

Switchgrass for Biomass Production by Variety Selection and Establishment Methods for Missouri, Illinois, and Iowa

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Switchgrass (*Panicum virgatum* L.) is a native, deep-rooted, warm-season grass with short, stout rhizomes and heavy biomass growth during late spring and early summer. It is an abundant seed producer. Clean seed yields of 225 pounds per acre have been documented at the USDA Natural Resources Conservation Service (NRCS) Plant Materials Center (PMC) at Elsberry, Missouri. The species occurs naturally in every state in the continental United States except for Oregon, Washington, and California (USDA, NRCS 2006b).

Switchgrass tolerates a wide range of soil conditions and is widely acclaimed as a conservation plant for erosion control, pasture and hay planting, wildlife habitat, and native prairie restoration. Interest in switchgrass as a renewable biofuel resource has grown in recent years.

Dry matter biomass yields and other information were compiled at three sites in Missouri from 1993 to 1995, Illinois from 1992 to 1994 and Iowa from 1994 to 1996. The effects of seed origin (parentage) on plant performance were apparent. Twelve seed sources/varieties of switchgrass were evaluated. Southern seed sources generally had heavier biomass production. Northern seed sources moved more than 200 miles southward from their origin generally performed poorly. Biomass was significantly less than local or more southern origin sources.

Trial Sites

The trial sites were studies in cooperation with several partners: the USDA NRCS PMC, Elsberry, Missouri; in cooperation with the University of Missouri, Southwest Research Center, Mt. Vernon, Missouri; the University of Illinois, Orr Agricultural Research Center, at Perry, Illinois; and the University of Northern Iowa, Tallgrass Prairie Center, Cedar Falls, Iowa.

Growing seasons at the three locations varied from an average 177 days at Cedar Falls to an average of 232 days at Mt. Vernon. Average annual precipitation ranged from 43.7 inches at the Mt. Vernon site to 33.7 inches at the Cedar Falls site. Seven different species of warm-season grasses were evaluated at each site. Switchgrass is the only species presented in this technical note.

University of Missouri, Southwest Research Center, Mt. Vernon, Missouri

Major Land Resource Area 116B - Springfield Plains, Ozark Border.

The soil is a Hoberg-silt loam. The Hoberg series consists of very deep, moderately well drained soils that have a fragipan. These soils formed in a thin mantle of loess and the underlying residuum from cherty limestone. Slopes range from 2 to 8 percent. Permeability is moderate above the fragipan, slow in the fragipan and moderate below the fragipan

Average annual precipitation for the four years of the biomass study was varied at this location. In 1991 the establishment year rainfall was 20% (-8.95 inches) below the normal average of 43.73 inches. The highest biomass production was in 1993 and 1994 following rainfall in 1992 that was 28% (12.26 inches) above normal and 1993 that was 40% (17.28 inches) above normal. Average biomass yields were generally excellent on the upland Hoberg silt loam soils. Alamo and Kanlow produced an average of 13,500 pounds per acre or greater. All varieties were in the 90% range in percent stand the second year after planting except for Grenville at 78%, and Shelter at 45%. Alamo and Kanlow were the tallest varieties at an average forage height of 6 feet. Alamo and Kanlow were also the latest by date of first seedhead emergence, Alamo (August 7), and Kanlow (July 28)

University of Illinois, Orr Research Center, Perry, Illinois

Major Land Resource Area 115C - Central Mississippi Valley Wooded Slopes.

The soil is a Muscatine silt loam. The Muscatine series consists of very deep, somewhat poorly drained soils formed in loess. These soils are on summits of interfluvies on dissected till plains and on treads and risers on stream terraces. Slopes range from 0 to 5 percent.

Average annual precipitation for the four years of the biomass study was varied at this location. In 1990 the establishment year was 23% (8.83 inches) above normal of a 17 year average of 39.18 inches. The highest biomass was in 1993 when rainfall was 38% (14.70 inches) above normal.

Average biomass yields were good. The highest production was Kanlow at 9,729 pounds per acre, followed by Alamo at 8,820 pounds per acre; however, Alamo did not achieve greater than 90% cover until the third year. The varieties Kanlow, Cave-in-Rock, Carthage and Pathfinder were in the 90% to 100% range in percent stand the year following planting. The remaining varieties did not achieve those levels until the third growing season. Kanlow was the tallest with an average forage height of 5.7 feet. Kanlow (July 25) and Alamo (July 17) were the latest by date of first seedhead emergence (late boot stage).

University of Northern Iowa, Tallgrass Prairie Center, Cedar Falls, Iowa

Major Land Resource Area 104 - Eastern Iowa Till Prairie

The soils on this site are a well drained Kenyon clay loam and Olin fine sandy loam. The Kenyon series consists of very deep, moderately well drained soils formed in 12 to 30 inches of silty or loamy sediments and the underlying till. These soils are on interfluves and side slopes on dissected till plains on the Eastern Iowa and Minnesota Till Prairies. Slope ranges from 2 to 35 percent.

The Olin series consists of very deep, well drained soils formed in 24 to 36 inches of loamy sediments and in the underlying glacial till. These soils are on interfluves and side slopes on dissected till plains. Slopes range from 2 to 14 percent.

Average annual precipitation for the four years of the biomass study was varied at this location. In 1992 the establishment year precipitation was below normal 8% (-2.73 inches). The highest biomass was in 1994 following above normal precipitation 57% (19.37 inches) in 1993 and 5% (1.60 inches) in 1994. In 1995 and 1996, 12% below normal precipitation resulted in lower biomass yields.

The highest biomass yield for the three year average was Kanlow at 12,143 pounds per acre, Blackwell at 11,731, Shelter at 11,147, and Carthage at 10,272.

