Biomass, Nitrogen, and Ash Content in Stands of Switchgrass and Big Blue Stem in Northwestern Pennsylvania

Editor

Lisa Alexander

Co-Editor

Abby Conroy

Principal Investigator

Richard D. Bowden, Ph.D

Co-Investigators

Lisa Alexander
Cassie Buseck
Robert Campbell
Juanita Campbell-Heredia
Abby Conroy
Leah Cover
James Fago
Margaret Findley
Elissa Gordon
Benjamin Greiner
Ryan J. Hollihan
Alexander Lee
Thomas Ludwig
Benjamin Marcy-Quay
Melissa Martin
Andrew Pfeifer
Melissa Robelo
Luca J. Scalera
Andrew Silling
Nicholas Silva
Emily Thornton
Timothy Wetsell
Kaitlyn Wills

Allegheny College Center for Environmental and Economic Development
Publication CEED-2008-4

Introduction

Climate change is an increasingly important global issue garnering governmental and media attention. In response to this pressing concern, biofuels are gaining increased attention as alternate energy sources. In 2001, biomass fuel generated about 1.8% of the total 307 trillion kilowatt-hours of electricity produced in the United States (Tenenbaum, 2002). Currently, almost 7% of the United State's energy is renewable, 43% of which is derived from biomass (Bull & Turner, 1999). The U.S. Department of Energy has set goals to replace 30% of the liquid petroleum transport fuel with biofuels by 2025 (Ragauskas et al. 2006).

A biofuel that appears to be a viable biomass crop is switchgrass (*Panicum virgatum*) Research on switchgrass as a potential energy crop began in 1998 (McDonald et al.2002), and according to Roth (2005), it valuable because it is a warm season perennial grass that has a high fiber content, high biomass yield, is drought resistant, easily established, and has a perennial growth strategy. Additionally, it is a relatively inexpensive crop because it can propagate seeds with low inputs of fertilizers and pesticides (Roth et al. 2005). As a biomass crop, switchgrass is generally carbon neutral, meaning that the CO_2 emissions from its combustion are recaptured by the next crop. Switchgrass is native to North America, which gives it a high resistance to local pests and diseases. It grows well in a wide range of soil types and moisture levels, has a high yield, and is compatible with current farming methods, including no-till and terraced farming (McLaughlin et al. 1999).

Switchgrass has numerous benefits aside from being a viable fuel alternative. It has been shown to improve water quality and reduce carbon emissions through carbon sequestration (Duffy and Nanhou 2002). When switchgrass is burned, the emissions contain little sulfur dioxide and mercury, two pollutants emitted by burning coal (Tenenbaum 2002). It has been found to positively influence the diversity of Wisconsin grassland bird species of management concern (Roth 2005) and can create breeding habitats for Iowa grassland birds (Murray and Best 2003).

Because biomass removal is also accompanied by nutrient removal during harvest, several studies have examined relationships between switchgrass and soil nutrients. Current work suggest that switchgrass affects and is affected by soil nitrogen content, and indicates that such affects vary by location. Hartnett (1993) selected 12 random switchgrass clones for nitrogen addition and found that although nitrogen addition caused no significant changes in rates of horizontal clonal expansion or ramet population growth rates, it did result in a significant increase in the percent of ramets flowering and producing seeds (Hartnett 1993). Sanderson and Reed (2000) found that N additions can increase the amount of developed root systems, thus influencing rates of above-ground competition and total productivity (Sanderson and Reed 2000). Muir et al. (2001) found that N fertilizer and rainfall influence switchgrass in the south-central United States; yearly biomass production increased after one application of fertilizer. Tiller mass and density increased in plots that received N fertilizer additions while plots that did not gradually deteriorated. This study concluded that sustained switchgrass production is not feasible without added N (Muir et. al 2001).

In addition to site N demands of biofuels, the ash content of biomass is an important concern. Although ash is not a pollutant, it is a remnant of combustion that must be removed. High ash contents may discourage household consumers as well as industrial users of biofuels. High ash content may affect power plants by corroding and fouling machinery (Monti et al. 2007).

Nitrogen clearly affects both the growth of switchgrass and soil quality. To be an economically feasible, environmentally sound biofuel source, it is critical to know the rate of nitrogen removal that will occur during biofuel harvest. Our goal for this study was to determine the nitrogen removed during harvest of two biofuel plant species (Switchgrass and Big Blue Stem) in northwestern Pennsylvania.

Methods

The study was conducted during September and October of 2007 on fields being used by Ernst Conservation Seeds in Northwestern Pennsylvania (Figure 1). In this region of Northwestern Pennsylvania, switchgrass is typically harvested during September and October. Two fields had been planted to switchgrass; one field was planted to a strain know as Cave-in-Rock, the other was planted to a strain known as Shawnee. A third field was planted to Big Blue Stem (*Andropogon gerardi*). The Big Blue Stem field was approximately within 15 miles of the switchgrass fields while the two switchgrass fields were approximately 1 mile apart. The fields were each in excess of 10 ha, and had similar soil composition, weather conditions, and surroundings.

