# Project Summary for

# *Expanding Opportunities for Biomass and Hay Production in Northern Kentucky*

## Funded by the Kentucky Forage and Grassland Council and

## The Kentucky Agriculture Development Fund

## 2007 – 2011

**Lee Carol Greenwell, Tom Keene, Dr. Ray Smith,**

**David Davis, Laura Schwer, Kenton Sena, Krista Cotten, Gene Olsen**

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Department of Plant and Soil Sciences

February 13, 2012



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## Background

Switchgrass (*Panicum virgatum* L.) is a warm-season grass native to most of the United States including Kentucky. It is a tall perennial bunch-type grass and not considered invasive. Switchgrass can be as tall as eight to ten feet. The grass blooms from June to August, then produces an abundance of seeds (1).

Switchgrass (*Panicum virgatum* L.) converting sunlight into energy.

While moderately difficult to establish, it is easy to maintain once established with minimum input required. Basic and timely management practices can ensure a healthy and lasting stand. Once a mainstay in mixed tall grass prairies, it is emerging as an effective, efficient biofuel and is well-known for its use in pastures, erosion control measures, and wildlife habitat management. We feel switchgrass can offer Kentucky producers several marketing opportunities. To investigate the opportunities for farmers who are interested in producing switchgrass, we performed a trial from 2007 through 2010 where we selected 20 farms within a 60 mile radius of Maysville, Kentucky (location of East Kentucky Power Cooperative Spurlock Station) and assisted them in successfully establishing five acres each of switchgrass. Once established, we assisted these farmers in the management, harvesting and transport of the biomass material to the power plant. Following is a summary of our journey with these producers:

## Study Purpose

Tobacco production has been an important income source for farmers in Kentucky for many years. The tobacco buyout program and the resulting decrease in income, rising production costs and labor sourcing difficulties has made tobacco a less viable income source. Producers in the Northeast Kentucky region are eager to find alternative production options on their farms. A number of alternatives have been suggested, but many of these require high capital investments and have limited market opportunities. Biomass production with switchgrass and similar crops

provide a renewable fuel alternative that works well with existing hay production systems and equipment. In other words, producers in Northeastern Kentucky can produce biomass using their existing machinery. There are numerous emerging options for biomass including electrical generation in co-fired units (like the one at East Kentucky Power in Maysville, Kentucky), pellet production for pellet fueled home heaters, and cellulosic ethanol production. Therefore, the objectives of this project were to (1) show the electrical generating utilities and the cellulosic ethanol industry that Northeast Kentucky producers can grow biomass crops sustainably and economically and (2) develop viable markets for biomass.

## Study Process

With the assistance of local county agriculture and natural resources (ANR) extension agents, the participating farmers were selected based on the producer's interest, resources, and management history. To maintain consistency throughout the trial, each farmer agreed to a protocol that would be used to establish and manage all stands. **(Appendix 1.)** We agreed to cost-share establishment, management and harvesting expenses with the producers.


Each producer first performed a minimum of two burn down sprays with glycophosate before planting (approximate cost: $20/acre/spray). Ideally one of these sprays occurred the fall prior to planting.

We contracted with Roundstone Seeds to establish all stands using their native grass no-till drills and high quality seed (approximate cost: $36/acre for seeding and $150 transportation cost to farm, $10.50/lb x 10 lb/acre = $105.00 for seed)

Establishment was evaluated and monitored by Mr. Tom Keene, Agronomy Specialist, the producers, and the ANR agents. Fields ranged in soil types and environmental conditions varied throughout the study. While some stands successfully established during the first year, others took two years for complete establishment and several required reseeding. Each producer was responsible for the management of their stand of switchgrass. Local county agents and members

of our team assisted in the management of these stands by making regular farm visits, analyzing the soil quality through soil testing, and helping harvest each stand.

Mid-size square baler provided by the University of Kentucky.

Baling switchgrass for biomass in November.

## Keys to No-Till Switchgrass Establishment Success

**Prior to Seeding**

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

**Seeding**

- Choose a variety adapted to your area.
- Choose an appropriate variety for the intended land use
- See 7-10 lb Pure Live Seed/acre from mid-May through mid-June.
- Plant at a depth of ¾ inch.
- Do not apply nitrogen during the establishment year

**Post-Seeding**

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

**Figure 1.** Keys to No-Till Switchgrass Establishment Success. "Switchgrass for Biomass Production in Kentucky. SR Smith, L Schwer, T Keene, K Sena, Department of Plant and Soi Sciences. Cooperative Extension Service, University of Kentucky College of Agriculture, Lexington, Kentucky. AGR-201. **Appendix 2.**

Annual soil tests showed that switchgrass can be grown over a range of soil conditions. Soil pH ranged from 4.6 to 7.3; Phosphorus (P) ranged from 8 lbs/acre to 475 lbs/acre; Potassium (K) ranged from 111 lbs/acre to 675 lbs/acre; Calcium (Ca) ranged from 1101 lbs/acre to 12,287 lbs/acre; Magnesium (Mg) ranged from 81 lbs/acre to 456 lbs/acre; and Zinc (Zn) ranged from

0.8 lbs/acre to 41.7 lbs/acre. The tests also showed that switchgrass removes minimal nutrients from the soil when harvested in late fall once the plants have gone dormant. **(Appendix 3.)**

Harvesting did not take place during the establishment year of 2007. During the years following, each stand was harvested once in November.

**Table 1.** Harvest yield data for Switchgrass for Biomass project. Plots have been named by the county in which the plot was located, followed by the first initial of the producer's last name.

| | County & Producer | Year Established | Tons/Acre 2008 | Tons/Acre 2009 | Tons/Acre 2010 |
|---|---|---|---|---|---|
| 1 | Boyd-Y | 2008 | - | 2.92 | 4.97 |
| 2 | Boyd-H | 2008 | - | 2.65 | 5.31 |
| 3 | Boyd-B | 2008 | - | 1.48 | 3.45 |
| 4 | Bracken-M | 2007 | 3.2 | 4.2 | 5.48 |
| 5 | Bracken-P | 2008 | - | 0.79 | 1.71 |
| 6 | Campbell-H | 2008 | 0.67 | 3.17 | 5.36 |
| 7 | Fleming-C | 2007 | 1.06 | 1.17 | 3.97 |
| 8 | Fleming-L | 2008 | - | 1.95 | 1.41 |
| 9 | Grant-S | 2008 | - | 2.49 | 3.66 |
| 10 | Harrison-S | 2007 | - | 1.02 | 2.36 |
| 11 | Harrison-D | 2008 | - | 2.5 | - |
| 12 | Lewis-W | 2007 | 1.7 | 4.92 | 6.18 |
| 13 | Lewis-M | 2008 | 0.53 | 1.99 | 3.91 |
| 14 | Mason-Co | 2007 | 1.57 | 3.25 | 4.77 |
| 15 | Mason-Cr | 2007 | - | 1.76 | 3.23 |
| 16 | Montgomery-S | 2008 | - | 2.03 | 3.14 |
| 17 | Nicholas-H | 2008 | - | 2.38 | 2.37 |
| 18 | Robertson-D (Totals combined with Robertson-C) | 2007 | - | - | - |
| 19 | Robertson-C | 2008 | - | 0.9 | 2.64 |
| 20 | Rowan-E | 2008 | - | 3 | 4.74 |

Most plots reached optimum production by year three. Because of variables in this trial such as management practices and environmental conditions, harvest yields varied greatly. Overall, we saw a 54% increase in production from 2009 to 2010.

