### Drilling

Switchgrass can also be planted on tilled or no-till seedbeds with grass drills or conventional grain drills. Drills having depth bands on double-disk openers insure consistent, proper planting depth. Packer wheels provide necessary seed-to-soil contact. No-till drills provide more down pressure and residue management than standard drills.

## 2.2 Seeding Rate

Recommended seeding rates range from 5 to 8 lb PLS per acre or about 25 seeds per foot of row in 6-inch rows, 30 seeds per foot of row in 7-inch rows, 35 seeds per foot of row in 8-inch rows, and 50 seeds per foot of row in 12-inch rows. Lower seeding rates may be adequate when the condition of the seedbed is optimum and the level of seed dormancy is low. Seeding rates will increase accordingly with poorer seedbed conditions and increased levels of dormancy in the seed.

## 2.3 Seeding Depth

Depth of planting for switchgrass depends on soil texture and other soil physical properties. In general, seed is planted deeper in coarse-textured soil than fine-textured soil, but is typically planted from 1/2 to 1 inch deep. We recommend not seeding deeper than 1 inch regardless of soil type. The deeper planting depth is typically used only to improve moisture conditions for the seed. Proper seed placement is critical for successful switchgrass establishment, particularly in arid regions.

## 2.4 Time of Planting

Two important factors to consider in determining time of planting are soil temperature and soil moisture. Switchgrass and other warm-season grasses require soil temperatures above 50°F (ideally 59–68°F) for satisfactory germination. Soil moisture level must also be adequate. Recommended planting time is early May to mid-June,

when soil temperatures have warmed sufficiently for optimum germination. Some growers have had success with switchgrass establishment if they planted within 3 weeks of optimum corn planting date.

We have had success no-till planting switchgrass in late November or December, after all chances of fall germination are past. This practice may be especially beneficial when using freshly harvested seed (i.e., < 18 months old) with higher levels of dormancy. In this case, dormancy in the seed is naturally broken down during the winter and spring months. However, dormant seeding requires further research to verify its consistent success.

### 3. Cultivar Selection

Most cultivars of switchgrass were developed primarily to enhance their value as forage crops. However, current breeding efforts are now directed toward improving biomass yield and quality for biofuel production. Switchgrass cultivars intended for bioenergy production in the NGP must have high biomass yield potential and be able to persist in cold climates.

In selecting cultivars, a simple rule of thumb is not to move a cultivar more than 300 miles north of its area of origin because of potential stand losses from winter injury. While more southerly sources tend to have a yield potential advantage, this cannot be traded for susceptibility to winter injury.

Biomass yield and quality components of several switchgrass cultivars evaluated in the NGP (Table 2) have been variable from site to site and year to year, confirming the presence of significant cultivar-by-environment interactions for these traits (Casler and Boe 2003). In central South Dakota for example, one study showed that annual biomass yields varied more than fivefold. This was largely attributed to variations in patterns and amounts of precipitation (Lee and Boe 2005).

Depending on the site, most switchgrass cultivars reach optimal productivity during the second or third year after establishment. In some cases, switchgrass may be harvested in the seeding year if established successfully and sufficient biomass is present to warrant harvesting. Biomass yield from a given site depends to a large extent on the amount of precipitation received. In the NGP, biomass yields vary from north to south and from east to west. The east-west variation is a result of precipitation, which is higher in the east and declines westward, while the length of the growing season increases from north to south.

Berdahl et al. (2005) recommended Sunburst as the best cultivar for biomass production in the NGP. Sunburst, Forrestburg, Nebraska 28, and Summer are well suited for sustainable biomass production in South Dakota. Cultivars with a higher yield potential, such as Pathfinder and Trailblazer, may be suitable for biomass production in southeastern South Dakota.