The varieties Kanlow, Cave-in-Rock, Shelter, Carthage, Alamo, and Forestburg were in the 90% to 100% range in percent stand the second year following planting. The remaining varieties did not achieve those levels until the third growing season.

Kanlow (August 18) and Alamo (August 14) had the latest average date of first seedhead emergence (late boot stage).

Methods and Materials

Procedure:

The three sites were located within the PMC service area for the study. The northern site is at Cedar Falls (Northeast Iowa), the central site is at Perry (West Central Illinois) and the southern site is at Mt. Vernon (Southwest Missouri). Varieties of the most commonly used switchgrass were planted in a randomized complete block with three replications. Plot sizes at Perry were 15 feet by 50 feet in a prepared seedbed. Seed was broadcast. Plot sizes for Mt. Vernon and Cedar Falls were 12 feet by 50 feet. Plots were a prepared seedbed planted with a drill.



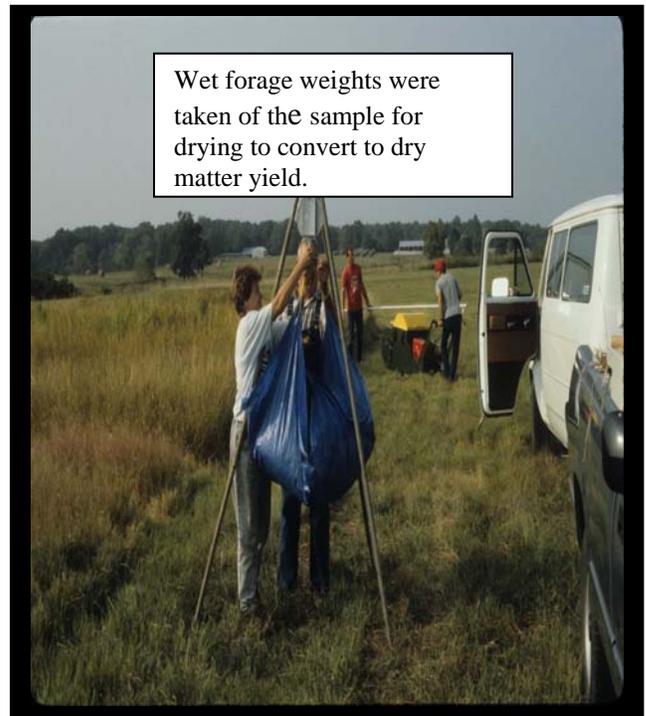
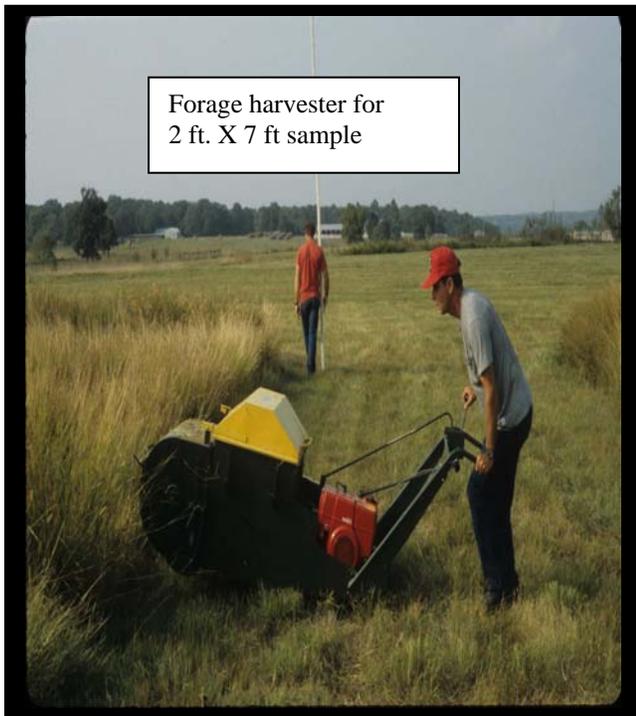
The second year after seeding each site was subjected to a spring burn. Each plot was monitored for establishment the year of planting but was not evaluated until the second year. Evaluation criteria are annual biomass yield, plant height, forage quality, percent stand, and plant phenology, which compared plant maturity.

Data for annual biomass yield production was collected only once per year, typically at the end of the growing season. This did not take into account regrowth potential but rather a full season total growth comparison. For nonplanted species, (primarily weeds), a sample was taken and used to adjust the dry matter yields to better represent the switchgrass being evaluated. (USDA, NRCS Elsberry Plant Materials Center. 1994-1998 Technical report.)

Biomass Production

A two-foot by seven-foot sample was cut with a forage harvester to determine biomass yield. A representative stand was harvested from each plot. Plot borders were excluded and an estimate of percent dry matter weed content in the sample was deducted from the total sample weight.

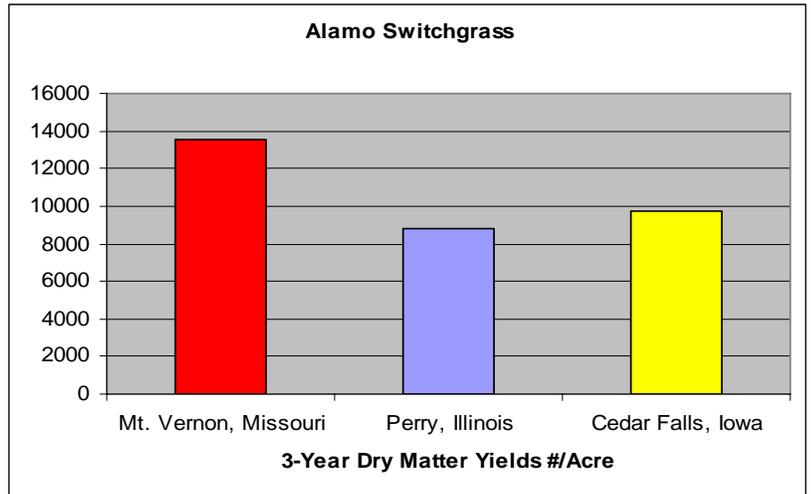
Annual biomass yields by variety are shown on pages 5, 6, 7, 8 and 9. A summary table of each site location is shown on page 11.



