Final Report

Project Title: Switchgrass and native rangeland management for grazing and bioenergy

Project manager: James Rogers

Timeframe Covered: September 24, 2009 – September 24, 2013

Grant number: NRCS 69-3A75-9-139

Deliverables: To establish demonstration areas showcasing switchgrass and native grazing and harvest best management practices. Conduct annual field days where experts speak on grazing management, soil and water conservation, grazing economics, beef cattle management, and wildlife. Develop a BMP guide for switchgrass and native rangeland management in multi-purpose grazing and bioenergy systems. Attend at least one NRCS CIG Showcase or comparable NRCS event during the period of the grant.

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Executive Summary

The primary goal of the project was to “educate producers, farm managers, and general public of best management practices (BMPs) for use of switchgrass and native rangeland in dual-purpose grazing and bioenergy systems”.

To meet this goal, The Noble Foundation through a series of experiments and demonstrations has successfully shown the use of a lowland ecotype of switchgrass as a multi-purpose crop. Lowland switchgrass can be grazed early in the growing season (April-June) with stocker cattle (lightweight, young beef type calves generally weighing between 400-650 lbs) to add additional weight gain prior to these cattle going to feedlots or placed on other forage resources after June. Switchgrass growth following this early season grazing period can then be deferred and harvested at the end of the growing season for biofuel feedstock. Stocking rate during the early season grazing period will effect feedstock production compared to feedstock production with no grazing. In a companion demonstration, stocker steers were grazed for a 52-day spring grazing period (April-June) at two stocking rates on a native range area. Stocker weight gains during the grazing period were not as high as stocker weight gains achieved on switchgrass only. However, the basic concept of early season grazing followed by grazing deferment and forage accumulation then feedstock harvest at the end of the season can be accomplished. Results from this study were used to write a best management practice guide sheet on the grazing and harvest of switchgrass that is publically available.

In support of the grazing and demonstrations studies, switchgrass and nativegrass research and demonstration projects were conducted to determine the best management practices for the establishment of these grasses with clean tillage and no-till approaches. Farmers and ranchers must be able to easily establish switchgrass and nativegrass for them to adopt these grazing management approaches. Results show that switchgrass and nativegrass can be successfully established with clean-till seedbed preparation. No-till establishment of switchgrass and nativegrass was often poor and additional research is needed in order to achieve no-till establishment results that are comparable to clean-till establishment. Results from these studies have been used to write a best management practice guide for the establishment of switchgrass that is publically available.

Results of these projects have been transferred to farmers and ranchers through field days, educational events, newsletters, scientific meetings, and journal articles satisfying the designated priority of this grant.

This project requested a one-year extension for completion and following the granting of the extension, the project was completed on time. Reasons for the one-year extension:

a delay in the development of the grazing facilities postponed the grazing demonstration by one year, the 2011 drought in the southern Great Plains shortened the 2011 grazing demonstration by at least 30 days and did not permit a compete demonstration of the system. The time extension allowed for the full demonstration of establishment practices for switchgrass and to conduct the grazing demonstration under improved moisture conditions. Project funds were spent as anticipated with no major changes in the budget.

Introduction

Switchgrass and native rangeland have been identified as next-generation feedstock sources for cellulosic ethanol production. The cellulosic ethanol industry has been slow to develop and production has failed to meet the mandates established in the Energy Independence and Security Act of 2007. There are several reasons for the slow development of the industry including farmer's willingness to grow a dedicated perennial energy feedstock without a market that is not fully developed. For producers to begin to grow energy feedstock, the opportunity costs that will be lost from their current cropping systems need to be covered. To begin to address this, feedstock/forage/livestock systems need to be developed that will integrate biofuel feedstock into farmer's existing production systems and develop management strategies for these integrated systems for multiple uses. Switchgrass and native rangelands have dual-purpose grazing and bioenergy potential because of their perennial life-form, high biomass yields, wide adaptability, and low fertilization requirements.

To develop and demonstrate these systems and distribute the results to producers and the scientific community, The Samuel Roberts Noble Foundation applied for and received grant funding from United States Department of Agriculture Natural Resources Conservation Service. Cost share matching requirements for the grant were met by the Samuel Roberts Noble Foundation.

Personnel

Name	Qualifications	Role
Jon Biermacher	Ph.D., Agricultural Economics	Provide economic analysis of the systems developed
Jagadeesh Mosali	Ph.D., Soil Science	Technical support for project development
James Rogers	Ph.D., Agronomy	Project management

Methods

Lowland switchgrass grazing management and biofuel feedstock production

Alamo switchgrass was established near Burneyville, OK, USA (33^{o}53' N, 97^{o}17'W) on 24 acres of a Slaughterville fine sandy loam (course-loamy, mixed, superactive, thermic Udic Haplustolls). After an establishment period, switchgrass was then grazed by stocker cattle to determine the value and utilization of switchgrass in a dual purpose system that would generate animal weight gain then following grazing, switchgrass regrowth would be deferred and harvested for bioenergy feedstock. The study area was soil tested to a 6 inch depth and the soil test results indicated a soil pH of 6.5, P (68 lb/acre), and K (255 lb/acre) which were sufficient to not limit switchgrass production. Nitrogen was added in the spring prior to the start of grazing at 70.0 lb/acre. The 24 acre study area was subdivided into twelve 0.72 acre paddocks. Four stock density treatments of 0 steers per acre (control), 1 steers per acre (light), 2.0 steers per acre (moderate) and 3 steers per acre (heavy) were randomly assigned to the paddocks with three replications. Sale barn purchased stocker calves (838±196 lb) were randomly assigned to treatments in the spring (April-May) when the average switchgrass height across treatments reached 14.0 inches and were removed when switchgrass was grazed down to a 3.0 inch height or when forage quality dropped to levels that would not support animal weight gain. The study took place over a three-year period. During the trial, steers were allowed unlimited access to water and a salt/mineral mix. After grazing, switchgrass was allowed to accumulate until after frost then harvested. The effect of stock density on feedstock biomass was compared to the un-grazed control. The biological data collected from this study were then used to simulate the economics of six alternative stocker weight gain/bioenergy feedstock systems.

Results

Grazing duration of Alamo switchgrass varied ($P < 0.05$) from 80 for light, 43 for moderate to 28 days for heavy stock density treatments (Table 1). The light stock density treatment had the greatest number of grazing days but lowest animal performance compared to the other treatments (Table 1). Compared to the other grazing treatments, the light stock density treatment produced the greatest amount of feedstock (Table 1) but significantly less than the control (Table 1).

Table 1. Switchgrass early season stocking rate effect on stocker performance and biomass feedstock production.

	Steers/acre	Grazing Days	ADG lbs.	Total Gain lbs.	Feedstock DM lbs/ac
Low	1.0	80a	1.85b	148b	9400b
Medium	2.0	43b	2.29a	197a	7233c
High	3.0	28c	2.31a	194a	6930c
Control	0	0	0	0	13682a

Means within columns with different letters are significantly different at P = 0.05.

The grazing data generated in the experiment was then used to simulate the economics of six alternative cattle gain/bioenergy feedstock systems. The animal weight gain from the experiment was combined with Chicago Mercantile Exchange (CME) cattle futures prices to assign a value of weight gain for each stock density treatment (Table 2). Animal weight gain value varied by stock density treatment due to differences in grazing termination dates creating varying end market points. Animal weight gain for the stock density treatments was determined to be 0.79, 0.70, and 0.59 $/lb for low, medium, and high stock density treatments using 2011 CME futures prices. At a feedstock price of $50/ton, a combination of low grazing followed by grazing deferment and harvest for feedstock would return the highest net return of the systems (Table 2). Feedstock value without returns generated form grazing would need to reach $100/ton for dedicated feedstock production to achieve the highest net return (Table 2).

Table 2. Net returns and optimal system by stocking rate, value of gain and feedstock price.