We used a 200 m X 200 m area in each field, and randomly selected thirty-six 1 X 2 m sampling plots. After the plots were delineated, we cut the grass at 10 centimeters (4 inches) above the soil to simulate the height at which plants are normally harvested. The cut grass was placed into airtight plastic bags, sealed, labeled, and transported back to the laboratory for analysis.

For each of the thirty-six biomass samples, all grass was hand-cut into approximately 10 centimeter (4 inch) pieces and mixed within each bag to insure random selection of sub-samples used for analysis. The bags were then weighed to determine total wet mass. For each sample, two paper bags were filled with approximately 100 g of wet material. One sample was dried at 60° for a minimum of 48 hours for N analysis. The other samples were weighed to determine total wet weight and then dried at 105° for a minimum of 48 hours to determine dry weight. An air dry to oven dry conversion determined the total dry weight of each biomass sample.

The samples used for N analysis were ground in a Wiley Mill, which was vacuumed between samples to prevent sample contamination. To determine N, ground samples ranging from 0.09-0.12 grams were weighed into sampling boats and analyzed with a Leco CNS Determinator. To measure ash content of the samples, one gram samples were weighed, placed into a crucible, and combusted in a muffle oven at 550°C for at least 4 hours.

Results

Productivity varied among the three types of biomass tested (Table 1, Appendix 1). Big Blue Stem was the most productive; it had 39 percent more mass than Switchgrass Shawnee and 16 percent more than Switchgrass Cave-in-Rock. Switchgrass Cave-in-Rock had 10 percent more mass than Switchgrass Shawnee, making Switchgrass Shawnee the least productive of the three species. Each grass type exhibited considerable variation in dry mass within each site (Figure 2). For Big Blue Stem, the total range was 0.868kg/m^2, approximately equal to the mean biomass content of each plot (Table 2). Switchgrass Cave-in-Rock and Switchgrass Shawnee had ranges of .0559kg/m^2 and 0.628kg/m^2, respectively, between the most and least productive plots.

