Northern NY Agricultural Development Program
2013 Project Report

Grass Biomass for Northern NY

Project Leader(s):
- J.H. Cherney, Cornell University Department of Crop & Soil Sciences
- Q. Ketterings, Cornell University Department of Animal Science
- D.J.R. Cherney, Cornell University Department of Animal Science
- M. Davis, Cornell Agricultural Experiment Station, Willsboro Research Farm, Willsboro, NY

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 there continues to be some interest in the Northeast, including NY, PA and VT. NYSERDA continues to fund a few projects involving densification and combustion of grasses. 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.

<u>Methods</u>:

<u>Willsboro Study</u>

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 for four years 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. For 2013, no treatments were applied, as this was a residual year, monitoring yield residual effects of past treatments. Reed canarygrass and tall fescue were harvested July 11, 2013. The single harvest of switchgrass was taken on Sept. 26, 2013. 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.

Chazy Study

Both big bluestem and coastal panic grass have been found to be higher yielding that switchgrass in Pennsylvania. Roger Samson at REAP-Canada has postulated that the highest potential yields might occur with mixtures of switchgrass and either bluestem or coastal panic grass. Mixtures of grass species may not work very well for conversions requiring an extremely uniform feedstock, like cellulosic ethanol, but would work fine for any combustion application. The grass with the lowest ash and mineral concentrations has consistently been big bluestem. All of these warm-season grasses are well adapted to northern NY conditions.

Effective evaluation of mixtures requires a very consistent seedbed and seeding, making this difficult to accomplish under farm field conditions. To ensure a consistent seeding rate for evaluation of the species interaction, they need to be seeded separately, ideally at right angles to one another. It is difficult to get the seed to mix uniformly, particularly when using the extremely fluffy bluegrass seed (much worse than bromegrass seed). This is best accomplished using small plots and small plot seeding equipment, under very controlled field conditions, as opposed to evaluation using farm fields. The Miner Institute plot area provided excellent conditions for such an evaluation. All of these grasses require a minimum of fertilization and management once established, and have the potential for high biomass yields.

Plots were sown May 26, 2010. There were three field replicates and individual plots were 15' x 15'. Mixtures were sown individually, with one species sown first, then the other species was sown in rows 90 degrees from the first species. Plots were fertilized with 50 lbs/a of N fertilizer, and P fertilizer based on soil tests, in the spring of 2012 and 2013. Potassium fertilizer was not applied, as one goal for grass biomass is low K content. "REAP" switchgrass (Resource Efficient Agricultural Production-Canada) was developed from a selection in a Cave-in-Rock stand. Treatments and seeding were as follows:

ID	Species	Seeding rates
		lbs/acre
1	Cave-in-Rock switchgrass	10
2	BoMaster switchgrass	10
3	Atlantic coastal panic grass	10
4	Prairie View big bluestem	12
5	Suther big bluestem	12
6	Cave-in-Rock SW + Atlantic CPG	5 + 5
7	Cave-in-Rock SW + Suther BB	5 + 6
8	Cave-in-Rock SW + Prairie View BB	5 + 6
9	BoMaster SW + Atlantic CPG	5 + 5
10	Cave-in-Rock SW + Southlow BB	5 + 6
11	BoMaster SW + Prairie View BB	5 + 6
12	REAP switchgrass	10

Stands were relatively well established in 2012, but not fully established until the 2013 growing season.

Results:

Willsboro Study

Reed canarygrass stands on the sand site continued to weaken, as did tall fescue on the sand site. Samples taken from 2009 to 2012 evaluated the contribution of different plant parts to the total yield of switchgrass. Results were consistent over years (Fig. 1). 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 (Table 1). 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.

Soil samples were collected from all plots in the late fall of 2013 and analyzed for residual effects of treatment applications from 2009-2012. Soil pH ranged from 6.4 to 6.8, with compost plots significantly higher in pH than other treatments (Fig. 4). Compost treatments also were significantly higher in soil P than all other treatments (Fig. 5). Manure treatments were also higher in P than other treatments, except compost. Soil K was much higher for manure treatments, with compost treatments higher than all other treatments except manure on the sand site, but not on the clay site (Fig. 6). In general, the sand site was much higher in P than the clay site, and much lower in K than the clay site, except for K on manure treatments on sand. For soil organic matter, there were no differences among treatments on the sand site, but the compost treatment was significantly higher for manure treatments on the clay site (Fig. 7). For both calcium (Fig. 8) and magnesium, the clay site was 2-4 times higher than the sand site. Compost treatments were higher in Ca than other treatments, while manure treatments were highest in Mg.