**Table 2.** Rainfall during growing season for Kentucky during Switchgrass for Biomass Project according to the National Climate Data Center and National Oceanic Atmospheric Administration: http://www.ncdc.noaa.gov

| Period | 2007 | | 2008 | | 2009 | | 2010 | |
|---|---|---|---|---|---|---|---|---|
| | Amount of Rainfall (inches) | Departure from Average (inches) | Amount of Rainfall (inches) | Departure from Average (inches) | Amount of Rainfall (inches) | Departure from Average (inches) | Amount of Rainfall (inches) | Departure from Average (inches) |
| **May** | 1.21 | -3.57 | 4.33 | +0.14 | 5.05 | +0.58 | 7.84 | +3.37 |
| **June** | 2.68 | -1.90 | 3.59 | -0.07 | 5.41 | -1.75 | 4.61 | +0.95 |
| **July** | 6.39 | +1.58 | 3.41 | -1.59 | 5.89 | +0.89 | 5.49 | +0.49 |
| **August** | 4.00 | +0.23 | 2.18 | -1.75 | 5.38 | +1.45 | 1.54 | -2.39 |
| **September** | 0.88 | -2.23 | 1.42 | -1.78 | 5.37 | +2.17 | 1.14 | -2.06 |

At harvest, all the switchgrass was baled into either large square bales or round bales.

Seeding switchgrass with a no-till drill

Cutting switchgrass for biomass

Baling switchgrass for biomass

Bales of switchgrass await grinding at EKPC

# Study Timeline

**2007** Seven of the prospective 20 plots were seeded in 2007. Kentucky experienced severe drought conditions throughout the growing season and some plots had to be re-seeded. We presented our initial findings and information about the project at three field days:

Fayette County Field Day - September 6, 2007
Mason County Field Day - September 27, 2007
Lewis County Field Day - October 4, 2007

Successful establishment of a switchgrass stand.

**2008** The remaining 13 plots were seeded in 2008. On April 29th, we presented a seminar on the project at Berea College in Berea, Kentucky. We also presented information regarding the project on June 12, 2008, at Spindletop Farm; August 14th and 15th at a bioenergy meeting at the Hyatt Regency in Lexington, Kentucky; and on August 28th at the Grant County Field Day. We had the opportunity to take the participating producers and ANR agents on a biomass tour in eastern Tennessee October 29 – 30, 2008. Coordinated by our project and the University of Tennessee, this tour was attended by producers, extension agents, and University faculty and staff. On December 8th, we took harvested biomass to the East Kentucky Power Cooperative Spurlock Station. On December 9th and 10th, the material was ground. 43.65 tons from six producers' fields plus additional material from UK farms was chopped and mixed with coal. On December 17th, we held a press conference at East Kentucky Power Cooperative highlighting the project and the participating parties.

Bales of switchgrass biomass to be ground

Ground switchgrass ready to be mixed with coal

**2009** All plots on the 20 farms were harvested in 2009, resulting in nearly 223 tons of biomass. The product was pelleted at Midwest Biofuels in Wurtland, Kentucky (Greenup County) and barged to the East Kentucky Power Plant-Spurlock Station. During this year, we took several opportunities to share information about this biomass project. On July 14th, the Bracken County Field Day was held at Tom Malone's farm where we were able to feature Mr. Malone's outstanding switchgrass plot. On July 23rd, we highlighted the project at the Princeton Field Day, and on August 20, 2009, we participated in a booth at the Kentucky State Fair sponsored by the Governor's Office of Agriculture Policy. Throughout the term of the project, several reports were provided to the legislative research committee of the Tobacco Settlement Agreement Fund Oversight Committee, including a presentation by Mr. Tom Keene on May 9, 2009.

Switchgrass pellets mixed with coal

Switchgrass pellets on barge mixed with coal

**2010** On January 6, 2010, we held a press conference at Midwest Biofuels, which included farmers, extension agents, members of the press, and University faculty and staff. On April 1st, we held a press conference at the East Kentucky Power Cooperative Spurlock Station. The standing crop was harvested in November of 2010 and produced 343.3 tons. In early 2010, the switchgrass was ground and mixed with coal. When the ground material got wet due to rain, we discovered this can cause problems feeding through the power plant's equipment.

A total of 684.75 tons of switchgrass (including material from 20 producers and two UK farms) was sold to East Kentucky Power Cooperative. The power company believed that the crop could be a viable source of energy for their plant as long as the supply can meet the demand.

**2011** In 2011, the occasions to discuss the opportunities of biomass for biofuels continued:

February 16 – 19, 2011 - Our project was featured one day at a booth sponsored by the Governor's Office of Agriculture Policy during the National Farm Machinery Show.

March 14, 2011 - *Growing Switchgrass in Kentucky for Electricity Production*. Kentucky Renewable Energy Consortium - KREC Bioenergy Summit. Louisville, Kentucky.

March 15, 2011 – Three presentations were made at the Maysville Community College Ag. Day in Maysville, Kentucky. (1) *Year Round Grazing for Livestock*, (2) *Recovering Forages: Post Drought*, and (3) *Options for Switchgrass on the Farm*

March 23, 2011 - *Helping Pastures Bounce Back*. Mercer County Cattleman's Association, Mercer County, Kentucky.

April 14, 2011 - *Estimating Clovers in Pastures*. Kentucky Grazing School. Princeton, KY.

## Producer and Agent Feedback

Several producers were interview during the preparation of this summary report and we learned their enthusiasm is strong for the prospects of biomass production, in particular switchgrass. They are optimistic about the future of switchgrass as a cleaner burning fuel and reducing the reliance upon coal. They did point out some aspects of growing switchgrass that need to be refined before it will be able to make an impact in the energy market.

Tom Malone, from Bracken County, is excited about the feasibility study his county is participating in to study the prospects of switchgrass, biomass, and a pelletizing plant in the area. They are looking to the Show Me Energy Cooperative from Missouri as an example of how biomass can fit into the landscape. The kickoff of the feasibility study was December 15, 2011, and will be completed in mid-March, 2012. He sees possible markets in nearby Ohio where there is a mandate that 12% of their energy has to come from renewable energy resources as well as a future in liquid fuel. He is concerned about Kentucky's heavy reliance on coal and lack of mandates for the use of biomass in energy production. The actual production of switchgrass for his plot went from 33 bales mid-sized square bales in 2008, to 55 bales in 2009, to 80 bales in 2010. He was pleased with these results. He felt any producer considering switchgrass production should be aware that the first year is an establishment year.

Randy Haas, from Campbell County, shares Mr. Malone's enthusiasm for the future of biomass. He enjoyed being a part of the study. His concerns from the study are the marketability of biomass for energy at this time and the ability to harvest the product with standard equipment. He said the height of the plant and stem thickness made harvesting the switchgrass a real challenge. Perhaps, he said, it was because his stand was so thick that he had such trouble raking and baling the hay. In 2011, Mr. Haas cut his switchgrass plot for hay twice and he is feeding it to his cattle this winter. Because of the wet weather in 2011, he acknowledged he was a little late in his harvests and tests showed his nutritional quality was not good. He felt palatability was an issue as well. He will cut it again next year for hay for his cattle and time the cuttings better to increase the nutritional value and palatability of the hay.

Danny Blevins, from Boyd County, is also encouraged about the prospects of switchgrass for biomass in Kentucky. He said there is the potential for a 33% increase in energy costs in the near future and he is certain this will drive the demand for biomass. Mr. Blevins likes

switchgrass for its biodiversity. He said one can do so much with it: biofuel, pellets to heat homes, hay for cattle, and wildlife habitat. He also commented on its pleasing appearance and appreciated its durability: during the establishment year, his cows broke into the young stand and ate it down, then it underwent a drought, and still it came back "like gangbusters". He did not have difficulty harvesting his stand and felt that was due to the variety he planted which was less than six feet tall. Because of its diverse nature, he expects to plant more switchgrass on his farm. He is currently using switchgrass hay for his cattle and also admitted to less than optimal timing for the cuttings because of the wet weather last summer. The hay didn't test as well as his other hay, but he feels like better timing of the harvest will improve those results. He has not seen a palatability issue with the switchgrass hay in his cow herd. Regarding marketing the switchgrass to the power plant, he says Kentucky producers will just have to wait: "There is an inevitable place for switchgrass." Mr. Blevins said, "I can do many things with this grass. I'll probably plant more."