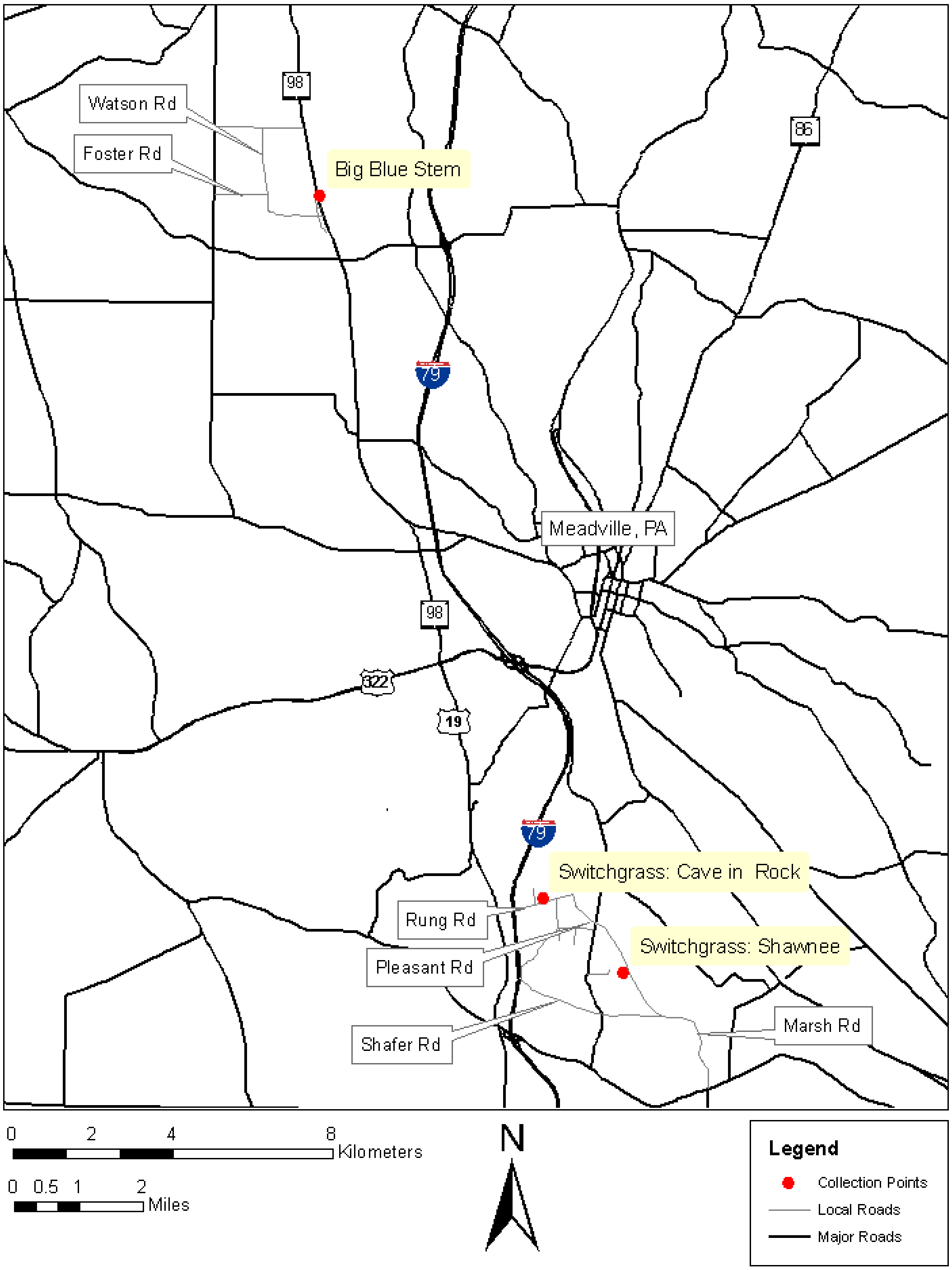

Figure 1. Locations of sampling sites.

Table 1. Mass of Big Blue Stem, Switchgrass Shawnee, and Switchgrass Cave-in-Rock.

	MT/ha	Tons/acre
Big Blue Stem	9.42	4.19
Switchgrass Shawnee	6.80	3.02
Switchgrass Cave-in-Rock	8.10	3.61

Table 2. Variability of biomass across sites

	(kg/m2)		
	Big Blue Stem	Switchgrass Shawnee	Switchgrass Cave-in-Rock
Mean	0.942	0.68	0.81
SE	0.073	0.048	0.043
Rel. Variation (%)	27.0	24.4	18.3
High	1.328	1.124	1.113
Low	0.46	0.496	0.554
Range	0.868	0.628	0.559

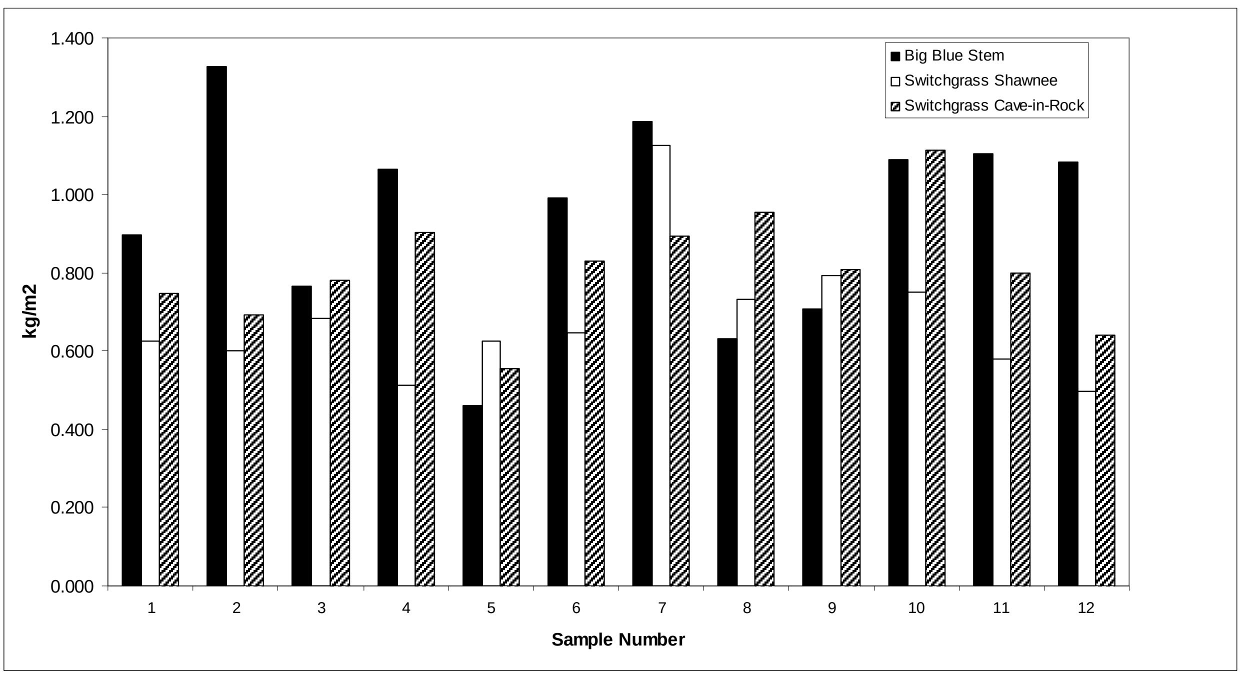

Figure 2. Variation of biomass among biofuel grasses.