Soil available Al and Fe were lower on manure and compost treatments on sand, but not on clay. Soil boron and zinc were significantly higher for manure and compost than other treatments on both sites. The residual effects of manure and compost application will persist for several years following application.

Switchgrass once again produced the highest yields, averaging 5.6 tons/acre in 2013, or about 90% of the yield average from 2012 when treatments were applied (Fig. 2 & 3). Yields were more variable on the sand site. Tall fescue yielded somewhat similar to reed canarygrass on the sandy soil, but about one ton/acre lower than reed canarygrass on the clay soil, as in 2012. Averaged over sites and former treatments, tall fescue yielded 65% of 2012 results, and reed canarygrass yielded 72% of 2012.

Former manure-treated plots and compost-treated plots were higher yielding than other treatments on the clay site, but generally not on the sand site. Residual treatment 2013 yields were 15% higher for N treatments, 25% higher for compost, and 46% higher for manure treatments, compared to check plots. 2013 yields from former N-treated plots were 68% of 2012, manure plots were 82% of 2012, compost plots were 93% of 2012, and check plots had similar yields in 2013 compared to 2012.

Chazy Study
Yields of warm-season grasses alone and in mixture were slightly higher in 2013, compared to 2012 (Table 2). In 2013, the mixture of BoMaster switchgrass plus Prairieview big bluestem was highest yielding at Chazy. This species combination yielded over one ton/acre more than all others in a similar experiment conducted in Ithaca in 2013, with over 8 tons/acre. It is not yet clear if these stands are fully established and stable for species composition and yield, but it appears that Prairieview big bluestem is performing well, while Atlantic coastal panic grass seems less productive than others. Atlantic coastal panic grass performed extremely well in PA, but does not look as promising in northern NY.

Conclusions/Outcomes/Impacts:
Switchgrass yields remained high without any treatments applied in 2013, making this a very desirable biomass species. The low-alkaloid reed canarygrass ‘Rival’ has not been very vigorous, uncharacteristic of reed canarygrass in general. Both from a yield standpoint and a compositional standpoint, switchgrass is considerably better than the cool-season grasses. Application of manure or compost will greatly increase the chlorine content of forage, as well as potassium content, both detrimental for combustion fuels. A combination of switchgrass and big bluestem may produce higher yields than switchgrass alone.

Outreach:
Results will be presented at ANCA 2014 Clean Energy Conference, June 4-6, Lake Placid, NY.

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

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

Cherney, J.H., K.M. Paddock, Q. Ketterings, M.D. Davis, and D.J.R. Cherney. 2013. Grass Biomass Yield as Influenced by Fertility. Bioenergy Information Sheet #12. www.grassbioenergy.org.

Cherney, J.H., K.M. Paddock, Q. Ketterings, M.D. Davis, and D.J.R. Cherney. 2013. Grass Biomass composition as Influenced by Fertility. Bioenergy Information Sheet #13. www.grassbioenergy.org.

Cherney, J.H., K.M. Paddock, M.D. Davis, M. Hunter, J. Lawrence, and W. Verbeten. 2013. Mulch Hay for Combustion in NYS. Bioenergy Information Sheet #14. www.grassbioenergy.org.

Cherney, J.H., K.M. Paddock, and Q. Ketterings. 2013. Soil Contamination of Grass Biomass. Bioenergy Information Sheet #15. www.grassbioenergy.org.

Cherney, J.H., K.M. Paddock, Q. Ketterings, M. Davis, and D.J.R. Cherney. 2013. Switchgrass Morphological Components. Bioenergy Information Sheet #16. www.grassbioenergy.org.

Cherney, J.H., K.M. Paddock, Q. Ketterings, M. Davis, and D.J.R. Cherney. 2013. Switchgrass Stubble Height. Bioenergy Information Sheet #17. www.grassbioenergy.org.

For more information:

Jerry H. Cherney
Cornell University Department of Crop and Soil Sciences
503 Bradfield Hall, Ithaca, NY 14853
Tel. 607-255-0945, JHC5@cornell.edu
www.grassbioenergy.org

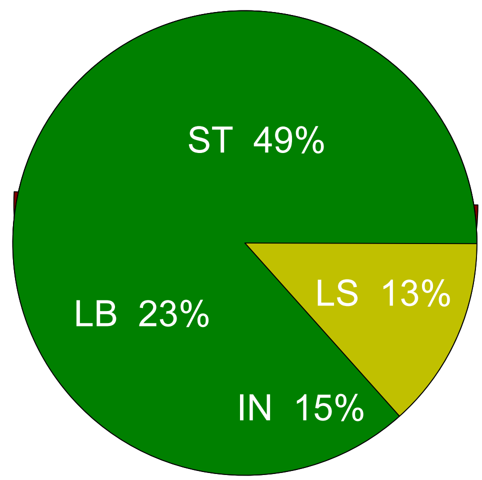

Fig. 1. Percent of dry matter for each morphological component of switchgrass in the fall at Willsboro, NY (average of 6 treatments, 2 sites and 4 years).