When speaking with the ANR agents who supported each of these producers, they expressed many of the same positive comments on the study and similar concerns. Dave Appleman of Bracken County (Tom Malone, producer) discussed the feasibility study his county is undertaking with Show Me Energy. He feels confident they are a good resource for this study because they have greater than ten years experience with biomass production and marketing. For the feasibility study he said any form of biomass will be considered: from switchgrass to other warm season grasses, and even old hay. Regarding this study, Mr. Appleman commented that it takes a tremendous amount of patience – especially in the first year – to grow switchgrass. He said a big challenge to overcome is waiting until the second year for results. He also believed equipment modifications would need to be made to standard hay equipment for a successful planting and harvesting. Mr. Appleman felt the contracted price for the project was slightly low, covering expenses but offering little profitability to the farmers. He would like to see a higher price offered from the power company.

Mr. Don Sorrell of Campbell County (Randy Haas, producer) felt the study was an overall good experience. He commented that growing switchgrass is easy and the potential yield per acre is impressive. His concerns stem from the marketability of the product to the power plant: that price/ton will be the driving force.

Mr. Lyndall Harned of Boyd County (Danny Blevins, producer) said three producers in his county participated in the study: one plot on a ridge top and two in river bottoms. He was very impressed with how the switchgrass survived both the drought and the floods that occurred during the study period. However, he was also concerned the contracted price for the project was not going to make it feasible for producers to enter this venture - especially if they have to be responsible for transporting the material to the power plant themselves. If, however, the power plant would agree to cover the transportation costs, it's possible growers would be interested in producing switchgrass for biofuel.

Producers, ANR Agents, UK Faculty and Staff attended a biomass tour sponsored by the project and the University of Tennessee in 2008.

## Deliverables from the Project

### Publications

**Switchgrass vs Hay Comparative Budgets**. Halich, G and Smith, R. University of Kentucky College of Agriculture, Department of Agriculture Economics http://www.ca.uky.edu/agecon/ March 31, 2010. This is an interactive spreadsheet developed by Dr. Ray Smith, University of Kentucky Department of Plant and Soil Sciences and Dr. Greg Halich, University of Kentucky Department of Agriculture Economics. It is a decision tool to help those considering switchgrass production to budget for biomass production and compare the profitability to hay production.

**Switchgrass for Biomass Production in Kentucky.** Smith, SR, Schwer, L, Keene, T, Sena, K. University of Kentucky College of Agriculture, Department of Plant and Soil Sciences. University of Kentucky Cooperative Extension Publication #AGR-201. http://www.ca.uky.edu/agc/pubs/agr/agr201/agr201.pdf. March, 2011. (Appendix 2)

### Learning Modules

Three educational units were made available on EcoLearnIt: Reusable Learning Object System (http://ecolearnit.ifas.ufl.edu/)

1. **A Decision Aid for Switchgrass for Biomass vs. Hay Production.** Dr. Ray Smith, University of Kentucky. RLO ID# 89. July 2011. http://ecolearnit.ifas.ufl.edu/viewer.asp?rlo_id=443&final_id=89

2. **Switchgrass for Biomass Project: Highlights from the University of Kentucky.** Dr. Ray Smith, University of Kentucky, Kenton Sena, Asbury University, Krista Cotton, University of Kentucky. RLO ID# 70. January, 2011. http://ecolearnit.ifas.ufl.edu/viewer.asp?rlo_id=466&final_id=70

3. **Switchgrass Stories: UK's Switchgrass Biomass Project.** Dr. Ray Smith, University of Kentucky. RLO ID# 71. January, 2011. http://ecolearnit.ifas.ufl.edu/viewer.asp?rlo_id=467&final_id=71

## News Stories: Video & Print

UK College of Agriculture Ag Communications Services News published eight stories on switchgrass for biomass during the period of 2008 - 2011:

1. Harvesting Switchgrass
2. Switchgrass Mixed with Coal as Biofuel at East KY Power
3. Pelletizing Switchgrass at Midwest Biofuels
4. Switchgrass Harvest, Fall 2010
5. Footage from Switchgrass Harvesting. Mixing with Coal. Pelletizing and on Barges at East KY Power.
6. Switchgrass Used to Fuel Power Plant, December 18, 2008
7. Switchgrass Pelletized for Biomass as Part of UK Research Project, January 15, 2010
8. Switchgrass Study at Crossroads, January 6, 2011

For copies of these stories, contact Dr. Ray Smith at raysmith1@uky.edu, or UK Ag Communications at http://www.ca.uky.edu/agcomm/.

## Research

Laura Schwer published **"Small mammal populations in switchgrass stands managed for biomass production compared to hay and cornfields in Kentucky"** *(2011).* Masters Theses. *Paper 138, http://uknowledge.uky.edu/gradschool_theses/138*

Christie Otto, a student from Asbury College, Wimore, Kentucky, published **"Optimizing Cellulosic Ethanol Production by Evaluation of grasses for Ethanol**

**Yield"** *Proceeding of the National Conference on Undergraduate Research (NCUR) 2009 University of Wisconsin La-Crosse, La-Crosse, Wisconsin, April 16-18, 2009.*

**"Prechilling Switchgrass Seed on farm to Break Dormancy"** was written by Dr. Ray Smith, Laura Schwer, Cindy Finneseth, Holly Boyd and Tom Keene. It has currently been submitted for publication as a UK Cooperative Extension Publication.

**David Davis began his Master's thesis project: Evaluation of Switchgrass Hay for Feeding Beef Cattle** - a feed study beginning in 2010 in partnership between the University of Kentucky and Eastern Kentucky University's Center for Renewable and Alternative Fuel Technology (CRAFT) to evaluate the effect of maturity of the digestibility and intake of switchgrass hay used for feeding beef steers. Using two varieties, Cave-in-Rock and Alamo, preliminary data suggests the stage of maturity in which the switchgrass is harvested effects dry matter intake (DMI) and dry matter digestibility (DMD). In the fall of 2011, beef steers were fed switchgrass hay harvested in the summer of that year at the vegetative, late boot, and flowering stages. Based on early information gathered from the study, hay harvested in the vegetative stage could offer higher DMI, DMD, and crude protein (CP).

Tom Keene began his Master's thesis project: **Evaluating Kanlow Switchgrass Yields with Multiple Fertilizer Applications and Varied Harvest Dates**

A separate research trial took place to determine the biomass potential of switchgrass and other perennial warm season grasses. The varieties of switchgrass, Indiangrass, and Big Bluestem were planted in 2008, then harvested in 2009, 2010, and 2011. Results ranged from 0.27 tons of dry matter/acre to 6.75 tons of dry matter/acre, with an average of 2.83 tons/acre. Results can be seen in **Appendix 4**.

As a part of this study, data was also collected on a planting of Miscanthus While not used as a forage crop, *Miscanthus* x *giganteus* is an excellent perennial biomass crop.

| | Tons/acre | | |
|---|---|---|---|
| **Miscanthus** | **2009** | **2010** | **2011** |
| Rep1 | 9.20 | 17.92 | 11.67 |
| Rep 2 | 6.24 | 10.30 | 10.48 |
| Rep 3 | 5.41 | 13.02 | 9.92 |
| Rep 4 | 4.61 | 7.75 | 8.04 |
| | | | |
| Average | 6.37 | 12.25 | 10.03 |

**Table 3.** UK College of Agriculture yield study of *Miscanthus x giganteus* as a possible biomass product adaptable to Kentucky agriculture.