Big Blue Stem had the highest N concentration (Figure 3, Appendix 2) of the three biofuels. Switchgrass Shawnee had a noticeably lower N concentration. Big bluestem had the highest productivity but was the least efficient in N use, as expressed in tissue N concentration.

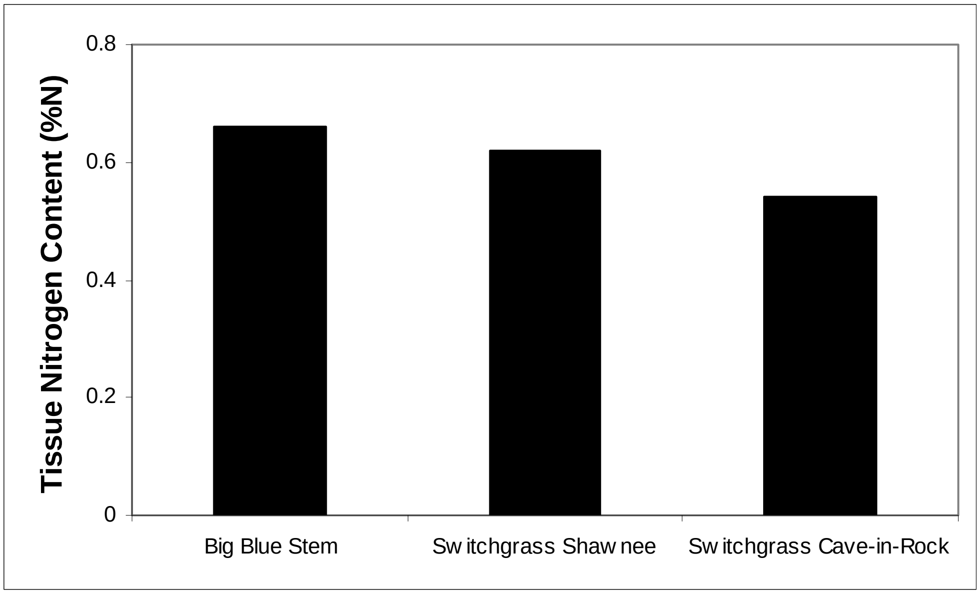

Figure 3. Tissue N concentration in Big Blue Stem, Switchgrass Shawnee, and Switchgrass Cave-in-Rock.

Big Blue Stem also had the highest total N withdrawal per site (Figure 4), removing removed 50% more N than Switchgrass Shawnee and 41% more than Switchgrass Cave-in-Rock. Switchgrass Cave-in-Rock removed 6% more N than Switchgrass Shawnee. While this is not a large difference, Switchgrass Shawnee did have the least amount of N withdrawal, once again making it the most efficient in terms of nitrogen removed per biomass produced.

Big Blue Stem had the lowest ash content (Figure 5, Appendix 3); Switchgrass Shawnee and Switchgrass Cave-in-Rock's were very similar in ash content. Overall, although Big Blue Stem was the most productive and had the lowest ash content, it also had the highest level of N withdrawal and N concentration. Switchgrass Shawnee had the lowest productivity and highest ash content, but had the lowest N concentration and lowest total N withdrawal. Switchgrass Cave-in-Rock was the second most productive and had the second highest N concentration, N withdrawal, and ash content.

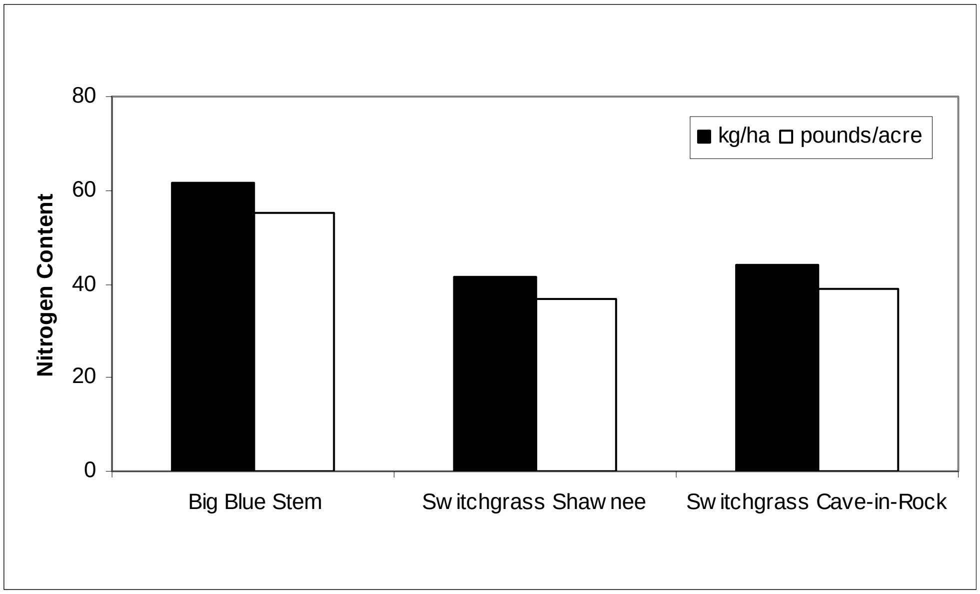

Figure 5. Nitrogen withdrawal of Big Blue Stem, Switchgrass Shawnee, and Switchgrass Cave-in-Rock.