Variety/Collection Source

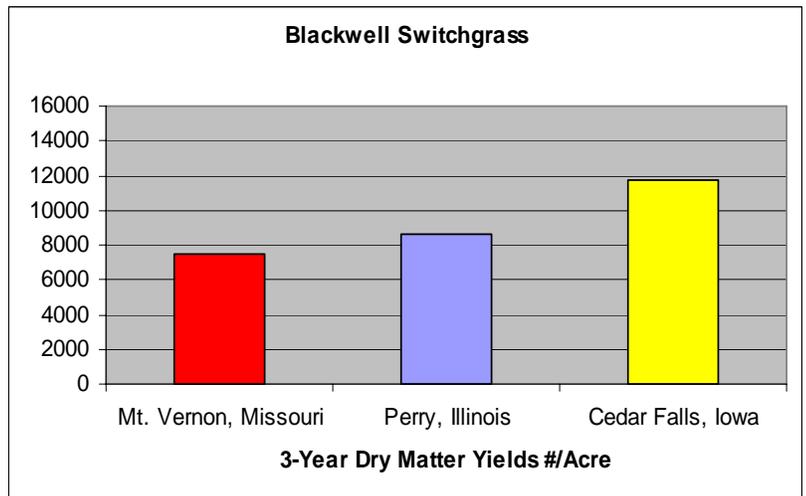
Alamo

Original seed was collected near the town of George West in south central Texas. Selection for longer wider leaves, taller and greater forage potential. Maturity is one to two months later than other southern selections like Blackwell. Alamo was a USDA NRCS release from Knox City Texas.



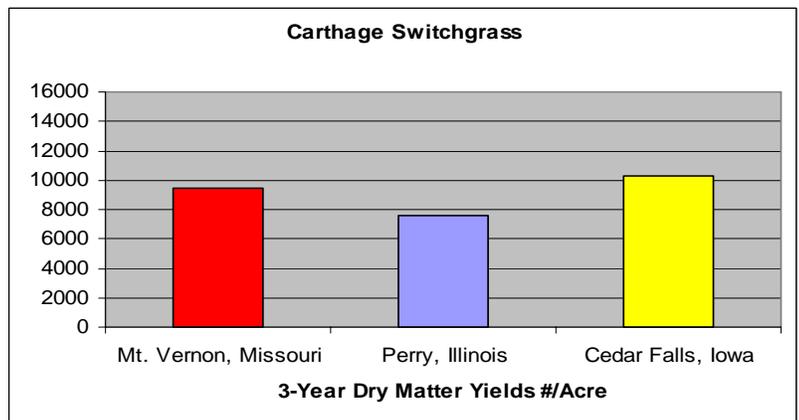
Blackwell

Harvested from a single plant in a native prairie near the town of Blackwell in north central Oklahoma. This is an upland type switchgrass of medium height that is leafy and has large stems. Total forage yield, disease resistance, and seedling vigor is good. It has a wide area of adaptation. Blackwell was released by the USDA NRCS and the Kansas Agricultural Experiment Station.



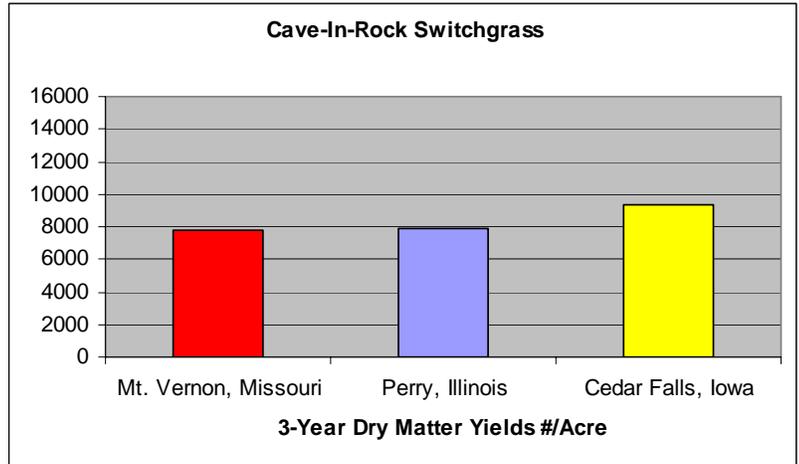
Carthage

A single clone collected vegetatively near the town of Carthage in central North Carolina. It is leafy and has better than average spread, high nutrient value, and early spring recovery. Seed production is fair. Carthage was released from the USDA NRCS, Cape May, New Jersey.



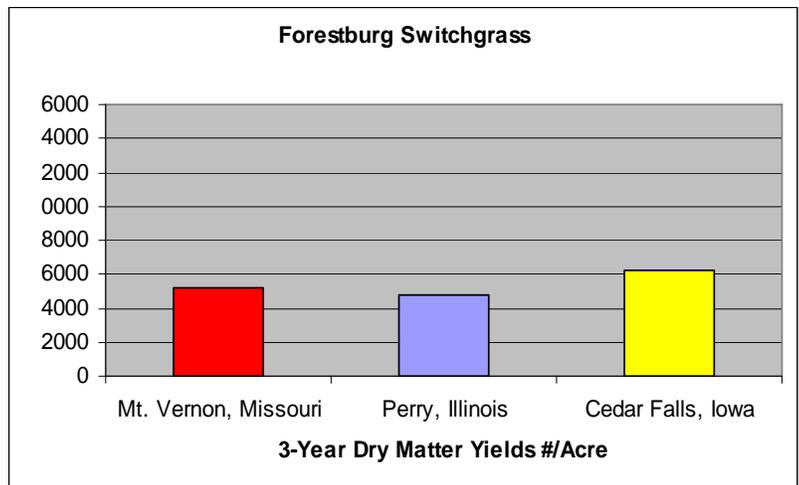
Cave-in-Rock

Selected from a native stand near the town of Cave-in-Rock in southern Illinois. It was selected for seedling vigor, disease resistance, higher seed yields, and resistance to lodging. This is a lowland type of switchgrass. It is tolerant to flooding, but will also withstand droughty soils. Cave-in-Rock was released by the USDA NRCS Elsberry, Missouri and the Agricultural Experiment Station.