	Stocking Rate					Optimal system
	CON	LOW	MED	HIGH	P>F	
2011 CME value of Gain ($/lb)	-	0.79	0.70	0.59	-	-
Feedstock Price						
$0/ton	-98	3	18	-11	< 0.01	MOD Graze only
$25/ton	-137	-23	-2	-30	< 0.01	MOD Graze-only
$50/ton	34	94	88	57	< 0.01	LOW Graze + feedstock
$75/ton	206	212	179	143	< 0.01	LOW Graze + feedstock
$100/ton	377	329	270	230	< 0.01	Feedstock- only
$150/ton	719	564	450	403	< 0.01	Feedstock-only
Breakeven ($/ton)	45	30	25	34	-	-

CON = no grazing; LOW = one steer per acre; MED = two steers per acre; HIGH = three steers per acre.

Methods

Nativegrass grazing management and biofuel feedstock production

A nativegrass early season grazing and feedstock production demonstration was established on Clarita silty clay soils (Fine, smectitic, thermic, Udic Haplusterts) with 3 to 5 percent slopes. Nativegrass species observed on the site include: switchgrass, little bluestem, big bluestem, dropseed (sp.), johnsongrass, tall fescue, old world bluestem, sideoats grama, silver bluestem, bermudagrass, Scribner's panicum, Texas grama, indiangrass, vine mesquite, Japanese brome, heath aster, western ragweed, thistle (sp.), buckwheat, silverleaf nightshade, persimmon, post oak, buttonbursh, willow (sp.), and Eastern red cedar. The demonstration area totaled 15 acres and was divided into two 7.5 acre paddocks. Paddocks were grazed with stocker steers (600-650 lb) to achieve a forage grazing utilization of either 25% or 50% during a 60-day grazing period. To achieve this utilization percentage, paddocks were stocked at a rate of 0.40 steers/acre for the 25% utilization treatment and 0.80 steers/acre for the 50% utilization treatment for the 60-day grazing period. The duration of the demonstration was three years. Following grazing, nativegrass was biomass was allowed to accumulate to frost and then harvested.

Results

Stocker steer performance on mixed nativegrass was low (Table 3). As in the switchgrass study, early season grazing of the nativegrass reduced feedstock production compared to un-grazed areas (Table 3).

Table 3. Nativegrass early season stocking rate effect on stocker performance and biomass feedstock production.

	Steers/acre	Average grazing days	ADG lbs.	Total Gain lbs.	Feedstock DM lbs/ac
Low	.40	52	1.10	57	1042
High	.80	52	0.85	44	1305
Control	0	0	0	0	3815

Methods

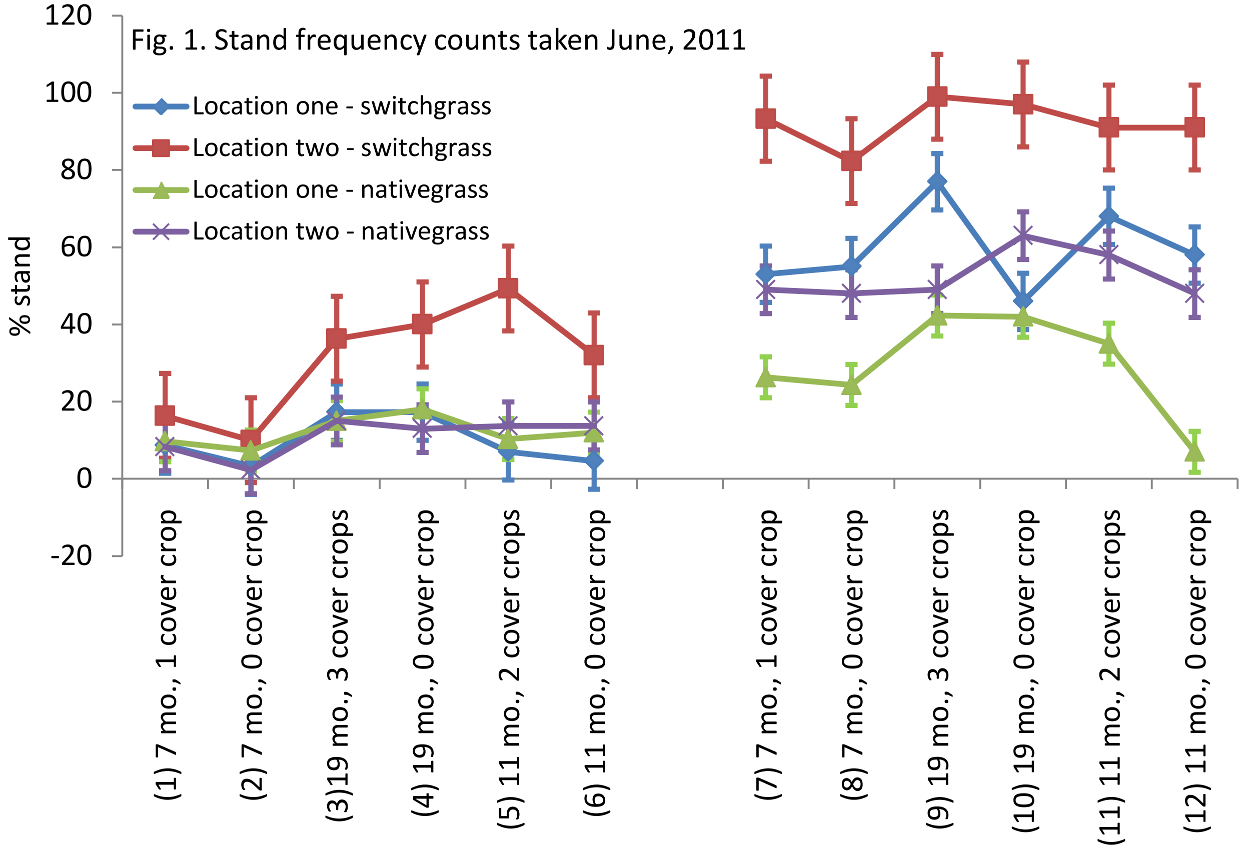
Development of establishment methods of mixed nativegrasses and switchgrass monocultures

Switchgrass (*Panicum virgatum*) is touted for its ability to produce biomass on marginal ground. This biomass is then used as a biofuel feedstock. In the Southern Plains, marginal ground is often in established bermudagrass (*Cynodon dactylon*). In recent years establishing nativegrass into areas occupied with bermudagrass has increased in interest because of wildlife benefits, land value and low maintenance cost. Bermudagrass is difficult to control because of its creeping growth habit due to its formation of rhizomes and stolons, and grass herbicide tolerance. For bermudagrass to be converted to switchgrass or nativegrass, establishment methods need to be developed to suppress or control the bermudagrass allowing time for switchgrass or nativegrass to establish. A two-year study was developed to evaluate the effectiveness of twelve treatments (Table 4) on bermudagrass suppression prior to the establishment of switchgrass ('Alamo') or a mixture of little bluestem (*Schizachyrium acoparium* 'Cimarron'), big bluestem (*Andropogon gerardii* 'Kaw'), indiangrass (*Sorghastrum nutans* 'common'), switchgrass ('Alamo'), and green sprangletop (*Leptochloa dubia* 'common'). Treatments consisted of six no-till and six conventional tillage planting methods, each with or without a winter cover crop of cereal rye (*Secale cereale* 'Maton II') and summer cover crop of sorghum sudan (*Andropogon bicolor* 'Sweet Sunny Sue') and combinations of glyphosate and preparation time (7 to 19 months prior to planting) across two locations. The first year of the study began in the fall of 2009 and the planting date for all first year treatments was April, 2011. Stand counts were taken in June 2011 and the first year harvest date was March 2013. The second year of the study was planted in April 2012. Results varied by location. Switchgrass and nativegrass stand counts across both locations that were no-till planted averaged 20% and 11% respectively (Fig. 1). Switchgrass and nativegrass stand counts across both locations planted with conventional tillage methods averaged 76% and 41% respectively (Fig. 1). On fine sandy loam soil (location 2) switchgrass tillage (Fig. 1) mean treatment yield (7245 lb/acre) was greater than no-till treatment (2821 lb/acre) $P < 0.05$. Tillage had no effect on switchgrass yields (Fig. 2) on a loamy fine sand location (location one). Tillage improved nativegrass yields (Fig. 4, Fig. 5) at both locations ($P < 0.05$). No single treatment appeared superior to others but within the tillage treatments, an 11 month preparation time with 2 cover crops produced more consistent results. Across both locations, weeds (mostly bermudagrass) composed 29.5% of switchgrass plots and 72.5% of nativegrass plots. The difference is attributed to the quicker development of switchgrass stands creating a canopy that shaded and suppressed bermudagrass and other weed development. Based on first year results, establishment methods with tillage are superior to no-till establishment.