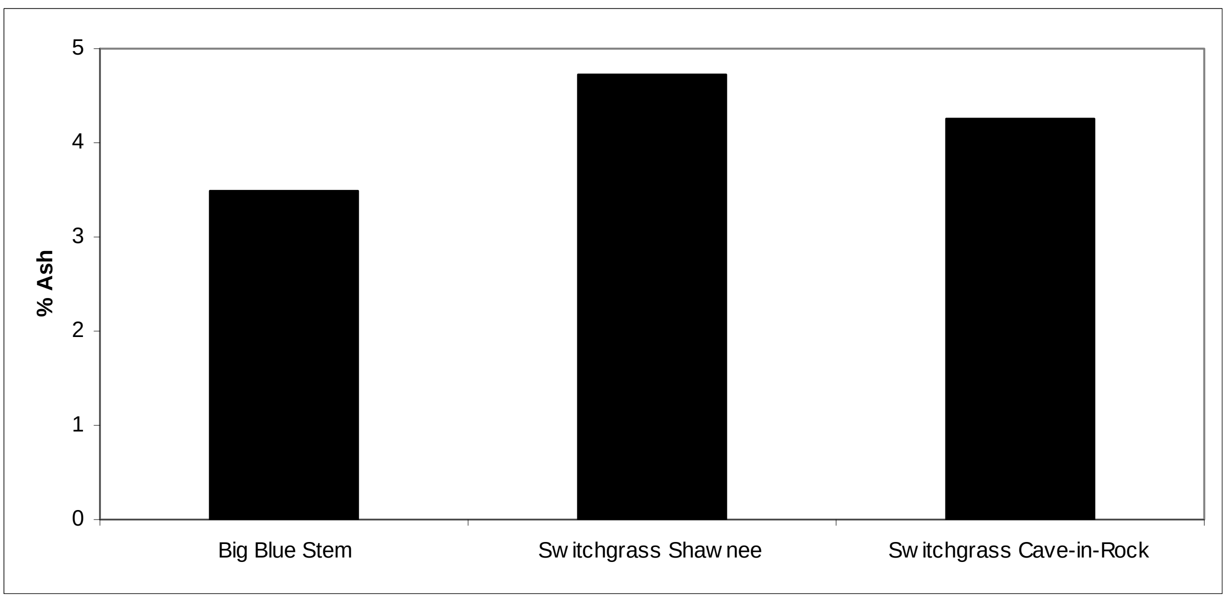

Figure 4. Ash content of Big Blue Stem, Switchgrass Shawnee, and Switchgrass Cave-in-Rock.

Discussion

Our results indicate that in terms of biomass growth, Big Blue Stem was the most productive and thus would have the largest yield. It also generated the least amount of waste as ash. However, it removed the most N from soil. Nitrogen must be replaced, either through a natural process or through fertilizer additions. Significant quantities of fertilizer would increase the cost of production as well as potentially affect soil and water quality. Huang and Lantin (1993) found that while N is essential to plant growth, it becomes a pollutant if it enters surface and ground water. Nitrogen pollution can disrupt food chains, accelerate algae growth, and cause human illness.

Both types of switchgrass had higher ash contents than Big Blue Stem. If the ash were to be recycled and used as fertilizer, it could reduce costs associated with chemical fertilizers. Whereas Switchgrass Shawnee had higher ash content than Switchgrass Cave-in-Rock, both had ash contents that were higher than those of Big Blue Stem. The lower ash content of Big Blue Stem would be beneficial when combusting pellets because there would be less ash residue, but Switchgrass Shawnee would yield more biomass with less nitrogen.

This study also showed strong variability of growth within the different plant types. Biofuel production rates differed even within the same field, as evidenced by differences in total dry weight among the plots. This study did not examine the reasons for such variance, but differences in occupation of plant growing space, soil variables, and plant competition are potential explanations. Differences also exist among particular switchgrass strains. Switchgrass Shawnee and Cave-in-Rock had different productivity, percent N, N withdrawal, and ash content. Every switchgrass strain is therefore likely to exhibit different combinations of these characteristics.