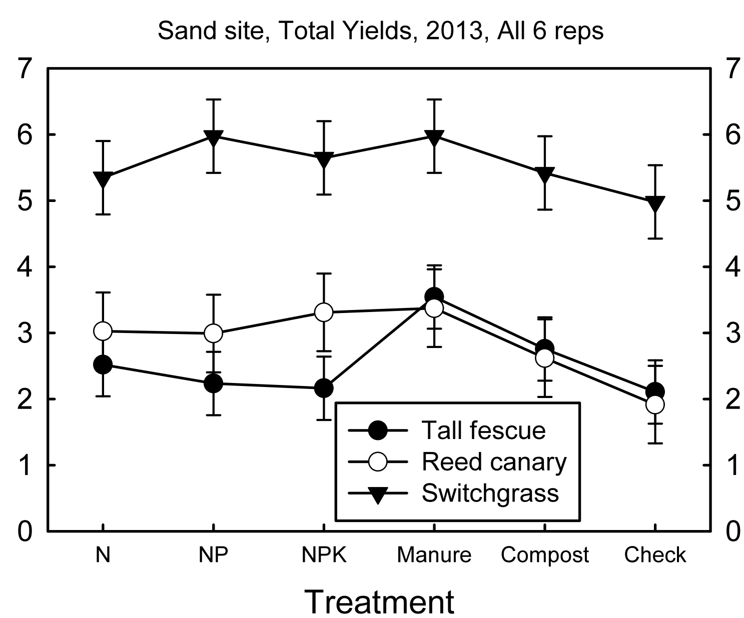

Figure 2. 2013 biomass yields of 6 treatments from previous years, with 6 replications on a sandy soil at the Cornell Willsboro Baker Research Farm. N, P, and K refer to nitrogen, phosphorus and potassium fertilization.

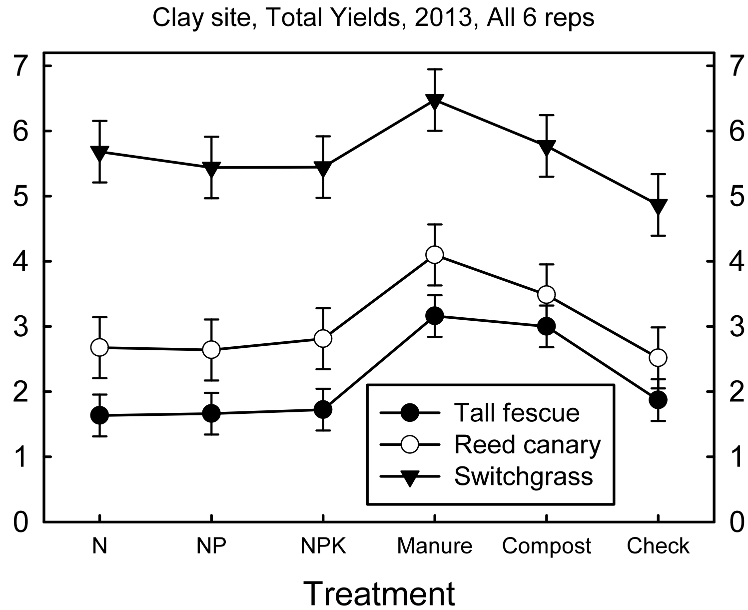

Figure 3. 2013 biomass yields of 6 treatments from previous years, with 6 replications on a clay soil at the Cornell Willsboro Baker Research Farm. N, P, and K refer to nitrogen, phosphorus and potassium fertilization.