Dr. Ray Smith with a stand of *Miscanthus x giganteus*

## Major Presentations

In addition to the field days, press releases, trade show booths, and governmental reports mentioned above, twelve presentations have been made to a broad base of audiences, including County Extension Agents, exposing many people to switchgrass and its potential role in Kentucky agriculture.

### *Forages for Fuel*

Dr. Ray Smith, University of Kentucky Forage Extension Specialist, Department of Plant and Soil Sciences
Kentucky Farm Bureau Annual Meeting, Louisville, Kentucky, December 6, 2007

### *Alternative Energy: National and International KFGC/UK Biomass Project*

Dr. Ray Smith, University of Kentucky Forage Extension Specialist, Department of Plant and Soil Sciences
Maysville, Kentucky, March 13, 2008

### *University of Kentucky Miscanthus and Switchgrass Test Plots*

Dr. Ray Smith, University of Kentucky Forage Extension Specialist, Department of Plant and Soil Sciences
Kentucky Renewable Energy Consortium Symposium, Louisville, Kentucky, September 10, 2009

### *Biomass Production and Use in Kentucky*

Dr. Ray Smith, University of Kentucky Forage Extension Specialist, Department of Plant and Soil Sciences
Agriculture and Natural Resource Agent Training, Winchester, Kentucky, October 20, 2009

### *Forages for Fuel in Kentucky: Current Status*

Dr. Ray Smith, University of Kentucky Forage Extension Specialist, Department of Plant and Soil Sciences
Kentucky Farm Bureau Annual Meeting, Louisville, Kentucky, December 3, 2009

### *Decision Aid for Switchgrass for Biomass vs Hay Production*

Ray Smith, Greg Halich, and Tom Keene, University of Kentucky College of Agriculture, Ecolearnit Presentation
Southern Pasture Forage Crop Improvement Conference, Aiken, South Carolina, May 11, 2010

***A New Extension Model for a Sustainable Biomass Industry on Marginal Lands***

Dr. Ray Smith, University of Kentucky Forage Extension Specialist, Department of Plant and Soil Sciences
Southern Pasture Forage Crop Improvement Conference, Aiken, South Carolina, May 12, 2010

***Growing Switchgrass for Biomass***

S. Ray Smith, Thomas C. Keene, Kenton Sena, University of Kentucky College of Agriculture, Department of Plant and Soil Sciences
Kentucky State University, Frankfort, Kentucky, July 14, 2010

***Determination of a Switchgrass Growth Curve***

Kenton Sena, Asbury University, Wilmore, Kentucky
Kentucky Academy of Science, Murray, Kentucky, November 13, 2010

## Regional Initiatives from the Project

The Bracken County Cooperative Extension Service is conducting a feasibility study with Show Me Energy of Missouri to study the potential for biomass in the northern Kentucky region. Show Me Energy is a farmer-owned not-for-profit cooperative that grows, buys, pellets and markets biomass. Its largest customers are utility plants. Show Me Energy's overall mission is *a commitment to establish an innovative, profitable, leading model for production of biomass-based fuels.* (From their website http://www.goshowmeenergy.com/) Their experience will be of great help to producers, extension agents and University of Kentucky staff wanting to expand upon this study and help make biomass a viable enterprise in Kentucky.

## Production Notes

Many things were learned as a result of this study. From a crop management perspective, we feel the following management tools are key to a successful stand of switchgrass:

Establishment – We learned that switchgrass can be difficult to establish based on the lay of the land, environmental conditions, weed pressure, and timeliness.

Weed control - We learned that a controlled burn can be an effective method of weed control if timed properly. We also saw Roundup ® (*glyphosate* by Monsanto) successfully used for early weed control.

Equipment – Depending on the variety planted, adjustments to existing hay harvesting equipment may be necessary.

Burning the field was a successful way of controlling the weed pressure on this young stand of switchgrass.

## Project Shows Multiple Advantages of Switchgrass

Switchgrass is a native grass to most of the United States. Many people prefer using native species because of their natural adaptation to the areas in which they live. Switchgrass is classified as a C-4 plant, a term used to describe the plant's carbon fixation process. C-4 grasses (typically warm-season grasses) tend to be more efficient at photosynthesis and produce more dry matter than C-3 grasses (typically cool season grasses) (2). This is a distinct advantage when producing the crop for biofuel, forage of other purposes.

## Forage

As a pasture grass, this warm season species can be used in conjunction with cool season grasses, like tall fescue (*Festuca arundinacea)* to provide consistently high volumes of forage for cattle production. While the two do not work well in the same pasture, they compliment each other very well in a pasture rotation scenario.

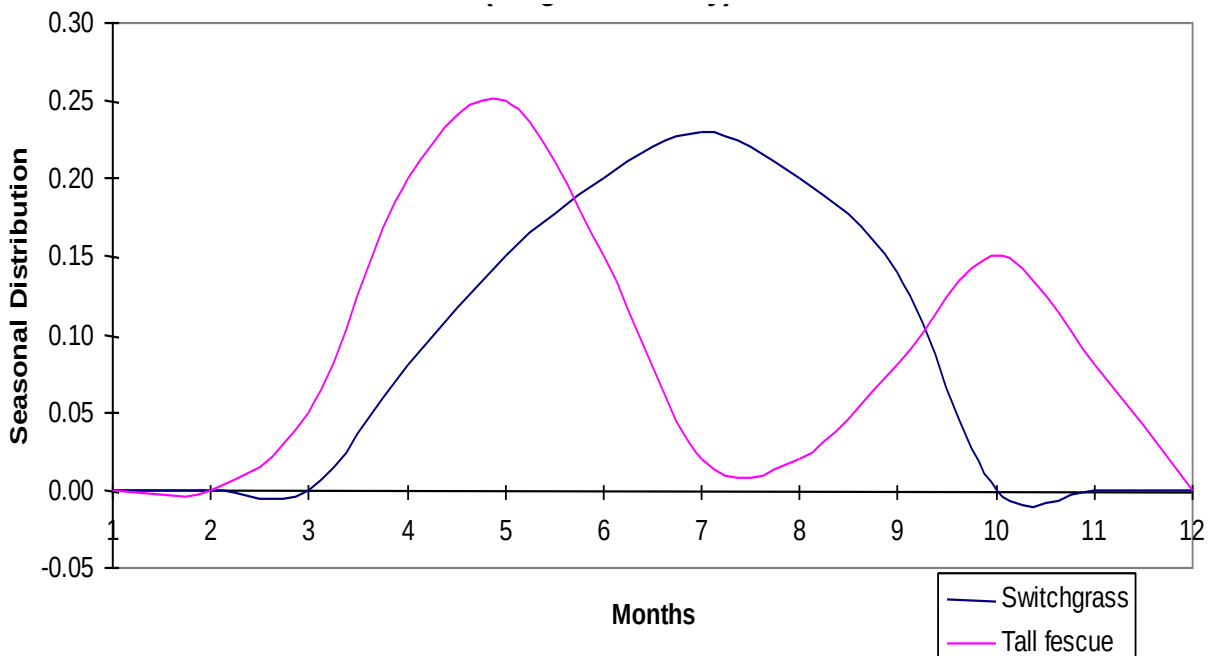
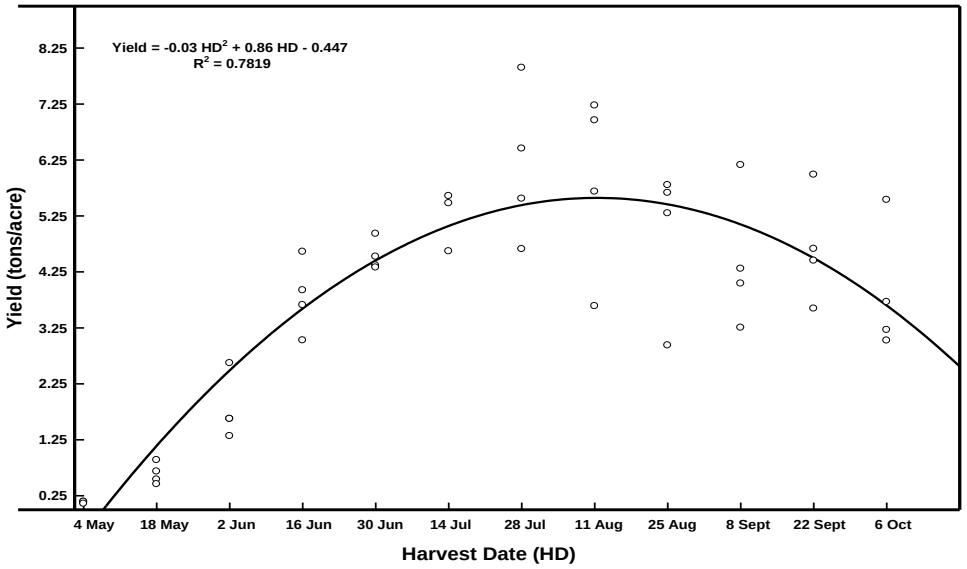