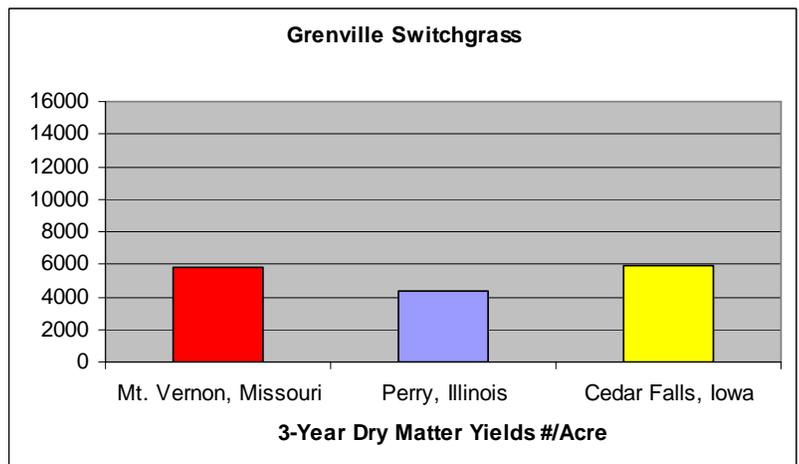
Forestburg

A composite of four accessions collected from native stands near the town of Forestburg in east central South Dakota. Early maturity, persistence, forage yield and quality, winter hardiness, and seed production were key selection criteria. Forage production at northern latitudes is similar to Nebraska 28 and Sunburst. Forestburg was a joint USDA NRCS and Agricultural Research Service release.



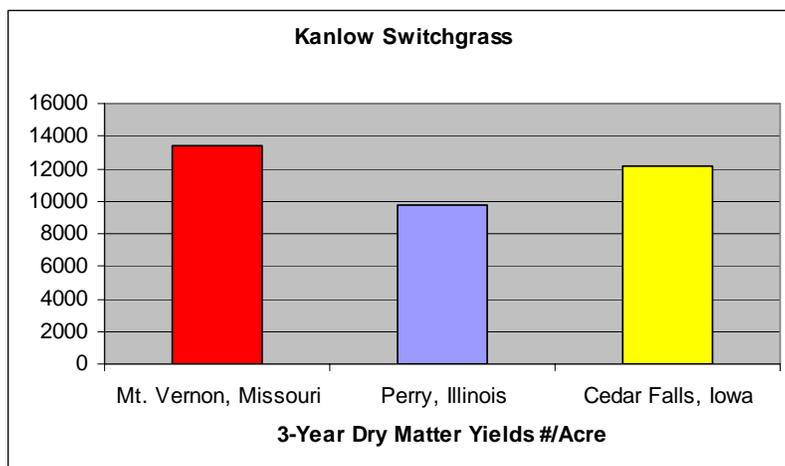
Grenville

A collection near the town of Grenville in northeast New Mexico at an elevation of 1800 m (4938 ft.) with annual precipitation of 400 mm (15.7 inches). An intermediate type between northern and southern geographic strains. Leafy, fine stemmed and remains green well into the fall. Medium maturity date. Grenville is a release from USDA, NRCS, Los Lunas, New Mexico.



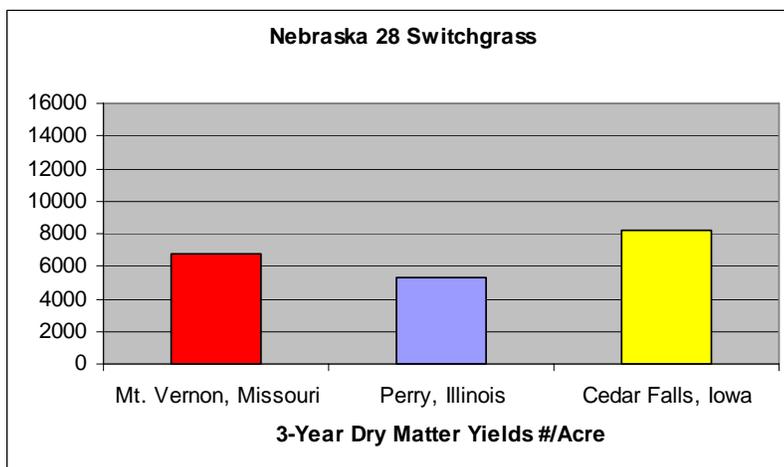
Kanlow

Original seed was collected near the town of Wetumka in east central Oklahoma on a bottomland site. Selection for leafiness, vigor, and retention of green leaf blades late in season. It is a tall coarse type adapted to lowlands with high water tables but will perform well on an upland soils. Kanlow was released by the Kansas Agricultural Experiment Station, the USDA NRCS and the Agricultural Research Service.