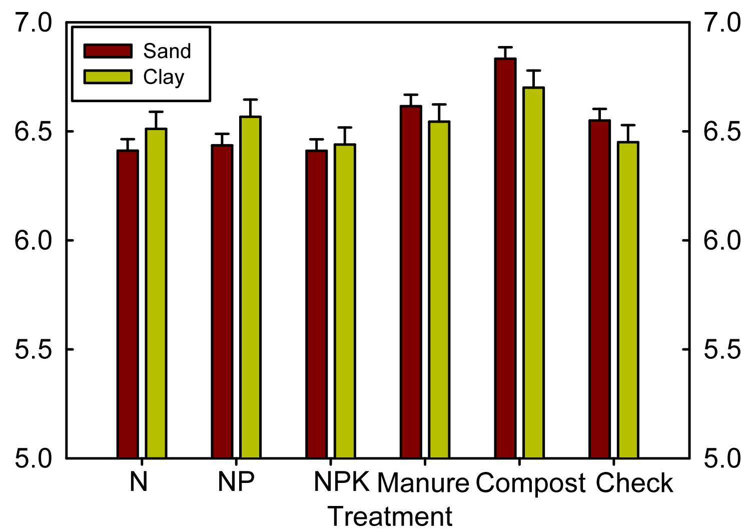

Figure 4. Soil pH by site and treatment after 2013 season at the Cornell Willsboro Baker Research Farm.

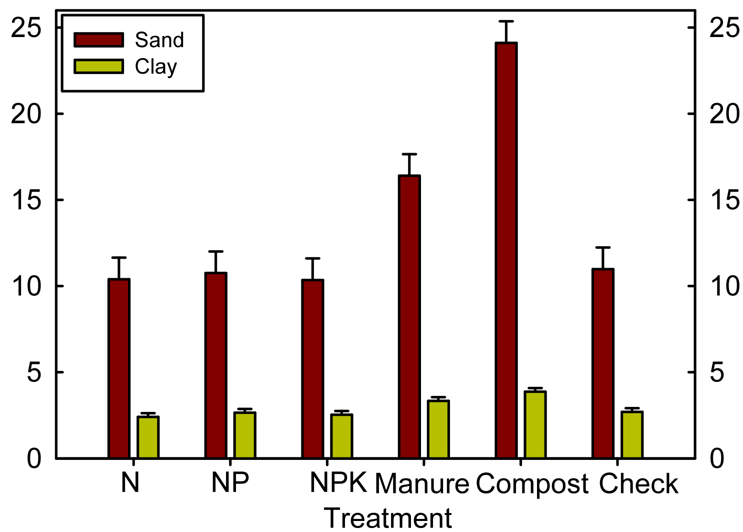

Figure 5. Soil P by site and treatment after 2013 season at the Cornell Willsboro Baker Research Farm.

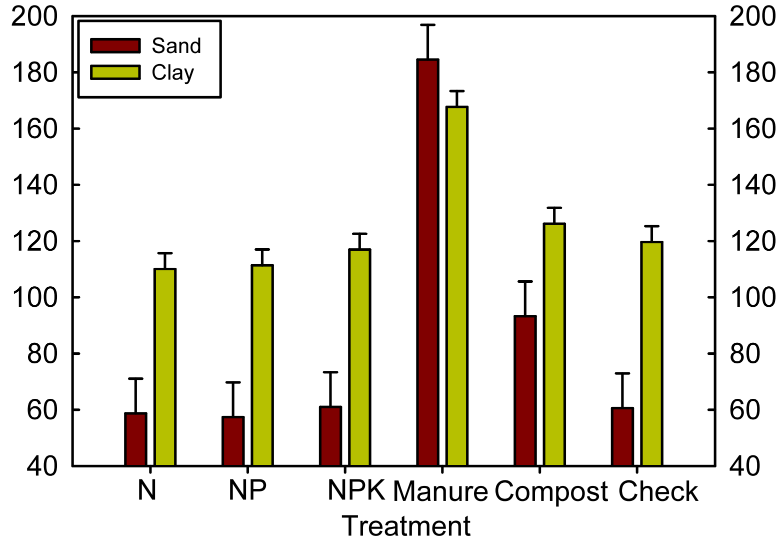

Figure 6. Soil K by site and treatment after 2013 season at the Cornell Willsboro Baker Research Farm.

