Soil Nitrogen Dynamics and Miscanthus Yield of an Amended, Reclaimed Mine Soil

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INTRODUCTION

Giant Miscanthus (*Miscanthus* x *giganteus*)

- Perennial C_4 Grass, Dedicated Biomass Crop
- Adapts to a variety of climate/soil conditions
- Projected yield potential of agricultural soils in PA: 15 – 30 Mg ha^{-1} (Miguez *et al*., 2011). Based on climate, soil physical properties, and plant physiology

<u>Can mineland soils produce Miscanthus yields comparable to prime farmland?</u>

Pennsylvania Minelands

- 76,500 ha of abandoned minelands in addition to active mines
  - Some of this could be reused to produce biomass
  - Soils typified by low nutrient status, high bulk density; low water-holding capacity, soil organic carbon, and pH

<u>What is miscanthus response to nutrient addition on mineland soil?</u>

PA Mushroom Production generates ~535,000 m^3 of spent Mushroom Compost (SMC)

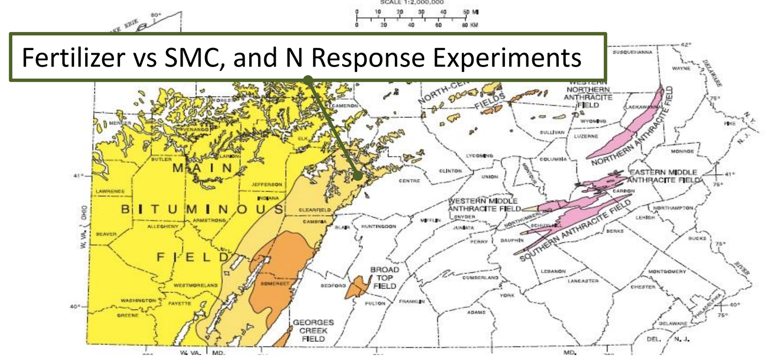
- SMC could be used as a nutrient source for mine soils
- May have additional benefits from added organic carbon

<u>Is miscanthus response to nutrient addition from SMC similar to its response to inorganic fertilizer?</u>

Conducted two experiments; one compared miscanthus response to inorganic fertilizer and SMC added at to provide similar amounts of N, P and K addition, the other determined miscanthus response to inorganic N addition when P and K were not limiting.

MATERIALS & METHODS

Both experiments were conducted on a PA reclaimed mine site



Experiment 1: Fertilizer and SMC Response

- Randomized Complete Block Design (4 reps)
- SMC applied at rates of 0, 13.45, 26.9, 40.35, and 53.8 Mg ha^{-1}.
- Inorganic fertilizer applied to add equivalent amounts of total P and K and equivalent plant-available N (PAN);

SMC Rate	Fertility Rate	Total N	PAN*	P	K
Mg ha^{-1}	----------------	kg ha^{-1}		kg ha^{-1}	
0	0	0	0	0	0
6.1	1x	123	24.6	31	112
12.2	2x	246	49.2	62	224
18.3	3x	369	73.8	93	336
24.4	4x	492	98.4	124	448

* Calculation of PAN assumes 20% constant mineralization of Total N in applied SMC

- Treatments incorporated, Miscanthus planted (April 2014)
- Treatments reapplied each May; harvested in November
- *In situ* soil N-mineralization covered core method (Ma *et al*., 1999) (2015/2016)
- 3 week intervals (May-Sept.); 6 week intervals (Sept. – Nov.)
- Biomass sampled 7 dates each growing season (2015/2016)

Experiment 2: Yield Response to Nitrogen

- Developed to determine yield response to nitrogen when P and K are not limiting.
- Fixed application of 30 kg P ha^{-1} and 56 kg K ha^{-1} to add equal amounts to each plot; N application rates were 0, 34, 68, 102, and 136 kg N ha^{-1}
- Treatments reapplied in 2016, harvest each November

RESULTS

Miscanthus rhizomes establishing at the reclaimed mine site (April, 2014)