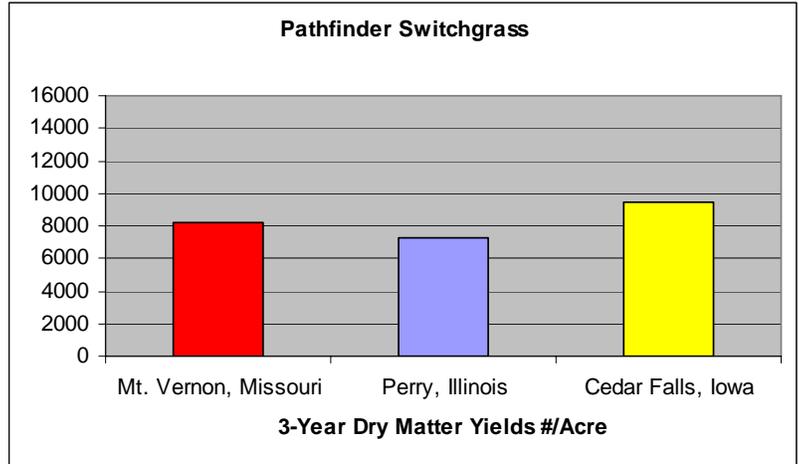
Nebraska 28

Collected from a native switchgrass stand in Holt County in northeast Nebraska. This is a relatively early maturing strain of switchgrass representative of the Nebraska sandhill types. There is considerable variation in plant type. The average plants are semi-decumbent with fine stems of moderate height, bluish green, and leafy. It is susceptible to rust in areas with longer growing seasons. Nebraska 28 was released by the Nebraska Agricultural Experiment Station, the USDA NRCS and the Agricultural Research Service.



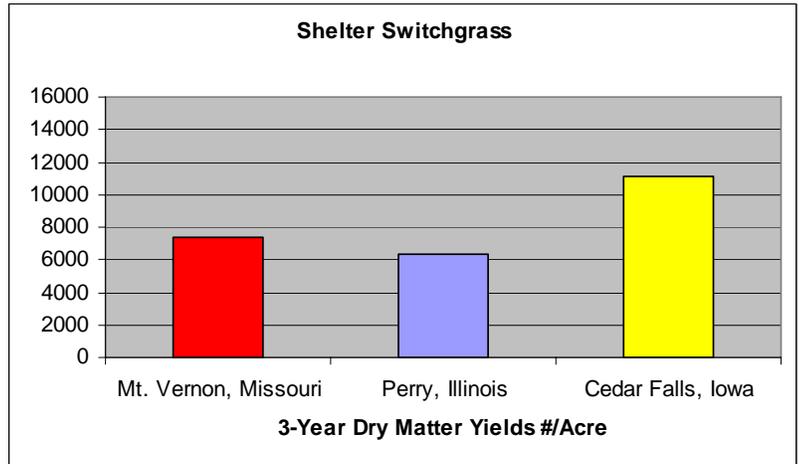
Pathfinder

Originated from numerous domestic collections from Nebraska and Kansas. It is winter hardy, vigorous, leafy, late maturing, and rust resistant in region of adaptation. Stand establishment and forage production is good. Pathfinder was released by the Nebraska Agricultural Experiment Station, the USDA NRCS, and the Agricultural Research Service.



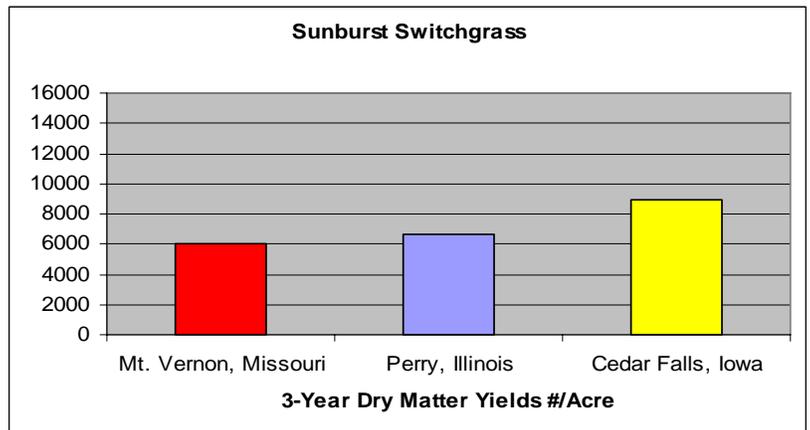
Shelter

Originated from a collection located near the town of St. Mary's in northwest West Virginia. The original selection was selected for upright form and stiff stems. Additional selections improved the number of stems, early maturity, and large stem diameter. Shelter has thick stems and fewer leaves than other released varieties, except for Kanlow. Shelter reaches full anthesis 7 to 10 days earlier than Blackwell. Shelter was released by the USDA, NRCS, Big Flats, New York.



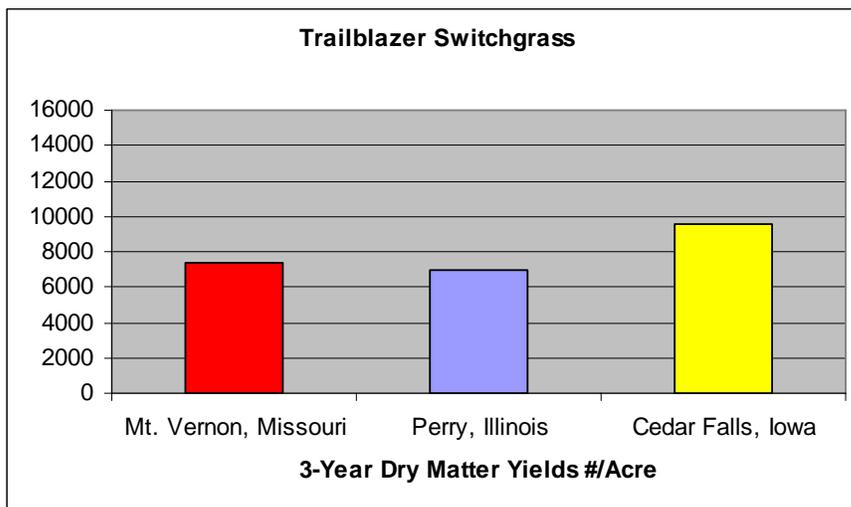
Sunburst

Original seed was collected near the town of Yankton in southeastern South Dakota. Selections from original seeded plants were chosen for large seed size, higher seedling survival and better stand establishment. It is a medium maturity selection with good forage yields. Sunburst has a broad area of adaptation and has performed well in trials along the Canadian border in North Dakota.