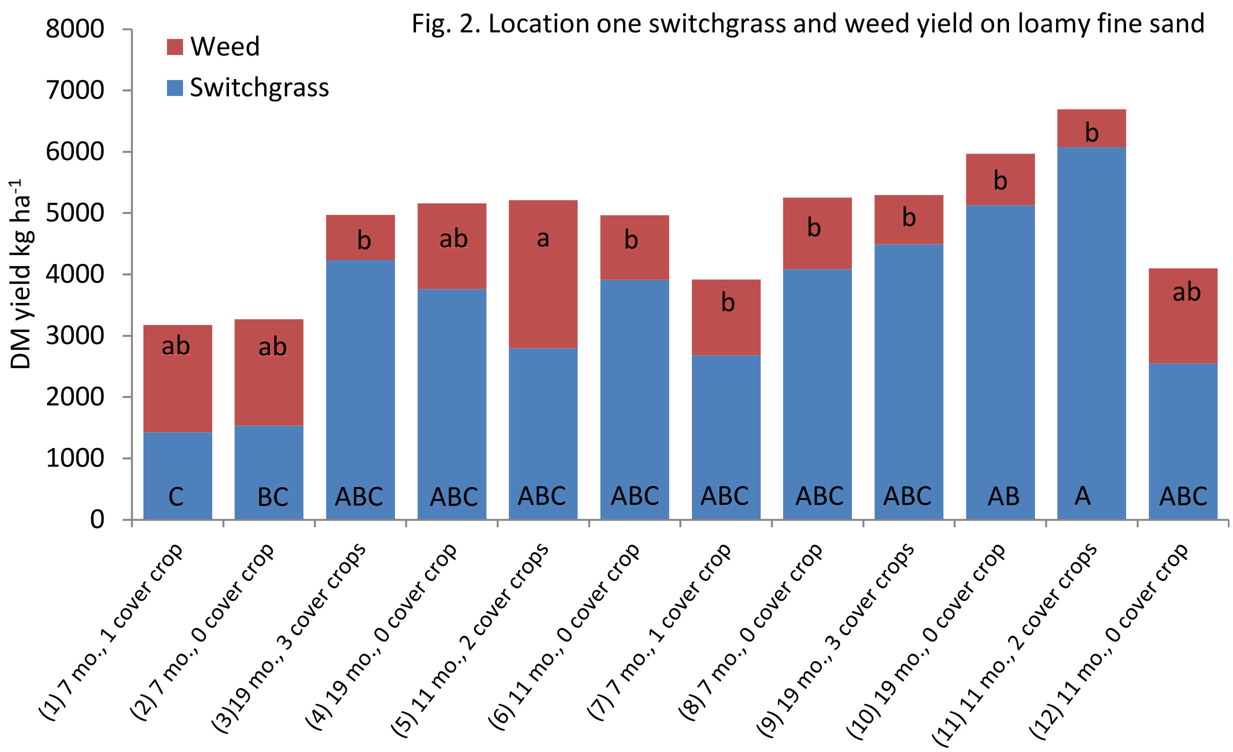
Table 4. Nativegrass and switchgrass establishment treatments

Trt.	Prep. time	Treatment start date	Planting date	# Tillage trips	#Cover crops	Total glyphosate qt/acre	#Glyphosate treatments
1	7 mo.	Sept., 2010	April, 2011	No-till	Cereal rye	14	2
2	7 mo.	Sept., 2010	April, 2011	No-till	0	14	2
3	19 mo.	Sept., 2009	April, 2011	No-till	Cereal rye/sorghum sudan/cereal rye	24	4
4	19 mo.	Sept., 2009	April, 2011	No-till	0	14	2
5	11 mo.	May, 2010	April, 2011	No-till	Sorghum sudan/cereal rye	18	3
6	11 mo.	May, 2010	April, 2011	No-till	0	14	2
7	7 mo.	Sept., 2010	April, 2011	2	Cereal rye	14	2
8	7 mo.	Sept., 2010	April, 2011	2	0	14	2
9	19 mo.	Sept., 2009	April, 2011	4	Cereal rye/sorghum sudan/cereal rye	24	5
10	19 mo.	Sept., 2009	April, 2011	3	0	14	3
11	11 mo.	May, 2010	April, 2011	3	Sorghum sudan/cereal rye	24	3
12	11 mo.	May, 2010	April, 2011	2	0	14	2

Results



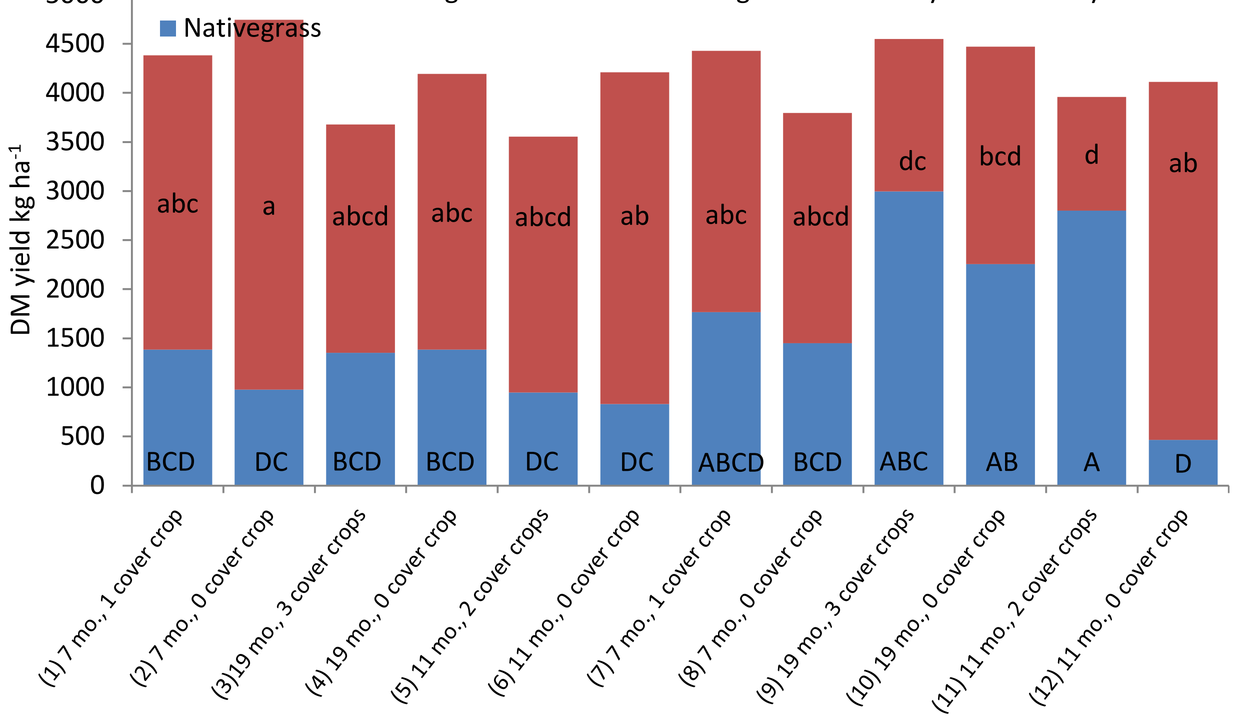
Values are means ± SE of three replications at each location



Means followed by the same letter were not significantly different at *P* < 0.05.