Application of SMC (May, 2015)

2nd year Miscanthus (July, 2015)

Harvesting Miscanthus (November, 2015)

Fertilizer vs SMC

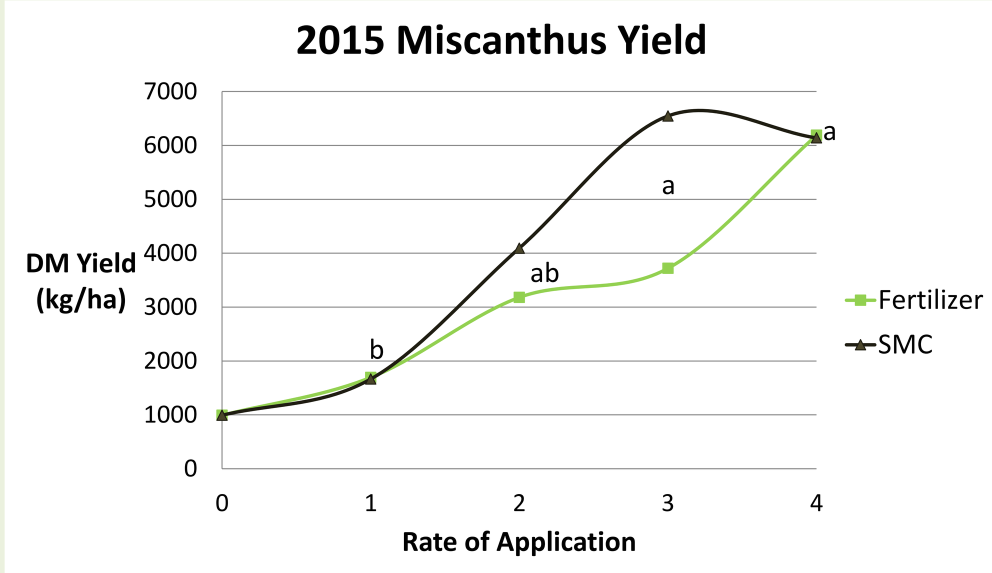


Figure 1. Yield response to SMC and Fertilizer in 2015. Nutrient application rates flagged with different letters are different at p=0.05.

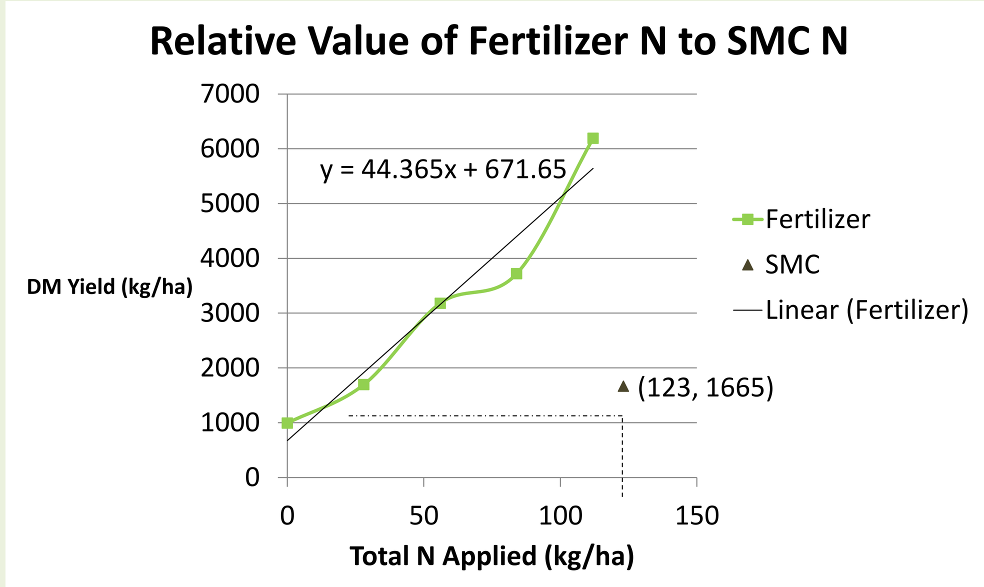


Figure 2. Regression equation determined for Fertilizer response curve. Yield of SMC (6.1 Mg ha^{-1}) was set equal to equation and solved for x to estimate the relative value of fertilizer to SMC.