Table 2: Upland switchgrass cultivars suitable for the Northern Great Plains

Variety	Recommendation	Origin			Seed weight (mg/100 seeds)	Comment
		Locality	Longitude (°W)	Latitude (°N)		
Forestburg	High	Sanborn Co. SD	98°08'	44°00'	146	Medium yield potential, winter hardy, persistent. Suitable for North Dakota, South Dakota.
Sunburst	High	Union Co., SD	96°30'	42°40' - 43°00'	198	Leafy, medium to high yield potential, winter hardy, good seedling vigor. Highly recommended for North Dakota and South Dakota.
Nebraska 28	Moderate	Holt Co. northern NE	98°45'	42°20'	162	Well adapted to diverse soils, susceptible to rust in areas with longer season. Suitable for North Dakota, South Dakota, and northern Nebraska. May suffer winter injury in North Dakota.
Summer	Moderate	South of Nebraska City, NE	96°00'	40°40'	114	Tall, upright, coarse leaves, high biomass and seed yield, mostly rust resistant. Suitable for South Dakota.
Pathfinder	Low	NE-KS	-	≈37°00' -43°00'	187	Late maturing, Good establishment, vigorous, leafy, winter hardy, rusts resistant. Suitable for Nebraska and southeastern South Dakota. May suffer winter injury in North Dakota. Similar origin to Trailblazer.
Trailblazer	Low	NE-KS	-	≈37°00' -43°00'	185	High yield potential. Suitable for Nebraska and southern South Dakota, similar to Pathfinder, but with higher forage quality.

### 3.1 Pests and Diseases

To date, few pests of economic importance have been recorded on switchgrass. However, this does not imply that the crop will be free from attack by insects and diseases. As the acres of switchgrass production increase, a corresponding increase in pests and diseases is likely.

### 3.2 Diseases

A few diseases have been reported in switchgrass, and some may potentially affect biomass and seed production in the future. Switchgrass has been found to be susceptible to some strains of barley yellow dwarf virus. Rust (*Puccinia emaculata*) has been found on switchgrass in central and eastern South Dakota, and symptoms have been more severe on cultivars of northern origin (Gustafson et al. 2003). A viral disease caused by Panicum mosaic virus has also been observed in switchgrass. Smut caused by *Tilletia maclagani* caused reduced biomass yields and stand decline in Iowa (Moser and Vogel 1995; Gravert et al. 2000).

### 3.3 Insects

Few insects have been identified as potential pests of switchgrass in the NGP. Grasshoppers are known to feed on switchgrass, but the extent of the damage has not been quantified. Recently, a stem boring moth was found infesting stands of switchgrass in central and eastern South Dakota. A study on the impact of that insect on biomass production and stand persistence is ongoing.

## 4. Management

### 4.1 Harvest Timing

Maximum biomass yields of harvested switchgrass are obtained during mid- to late summer when the panicle is fully emerged from boot to post-anthesis. However, based on recent studies at SDSU, we recommend that for biomass purposes switchgrass should be harvested once annually in early to mid-October, after a killing frost (Mulkey et al. 2006; Lee et al. 2007). Harvesting around a killing frost may result in slightly lower yields than during midsummer, but persistence and winterhardiness are improved.

### 4.2 Cutting Height

To improve stand persistence, switchgrass should be cut no shorter than 4 inches. This helps prevent crown and lower stem injury, allows collection and retention of snow and moisture in drier regions, reduces soil erosion, and provides better cover for wildlife.

### 4.3 Fertilization and Soil Fertility

Fertilizer requirements of switchgrass managed for bioenergy largely depend on yield potential and management practices. The main fertilizer requirement of switchgrass is nitrogen. Optimum N rates for switchgrass managed for bioenergy range from 50 to 100 lb per acre in the NGP. Nitrogen fertilization is not recommended in the seeding year since this will stimulate weed competition. The best time to apply fertilizers to established stands is during spring. Soil tests should be taken to determine recommended fertilizer rates to apply.

Less N is likely needed when switchgrass is harvested for biomass around a killing frost. By this time, much of the N in the plant will have been translocated from the aboveground portion of the plant to the roots (Vogel et al. 2002).



#### 4.4 Weed Control Options

Weed competition, especially during the seeding year, is often a major cause of establishment failure in switchgrass. Weed species of concern vary from region to region and even between nearby sites. Generally, perennial forbs and cool season grass species, especially those that can germinate in cooler soils, provide the most severe competition to switchgrass growth. This is exacerbated by the fact that there are few labeled herbicides to control these weeds after switchgrass emergence. Populations of some perennial weeds, such as Canada thistle (*Cirsium arvense*), are especially problematic as they can develop extensive root systems during the first year after switchgrass seeding and there are few effective herbicide options available until after the switchgrass develops a secondary root system.