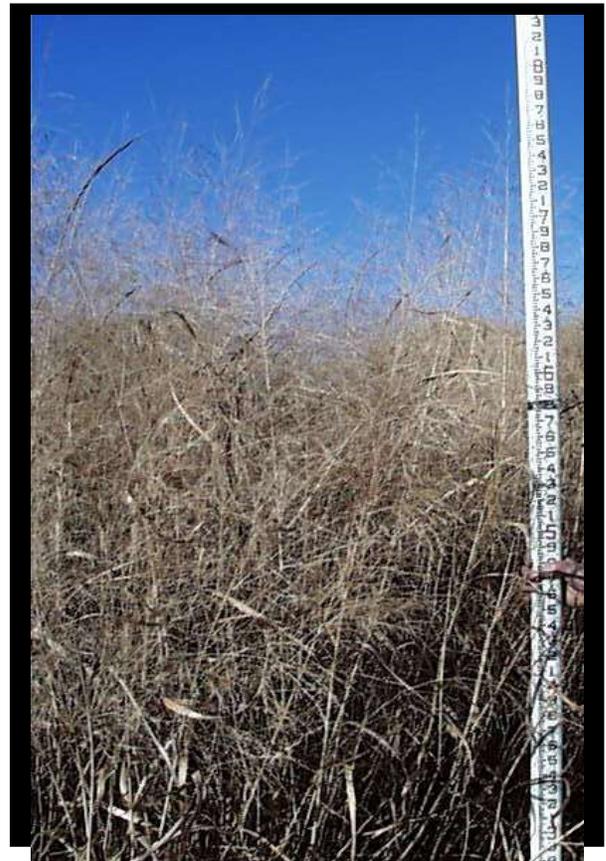
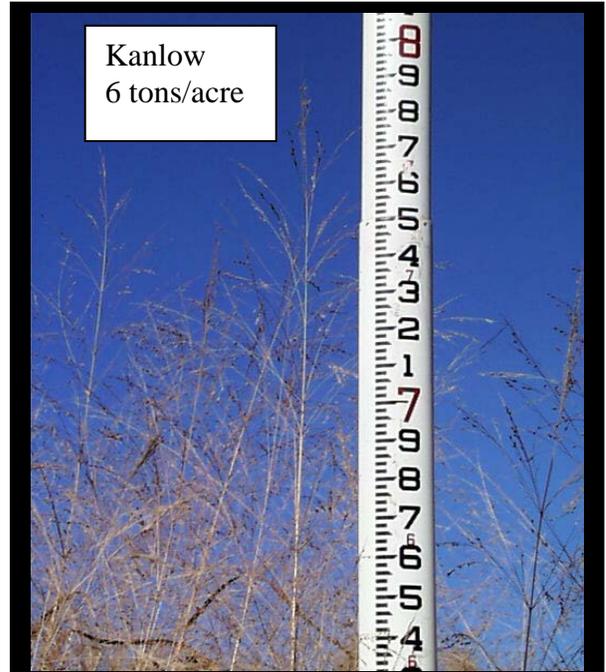
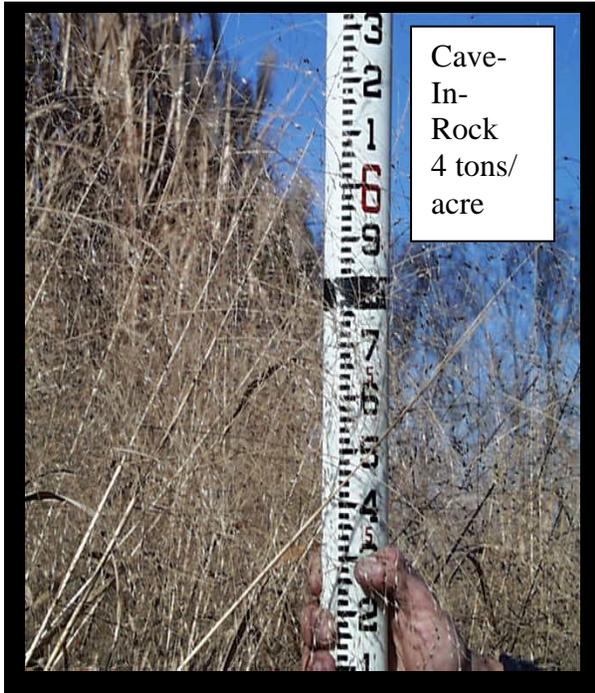
Trailblazer