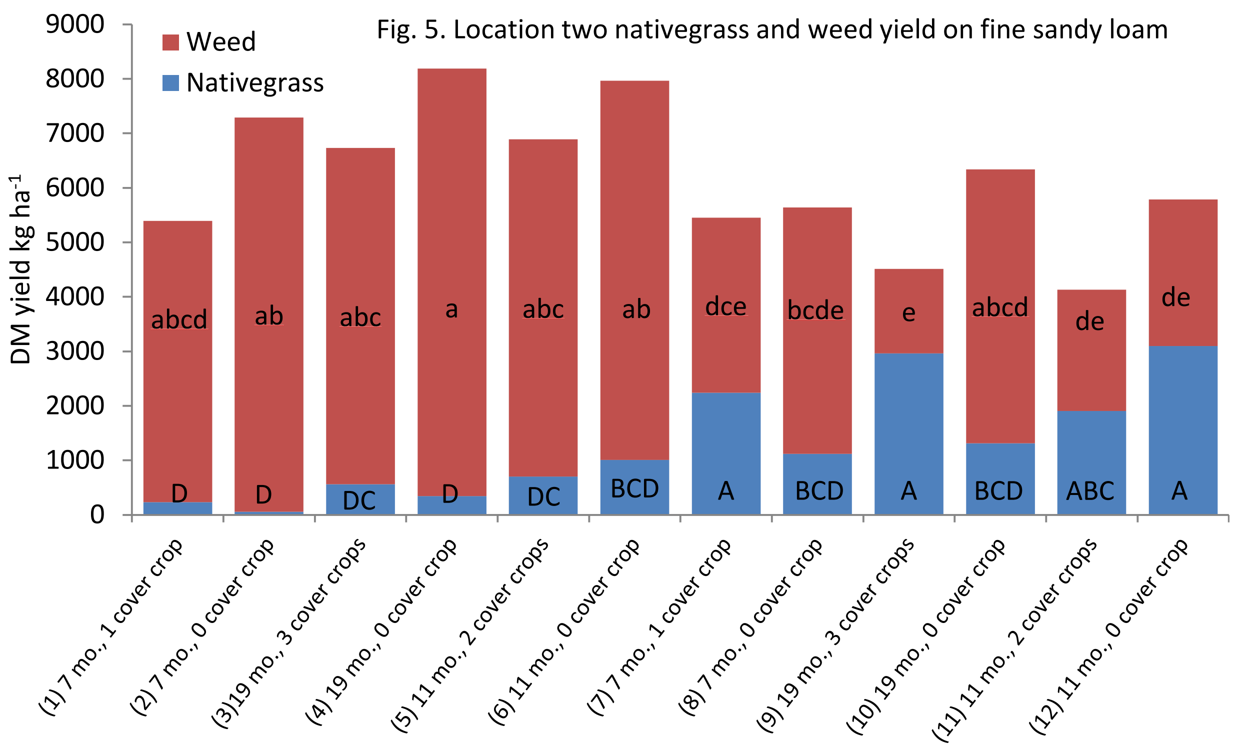
Means followed by the same letter were not significantly different at *P* < 0.05.

Fig. 4. Location one nativegrass and weed yield on loamy fine sand



Means followed by the same letter were not significantly different at $P < 0.05$.

Fig. 5. Location two nativegrass and weed yield on fine sandy loam



Means followed by the same letter were not significantly different at $P < 0.05$.

Establishment summary

Switchgrass stand counts established with tillage (Fig. 1) were greater than 40% across both locations while only one no-till treatment (5) was greater than 40%. A 40% stand has been previously established as a threshold for good stand establishment for potential biofuel feedstock production. Nativegrass stand counts reached 40% only at location two and only for the tillage treatments. Cover crops and preparation time had no effect on switchgrass or native grass yields (Figures 2-5). Suppression of weeds which in this study was primarily bermudagrass was greater in switchgrass plots. Seedbed preparation with tillage improved stand counts and yield of switchgrass and nativegrass. Additional research is needed to improve no-till establishment of switchgrass and nativegrass.

Outreach

Publications:

Rogers, J.K., B. Nichols, J.T. Biermacher, and J. Mosali. 2013. The values of warm-season perennial grasses grown for pasture or biofuel in the southern Great Plains, USA. Crop & Pasture Science. In press.

Rogers, J.K., B. Nichols, J.T. Biermacher, and J. Mosali. 2013. The values of warm-season perennial grasses grown for pasture or biofuel in the southern Great Plains, USA. Proceedings of the 22nd International Grassland Congress. Sydney, AU. September 15-19. pp. 352-353.

Rogers, J. and B. Nichols. 2013. Switchgrass establishment. Noble Foundation Press, NF-FO13-01.

Nichols, B., Rogers, J., Biermacher, J., and Mosali, J. 2012. Switchgrass as a dual-purpose grazing and bioenergy crop. Noble Foundation Press, NF-AS-12-03.

Mosali, J., J.T. Biermacher, B. Cook, and J. Blanton, Jr., 2013. Bioenergy for cattle and cars: a switchgrass production system that engages cattle producers. Agron. J. 105:960-966.

Haque, M., J.T. Biermacher, M.K. Kering and J.A. Guretzky. “Economic Evaluation of Switchgrass Feedstock Production Systems Tested in Potassium-Deficient Soils” *BioEnergy Research*. Published online: DOI 10.1007/s12155-013-9368-6

Kering M.K., J.A. Guretzky, S.M. Interrante, T.J. Butler, J.T. Biermacher, and J. Mosali. “Harvest Timing Affects Switchgrass Production, Forage Nutritive Value, and Nutrient Removal.” *Crop Science* 53(2013):1809–1817.

Haque, M., J.T. Biermacher, M.K. Kering and J.A. Guretzky. “Economics of Alternative Fertilizer Supply Systems for Switchgrass Produced in Phosphorus Deficient Soils for Bioenergy Feedstock.” *BioEnergy Research* 6,1(2013): 351-357.

Kering, M.K., T.J. Butler, J.T. Biermacher, J. Mosali, and J.A. Guretzky. “Effect of Potassium and Nitrogen Fertilizer on Switchgrass Productivity and Nutrient Removal Rates Under Two Harvest Systems on a Low Potassium Soil.” *BioEnergy Research*. 6,1(2013): 329-335.

Biermacher, J.T., M. Haque, M.K. Kering, J.A. Guretzky. “Economic Costs of Soil Nutrient Mining and Benefits from Plant Nutrient Recycling: The Case of Switchgrass Produced for Bioenergy Feedstock.” Proceedings of the 19th International Farm Management Association’s Congress, 2013: 31-38.

Abstract:

Rogers, J.K., and J. Mosali. 2013. Conversion of bermudagrass to a switchgrass monoculture or mixed nativegrass. ASA, CSSA, and SSSA Annual Meeting. Tampa, FL. November 3-6.

Tours, presentations, and field days:

"Rogers, J.K. The value of warm-season native perennial grasses grown for pasture or biofuel in the Southern Great Plains." Invited presentation at the 2013 International Grassland Congress. September 15-19, 2013. Sydney, Australia.

Biermacher, J.T., M. Haque, M.K. Kering, J.A. Guretzky. "Economic Costs of Soil Nutrient Mining and Benefits from Plant Nutrient Recycling: The Case of Switchgrass Produced for Bioenergy Feedstock." Selected paper prepared for presentation at the 19th International Farm Management Association's Congress, Warsaw, Poland, July 21-26, 2013.

Biermacher, J.T., M. Haque, M.K. Kering, J.A. Guretzky. "Economic Costs of Soil Nutrient Mining and Benefits from Plant Nutrient Recycling: The Case of Switchgrass Produced for Bioenergy Feedstock." Invited paper prepared for presentation to members of the 19th International Farm Management Association's Congress, Warsaw, Poland, July 21-26, 2013.