Delaying switchgrass planting to allow weeds to emerge and controlling these weeds prior to planting is one way to reduce the number of weeds that may compete with switchgrass seedlings. However, the delay must allow switchgrass to be planted during the normal planting time (mid-May to mid-June) as late planting itself may affect switchgrass establishment success.

##### Mechanical weed control

Tillage provides the first stage of weed control in conventionally seeded switchgrass. Although tillage will usually control actively growing weeds, it may also cut a weed's roots into two or more independent parts, encouraging the growth of two weeds where there was one. Tillage can also bring dormant weed seeds to the soil surface.

Mowing can control some annual weeds. Mowing is most effective if it is carried out when the annual weeds are at an early seedhead stage.

##### Herbicide weed control during establishment

Because the growing of switchgrass as a dedicated bioenergy crop is still in its initial stages, it is critical to check the registration status of herbicides in your state before using them on switchgrass. When switchgrass is established in no-till seedbeds, a nonselective herbicide such as glyphosate will help eliminate many weeds before sowing or emergence of the switchgrass. The use of such non-selective herbicide may be more environmentally benign, less costly, and more effective than selective herbicide options used after switchgrass emergence.

Atrazine has been applied pre- or post-emergence in the past to control other warm-season grasses in research trials, but it is not currently registered for use in switchgrass in many states. It is registered for CRP in Nebraska, Oklahoma, Oregon, and Texas and has also been authorized for special use on a pilot switchgrass project grown for biomass feedstock in Iowa. In most research trials in the NGP, atrazine has been used successfully as a pre-emergence herbicide. Switchgrass is generally atrazine-tolerant, but will be injured when higher rates are used.



Deer in switchgrass at Dakota Lakes, SD. Fall 2005. Photo by Arvid Boe



Snow cover over switchgrass in December 2005 near Aurora, SD. Photo by Arvid Boe.

#### Herbicide weed control after establishment

Although an established and well-managed switchgrass stand will eventually become competitive with most weed species, post-emergence herbicide applications may still be necessary. Several post-emergence herbicides are labeled for broadleaf weed control while quinclorac (Paramount) may be used to control annual grass weed species, and sulfosulfuron (Outrider) may be used to control some perennial grass and sedge weed species (Table 3).

#### 4.5 Persistence

Switchgrass is a true perennial grass species. Plants can spread by rhizomes and persist over many seasons. Research has shown that switchgrass stands will normally remain productive for periods of more than 10 years and some have speculated that production can even be maintained for more than 20 years when managed properly. Removing biomass only after full senescence, periodically replacing nutrients removed, and controlling any weed invasion could potentially keep stands productive for many years. Biotic pests, if found in greater abundance with large-scale switchgrass production, may also affect stand persistence.

## 5. Other Benefits of Switchgrass

### 5.1 Biodiversity Conservation and Wildlife Habitat

Only 4% of the original tall-grass prairie grasslands of North America remain since most were converted to agriculture production. New plantings of switchgrass, even as monocultures, are expected to enhance prairie biodiversity by providing forage, habitat, cover, and nesting areas for many mammals, birds, amphibians, reptiles, invertebrates, and insects. Switchgrass that remains standing throughout the winter provides excellent protective and concealment cover for upland game birds and ducks. These birds use switchgrass cover for night roosting, escaping from predators, protection from blizzards, and nesting.

### 5.2 Carbon Sequestration

Switchgrass has many traits that make it an attractive crop for sequestration of atmospheric carbon dioxide (CO<sub>2</sub>). It has an extensive and deep root system, about 50% greater water-use efficiency than cool season forage grasses, relatively low nutrient requirements, and the potential to produce large amounts of biomass. Stored carbon enhances the productivity of the soil by increasing soil fertility, protecting against erosion, retaining water more effectively, and minimizing the severity of drought conditions.