1665 = 44.365x – 671.65; X ≈ 22.39
22.39 kg fertilizer / 123 kg SMC ≈ 0.18

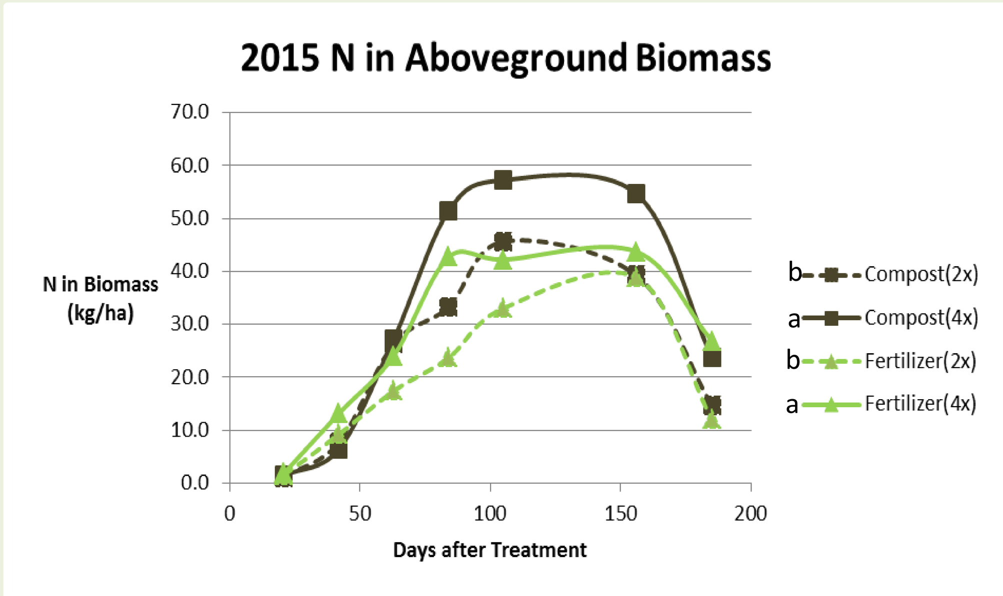


Figure 3. N Uptake in aboveground tissues during 2015 sampling. Nutrient application rates flagged with different letters are different at p=0.05.

