Northern NY Agricultural Development Program
2012 Project Report

Optimizing Grass Biomass Yield and Quality for Combustion

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Background:
Northern NY imports most of its energy and is therefore heavily reliant on these greatly fluctuating outside energy sources. Grass biomass for residential and light industrial heating has the potential to be a local closed-loop energy system, with the grass produced, densified and marketed locally. The energy content in pelleted grass is similar to premium wood pellets, and the efficiency of a grass bioheat system has been estimated at 14:1 (energy output:energy input). Conversion efficiencies of other biomass processes rarely exceed a 4:1 ratio and can be considerably lower than that.

In general, the federal government continues to ignore the potential for grass bioheat, while the interest in the Northeast continues to increase. NYSERDA has funded several projects in NY to evaluate grass pelleting and the use of grass pellets for residential heating. Heating appliances are being evaluated in two NYSERDA projects for effective combustion, focusing on emissions issues. SUNY-Cobleskill has developed a mobile grass pelleting machine that is currently being tested on farms in the Hudson Valley. Enviro-Energy, LLC in Delaware County is currently pelleting grass for residential heating. Other densification equipment capable of generating various briquettes also are being tested with grass in the Northeast. The northern NY region would have the most to gain from adoption of a grass bioheat industry, compared to other regions in the Northeast.

The impact of organic matter application (manure or compost) on tradeoffs between grass biomass production, composition, and soil test N, P and K dynamics needs to be investigated. Phosphorus content of grass has very little impact on combustion, but soil test P needs to be monitored to ensure P levels do not exceed the environmental (soil-specific) threshold. Recent studies with corn showed compost increased soil C content and moisture holding capacity while liquid manure tended to sustain C levels and inorganic fertilizer applications decreased C reserves and moisture holding capacity over time. It is unknown what the dynamics would be under grass systems. It is well-known that harvest management has a major impact on grass yield and composition. Warm-season grasses tend not to persist if harvested more than once a year, while cool-season grasses have optimum yield with two harvests per season. Mature grass, left cut in the field for a week or more to leach, will result in reduced ash, N, K and Cl content.

For economically viable grass production we want to maximize forage yield. The biomass should be relatively low in total ash content (primarily silica), but more importantly relatively low in nitrogen (N), potassium (K), chlorine (Cl) and sulfur (S) content. The basic factors influencing N, K, Cl, and silica uptake by grasses include plant species, soil type, plant water uptake, N, K and Cl fertilizer use, manure application, and harvest management. Warm-season grasses such as switchgrass have lower water uptake than cool-season grasses such as reed canarygrass or tall fescue, with potentially lower silica and total ash content. Water use efficiency may also result in higher yields for warm-season grasses under limited rainfall, which can be assessed by including an irrigation treatment. Silica is much more available to grasses in clay soils compared to sandy soils, which can result in increased total ash content of grasses grown on clay soils.

Switchgrass currently is the top warm-season grass of choice for biomass in much of the country. Results obtained from switchgrass in this study will readily apply to other warm-season grasses. Reed canarygrass and tall fescue were also chosen for their high yield potential, as well as their superior persistence for northern NY winters. Results from these grasses can easily be transferred to other cool-season grass species with biomass potential. Maximum yield and persistence for warm-season grasses occurs with one harvest per season, while cool-season grasses have considerably more productivity with two harvests per season.

Methods:
It is impossible to evaluate all important factors and their interactions in field-scale studies, therefore small plot work is required. We selected three species with high yield potential (switchgrass, reed canarygrass and tall fescue) and focused on the impacts of (1) soil type, (2) soil moisture, and (3) fertility management, on yield and composition of these grass species.

Thirty-six species blocks were established [12 blocks each of switchgrass (Cave-in-Rock), reed canarygrass (Rival) and tall fescue (KY-31)], each 20’ x 60’. Of these 36 blocks, 18 are on a sandy site and 18 are located on a clay soil, both on the Willsboro research farm. It took 3 years to fully establish switchgrass at both sites. For biomass endophyte-infected tall fescue and high alkaloid reed canarygrass would be preferred, as both are more vigorous and persistent than their higher quality counterparts. No high alkaloid reed canarygrass seed is currently available, but we did find a source of endophyte-infected tall fescue. We tested for and confirmed the endophyte infection. The six treatments applied to each block were:
1) Check treatment with no additional manure or fertilizer.
2) Dairy manure, 40 tons/a wet-basis, early spring application.
3) Composted dairy manure, similar rate of dry matter as with dairy manure.
4) 150 lbs/a of N fertilizer for cool-season grasses, split-applied. 75 lbs/a for switchgrass, no P or K fertilizer.
5) 100 lbs/a of 0-0-60 plus phosphorus at 50 lbs/a of 0-46-0. (same N rate as #4).
6) Recommended rate of potassium as KCl (100 lbs/a of 0-0-60) (same N & P rates as #5).