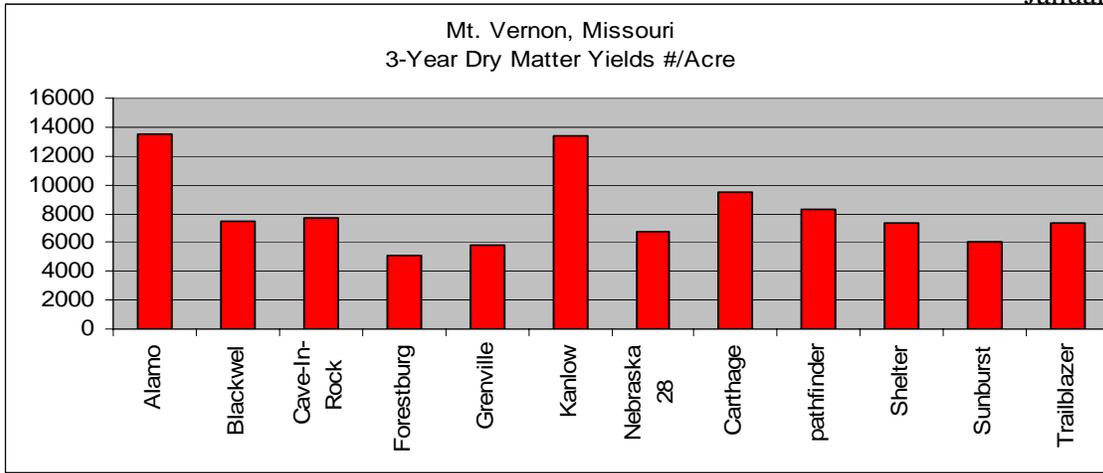
Collected from grasslands in Nebraska and Kansas. Trailblazer is similar to Pathfinder in maturity, appearance, and area of adaptation. It was selected for improved forage quality and the invitro dry matter digestibility is greater than Pathfinder. Trailblazer was released by the USDA Agricultural Research Service and the University of Nebraska Department of Agronomy.



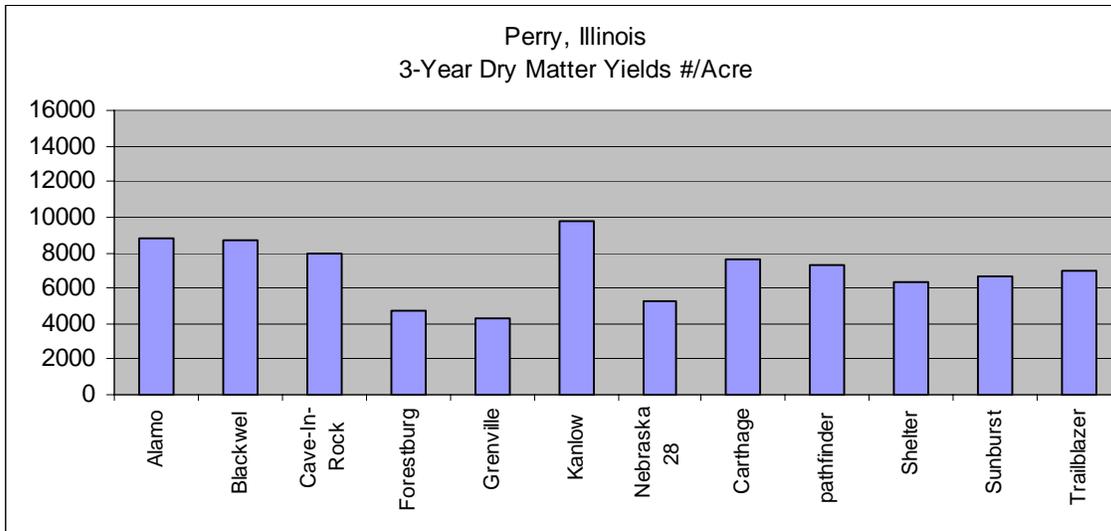
Summary of Results

	Cedar Falls, Iowa North Location	Perry, Illinois Central Location	Mt. Vernon, Missouri South Location
Switchgrass			
Best Varieties Biomass Yields range, 6-7 tons/acre	Kanlow	None	Alamo Kanlow
Better Varieties Biomass Yield range, 5-6 tons/acre	Blackwell Shelter Carthage	None	None
Good Varieties Biomass Yield range, 4-5 tons/acre	Alamo Trailblazer Pathfinder Cave-in-Rock Sunburst Nebraska 28	Kanlow Alamo Blackwell Cave-in-Rock	Carthage Pathfinder Cave-in-Rock

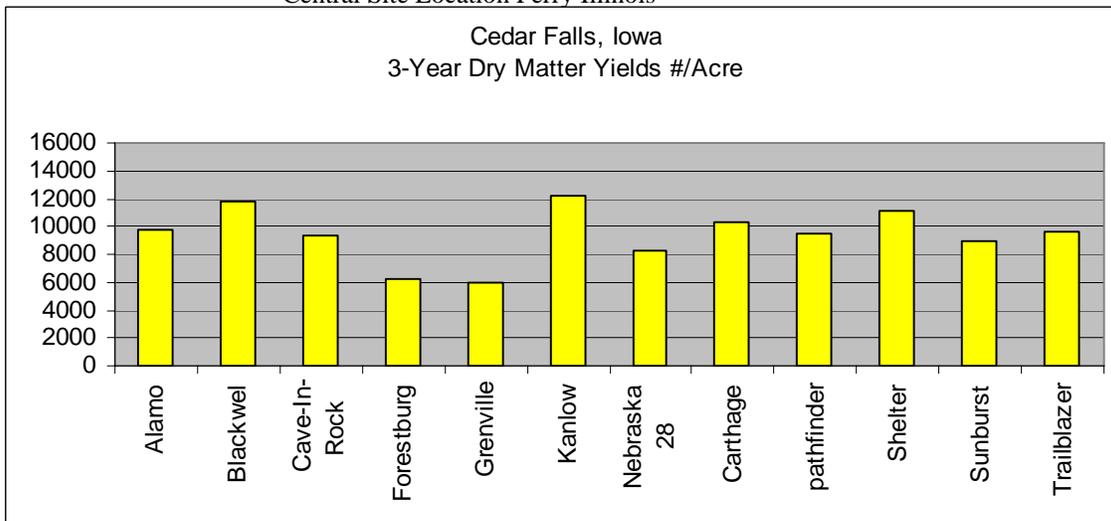




Southern Site Location- Mt Vernon Missouri



Central Site Location Perry Illinois



Northern Site Location Cedar Falls Iowa

Results and Discussion

Biomass yields at all locations were dependent on seasonal precipitation patterns. Seed origin is also critical in overall performance. Previous studies at the Bismarck PMC have shown that generally, warm-season grass species can be moved about 300 miles north or 200 miles south of their original collection location. East and west movement is affected by moisture and elevation (USDA, NRCS Northland News 2004/2005).