Haque, M., J.T. Biermacher, M.K. Kering and J.A. Guretzky. "Economic Evaluation of Switchgrass Feedstock Production Systems Tested in Potassium-Deficient Soils." Selected paper prepared for presentation at the Western Agricultural Economics Association's Annual Meeting, June 24-28, Monterey, California, June 24-28, 2013.

Rogers, J.K. "Conversion of bermudagrass to a monoculture of switchgrass or mixed native grasses." Presented at the Australian Nuffield Scholar Tour, Noble Foundation, Ardmore, OK. April 2, 2013.

Rogers, J.K. "Native pasture establishment and management." Presented at the East Texas Forage Conference. March 1, 2013. Enlow, TX.

Biermacher, J.T. "Economic Evaluation of Switchgrass Feedstock Production Systems Tested in Potassium-Deficient Soils." Presentation presented to Ceres, Inc. research staff and administration, College Station, TX, February 26, 2013.

Biermacher, J.T. "Economic Potential of Using Switchgrass Pastures to Produce Beef Gain and Bioenergy Feedstock." Presentation presented to Ceres, Inc. research staff and administration, College Station, TX, February 26, 2013.

Rogers, J.K. "Small plot research." Presented to the Farm Journal Editorial Staff. December 13, 2012. Noble Foundation, Ardmore, OK.

Biermacher, J.T. “Economics Opportunities and Challenges for Producing Switchgrass in the Cattle Belt.” Invited Speaker. Economic Viability of Switchgrass as a Biofuel Feedstock Workshop, Ardmore, Oklahoma, August 27, 2012.

Biermacher, J.T. M. Haque, M.K. Kering, and J.A. Guretzky. **“**Economic Considerations of Soil Nutrient Mining and Remobilization Associated with Switchgrass Feedstock Production.” Selected paper presented at the Agricultural and Applied Economics Association’s Annual meetings, Seattle, Washington, August 12-14, 2012.

Rogers, J.K. “Forage and grazing research.” Presented at the Australian Nuffield Scholar Tour, Noble Foundation, Ardmore, OK. August 14, 2012.

Blanton, J.R., J.T. Biermacher, J. Mosali, and B.J. Cook. “Using Switchgrass Pastures to Produce Stocker Cattle Gain and Bioenergy Feedstock I: Production Potential.” Selected paper prepared for presentation at the American Animal Science Association’s Annual meeting, Phoenix, Arizona, July 15-19, 2012.

Biermacher, J.T., J.R. Blanton, Jr., J. Mosali, and B.J. Cook. “Using Switchgrass Pastures to Produce Stocker Cattle Gain and Bioenergy Feedstock II: Economic Potential.” Selected paper prepared for presentation at the American Animal Science Association’s Annual meeting, Phoenix, Arizona, July 15-19, 2012.

Rogers, J.K. “Switchgrass establishment, grazing, and biofuels.” Presented at the Noble Foundation Grazing Workshop, Ardmore, OK. June 21, 2012.

Rogers, J.K. “Understanding forage quality.” Presented at the Noble Foundation Grazing Workshop, Ardmore, OK. June 21, 2012.

Rogers, J.K. “Re-establishment of warm-season grasses.” Presented at the Northeast Texas pesticide seminar and licensing school, Mount Pleasant, Texas. January 17, 2012.

Rogers, J.K. “Converting established bermudagrass to a monoculture of switchgrass or mixed native grass.” Presented to the Noble Foundation Agriculture Division, Noble Foundation, Ardmore, OK. November 9, 2011.

Rogers, J.K. “Yield, yield distribution, and forage quality of warm-season perennial grasses grown for pasture or biofuel in south central Oklahoma.” Presented at the ASA, CSSA, SSSA annual meetings, San Antonio, TX. October 17, 2011.

Rogers, J.K. “Converting established bermudagrass to a monoculture of switchgrass or mixed native grass.” Invited presentation at the S319 Water Quality Session, Jay Community Center, Jay, OK. September 13, 2011.

Rogers, J.K. “Switchgrass biofuel research.” presented to the Aberystwyth University Ibers tour group, Noble Foundation, Ardmore, OK. 2011.

Rogers, J.K. “Switchgrass biofuel potential.” presented to the North Central Texas College Biology Class tour, Noble Foundation, Ardmore, OK. 2011.

Rogers, J.K. “Converting established bermudagrass to a monoculture of switchgrass or mixed native grass.” Invited presentation to The Oklahoma Invasive Plant Council annual meeting, Oklahoma City, OK. 2011.

Rogers, J.K. “Converting established bermudagrass to a monoculture of switchgrass or mixed nativegrass.” presented at the Texas A&M research tour, Noble Foundation, Ardmore, OK. 2011.

Rogers, J.K. “Converting established bermudagrass to a monoculture of switchgrass or mixed nativegrass.” presented at the Texas A&M Overton Experiment Station research tour, Noble Foundation, Ardmore, OK. 2011.

“Rogers, J.K. “Bio-energy opportunities in switchgrass.” presented at the retired veterinarians tour, Noble Foundation, Ardmore, OK. 2011.

Rogers, J.K. “Nativegrass establishment.” presented at the Pasture Management Conference, Texas Agri-Life Extension, Myers Park, McKinney, TX. 2011.

Rogers, J.K. “Bio-energy opportunities in switchgrass.” presented to Nebraska FFA Tour Group, Noble Foundation, Ardmore, OK. 2011.

Rogers, J.K. “Grazing preferences of warm season perennial grasses.” presented at the Fannin County Forage Tour. November 5, 2010. Bonham, TX.

Pictures

Stocker cattle grazing switchgrass.

Stocker cattle grazing switchgrass.

Planting no-till cover crops for the establishment study.

Switchgrass established for the grazing study.

Emerging switchgrass planting for the establishment study.

Switchgrass as a Dual-Purpose Grazing and Bioenergy Crop

THE SAMUEL ROBERTS NOBLE FOUNDATION

by Bryan Nichols, James Rogers, Jon Biermacher and Jagadeesh Mosali

NF-AS-12-03

Introduction

The Energy Independence and Security Act of 2007 set U.S. renewable fuel standards requiring the production of 16 billion gallons of ethanol from cellulosic biomass feedstocks by 2022. Switchgrass (*Panicum virgatum* L.), a native warm-season perennial grass, was evaluated by research funded through the United States Department of Energy as a primary cellulosic feedstock to achieve this goal. Switchgrass was identified because of its high biomass potential, perennial life-form and adaptability to marginal soils (McLaughlin and Kszos, 2005).

Switchgrass is grouped into two ecotypes, lowland and upland. Lowland switchgrass ecotypes (i.e., Alamo), in particular, have been identified as ideal feedstocks for the Southern Great Plains due to their adaptation to the region (Cassida et al., 2005). However, the expense and risk associated with establishment, maintenance and harvest of this crop combined with a lack of markets has prevented widespread adoption by landowners. In addition, biorefineries are reluctant to expend funds for the development of cellulosic refineries when production costs remain higher than costs for corn ethanol or other alternative fuels (Yaccobucci and Schnepf, 2007). Therefore, an alternative use for switchgrass is needed to encourage establishment as a potential feedstock in support of future biorefineries.

The stocker cattle industry is characterized by the development of young, lightweight calves on forage-based diets. As of Jan. 1, 2012, there were 1.59 million stocker cattle grazing small grains pastures (wheat, rye, etc.) in Oklahoma, Kansas and Texas (NASS, 2012). Traditionally, these forages are grazed from November through April, at which time cattle are either returned to the ranch for breeding purposes or moved to a feed yard for finishing prior to slaughter.

Up to 43% of lowland-type switchgrass total yield is produced in May, with crude protein measured above 10% (Rogers et al., 2012). Because of its early spring, high-quality forage production, switchgrass has the potential to be utilized in stocker grazing systems by complementing traditional cool-season annual forage systems and extending grazing through May. In addition, switchgrass possesses considerable regrowth potential following grazing, enabling significant end-of-season biomass production for use as bioenergy feedstocks (Anderson and Matches, 1983). The dual-use potential of this forage allows the producer an opportunity to diversify utilization of establishing switchgrass as biorefineries are developed.