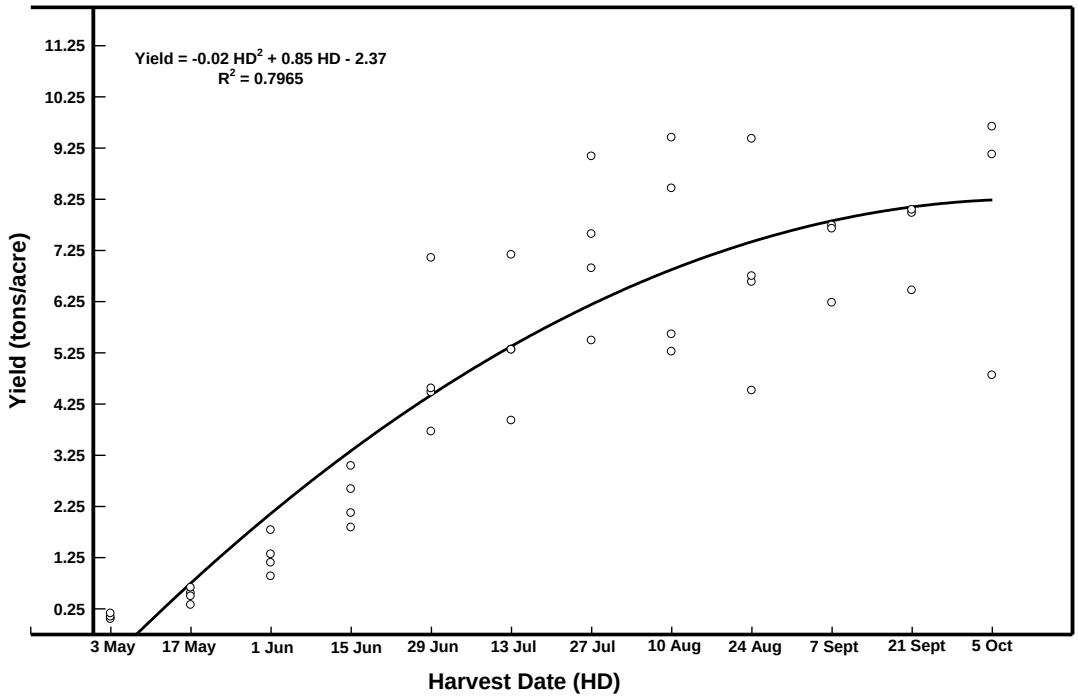

**Figure 2.** Average growth patterns of Switchgrass and Tall Fescue throughout the year, January (1) through December (12).

Switchgrass can be used to provide an additional cutting of hay during the traditional 'summer slump' period for cool season grasses. As the biofuel market develops, many producers are considering using it as a dual purpose crop with one cutting for hay followed by a late season "frost" cutting for biomass. Since it is a perennial crop, it does not have to be planted each year like many other annual warm season forages. Producing switchgrass for forage can be difficult because as it matures, forage quality rapidly decreases. Harvesting early maturity switchgrass should provide a better quality product for feeding beef cattle. In 2010 and 2011 a collaborative study was initiated between the University of Kentucky and Eastern Kentucky University's Center for Renewable and Alternative Fuel Technology (CRAFT) to evaluate the effect of maturity on the digestibility and intake of switchgrass hay used for feeding beef steers. David Davis is working on this project as a part of his Master's degree program. (10) Kenton Sena, from Asbury University, David Davis and Dr. Ray Smith, of the University of Kentucky, published an abstract "The Determination of Switchgrass Growth Curves" showing the following growth curves which provide a useful tool for predicting the switchgrass biomass production at any given point during the growing season. They are a first step in developing useful and reliable prediction tools for farmers and researchers on seasonality of switchgrass production. (11)

## Figure 1: "Cave-in-Rock" Seasonal Growth Curve




## Figure 2: "Alamo" Seasonal Growth Curve



## Bio-Fuel

Because it can be used as a biofuel, switchgrass offers an opportunity to producers to explore new markets.

East Kentucky Power Cooperative Spurlock Station located in Maysville, Kentucky, may be a viable consumer of biomass.

Dictionary.com defines biofuel as *a gaseous, liquid, or solid substance of biological origin that is used as a fuel.* Switchgrass has proven to be an economical biofuel. It can be pelleted into small dense pellets and used in furnaces to heat homes and other small structures; a common practice in Canada. On a greater scale, it can be pelleted into large pellets or cubes, or ground, to be burned at coal plants, such as East Kentucky Power's Spurlock plant in Maysville, Kentucky. This provides an economical fuel source that lowers the carbon emissions of these plants.