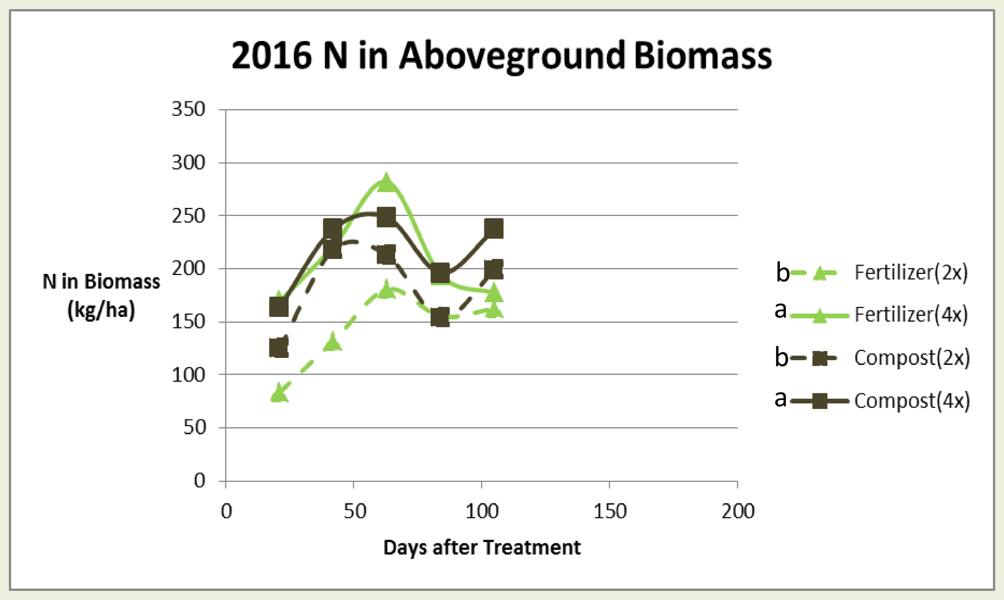


Figure 4. N Uptake in aboveground tissues during 2016 sampling. Nutrient application rates flagged with different letters are different at p=0.05.

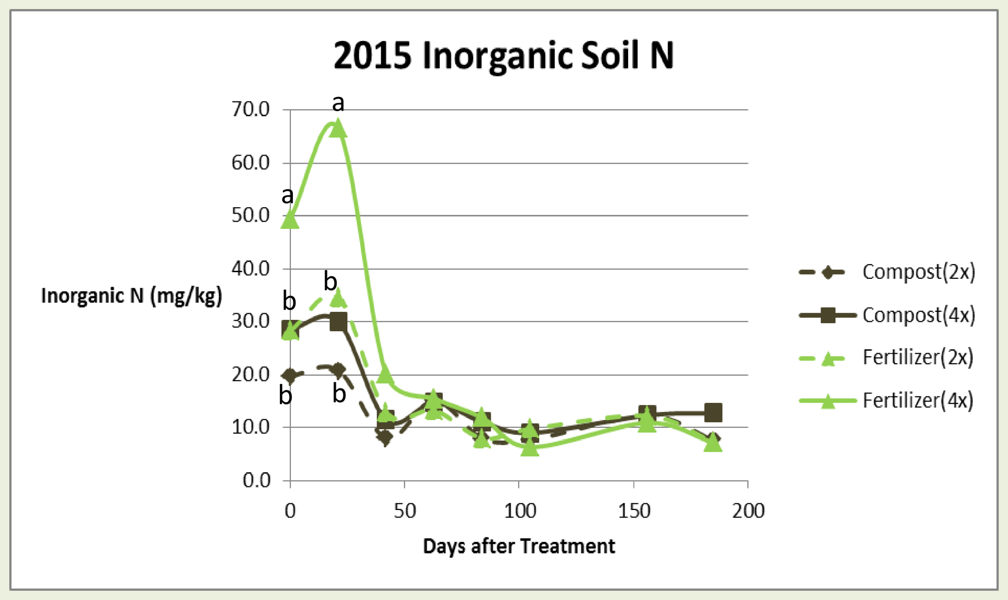


Figure 5. Soil inorganic N (NH_4^+ + NO_3^-) during 2015 sampling. Nutrient application rates flagged with different letters are different at p=0.05.