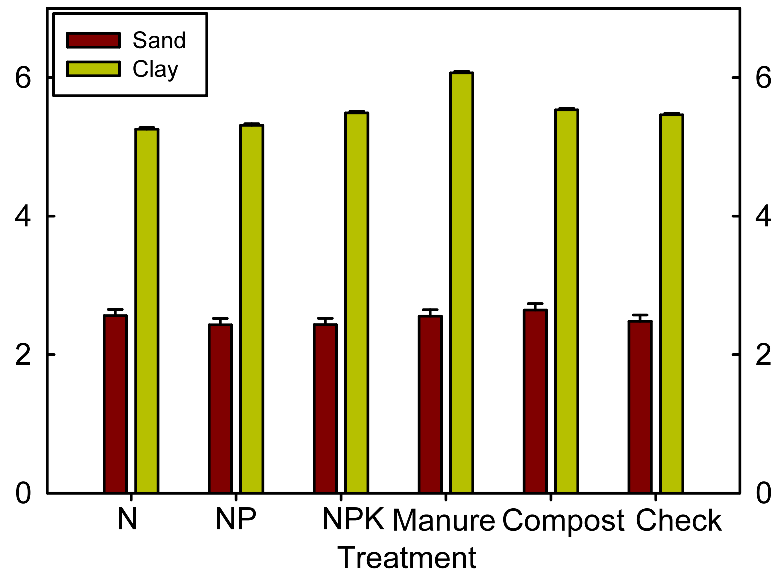

Figure 7. Soil organic matter by site and treatment after 2013 season at the Cornell Willsboro Baker Research Farm.

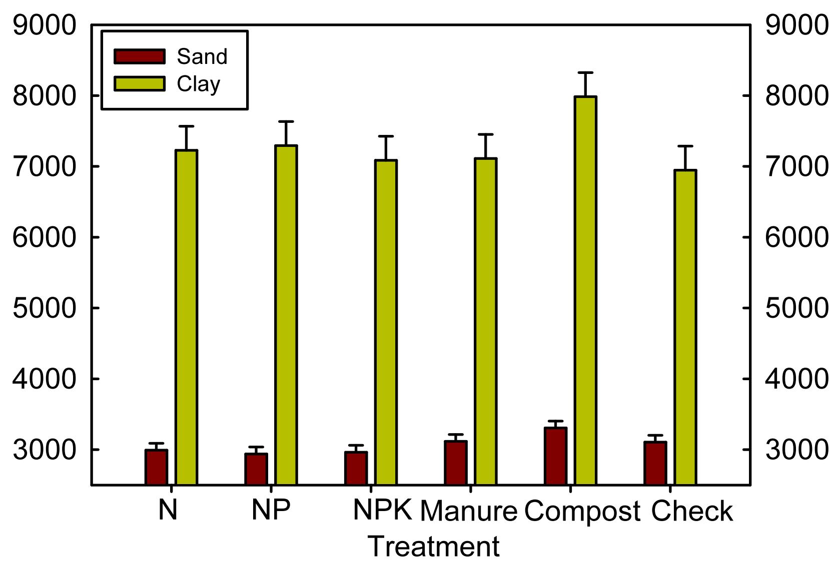

Figure 8. Soil Ca by site and treatment after 2013 season at the Cornell Willsboro Baker Research Farm.

Table 1. Yield loss per inch of stubble height in 'Cave-in-Rock', as influenced by fertility treatments at Willsboro, NY. Average of two sites with 3 replicates each.

Fertility	2010	2011	2012	Ave.
% of total yield per inch				
N	1.89	2.14	2.10	**2.04**
NP	1.89	2.25	1.96	**2.03**
NPK	1.91	2.33	1.99	**2.08**
Manure	2.05	2.16	2.11	**2.11**
Compost	2.07	2.20	2.10	**2.12**
Check	2.21	2.58	2.75	**2.51**

Table 2. Yields of warm-season grasses and mixtures, 2012 and 2013, Chazy, NY.

Cultivar/Species	2012		Cultivar/Species	2013
	Tons DM/a			Tons DM/a
Cave-in-Rock SW	5.62		BoMaster SW + Prairieview BB	6.03
Prairieview BB	5.51		Prairieview BB	5.87
Cave-in-Rock SW + Suther BB	5.36		Cave-in-Rock SW + PrairieView BB	5.83
Cave-in-Rock SW + PrairieView BB	5.28		Cave-in-Rock SW	5.56
Cave-in-Rock SW + Atlantic CP	5.26		REAP SW	5.55
REAP SW	5.21		Cave-in-Rock SW + Suther BB	5.31
BoMaster SW + Prairieview BB	5.02		Cave-in-Rock SW + Southlow BB	5.04
Atlantic Coastal Panic	4.87		Cave-in-Rock SW + Atlantic CP	4.94
BoMaster SW + Atlantic CP	4.57		Suther BB	4.82
Suther BB	4.47		Atlantic Coastal Panic	4.80
BoMaster SW	3.76		BoMaster SW + Atlantic CP	4.71
Cave-in-Rock SW + Southlow BB	3.60		BoMaster SW	3.47
LSD 0.10	1.34		LSD 0.10	1.29
CV	15.0		CV	13.8

Photo

Willsboro Research Farm biomass trial results in 2013 showed switchgrass was more productive with less fertilization, and had more favorable mineral composition, compared to cool-season grasses. Photo by J. Cherney.