Switchgrass blocks were sprayed with Roundup in early spring. Both dairy manure and composted dairy manure were applied in early spring at greenup of the cool-season grasses. Samples of manure and compost were taken to DairyOne labs for analysis. Nitrogen, P and K fertilizers were applied to cool-season grasses at spring green-up. Nitrogen fertilizer applied was 100 lbs/a. N, P, and K were applied to switchgrass in mid-May, with 75 lbs N/a. Three of the six field replicates were irrigated in 2012, to assess the impact of moisture availability on yield and quality.

Reed canarygrass and tall fescue were harvested Jun 27-28, 2011. The remaining 50 lbs of N fertilizer was applied following harvest. The single harvest of switchgrass was taken after frost in mid-October, 2011 after a hard freeze. A second harvest of reed canarygrass and tall fescue was also taken at that time. Soil samples were taken from all plots following the fall harvest. Soil samples were sent to the University of Maine Soil Testing Laboratory. Plant samples from all harvests were sent to Dairyland Labs for analysis, and results have not yet been returned.

Results:

Reed canarygrass stands on the sand site continued to weaken, all other stands were good. Weeds were effectively controlled in switchgrass with an application of Roundup just prior to switchgrass breaking dormancy in the spring. Broadleaf weeds were controlled in the cool-season grasses. More wild grasses were present in the reed canarygrass on the sandy site than in past years, but this would not have a significant impact from a biomass standpoint. Switchgrass and tall fescue were essentially free of weeds.

Samples were taken from 2009 to 2012 to evaluate the contribution of different plant parts to the total yield of switchgrass. Results were consistent over years. Stem contributed 49% of yield, leaf blade was 23%, leaf sheath was 15%, and the inflorescence or head was 13% of total yield. Samples also were taken from 2010 to 2012 and evaluated for the effect of stubble height on total yield. N fertilized treatments averaged 2% of the total dry matter lost for every one inch of stubble left on the field, compared with 2.5% of total dry matter lost for every one inch of stubble left on the field for unfertilized switchgrass.

On average, for 2009-2011, the only fertility treatments to increase soil P and K were manure and compost (Fig. 1). Commercial P and K treatment applied 10 or 50 lbs/a of P or K, respectively. Manure and compost both resulted in P applications of about 65 lbs/a. Compost resulted in K application of 149 lbs/a, while fresh manure resulted in K application of 293 lbs/a. Potassium is very soluble and is likely leached out of composted manure to some extent. Chloride analysis of manure and compost in 2010 and in 2012 produced almost identical results. Compost application resulted in 58 lbs Cl/a applied, while fresh manure application resulted in 146 lbs Cl/a applied.

Irrigation following spring harvest had minimal impact on Tall fescue yields for both 2011 and 2012. In 2012, irrigation increased reed canarygrass yields about one half ton/acre. Irrigation also increased switchgrass yields about one half ton/acre, if plots received any of the fertilization treatments. Check plots that do not receive any fertilization treatments were the exception, as they were in 2011. In 2011, switchgrass check plots on sandy soil averaged 32% higher yield when irrigated, and check plots on clay soil averaged 39% higher yield when irrigated. In 2012, switchgrass check plots on sandy soil averaged 48% higher yield when irrigated, and check plots on clay soil averaged 84% higher yield when irrigated.

Switchgrass once again produced the highest yields, with 5.8 tons/acre on the sand site under fertilized conditions (Fig. 2), and 6.7 tons/acre on the clay site (Fig. 3). Switchgrass yields in 2012 were the highest of the four study years. Tall fescue yielded similar to reed canarygrass on the sandy soil, but more than one ton/acre lower than reed canarygrass on the clay soil. Both cool-season grasses were very low yielding if commercial N fertilizer was not applied.