N Response

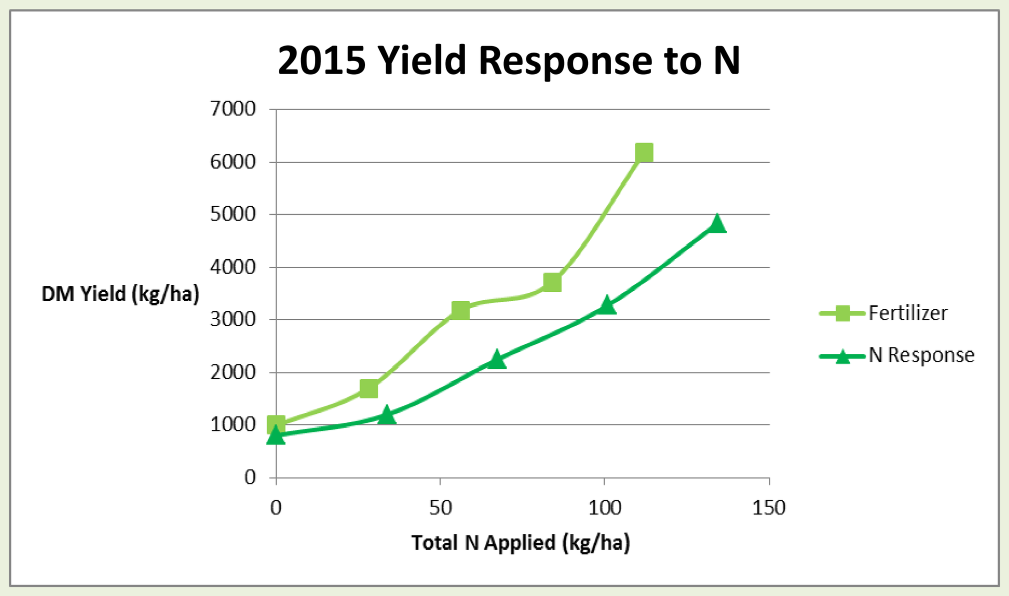


Figure 6. Yields of the N Response experiment in 2015 compared to the Fertilizer treatments in Experiment 1

CONCLUSIONS

<u>Can mineland soils produce Miscanthus yields comparable to prime farmland?</u>

- 2014 and 2015 yields were much lower than the projected 15-30 Mg ha^{-1} for PA (Miguez *et al.*, 2012)
- Stand will not reach maturity until 2017 and yields are expected to increase
- Biomass N increased 4x from 2015 to 2016; suggests a sizeable yield increase in 2016 (Fig.3,4)
- Too early to determine if yields on mine soil will reach expected yields on agricultural soils

<u>What is miscanthus response to nutrient addition on mineland soil?</u>

- Yield increases with nutrient addition (44 kg/ha for each additional kg N ha^{-1}; Fig. 2)
- No clear yield plateau was reached in 2015. This indicates greater nutrient addition may be needed to achieve maximum yield on mine soil.
- Higher aboveground biomass N (kg ha^{-1}) from 4x rate than 2x rate in both years (Fig.3,4)

<u>Is miscanthus response to nutrient addition from SMC similar to its response to inorganic fertilizer?</u>

- No yield difference between SMC and Fertilizer; yields increase with application rate (Fig.1)
- Relative value of Fertilizer: SMC ≈ 0.18; close to 0.2 value used to estimate PAN (Fig.2)
- Aboveground biomass N (kg ha^{-1}) : no difference between SMC and Fertilizer (Fig. 3,4)

<u>Impacts of treatments on inorganic soil N</u>

- Inorganic soil N significantly higher with 4x Fertilizer than other treatments on days 0, 21 (Fig. 5).
- Large inorganic N values early in the season likely reflect the high rate of addition of N as ammonium with fertilizer, whereas organic N is added with SMC.
- A large decrease occurs from late June to mid-July, just before period of highest N uptake by Miscanthus (Figs. 3,5)

<u>Overall</u>

- 2015 biomass N: late August peak, senescence/translocation reduced N until harvest
- 2016 biomass N: drought may have played a role. August (day 84) samples may impacted by the drought from late June to mid-August. N content did not change, but biomass might have decreased.
- May see a buildup of soil fertility with annual amendment application, and plants may further reflect that due to their ability to translocate nutrients.

REFERENCES

Ma, B. L., Dwyer, L. M., & Gregorich, E. G. (1999). Soil nitrogen amendment effects on seasonal nitrogen mineralization and nitrogen cycling in maize production. *Agron. J.*, **91**:1003-1009.

Miguez, F. E., Maughan, M., Bollero, G. A., & Long, S. P. (2012). Modeling spatial and dynamic variation in growth, yield, and yield stability of the bioenergy crops Miscanthus× giganteus and Panicum virgatum across the conterminous United States. *GCB Bioenergy*, **4**: 509-520.