Northern NY Agricultural Development Program
2011 Project Report

Project Title: Optimizing Grass Biomass Yield and Quality for Combustion

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Cooperating Producers:

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 2011, to assess the impact of moisture availability on yield and quality.

Reed canarygrass and tall fescue were harvested July 6 and 7, 2011. The remaining 50 lbs of N fertilizer was applied following harvest. The single harvest of switchgrass was taken after frost on Oct. 11, 2011. 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. Plant samples from all harvests were sent to Dairyland Labs for analysis.

Results:

Grass stands appeared as healthy as they have been to-date, except for reed canarygrass on the sandy soil. Those stands continue to be weak. 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. A few wild grasses were present in the reed canarygrass on the sandy site, but this would not have a significant impact from a biomass standpoint.

Irrigation following spring harvest had minimal impact on cool-season grass yields for the season. Irrigation also had minimal impact on switchgrass yield, if plots received any of the fertilization treatments. Check plots that do not receive any fertilization treatments were the exception. Switchgrass check plots on sandy soil averaged 32% higher yield when irrigated, and check plots on clay soil averaged 39% higher yield when irrigated. Irrigation of switchgrass check plots resulted in yields similar to all the fertilization treatments. Irrigation results in 2011 were likely impacted by the excessively wet spring season.

Switchgrass once again produced the highest yields, with 5.4 tons/acre on the sand site under fertilized conditions (Fig. 1), and 6.0 tons/acre on the clay site (Fig. 2). Switchgrass yields were slightly less in 2011 compared to 2010. Tall fescue yielded higher than reed canarygrass on the sandy soil, but 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 higher yielding than either the N or NP treatments. Commercial fertilizer treatments had a small effect on switchgrass yields. Cool season grasses with manure application produced similar yields to the NPK commercial fertilizer treatment. Once again, compost-treated cool season grasses yielded much less than other treatments, averaging 50% lower yields than manure treatment (Fig. 1 & 2). There was no difference in yield, however, between compost and manure for switchgrass. It is not clear why cool-season grasses are so unresponsive to dairy manure composted, the same total amount of organic nitrogen is applied with either compost or fresh manure.

From a biomass composition standpoint, the elements of most concern are chlorine, potassium, nitrogen, and total ash content. The elemental concentration response to treatments has been very consistent over the 3 years of treatment applications. Adding potassium in either KCl, manure or compost, significantly increased the forage K content (Fig. 3). The same was true for chlorine (Fig. 4), with very high chloride uptake for the manure treatment.

Ash content tends to follow the patterns of K and Cl uptake, with higher ash in manure and compost treatments (Fig. 5). Nitrogen content (shown as CP, Fig. 6) is similar for all treatments except compost and the check. In all cases, switchgrass is much lower in ash and elemental concentrations than the cool-season grasses, making it a more acceptable biomass combustion feedstock.

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 has 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 2011 had minimal impact on forage yields, except that it increased switchgrass yield considerably, in plots that received no fertility treatments. The excessively wet spring impacted the results, hopefully 2012 will be normal or below normal in rainfall at Willsboro, to better evaluate the influence of water availability on yield and composition.

Outreach:

One more year of data collection is necessary before coming to final conclusions and distributing them through meetings and publications.

Next steps if results suggest continued work is needed in the areas of research, demonstration and/or education.

To evaluate the lingering effects of manure and compost on yield, biomass composition, and persistence of perennial grasses we need to collect four years of data from this experiment.

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

Reports and/or articles in which the results of this 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.

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Photos

Photos were taken by J. Cherney and are all from the Cornell Willsboro Baker Research Farm, Essex Co.