Grenville, a New Mexico variety coming from an elevation of 4938 feet (800 meters), and Forestburg, from South Dakota and the northern most variety, ranked lowest in three year average biomass yield at all three sites. Varieties producing the most biomass varied across the plot locations, but generally, the more southern origin varieties produced the most biomass.

Switchgrass is a species with a broad range of adaptation. Alamo and Kanlow were the two highest yielding varieties for dry matter yield except Alamo yields decline at the northern location. At the Cedar Falls location, Blackwell and Shelter followed Kanlow. Carthage is a variety of eastern origins but is not on the commercial market at this time. It looked very good at all three locations and stays green longer in the fall. Cave-In-Rock and Pathfinder, also looked good at all three locations.

Alamo and Kanlow are the latest maturing varieties at each location, except Carthage is later than Alamo at the central location. Maturity of Pathfinder, Cave-In-Rock and Blackwell are all within about a week at all locations.

Percent stand is an indication of how quickly the variety/selection established and how well it maintained itself. Warm season species generally establish slower than cool season species. A warm season planting should be useable the second growing season and be in full production by the third.



Origin of varieties

Alamo - USDA NRCS. PMC, Knox City, TX. Origin Frio River South Central Texas.

Blackwell - USDA NRCS PMC, Manhattan, KS. Origin Blackwell, OK in North Central Oklahoma.

Carthage - USDA NRCS PMC, Cape May, NJ.. Origin Central North Carolina.

Cave-In-Rock - USDA NRCS PMC, Elsberry, MO. Origin Southern Illinois near Cave-in-Rock, IL, in Hardin County.

Forestburg - USDA NRCS PMC, Bismark, ND. Origin Sanborn Co., near Forestburg, SD. East Central South Dakota.

Grenville - USDA NRCS PMC, Los Lunas, NM. Origin Grenville, NM, in north east New Mexico.

Kanlow - USDA NRCS PMC, Manhattan, KS. Origin Wetumka, OK, in East central Oklahoma.

Nebraska 28 - USDA ARS Holt Co., NE, and NRCS-NEAES north central NE. Origin in Holt County, Nebraska.

Pathfinder - USDA ARS, KS, and NE. Origin collections from Nebraska and Kansas.

Shelter - USDA NRCS PMC, Big Flats, NY. Origin St. Marys, West Virginia.

Sunburst – South Dakota State University, Brookings, SD. Origin of collection near Yankton, SD, in southeast South Dakota.

Trailblazer - USDA ARS KS and NE., NEAES Lincoln, NE. Origin of collections from Kansas and Nebraska.

Key Establishment and Management Considerations

- **Soils/Adaptation:** Plant performance is best on moderate to fine textured deep soils in areas of greater than 14 inches of average annual precipitation.
- **Seeding:** Switchgrass is a small, smooth seed with approximately 259,000 seeds per pound,(USDA NRCS 2006b).

The Missouri NRCS recommended drilled seeding rate for switchgrass is 5.9 pounds per acre as a pasture and hay seeding rate (USDA, NRCS 2007). Rates are calculated on Pure Live Seed (PLS). The recommended broadcast seeding rate is 1.50 times the recommended drill rates. Seeding rates vary across the United States, generally increasing from west to east. The recommended seeding rate is 10 PLS pounds per acre in the southeastern United States (USDA, NRCS 2006b). Spring or fall dormant seeding dates are recommended. A firm seedbed is essential for a shallow seeding depth (1/4 inch). Studies have shown an average germination of 65 percent when planted 1 inch deep, and zero germination when planted 2 inches deep (USDA, NRCS 2003).

- **Weed Control:** Abundant broadleaf weeds and annual grasses need to be controlled by mowing and/or herbicide application. Young plants of annual foxtails (*Setaria* species) look very similar to switchgrass seedlings. Dense stands of foxtail can be very competitive and significantly reduce stand establishment. Herbicides generally are more effective than mowing in controlling annual grasses.
- **Grazing/Haying:** Palatability and digestibility of switchgrass are good for beef livestock when harvested in the early boot stage. Allow for 8 inches of stubble in early summer and 12 inches in late summer (USDA, NRCS 2006b).
- **Mowing:** Switchgrass has an elevated growing point. A mowing height of less than 6 inches in late spring or early summer may reduce stand density. Boe (2005) recommends delaying harvest until late summer or early fall for stand longevity and stable long-term biomass production.
- **Phytotoxicity:** Switchgrass is reported to be toxic to horses, sheep, and goats when grazing pure stands. The toxicity can cause photosensitivity and affect internal organs and liver function (USDA, NRCS 2002). No problems have been noted for cattle.
- **Fertilization:** Biomass quality and yield, and seed production can be improved with nitrogen application. A soil test is required to achieve maximum productivity.
- **Burning:** Switchgrass benefits from burning of plant residues prior to initiation of spring growth. Advantages include low impact residue removal; weed control; more uniform growth initiation and seed ripening; improved nutrient recycling; and more vigorous growth.
- **Seed Harvest:** Seed shattering may occur shortly after the first seed is ripe. Conventional grain harvesting equipment can be used with proper setting adjustments. Seed is subject to heating. Fields should be as weed free as possible prior to harvest. Many weed seeds (especially foxtails) are similar in size and shape to switchgrass and can be difficult to remove during the cleaning process.



Burning residue on plots

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