2011 showed differences among commercial fertilizer treatments for the first time in three years. The NPK treatment on cool season grasses was generally higher yielding than either the N or NP treatments. Commercial fertilizer treatments had a small effect on switchgrass yields. Cool season grasses with fresh manure application produced similar or higher yields to the NPK commercial fertilizer treatment. Once again, compost-treated cool season grasses yielded much less than other treatments, averaging 1/3 lower yields than the manure treatment (Fig. 2 & 3). There was no difference between manure and compost for switchgrass in past years, but in 2012 switchgrass yields were about 12% lower with compost compared to fresh manure. It remains clear why these grasses are relatively unresponsive to composted dairy manure.

Conclusions/Outcomes/Impacts:

Switchgrass yields are good, regardless of any fertilization, making this a very desirable biomass species. The low-alkaloid reed canarygrass ‘Rival’ has not been very vigorous, uncharacteristic of reed canarygrass in general. Biomass composition in past years was been greatly impacted by fertility treatments. Both manure and compost contain large quantities of highly available chloride, greatly increasing the Cl content of the forage for cool-season grasses, but having much less impact on switchgrass. Irrigation in 2012 had more impact on forage yields than in 2011. Switchgrass yield increased considerably in irrigated plots that received no fertility treatments.

Outreach:

A residual year of data collection without treatment applications (2013) is necessary before coming to final conclusions and distributing them through meetings and publications.

Next steps.

Acknowledgments:

We gratefully acknowledge the Cornell Agricultural Experiment Station for providing the irrigation equipment that was used in this experiment in 2011 and 2012, for purchase of a bomb calorimeter to measure energy content of biomass samples.

Reports/articles in which results of project have already been published.

Cherney, J.H. 2012. Grass Biomass as an Alternative Energy Source. New Brunswick (Canada) Soil and Crop Improvement Association Annual meeting, Mar. 1-2, 2012, Sussex, NB, CAN.

Cherney, J.H., and V.K. Verma. 2013. Grass pellet quality index: A tool to evaluate suitability of grass pellets for small scale combustion systems. Applied Energy 103:679-684.

Cherney, J.H. 2012. Herbaceous biomass for heat. Carbon, Energy, and Climate Conference. Sept. 26-28, 2012, Kellogg Biological Station, MI. North Central SARE.

Cherney, J.H. 2012. Non-traditional roles for forage crops. (invited presentation). Agronomy Abstracts. Cincinnati, OH.

Cherney, J.H., Q. Ketterings, M. Davis, D.J.R. Cherney, K. Paddock. 2012. Grass Biomass Management for Bioheat. Agronomy Abstracts, Cincinnati, OH.

Stoof, C.R., B. Richards, P. Woodbury, H. Mayton, and J.H. Cherney. 2012. Untapped Potential: Sustainable Bioenergy Production from Marginal Lands in the Northeast US. Agronomy Abstracts, Cincinnati, OH.

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Photo: Summer biomass harvest at Willsboro Research Farm, Willsboro, NY; photo: J. Cherney

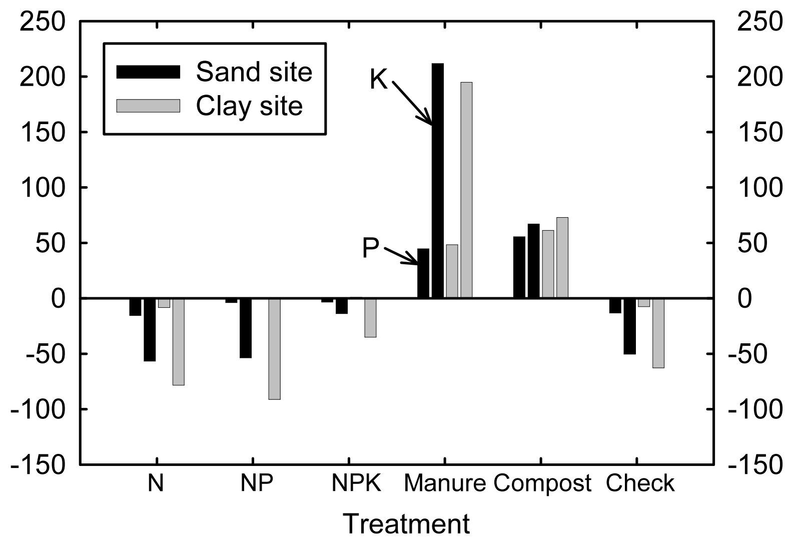

Figure 1. 2009-2011 Net P and K addition to soil for switchgrass treatments at the Cornell Willsboro Baker Research Farm. Irrigation treatments are averaged here.