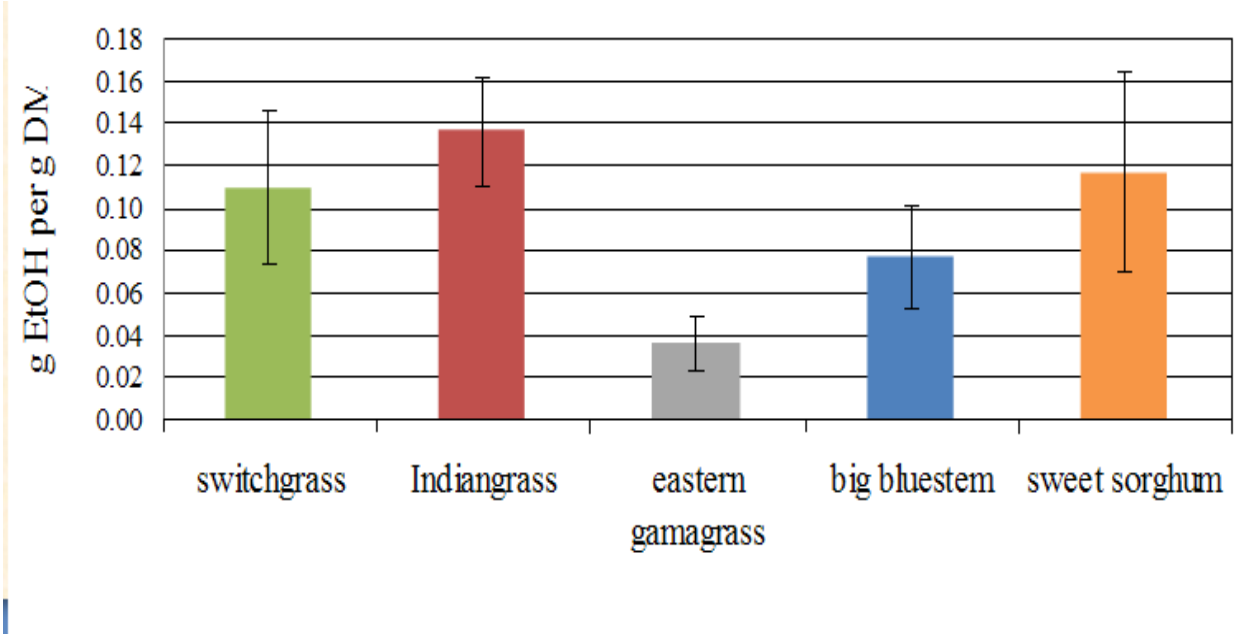



**Figure 3.** Ethanol yields from grasses ground to 1mm **(3)**

## Wildlife and the Environment

Other characteristics of switchgrass provide many environmental benefits. Its extensive root system (up to nine feet deep) offers excellent soil conservation, drought tolerance and hardiness. Because of this extensive root system, switchgrass stands may show decreased water runoff (reducing agricultural chemical loss), and increased organic matter. Switchgrass is very disease resistant and salt tolerant, hence some transportation departments, such as those in Kansas, Iowa and Tennessee are using it along highways and roads (4-8). Once established, nutrient requirements are low, resulting in a lower cost of production.

Used as a pure stand or in combination with other native warm-season grasses, switchgrass offers an excellent habitat for wildlife. Laura Schwer published her master's thesis on the benefits of switchgrass for wildlife. In her paper "Small Mammal Populations in Switchgrass Stands Managed for Biomass Production Compared to Hay and Cornfields in Kentucky" (2011), Laura discussed the attributes of switchgrass as a food source, shelter and cover, and bedding and nesting areas for wildlife, primarily small mammals. The Natural Resources Conservation Service (NRCS) also recognizes the benefits of switchgrass for wildlife at *www.**nrcs**.usda.gov*.

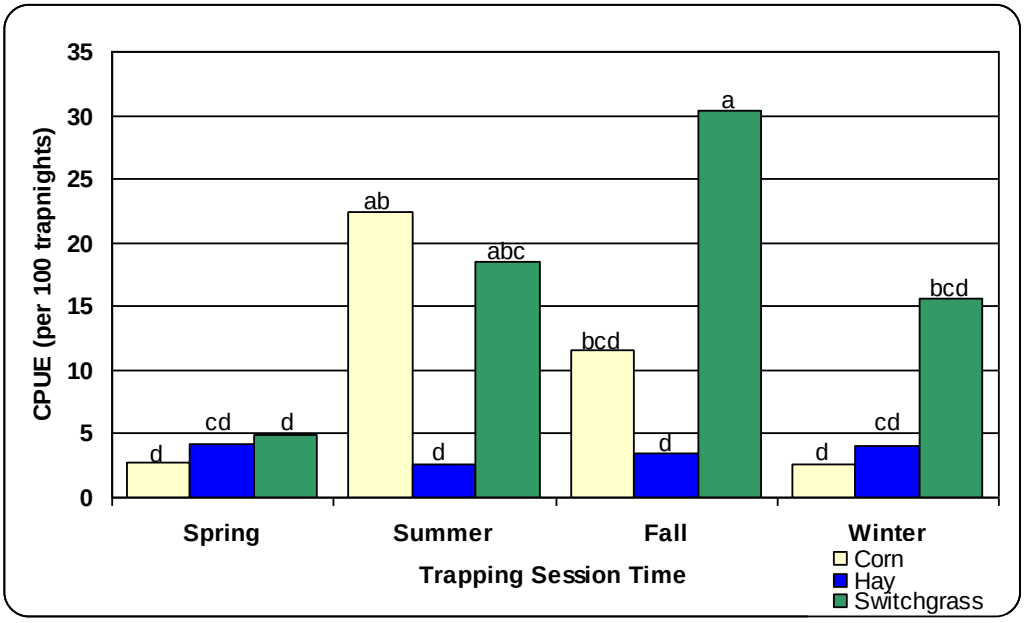



**Figure 4.** Relative abundance of small mammals (CPUE) comparison for corn, hay, and switchgrass. Least square means with the same letter are not significantly different ($P \leq 0.05$). (9)

Some of the wildlife that finds switchgrass as a source of food include Canadian Goose, Mourning Dove, Northern Bobwhite, Wild Turkey, Red-winged Blackbird, Northern Cardinal, Brown-headed Cowbird, Dark-eyed Junco, Meadow Vole, White-footed Mouse, Eastern Gray Squirrel, Mallard, Eastern Chipmunk, and a variety of sparrows. White-tailed deer bed down in its thick cover in the winter and Eastern Cottontails and Muskrats find the leaves as a good food source. (1)

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## Photography

Photographs by Mr. Tom Keene and Dr. Ray Smith, University of Kentucky College of Agriculture, Department of Plant and Soil Sciences

**Appendix 1.** **Project Summary for *Expanding Opportunities for Biomass and Hay Production in Northern Kentucky***

# Producer Criteria

## Switchgrass for Biomass Field Demonstration Project

### 2008-2010

**Kentucky Forage and Grassland Council and**

**The University of Kentucky**

County: _____ County Agent _____

Producer Name _____

Address _____

_____

Phone # _____

E-mail: _____

Field Name/# _____

GPS Coordinates if available _____

---

Thank-you for your interest in this project. I wish that we could include each of your farms, but funding is limited. We will put each of you into a special mailing list and personally inform you of the progress of this project and the opportunities for growing switchgrass or other biomass crops on your

farm. Although the primary requirement for participation is a 5 acre field and a willingness to participate, the following criteria will help us decide the farms that are best suited for this project. **The deadline to submit enrollment forms is September 11, 2007**

Dr. Ray Smith, UK Forage Extension Specialist

Are you a "tobacco dependant farm?" _____

Provide directions to your farm including approximate mileage from a main highway.

_____

_____

Describe access to the field including the ability to bring in a heavy truck and trailer used to haul the large square baler and tractor.

---

_____

_____

Describe the approximate slope, soil type, and other characteristics of your field including fencing in place or that you will build and location of fence to the 5 acre field.

_____

_____

Describe current status of this field and potential weed problems: grass sod, crop stubble, etc…

_____

Provide the most recent soil test from this field and/or recent lime and fertilizer applications.

_____

_____

How will you have field sprayed (Roundup burndown spray and subsequent herbicide applications)? In other words, who does your contract spraying or describe your spray equipment?

_____

_____

Describe your haying equipment (mower, baler, etc…). Note: A large round baler is required.

_____

Describe your willingness to host field days, questions from the local press, etc….

_____

_____

_____

Describe your hay storage facility and access to this facility

_____

_____

How will you transport or arrange transport of the bales to the drop off point? At present, this drop off point will be in the Maysville area.

_____

Briefly describe your past involvement with your local county agent and with local extension programming.

_____

_____

If a viable market develops for biomass, what is your interest in planting switchgrass or other biomass crops? How many acres could you see planting in a 5-6 year window?

_____

_____

Why do you believe your farm is well suited for this demonstration project?