Nitrogen concentration also differed among the three species. Variables such as soil water and fertility affect productivity and plant N availability and uptake. Field locations and different soil makeup are other potential variables to consider. Big Blue Stem was located 15 miles from the two switchgrass fields, which may partially explain its higher percent N. Variations in growth and N demand may be due to plant competition and root system size. Sanderson and Reed (2000) found that switchgrass plants increased in dry weight when plant spacing increased. Young plants were less affected, probably due to the fact that their root systems were less developed and thus used less N. Larger root systems draw more N from the soil (Sanderson and Reed 2000). Plants with full root systems grown close together may remove more N. If they are spaced farther apart and have smaller root systems, then they will remove less N but have less total mass. Big Blue Stem removed the most N and had the highest yield while Switchgrass Shawnee removed the least N and had the smallest yield. Big Blue Stem's nitrogen withdrawal may be due to elevated protein production (Trautmann et al. 1989). This level of withdrawal needs to be considered because nitrogen removed from soil needs to be replaced with fertilizer, or else the long term productivity of sites may be compromised.

From this research, Switchgrass Cave-in-Rock may be the most viable choice. It fell in the middle of productivity, N concentration, N withdrawal, and ash content. Its productivity was only 14 percent less than Big Blue Stem but it removed 29 percent less N than Big Blue Stem. Future research should address the variation between species, as well as examine other varieties of perennial grasses.

Acknowledgements

We thank Mark Fiely of Ernst Conservation Seeds for helping to establish the field study, Sam Reese for invaluable laboratory assistance, and Eric Winter for map preparation.

Literature Cited

Bull, T. E. and J. A. Turner. 1999. Biomass in the Energy Picture. Science 285:1209-1210.

DOE Report. 2006. United States Department of Energy Annual Energy Review.

Duffy, M. D. and V. Y. Nanhou. 2002. Costs of Producing Switchgrass for Biomass in Southern Iowa. In: J. Janick and A. Whipkey (eds.), Trends in New crops and New Uses. ASHS Press, Alexandria, VA, p. 267–275.

Hartnett, D C. 1993. Regulation of Clonal Growth and Dynamics of *Panicum virgatum* (Poaceae) in Tallgrass Prairie: Effects of Neighbor Removal and Nutrient Addition. American Journal of Botany 80:1114-1120.

Huang, W. and R. M. Lantin. 1993. A Comparison of Farmers' Compliance Costs to Reduce Excess Nitrogen Fertilizer Use under Alternative Policy Options. Review of Agricultural Economics 15(1):51-62.

McDonald, Scott, S. Robinson and K. Thierfelder. 2002. Impact of Switching Production to Bioenergy crops: The Switchgrass Example. Energy Economics 28(2):243-265.

McLaughlin,S., J. Bouton, D. Bransby, B. Conger, W. Ocumpaugh, D. Parrish, C. Taliaferro, K. Vogel, and S. Wullschleger. 1999. Developing Switchgrass as a Bioenergy Crop. Perspectives on New Crops and New Uses. ASHS Press.

Monti, A., N. Di Virgilio and G. Venturi. 2007. Mineral composition and ash content of six major energy crops. Biomass and Bioenergy. In Press.

Muir, J. P. et al. 2001. Biomass Production of ‘Alamo’ Switchgrass in Response to Nitrogen, Phosphorus, and Row Spacing. Agronomy Journal 93:896-901.

Murray, L. D. and L. B. Best. 2003. Short-Term Bird Response to Harvesting Switchgrass for Biomass in Iowa. The Journal of Wildlife Management 67:611-621.

Porter, C. L. 1966. An Analysis of Variation Between Upland and Lowland Switchgrass, Panicum Virgatum L., in Central Oklahoma. Ecology 47:980-992.

Ragauskas, A. J., C. K. Williams, B. H. Davison, G. Britovsek, J. Cairney, C. A. Eckert, W. J. Frederick, Jr., J. P. Hallett, D. J. Leak, C. L. Liotta, J. R. Mielenz, R. Murphy, R. Templer, T. Tschaplinsi. 2006. The Path Forward for Biofuels and Biomaterials. Science 311:484-489.

Roth, A. M., D. W. Sample, C. A. Ribic, L. Paine, D. J. Undersander, G. A. Bartelt. 2005. Grassland bird response to harvesting switchgrass as a biomass energy crop. Biomass and Bioenergy 28(5):490-498.

Roth, A. M., et al. 2005. Grassland bird response to harvesting switchgrass as a biomass energy crop. Biomass and Bioenergy 28:490-498.

Sanderson, M.A and R. L. Reed. 2000. Switchgrass Growth and Development: Water, Nitrogen, and Plant Density Effects (in Plant Physiology). Journal of Range Management 53(2):221-227.

Tenenbaum, D. J. 2002. Recycling: Switching to Switchgrass. Environmental Health Perspectives 110:A18-A19.

Tenenbaum, D. J. 2005. Harvesting the Potential of Biomass. Environmental Health Perspectives 113:A750-A753.

Trautmann, N. M., K. S. Porter, R. J. Wagenet. 1989. Natural Nitrogen: The Essential Element. Resources Cornell Cooperative Extension. http://hdl.handle.net/1813/3911.