Methods

In 2008, researchers at the Noble Foundation began a three-year study to determine the effects of grazing switchgrass at different stock densities in a dual-purpose stocker cattle grazing/bioenergy feedstock system. Switchgrass pastures used in this study were established in 2007 and had been in clean-tilled small grain production for the previous 25 years.

Steers used in this experiment had grazed cool-season annual rye pastures for a minimum of 100 days prior to the beginning of this trial and weighed an average of 765 pounds at grazing initiation. Treatments were four stock densities: control (no grazing; CON), low density (one steer per acre; LOW), moderate density (two steers per acre; MOD) and high density (three steers per acre; HIGH). Grazing began when plants reached a height of 14 inches. This initial grazing height was determined by researchers in Nebraska to result in optimal animal gains when grazing switchgrass (Anderson et al., 1988). Steers were removed from pastures when forage height was reduced to 3 inches or quality was deemed too low to support animal growth. The three-year average crude protein content of the LOW stocking density at grazing termination was 9.0%.

Results

By design, forage availability was not different among treatments at trial commencement and averaged 1,522 pounds per acre. Grazing began on April 21, May 7 and April 30 in 2008, 2009 and 2010, respectively. Forage quality was very good when grazing began and declined over the duration of the study with the most rapid decrease occurring over the first 28 days (Figures 1 and 2). As expected, grazing duration differed ($P < 0.05$) among treatments (80, 43 and 28 days for LOW, MOD and HIGH, respectively).

Average daily gain of the LOW treatment tended to be less ($P = 0.12$) than the MOD and HIGH treatments (Figure 3). Although forage intake was not measured, forage quality of the standing crop is reported in Table 1. Crude protein and total digestible nutrient content were greater for MOD and HIGH stocking densities compared to the LOW stocking

Figure 1. Three-year average crude protein content of switchgrass during the growing season

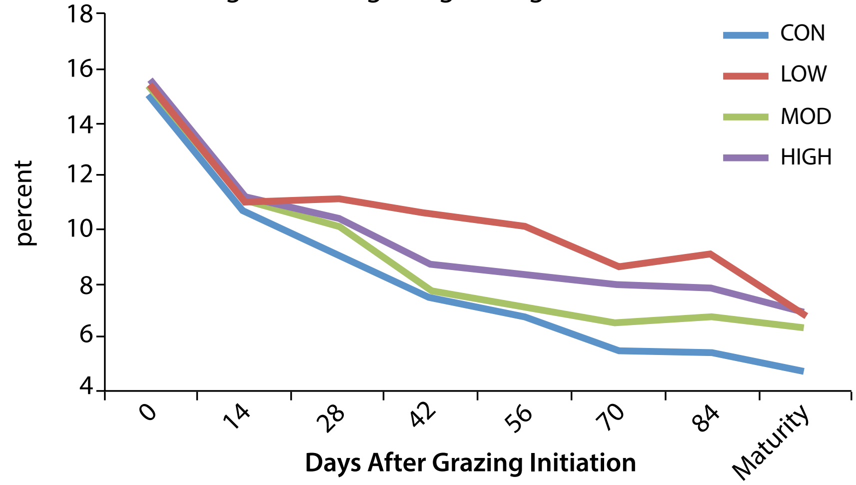


Figure 2. Three-year average *in vitro* dry matter digestibility of switchgrass during the growing season

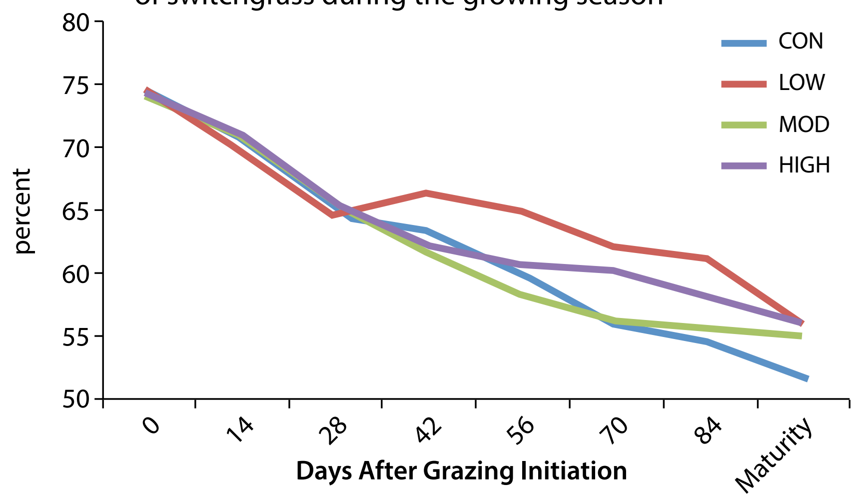


Table 1. Average forage quality during switchgrass grazing over three years

Treatment[1]	CP, %	TDN, %
LOW	8.73[a]	59.44[a]
MOD	11.08[b]	61.84[b]
HIGH	10.45[b]	62.77[b]

[1]LOW = one steer per acre; MOD = two steers per acre; HIGH = three steers per acre.
[a,b,c]Values with differing superscripts in a column differ (P < 0.05).

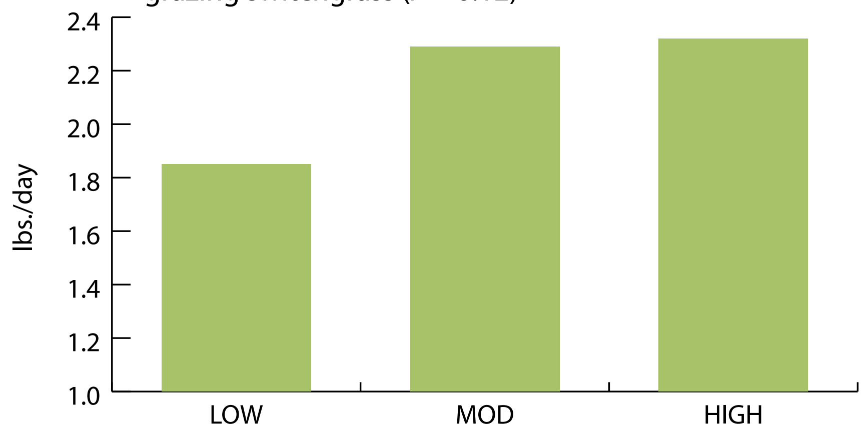
density ($P < 0.05$). Total gain per acre tended to be greater ($P = 0.08$) for MOD and HIGH treatments over the LOW stock density (Figure 4).

Economics

Production data collected from this experiment were used to determine the expected benefits and costs for seven grazing, feedstock, or grazing and feedstock systems for a range of cattle and feedstock price scenarios. The seven systems included: feedstock-only; three grazing-only systems at LOW, MOD or HIGH stock densities; and three systems representing grazing plus feedstock at LOW, MOD or HIGH stock densities. Value of gain estimates were determined using 2011 CME cattle futures prices. Oklahoma custom rates for establishment and harvest costs published by the Oklahoma Cooperative Extension Service were used in the analysis (Doye and Sahs, 2011). Net returns to land, owner's labor and management, and farm overhead are summarized in Table 2.