_____

_____

_____

_____

_____

**Full Description of Producer Responsibilities for Switchgrass Biomass Project**

This project is designed to establish, maintain, and harvest 5 acre fields of Switchgrass on 20 farms in East Central Kentucky with locations that are within a 60 mile radius of Maysville, KY. The project is a component of a larger project being conducted by the Kentucky Forage and Grassland Council with funding from the Agricultural Development Board. The University of Kentucky is managing the project with county agents as the local coordinators and over project coordination through the Project Coordinator (PC) and the Principle Investigator (PI) located in Lexington. Up to eight fields will be established in 2007 and the remaining fields (12) in 2008.

Producers must provide a contiguous 5 acre field that is accessible at all times and must be able to accommodate the needed machinery for establishment and harvesting the switchgrass crop. The field must not contain rock outcroppings or other hindrances that would slow establishment, harvesting, or any other phase of the project. The field must also be fenced to keep livestock off the demonstration area. A minimum 8' buffer strip is preferred around the switchgrass field.

The Producer must take annual soil samples from the field prior to initial establishment and then immediately after the crop is removed each year (between late October and early December). The soil test results must be provided to the local County Agent contact for dissemination to the Project Coordinator (PC). The Producer will be responsible for required lime and fertilizer applications. Note: fertility requirements are lower for switchgrass than for traditional forages with pH above 5.5 and medium P and K. No nitrogen will be applied during the establishment year. We expect annual nitrogen applications to be 50 to 75 lbs per year. Lime, P and K applications will depend on your soil conditions.

Preference will be given to fields that have low weed percentages. The existing vegetation must be sprayed with 2 applications of a Roundup/Ammonium sulfate mixture prior to establishment (approx. 1 ½ qts Roundup and 1 qt Amm. Sulfate). These burndown sprays will be coordinated by the Producer, but the application cost will reimbursed to the Producer by the Kentucky Forage and Grassland Council. The initial application of Roundup is to be applied as soon as possible after field selection. The second treatment is to be applied approximately three weeks later. After the first spray excess top growth must be removed by the Producer to facilitate Switchgrass establishment with a no-till drill. The PC will directly contract the actual establishment (including seed purchase and seeding) with Roundstone Seeds. Producer will not pay for establishment.

The Producer will be responsible for the cost of one or two post-emergent herbicide applications per year during the establishment and following years (For example: we expect that a 2,4-D/dicamba product will be required for broadleaf weed control). The Producer will be responsible for cutting, raking, and swathing the switchgrass at harvest time. Selected fields will be baled with a midsize square baler

furnished by the Project with the remaining fields to be baled with the Producer's own hay equipment. We will rotate the use of the midsize square baler between farms each year. The Producer is expected to own or have ready access to round baler. A representative sample of the bales will be weighed (scales provided by PC) at the time of baling to provide accurate production numbers from each plot.

The Producer will be responsible for inside storage of the bales of switchgrass. The storage must be accessible year round to facilitate timely delivery of the product to the end user. The Producer will work with PC to arrange delivery of all harvested product to a specific destination. The Producer will be responsible for transportation costs. Note: It is expected that the primary delivery location will be in the Maysville area.

In return for land and services provided, the Producer will receive $400.00 per acre per year. The majority of establishment costs will also be covered as outlined above. ***The Producer will not receive any funds from the sale of the product itself.*** Any funds generated by such sales will be deposited into an account for future biomass related research.

**Appendix 2.** **Project Summary for *Expanding Opportunities for Biomass and Hay Production in Northern Kentucky***

**COOPERATIVE EXTENSION SERVICE** • UNIVERSITY OF KENTUCKY COLLEGE OF AGRICULTURE, LEXINGTON, KY, 40546
AGR-201

# Switchgrass for Biomass Production in Kentucky

*S. Ray Smith, Laura Schwer, Tom Keene, and Kenton Sena, Department of Plant and Soil Sciences*

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

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

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

## Types of Switchgrass

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

### Keys to No-Till Switchgrass Establishment Success

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

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

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

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

## Phases of Switchgrass Establishment

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

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

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

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

### Upland Varieties

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

### Lowland Varieties

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

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

### Varieties for Biomass

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

## Site Preparation and Establishment

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

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

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

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

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

### No-till

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

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

### Conventional Tillage

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

## Seeding

### Date, Depth, and Rate

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

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

### Stand Assessment

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

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

**Herbicides at a Glance**

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

## Weed Control

### Mowing in the Establishment Year

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

### Using Herbicides after Planting

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

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

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

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

## Insect and Disease Control

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

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

## Fertilization

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

### Nitrogen

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

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

### pH, P, and K

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

## Prescribed Burns

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

## Harvest

### In the Fall

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

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

### In the Spring

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

## Dual-use Switchgrass Stands

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

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

### Harvesting

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

### Fertilization

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

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

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

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

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**Appendix 3.** **Project Summary for *Expanding Opportunities for Biomass and Hay Production in Northern Kentucky***

## Switchgrass Biomass Trial
## Soil Test Results for Fall 2008, 2009, 2010

| | P | | | K | | | pH | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2008 | 2009 | 2010 | 2008 | 2009 | 2010 | 2008 | 2009 | 2010 |
| Boyd-B | 30 | 21 | 65 | 385 | 299 | 363 | 5.2 | 5.2 | 6.5 |
| Boyd - H | 50 | 62 | 57 | 188 | 330 | 207 | 6.6 | 6.1 | 6.3 |
| Boyd - Y | 22 | 108 | 70 | 198 | 313 | 328 | 5.8 | 7.1 | 7.1 |
| Bracken - M | 40 | 40 | 46 | 253 | 195 | 174 | 6.1 | 5.9 | 5.9 |
| Bracken - P | 27 | 21 | 21 | 200 | 121 | 111 | 6.4 | 6.5 | 6.6 |
| Campbell - H | 28 | 31 | 38 | 267 | 258 | 268 | 6.0 | 6.0 | 5.8 |
| Fleming - C | 87 | 20 | 30 | 329 | 183 | 216 | 6.9 | 7.0 | 6.9 |
| Fleming - L | 52 | 48 | 44 | 378 | 286 | 240 | 6.0 | 6.2 | 5.7 |
| Grant - S | 69 | 109 | 85 | 255 | 320 | 342 | 6.5 | 6.5 | 6.3 |
| Harrison - D | 475 | 374 | - | 438 | 675 | - | 7.2 | 7.3 | - |
| Harrison - S | 23 | 31 | 42 | 218 | 274 | 363 | 5.4 | 5.5 | 6.3 |
| Lewis - M | 43 | 68 | 50 | 317 | 270 | 279 | 6.8 | 6.9 | 6.5 |
| Lewis - W | 100 | 72 | 59 | 642 | 352 | 330 | 5.5 | 5.7 | 5.7 |
| Mason - Co | 31 | 26 | 52 | 147 | 205 | 202 | 6.3 | 6.1 | 5.8 |
| Mason - Cr | 107 | 121 | - | 326 | 288 | - | 5.9 | 5.6 | - |
| Montgomery - S | 164 | 164 | - | 366 | 310 | - | 6.0 | 5.9 | - |
| Nicholas - H | 59 | 38 | 20 | 373 | 260 | 252 | 6.0 | 4.6 | 4.9 |
| Robertson - C | 20 | 8 | - | 351 | 285 | - | 7.0 | 6.7 | - |
| Robertson - D | 84 | 20 | - | 320 | 259 | - | 7.0 | 6.2 | - |
| Rowan - E | 348 | 397 | 270 | 540 | 569 | 358 | 5.8 | 5.6 | 5.4 |