### 5.3 Revegetation and Soil Erosion Control

Switchgrass is used for a variety of revegetation and erosion control purposes. It is commonly planted along waterways to provide erosion control. It is seeded alone or in mixtures with other native grasses on mine spoils where it typically requires 2 to 4 years to develop good ground cover.

### 5.4 Farmer Friendly

Because switchgrass can be grown and harvested with equipment that most farmers already possess there should be no need for new equipment. Harvesting during early autumn is a period when haying equipment is generally not in use and therefore presents opportunities to improve returns on equipment investment.

Table 3: Herbicides registered for use in switchgrass\*

Herbicide	Trade name (product/acre)	Application rate (a.i./acre)	When to apply	Comments
Atrazine	Several	0.5 – 2 lb	Pre- and post-emergence	Provides residual control of grasses and broadleaf weeds. High rates of application may damage switchgrass, especially seedlings. Registered for controlling weeds in switchgrass planted along roadsides (Colorado, Kansas, North Dakota, South Dakota, Montana, Nebraska, and Wyoming) or CRP (Nebraska, Oklahoma, Oregon, and Texas).
Quinclorac	Paramount (5.3 oz)	0.25 lb	Pre and Post-emergence	Controls many annual broadleaf and grass weeds (crabgrass, foxtail species, and barnyard grass). For post-emergence applications, add 1.5pt/acre of methylated seed oil or other surfactant as indicated on the herbicide label.
Dicamba	Several (0.5-1 pt)	0.25-0.5 lb	Post-emergence	Broadleaf weed control. Switchgrass must be at 4-5 leaf stage or year-old. Apply when grass is fully tillered and weeds are less than 4 inches tall.
2,4-D	Several (1-4 pt)	0.5-2 lb	Post-emergence	Primarily for broadleaf weed control. Apply after switchgrass has 3-4 leaves.
Dicamba + 2,4-D	Weedmaster (1-2 pt)	0.125-0.25 lb dicamba + 0.36-0.72 lb 2,4-D	Post-emergence	Broadleaf weed control. Switchgrass must be at 4-5 leaf stage or year-old. Apply when grass is fully tillered and weeds are less than 4 inches tall.
Metsulfuron	Cimarron, Escort (0.1 oz)	0.06 oz	Pre and Post-emergence	Broadleaf weed control. Can be applied pre-plant, pre- and post-emergence (at least 3-4 switchgrass leaves per plant). For post-emergence applications, add NIS at 0.25% v/v. Do not apply to stressed plants.
Sulfometuron	Outrider, Certainty (0.75-2 oz)	0.5-1.5 oz	Post-emergence	Controls some perennial grasses, sedges, and broadleaf weeds. Must be applied when switchgrass has more than 3 leaves. Use a non-ionic surfactant at a rate of 0.25% of the spray volume (1 qt per 100 gal spray solution). Most effective when weeds are in the early stages of growth.
Chlorsulfuron	Telar XP (0.25-0.5 oz)	0.19-0.38 oz	Post-emergence	Can be used to control many broadleaf weeds. Apply to established stands. Use a NIS (0.25% v/v) to improve weed control, but this may cause temporary chlorosis on grass.
Imazethapyr	Pursuit 2L (4 fl.oz)	1 oz	Post-emergence	Controls several annual broadleaf and some grass weeds. Apply when switchgrass has at least 4 leaves. Apply herbicide with non-ionic surfactant (1 qt per 100 gal spray solution) and an N fertilizer such as 28% N at 1.25 to 2.5 gal per 100 gal spray solution. May use COC (1% v/v) or MSO (1.25% v/v) rather than a NIS (0.25% v/v).

\*Always check whether any of these herbicides are registered in your state for use in switchgrass as this information changes. Some herbicides may be registered for use on switchgrass grown for pasture and hay but not explicitly for bioenergy feedstock. Where a farmer decides to use the grass for other purposes (e.g. pasture or hay) other than biomass feedstock, check for possible herbicide restrictions first before feeding animals.

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### Follow the label.

**Federal regulations make it unlawful for any person to use a pesticide in a manner inconsistent with its labeling. This includes the crop, weed, rate, carrier, and other application directions; storage, disposal, and protective clothing; or other precautions stated.**