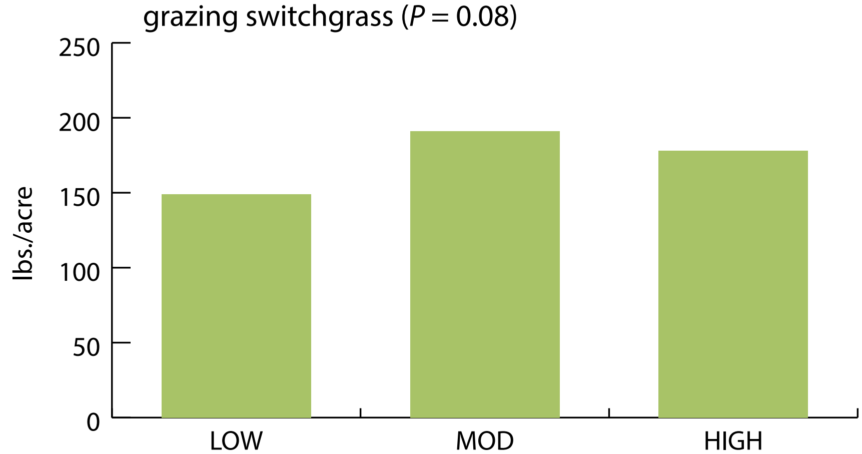
Value of gain for 2011 was 79 cents, 70 cents and 59 cents per pound for LOW, MOD and HIGH stock densities, respectively. These values are different because grazing

Figure 3. Three-year average daily gain of steers grazing switchgrass ($P = 0.12$)



[1]LOW = one steer per acre; MOD = two steers per acre; HIGH = three steers per acre.

Figure 4. Three-year average total gain per acre of steers grazing switchgrass ($P = 0.08$)



[1]LOW = one steer per acre; MOD = two steers per acre; HIGH = three steers per acre.

Table 2. Net Returns and Optimal System by Stocking Rate, Value of Gain and Feedstock Price

	Stocking Rate					
	CON	LOW	MOD	HIGH	P > F	Optimal System
2011 CME Value of Gain ($/lb)	-	0.79	0.70	0.59	-	-
Feedstock Price	Net Return ($/acre)					
$0/ton	-98	3	18	-11	< 0.01	MOD Graze-only
$25/ton	-137	-23	-2	-30	< 0.01	MOD Graze-only
$50/ton	34	94	88	57	< 0.01	LOW Graze + feedstock
$75/ton	206	212	179	143	< 0.01	LOW Graze + feedstock
$100/ton	377	329	270	230	< 0.01	Feedstock-only
$150/ton	719	564	450	403	< 0.01	Feedstock-only
Breakeven ($/ton)	45	30	25	34	-	-

[1]CON = no grazing; LOW = one steer per acre; MOD = two steers per acre; HIGH = three steers per acre.

duration was different between treatments, which affected the time of marketing. At these cattle prices, grazing only at a MOD stock density was the most profitable system with net returns of $20/acre for feedstock prices at or below $25/ton. At feedstock prices of $50/ton, the LOW stock density plus feedstock system was the most profitable choice, realizing a net return of $94/acre. Grazing was no longer economically competitive at a feedstock price between $75 and $100/ton. At $100/ton, net return was greatest for the feedstock-only system, which realized an average net return of $376/acre.

Conclusion

The results of this study indicate that the most economical grazing/feedstock system depends on both feedstock and cattle prices. We found that under 2011 cattle market conditions and assuming that a biorefinery does not currently exist in the region (the current price of feedstock is $0/ton), switchgrass should be grazed at a moderate stocking density (approximately 1.7 AUE/acre) for a duration of roughly 45 days. Under this market scenario, producers could earn a marginal profit of $20 per acre, which could be sustainable during the construction phase of a large-scale biorefinery. However, long-term success of the switchgrass grazing enterprise hinges significantly on a biorefinery's ability to purchase feedstock at a price between $50 and $75/ton. For this market scenario, producers could earn between $94 and $212 per acre by grazing switchgrass at a low stock density (0.85 AUE/acre) for approximately 80 days. In cases where a biorefinery offered a price of $100/ton or more, it would be most economical to produce only feedstock. Producers are encouraged to formulate budgets based on current market conditions before developing a grazing strategy. ■

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This research was partially funded by a Conservation Innovation Grant from the Natural Resources Conservation Service.

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Switchgrass Establishment

THE SAMUEL ROBERTS NOBLE FOUNDATION

by James Rogers and Bryan Nichols

NF-FO-13-01

Introduction

Switchgrass (*Panicum virgatum* L.), is a native, warm-season (C_4) perennial grass that can be found growing over the eastern two-thirds of the United States, Central America and southern Canada (Fig. 1). Interest in switchgrass propagation has increased over the past few years due to its potential as a bioenergy feedstock, high yields and ability to provide early season high quality forage to grazing animals (NF-AS-12-03).

Switchgrass can be divided into two major ecotypes: "upland" and "lowland." Lowlands are taller, higher yielding, possess coarser leaves and tend to be more rust resistant than upland types (Fig. 2). Lowland types can have a very strong bunch-type growth habit if left unharvested and tend to be very rapidly growing. Lowland switchgrass is often found on floodplains and similar areas with high moisture availability. Upland types are shorter and tend not to be as rapidly growing as lowlands, but are more cold tolerant and are often found as a component of the native grass prairies in more northern latitudes (Rogers et al., 2012). In general, lowland types are adapted from the northern edge of the transition zone and south, while upland types are adapted from the southern edge of the transition zone and north (Fig. 3). In Oklahoma, lowland types are best suited from I-40 south and I-35 east, while the northwest portion of the state is best suited for the upland types. Maximum production will occur in regions receiving annual precipitation in excess of 35 inches. Switchgrass can grow on a wide range of soil types

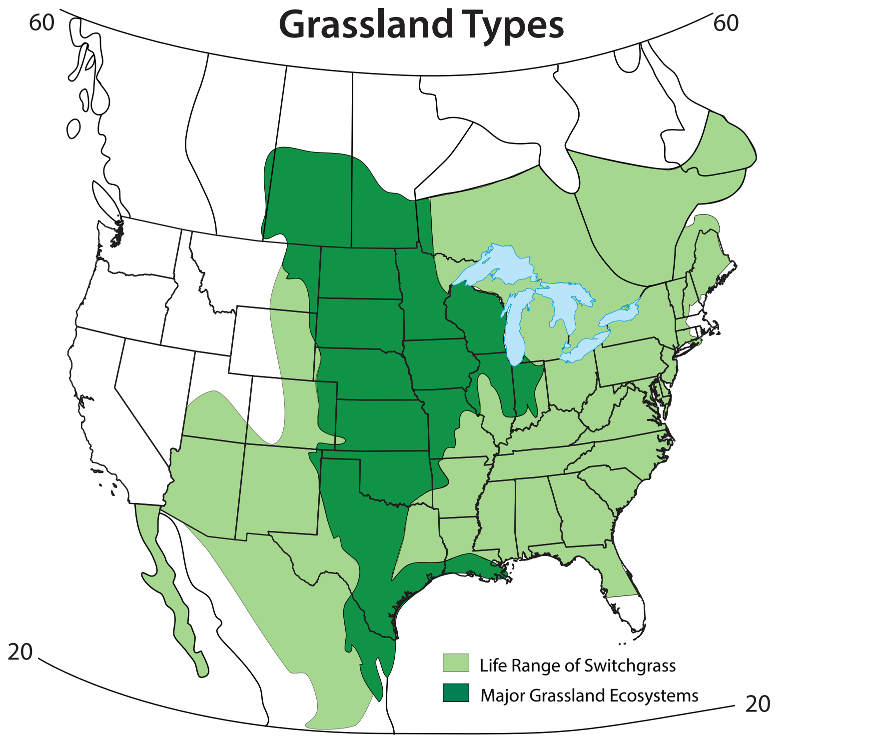

Fig. 1. Switchgrass adaptation areas in North America. (McLaughlin and Walsh, 1998)

Fig. 2. Lowland switchgrass on the left and upland switchgrass on the right. Photo from Michael D. Casler, USDA.

from sands to clay loams, but is best suited to well drained, finer textured soils with a pH range of 5 to 8.