Appendix 1. Field and oven-dry sample weights.

Grass	Sample	Wet Weight g	Wet Weight (Grass only) g	105ºC Bag + Grass g	105ºC Dry Bag g	105ºC Dry Grass g	Dry/Wet	Total Dry Weight kg/m^2
Big Blue Stem	B1	3880	75.20	42.15	7.36	34.79	0.463	0.898
	B2	5784	92.80	49.97	7.37	42.60	0.459	1.328
	B3	3310	71.10	40.45	7.57	32.88	0.462	0.765
	B4	4342	94.85	53.98	7.50	46.48	0.490	1.064
	B5	1816	86.08	51.00	7.43	43.57	0.506	0.460
	B6	4185	55.94	34.00	7.49	26.51	0.474	0.992
	B7	4944	50.90	31.80	7.40	24.40	0.479	1.185
	B8	2409	54.21	35.80	7.40	28.40	0.524	0.631
	B9	2745	94.80	56.34	7.43	48.91	0.516	0.708
	B10	4076	68.50	44.01	7.38	36.63	0.535	1.090
	B11	4396	72.38	43.78	7.45	36.33	0.502	1.103
	B12	4866	61.95	35.13	7.52	27.61	0.446	1.084
Switchgrass Shawnee	SS1	2468	59.95	37.60	7.30	30.30	0.505	0.624
	SS2	2592	58.23	34.30	7.30	27.00	0.464	0.601
	SS3	2704	76.42	46.48	7.81	38.67	0.506	0.684
	SS4	2195	54.84	32.94	7.40	25.54	0.466	0.511
	SS5	3070	52.33	28.60	7.30	21.30	0.407	0.625
	SS6	3110	57.69	31.30	7.30	24.00	0.416	0.647
	SS7	2824	48.91	46.19	7.27	38.92	0.796	1.124
	SS8	3033	88.81	50.18	7.30	42.88	0.483	0.732
	SS9	3218	87.67	50.63	7.42	43.21	0.493	0.793
	SS10	3733	96.95	46.30	7.39	38.91	0.401	0.749
	SS11	2314	42.85	28.77	7.35	21.42	0.500	0.578
	SS12	1693	42.87	32.50	7.40	25.10	0.585	0.496
Switchgrass Cave-in-Rock	SC1	2823	54.85	36.30	7.30	29.00	0.529	0.746
	SC2	2707	84.88	50.70	7.30	43.40	0.511	0.692
	SC3	3528	57.50	32.70	7.28	25.42	0.442	0.780
	SC4	3605	86.79	50.70	7.20	43.50	0.501	0.903
	SC5	2742	76.51	38.20	7.30	30.90	0.404	0.554
	SC6	3187	70.34	44.10	7.40	36.70	0.522	0.831
	SC7	2926	65.82	47.48	7.25	40.23	0.611	0.894
	SC8	4477	128.37	62.00	7.26	54.74	0.426	0.955
	SC9	3612	110.25	56.74	7.35	49.39	0.448	0.809
	SC10	4526	75.34	44.49	7.43	37.06	0.492	1.113
	SC11	3218	54.08	34.20	7.30	26.90	0.497	0.800
	SC12	3086	84.40	42.30	7.30	35.00	0.415	0.640

Appendix 2. Carbon, sulfur, and nitrogen content of grass samples.