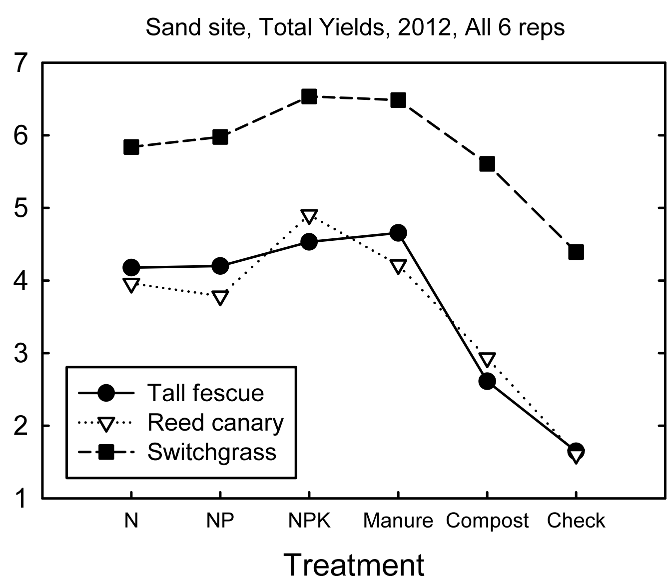

Figure 2. 2012 biomass yields of 6 treatments with 6 replications on a sandy soil at the Cornell Willsboro Baker Research Farm. N, P, and K refer to nitrogen, phosphorus and potassium fertilization. Irrigation treatments are averaged here.

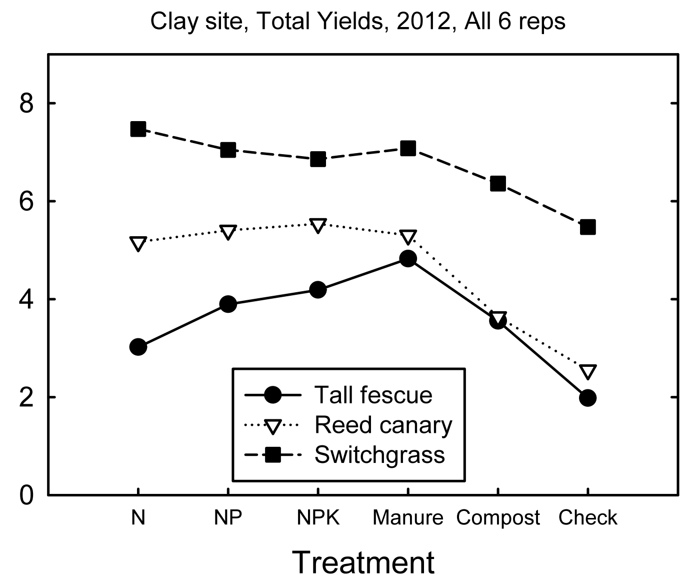

Figure 3. 2012 biomass yields of 6 treatments with 6 replications on a clay soil at the Cornell Willsboro Baker Research Farm. N, P, and K refer to nitrogen, phosphorus and potassium fertilization. Irrigation treatments are averaged here.

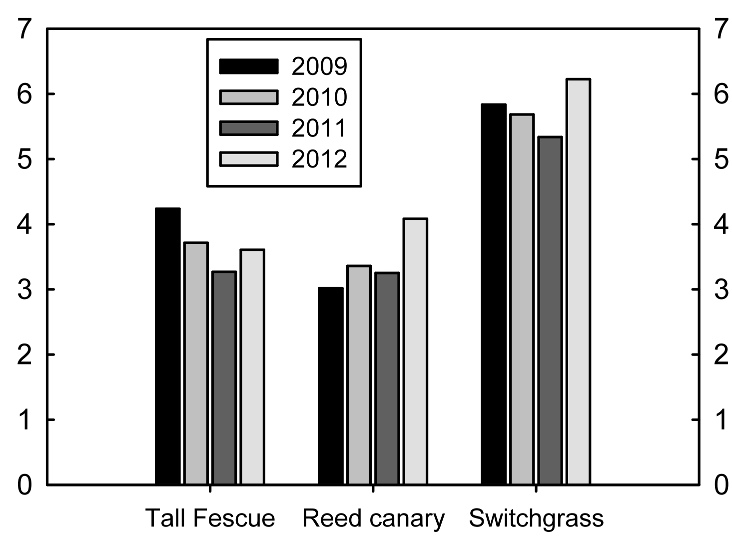

Figure 4. Biomass yields of three grass species over 4 years at Willsboro. Average of all treatments and two sites.