Appendix 3 (cont)
Project Summary for *Expanding Opportunities for Biomass and Hay Production in Northern Kentucky*

| **Switchgrass Biomass Trial** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Soil Test Results for Fall 2008, 2009, 2010** | | | | | | | | | | | | |
| | **B pH** | | | **Ca** | | | **Mg** | | | **Zn** | | |
| | **2008** | **2009** | **2010** | **2008** | **2009** | **2010** | **2008** | **2009** | **2010** | **2008** | **2009** | **2010** |
| **Boyd-B** | 6.2 | 6.3 | 7.1 | 2184 | 2352 | 4893 | 374 | 352 | 331 | 3.7 | 2.8 | 3.3 |
| **Boyd - H** | 6.9 | 6.8 | 7.1 | 3761 | 3413 | 3504 | 195 | 197 | 189 | 2.5 | 2.4 | 2.3 |
| **Boyd - Y** | 6.6 | 7.2 | 7.3 | 3227 | 5202 | 5238 | 416 | 357 | 349 | 6.1 | 6.5 | 7.1 |
| **Bracken - M** | 6.5 | 6.8 | 6.8 | 3440 | 3652 | 3296 | 316 | 250 | 231 | 3.8 | 2.7 | 3.2 |
| **Bracken - P** | 6.8 | 7.0 | 7.1 | 3273 | 3273 | 3815 | 153 | 147 | 149 | 1.9 | 3.0 | 1.8 |
| **Campbell - H** | 6.5 | 6.9 | 6.8 | 6170 | 5946 | 5562 | 360 | 313 | 341 | 2.6 | 41.7 | 2.6 |
| **Fleming - C** | 7.1 | 7.2 | 7.2 | 4077 | 4681 | 4662 | 456 | 414 | 433 | 2.5 | 2.3 | 2.4 |
| **Fleming - L** | 6.5 | 6.8 | 6.6 | 3183 | 3587 | 2556 | 211 | 244 | 194 | 1.9 | 1.9 | 1.6 |
| **Grant - S** | 6.8 | 6.8 | 6.9 | 4646 | 3735 | 3629 | 228 | 235 | 238 | 2.8 | 2.2 | 2.2 |
| **Harrison - D** | 7.2 | 7.2 | - | 6103 | 5909 | - | 139 | 185 | - | 8.3 | 12.2 | - |
| **Harrison - S** | 6.1 | 6.4 | 6.9 | 4315 | 4378 | 5976 | 168 | 244 | 306 | 1.4 | 1.7 | 15.3 |
| **Lewis - M** | 7.1 | 7.2 | 7.0 | 4285 | 4441 | 3807 | 249 | 208 | 177 | 4.3 | 2.8 | 2.7 |
| **Lewis - W** | 6.5 | 6.7 | 6.6 | 3074 | 3029 | 3010 | 318 | 278 | 267 | 7.3 | 5.9 | 4.5 |
| **Mason - C** | 6.7 | 6.7 | 6.8 | 3628 | 3639 | 2858 | 175 | 220 | 122 | 1.4 | 1.6 | 0.8 |
| **Mason - C** | 6.7 | 6.6 | - | 3552 | 3133 | - | 243 | 223 | - | 3.7 | 2.6 | - |
| **Montgomery - S** | 6.5 | 6.6 | - | 3595 | 3279 | - | 250 | 239 | - | 4.0 | 3.6 | - |
| **Nicholas - H** | 6.7 | 5.6 | 5.9 | 6535 | 5592 | 4448 | 331 | 306 | 299 | 6.2 | 11.0 | 2.3 |
| **Robertson - C** | 7.1 | 6.9 | - | 12287 | 10211 | - | 377 | 341 | - | 3.2 | 1.9 | - |
| **Robertson - D** | 7.1 | 6.7 | - | 8794 | 5663 | - | 358 | 367 | - | 2.1 | 1.9 | - |
| **Rowan - E** | 6.5 | 6.7 | 6.8 | 1468 | 1280 | 1101 | 81 | 96 | 83 | 1.4 | 2.0 | 1.5 |

**Appendix 4.** **Project Summary for *Expanding Opportunities for Biomass and Hay Production in Northern Kentucky***

## Yield data from project to determine biomass potential of switchgrass

| Dry matter yields of switchgrass varieties sown June 4, 2008 at Princeton, Kentucky | | | |
|---|---|---|---|
| | Yield (tons/acre) | | |
| | 2009 | 2010 | 2011 |
| **Variety** | **Oct 28** | **Oct 20** | **Oct 25** |
| Alamo | 1.90 | 5.86 | 6.27 |
| Kanlow | 1.58 | 5.48 | 3.54 |
| Bomaster | 1.00 | 4.91 | 4.49 |
| Cave in Rock | 0.81 | 3.59 | 2.84 |
| Performer | 0.54 | 3.33 | 3.18 |
| Trailblazer | 1.03 | 3.03 | 1.90 |
| Blackwell | 0.73 | 3.16 | 1.69 |
| | | | |
| Mean | 1.08 | 4.19 | 3.42 |
| CV,% | 39.49 | 16.21 | 28.82 |
| LSD,0.05 | 0.63 | 0.91 | 1.33 |
| *Not significantly different from the highest numerical value in the column, based on the 0.05 LSD | | | |

| Dry matter yields of switchgrass varieties sown June 5, 2008 at Lexington, Kentucky | | | |
|---|---|---|---|
| | Yield (tons/acre) | | |
| | 2009 | 2010 | 2011 |
| **Variety** | **Oct 26** | **Nov 2** | **Nov 10** |
| Alamo | 3.21 | 6.09 | 4.36 |
| Kanlow | 2.74 | 5.83 | 4.06 |
| Bomaster | 1.77 | 5.39 | 4.37 |
| Cave in Rock | 2.10 | 3.66 | 2.90 |
| Blackwell | 1.52 | 2.76 | 2.08 |
| Performer | 0.27 | 2.48 | 2.85 |
| Trailblazer | 1.20 | 2.11 | 1.64 |
| | | | |
| Mean | 1.83 | 4.05 | 3.18 |
| CV,% | 29.18 | 15.47 | 44.98 |
| LSD,0.05 | 0.71 | 0.83 | 1.78 |
| *Not significantly different from the highest numerical value in the column, based on the 0.05 LSD. | | | |

| Dry matter yields of native grasses sown June 5, 2008 at Lexington, Kentucky. | | | | |
|---|---|---|---|---|
| | | Yield (tons/acre) | | |
| | | 2009 | 2010 | 2011 |
| **Variety** | **Species** | **Nov 12** | **Nov 2** | **Nov 11** |
| Alamo | switchgrass | 3.33 | 6.10 | 6.75 |
| Kanlow | switchgrass | 2.54 | 5.32 | 6.05 |
| Cave in Rock | switchgrass | 1.81 | 3.88 | 4.34 |
| Shawnee | switchgrass | 1.97 | 3.76 | 3.77 |
| Carthage | switchgrass | 1.55 | 3.12 | 4.73 |
| Blackwell | switchgrass | 1.46 | 3.20 | 3.15 |
| Shelter | switchgrass | 0.96 | 3.27 | 3.55 |
| Trailblazer | switchgrass | 1.23 | 2.57 | 2.49 |
| NE28 | switchgrass | 0.58 | 1.99 | 3.49 |
| Ky ecotype | Indiangrass | 0.95 | 1.61 | 1.44 |
| Ky ecotype | Big bluestem | 0.95 | 1.54 | 1.40 |
| Kaw | Big bluestem | 0.71 | 0.93 | 1.88 |
| Roundtree | Big bluestem | 0.53 | 0.65 | 0.43 |
| | | | | |
| Mean | | 1.43 | 2.92 | 3.34 |
| CV,% | | 22.34 | 31.04 | 24.32 |
| LSD,0.05 | | 0.46 | 1.30 | 1.17 |
| *Not significantly different from the highest numerical value in the column, based on the 0.05 LSD. | | | | |