Considerations Prior to Establishment

In ideal planting conditions, switchgrass can emerge in as little as three to seven days. In less than ideal conditions, switchgrass can be a slow and difficult crop to establish due to several factors. Weed competition is the factor under producer control that most commonly causes stand failures. Switchgrass is a weak seedling and is not very tolerant of weed competition, especially grassy weeds. Planting switchgrass in a field that is known to have high levels of crabgrass or johnsongrass can cause establishment failures unless these are controlled. Planting depth is another consideration. Planting at depths greater than ¾ inch can result in delayed or failed emergence due to small seed size (Fig. 4) and low seedling vigor. Switchgrass can also have a high percentage of naturally dormant seed. In general, seed that is two to three years old will have lower levels of seed dormancy than new seed. Approaches to manage seed with high dormancy include storing the seed for at least a year, wet-cold stratification prior to planting, dormant season planting or using a planting rate based on percent germinable seed. Germination tests must be performed in order to determine the proper course of action. Because of seed dormancy issues, producers need to be patient with a developing stand. What may look like a poor stand in year one can develop into a vigorous stand by year three. Switchgrass stands are typically fully developed by year two or three

Site Preparation

Research at the Noble Foundation has shown that stand establishment

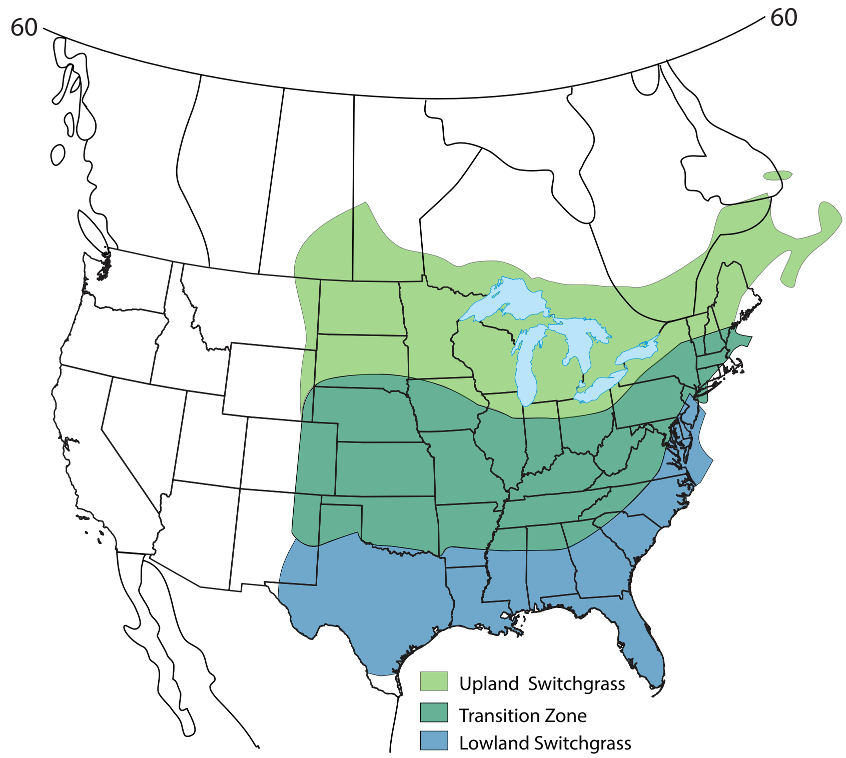

Fig. 3. Approximate adaptation ranges for upland and lowland switchgrass ecotypes (Casler et al., 2011)

Fig. 4. Switchgrass seed. Source: Noble Foundation

is much higher when a seedbed is prepared with tillage versus using no-till methods. A two-year study was conducted where switchgrass was planted into a site that had previously been bermudagrass. Switchgrass planted into a tilled, prepared seedbed resulted in a 62 percent first-year stand compared to a 14 percent first-year stand no-tilled into terminated bermudagrass residues.

The amount of time required for preparation depends on the current state of the intended site. Preparing a retired crop field that has been left fallow over winter is fairly simple. Begin site preparation at least six months in advance with a soil test and initial tillage. Avoid planting into areas that have a high weed seedbank. Switchgrass was chosen as a potential biofuel due to its ability to grow in marginal soils. It can withstand slightly acidic soils with a pH of 5.5, but an optimal pH range is 6.0 to 7.0. Soil fertility requirements for switchgrass establishment are low compared to many other crops. A Mehlich III soil phosphorus (P) index of 20 and potassium (K) index of 125 should be sufficient for switchgrass establishment. If P and K are needed, apply prior to seeding and incorporate with tillage. Avoid nitrogen application at establishment as this tends to increase weed competition. If using conventional tillage, begin initial tillage in the late fall. In the spring, tillage can again be used to eliminate weeds and create a firm seedbed. Another option if additional spring tillage is not required is to apply a burndown herbicide to eliminate existing weeds, then plant. If switchgrass is being established into warm-season perennial pastures such as bermudagrass, multiple years may be required to eradicate the existing vegetation.

Fig. 5. Switchgrass seedlings. Source: Noble Foundation

Planting

Switchgrass seed is small (280,000 seeds/pound), slick and tends to flow through planting equipment very well (Fig. 4). Seeding rate is 5 to 6 pounds pure live seed (PLS)/acre in high rainfall areas and 5 to 10 pound PLS/acre in low rainfall areas. Because switchgrass seed flows very well, it can be planted using conventional seeding equipment such as conventional grain drills, Brillion seeders or no-till drills, or by broadcasting. Prior to planting, make sure that the equipment you are using is in good working order, drop tubes are free of obstructions and the planter is calibrated for the target seeding rate. Successful stands have resulted from planting dates from December to May. Dormant season plantings should be done from December through February. Spring plantings should occur from April 1 through May 1 or when the average soil temperature reaches 58° F to 60° F at 2 inches. Switchgrass seed germination occurs at 60° F and higher. Planting later than early May does not allow time for adequate root system establishment before the hot and dry periods of summer. Seed should be planted ¼ inch to ½ inch deep, into a firm seedbed and with good seed-to-soil contact. Planting equipment should be checked regularly to ensure that it is functioning correctly and that the correct seeding depth and soil coverage is being achieved.

Stand Evaluation

Switchgrass stands can be evaluated two to three weeks post-planting. It is important that switchgrass seedlings are identified correctly when evaluating the stand (Fig. 5). The easiest way to identify switchgrass seedlings is to pull the plant while leaving the root structure intact. The seed coat should still be attached to the primary root in young seedlings. Seedlings will also be smooth in appearance and have a lower stem that is purplish in color.

One easy way to evaluate the stand is by using a 5-foot by 5-foot cattle panel with 1-foot squares. Place the panel on the ground in a random location and count the number of squares where switchgrass seedlings are present. Repeat this process four times. The sum of the number of squares with switchgrass seedlings present is equal to the stand percentage. Percent stand will change over time. Stands with an initially high stand may thin over time while a thin initial stand may thicken over time until stand equilibrium is reached. An initial stand count of 50 percent or higher is considered successful.

Weed Control

Switchgrass stands in the establishment year may have high weed competition. These weeds may be managed by either mowing or applying herbicides labeled for use in switchgrass. If mowing to reduce weed cover, do not mow into the tops of the switchgrass. Avoid mowing once switchgrass stems begin to elongate. There are few labeled herbicides for use in switchgrass. Glyphosate or paraquat may be used for preemergence burn-down applications, but care must be taken to make sure that switchgrass has not begun to emerge at the time of application. In no-till plantings, glyphosate can be used within three days of planting to kill emerged weeds prior to the emergence of switchgrass. Several postemergence herbicides, such as 2,4-D, can be used on switchgrass, but should not be applied until three or four leaves are present or plants are 3 to 4 inches tall to avoid injury. Note that switchgrass is not necessarily tolerant of all herbicides labeled for use on native or range grasses. Be sure to consult the label or a local authority for switchgrass tolerance to a particular herbicide. For example, herbicides containing the active ingredient imazapic are labeled for weed control in range grasses, but are very hard on switchgrass. Follow all herbicide label directions.

Summary

Successful switchgrass establishment requires adequate preparation, time and patience. Good stands result when seedbeds are prepared well, good seed is planted at the correct seeding rate and depth, and, as always, weather conditions are favorable. Producers need to keep in mind that a successful stand may not result in one year; full stand development may not be reached until year three. ■

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