Northern NY Agricultural Development Program
2010 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. Even though many residents are unconcerned about potential global warming issues, most believe that energy prices will continue to rise and fluctuate. 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. Interest in Europe also continues to increase. Mobile grass pelleting equipment is being developed in the UK. Agro-Bio-Tech in Germany has a recently developed a mobile grass biomass pelleting unit for sale in Europe. 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, and Dirk-Jan Rosse is pelleting mixed grass and goldenrod in Dutchess County for residential and light industrial 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 carbon 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.

<u>Methods</u>:
It is impossible to evaluate all important factors and their interactions in field-scale studies, therefore small plot work is initially 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. In 2009 we tested for and confirmed the endophyte infection. In the fall of 2010 each individual plot was soil-sampled. 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) Recommended rate of potassium as KCl (100 lbs/a of 0-0-60) (same N rate as #4).

6) 100 lbs/a of 0-0-60 plus phosphorus at 50 lbs/a of 0-46-0. (same N rate as #4).

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. Due to the expense, irrigation of half of all blocks was dropped as an option for 2010. This meant that we had 6 replicates per site, instead of 3 replicates of irrigated and non-irrigated plots.

Reed canarygrass and tall fescue were harvested July 7, 2010. The remaining 50 lbs of N fertilizer was applied following harvest. The single harvest of switchgrass was taken after frost on Oct. 12, 2010. 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 taken to the Cornell Nutrient Analysis lab for analyses. Plant samples from all harvests were held for analysis, with some results from our forage lab.

Results:

Tall fescue stands remained excellent in 2010. The low-alkaloid reed canarygrass, however, continues to have weaker stands, particularly on the sandy site. Switchgrass stands were excellent again in 2010. 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, but this would not have a significant impact from a biomass standpoint.

Switchgrass produced the highest yields, with slightly less than 6 tons/acre on the sand site under fertilized conditions, and almost 6.5 tons/acre on the clay site (Fig. 1 & 2). Switchgrass yields were slightly less in 2010 compared to 2009. Tall fescue yielded reasonably well on both sites if fertilized with commercial fertilizer. Reed canarygrass yield improved in 2010 compared with 2009, and was not different from tall fescue fertilized yields on the clay site in 2010. Both cool-season grasses were very low yielding if commercial N fertilizer was not applied.

There were no differences among the three commercial fertilizer treatments in 2009 or 2010 on either site. In 2009, manure application resulted in significantly higher yields than compost on the sand site, but not on the clay site. In 2010, manure application resulted in higher yields than compost at both sites. In both 2009 and 2010, manure application yielded higher checks at both sites. On the sand site, compost application yielded similar to the check in both years.

Species reacted differently to the set of treatments again in 2010, resulting in an interaction between species and treatments (Fig. 1 & 2). Switchgrass has only a modest need for N fertilization, such that the response to commercial N fertilizer was small. Switchgrass check plots actually yielded numerically the highest among all treatments. Tall fescue and reed canarygrass, on the other hand, had a very significant response to commercial N fertilizer. The response of cool-season grasses to manure application was intermediate between checks and commercial N fertilizer treatments. After two years of treatments, however, manure and compost would be expected to produce yields as high as N fertilizer treatments. The response to compost is particularly small to-date.

Conclusions/Outcomes/Impacts:

Preliminary observations:
Switchgrass can be difficult to establish, but full stands were eventually achieved. Although not currently labeled for commercial production use, the application of Roundup in the early spring was very effective in controlling weeds. The only weed that Roundup could not effectively control was milkweed. Yields are good, regardless of any fertilization, making this a very desirable biomass species.

Tall fescue 'KY-31' seed was not guaranteed to contain endophyte, but when we tested the stands in 2009, the endophyte had spread to most of the plants present, with over 90% of the tillers infected in some blocks. For biomass use an endophyte-infected stand is desirable, as the endophytic fungus makes fescue more vigorous and persistent. Endophyte-infected fescue, however, is very undesirable as a ruminant forage.

The low-alkaloid reed canarygrass 'Rival' has not been very vigorous, uncharacteristic of reed canarygrass in general. We collected a large group of wild-type reed canarygrass plants from across the Midwest and Northeast (including a number of plants collected in northern NY) and identified wild, high-alkaloid germplasm that is 20-30% higher yielding than all current low-alkaloid varieties. Seed is not yet available for commercial use, but release of specific biomass varieties is anticipated at some point in the future.

Outreach:

Another year of data collection is necessary before coming to any conclusions and distributing them through meetings and publications.

Next steps:

To evaluate the effects of manure and compost on yield, biomass composition, and persistence of perennial grasses we will need to collect three 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, and providing funds for analysis of samples.

Reports and/or articles in which the results of this project have already been published.

Cherney, J.H., Q.M. Ketterings, M.H. Davis, and D.J.R. Cherney. 2010. Perennial grass management influences combustion characteristics. Northeast Agronomy Abstracts, Ithaca, NY.

Cherney, J.H. 2010. Feasibility of grass pellet combustion for residential heating. Biofuel combustion symposium. 37th Northeast Regional American Chemical Society meeting. 2-4 June, 2010, SUNY-Potsdam, Potsdam, NY.

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Photos

Attached photos were taken by J. Cherney and are all from the Cornell E.V. Baker Research Farm, Willsboro, Essex Co.