Grass	Sample	Sample Weight (g)	%C	%S	%N	gC/m^2	gS/m^2	gN/m^2
Big Blue Stem	1	0.1013	46.76	0.109	0.934	420	0.978	8.39
	2	0.1081	45.41	0.135	0.977	603	1.787	12.97
	3	0.1165	46.02	0.105	0.657	352	0.803	5.02
	4	0.1472	45.38	0.086	0.593	483	0.912	6.31
	5	0.1099	46.08	0.104	0.757	212	0.478	3.48
	6	0.1054	46.05	0.097	0.603	457	0.966	5.97
	7	0.1458	45.79	0.097	0.593	543	1.151	7.03
	8	0.1093	46.64	0.083	0.553	294	0.525	3.49
	9	0.1097	45.60	0.104	0.733	323	0.738	5.19
	10	0.0998	45.22	0.087	0.470	493	0.950	5.13
	11	0.1075	45.49	0.077	0.464	502	0.853	5.11
	12	0.1014	45.61	0.101	0.558	495	1.097	6.05
		X	**45.84**	**0.099**	**0.658**	**431**	**0.936**	**6.18**
		SE	**0.15**	**0.005**	**0.052**	**36**	**0.106**	**0.80**
Switchgrass Shawnee	1	0.1012	44.98	0.117	0.598	281	0.728	3.73
	2	0.0983	45.32	0.140	0.651	272	0.842	3.91
	3	0.1165	44.98	0.111	0.528	308	0.762	3.61
	4	0.1141	44.93	0.151	0.679	230	0.774	3.47
	5	0.1071	46.01	0.118	0.547	287	0.736	3.41
	6	0.1088	45.32	0.134	0.500	293	0.866	3.24
	7	0.1069	44.01	0.133	0.461	494	1.489	5.18
	8	0.1133	43.73	0.125	0.680	320	0.915	4.98
	9	0.1107	44.03	0.135	0.591	349	1.071	4.68
	10	0.0997	43.61	0.154	0.832	327	1.151	6.23
	11	0.0918	44.72	0.163	0.702	259	0.940	4.06
	12	0.0960	43.55	0.147	0.612	216	0.731	3.04
		X	**44.60**	**0.136**	**0.615**	**303**	**0.917**	**4.13**
		SE	**0.25**	**0.005**	**0.032**	**23**	**0.071**	**0.30**
Switchgrass Cave-in-Rock	1	0.0999	44.54	0.122	0.311	332	0.911	2.32
	2	0.0933	45.25	0.106	0.514	313	0.732	3.56
	3	0.0994	43.62	0.131	0.642	340	1.019	5.00
	4	0.0900	44.55	0.114	0.659	402	1.030	5.95
	5	0.0925	43.61	0.132	0.633	241	0.731	3.50
	6	0.0943	44.02	0.142	0.503	366	1.180	4.18
	7	0.0960	44.12	0.148	0.573	395	1.319	5.12
	8	0.0963	45.17	0.139	0.481	431	1.327	4.59
	9	0.0960	45.18	0.208	0.685	366	1.686	5.54
	10	0.1077	44.85	0.117	0.552	499	1.300	6.14
	11	0.0974	45.14	0.122	0.503	361	0.972	4.03
	12	0.0980	43.71	0.097	0.429	280	0.619	2.75
		X	**44.48**	**0.131**	**0.540**	**361**	**1.069**	**4.39**
		SE	**0.20**	**0.009**	**0.034**	**22**	**0.097**	**0.39**

Appendix 3. Ash content of grass samples.

Grass	Sample	Crucible Weight (g)	Sample Weight (g)	Crucible Plus Ash (g)	Ash Weight (g)	% Ash
Big Blue Stem	1	11.4700	1.0323	11.5094	0.0394	3.82
	2	11.5083	1.0730	11.6420	0.0337	3.14
	3	12.6043	0.9312	12.6362	0.0319	3.43
	4	12.4524	0.9972	12.4908	0.0384	3.85
	5	12.2957	0.9424	12.3277	0.0320	3.40
	6	12.3215	0.8466	12.3515	0.0300	3.54
	7	13.0863	0.8715	13.1179	0.0316	3.63
	8	12.7594	0.8900	12.7823	0.0229	2.57
	9	12.3160	0.9061	12.3475	0.0315	3.48
	10	12.5469	0.9479	12.5819	0.0350	3.69
	11	11.5838	1.1402	11.6185	0.0347	3.04
	12	12.0445	1.0816	12.0874	0.0429	3.97
					X	**3.46**
					SE	**0.11**
Switchgrass Shawnee	1	11.7801	0.8595	11.8239	0.0438	5.10
	2	12.5662	0.8364	12.6066	0.0404	4.83
	3	11.1753	0.8431	11.2121	0.0368	4.36
	4	12.4023	0.8386	12.4396	0.0373	4.45
	5	12.4937	0.8832	12.5294	0.0357	4.04
	6	12.8557	0.8196	12.8894	0.0337	4.11
	7	12.5068	0.9196	12.5434	0.0366	3.98
	8	11.9166	0.8962	11.9685	0.0519	5.79
	9	12.1834	0.9915	12.2338	0.0504	5.08
	10	12.7871	0.8665	12.8348	0.0477	5.50
	11	12.0712	0.9613	12.1145	0.0433	4.50
	12	11.8893	0.9770	11.9379	0.0486	4.97
					X	**4.73**
					SE	**0.18**
Switchgrass Cave-in-Rock	1	12.5936	1.1784	12.6391	0.0455	3.86
	2	11.1748	0.8832	11.2124	0.0376	4.26
	3	11.6028	1.0580	11.6578	0.0550	5.20
	4	11.2528	0.8100	11.2847	0.0319	3.94
	5	12.1397	0.8334	12.1791	0.0394	4.73
	6	12.3919	0.8777	12.4282	0.0363	4.14
	7	11.5455	0.8212	11.5818	0.0363	4.42
	8	12.0637	0.9438	12.0989	0.0352	3.73
	9	11.5501	0.9583	11.5931	0.0430	4.49
	10	11.6683	0.9773	11.7069	0.0386	3.95
	11	12.3675	0.8793	12.4025	0.0350	3.98
	12	11.8392	0.8700	11.8766	0.0374	4.30
					X	**4.25**
					SE	**0.13**