NITROGEN MANAGEMENT OF BIOENERGY MISCANTHUS ON CLAYPAN SOIL LANDSCAPES

Bryan. K. Randall[1], Newell R. Kitchen[2], Emily A. Heaton[3],
D. Brent Myers[1], Allen L. Thompson[1]
[1]University of Missouri, Columbia, Missouri,
[2]USDA-ARS, Columbia, Missouri,
[3]Iowa State University, Ames, Iowa

Abstract

Bioenergy crop *Miscanthus x giganteus* has been well studied for its yield in Europe and certain parts of the US Midwest but little has been done to investigate Miscanthus production in settings economically marginal for grain production. This study was conducted to determine nitrogen (N) requirements and yield potentials of *M. x giganteus* in degraded claypan soils. The effects of N fertilizer rates were investigated at four different locations in central Missouri on a Mexico series soil (fine, smectitic, mesic Aeric Vertic Epiaqualfs). In 2013, treatments of 0, 34, 68 and 134 kg ha^{-1} had no effect on the yield at two of the three sites locations. The fourth site with treatments of 0, 45, 90 and 134 kg ha^{-1} also had no effect on yield. This could be due to the ability for miscanthus to recycle nutrients from previous year's growth, along with its ability to re-partition N into the most photosynthetic-active upper leaves throughout the growing season. Higher N rates correlated with increased SPAD chlorophyll readings at all locations early in the growing season in both 2013 and 2014; however, little difference was observed in chlorophyll readings by September.

Introduction

Degraded soils, in traditional agricultural settings, are often typified as being less productive, and consequently, economically marginal. In addition, they are environmentally vulnerable; being more subject to erosion and topsoil loss. Farmers are motivated by strong economic return, but must also balance the return with the environmental impact on their land. *Miscanthus x giganteus* (hereafter referred to as miscanthus), an emerging bioenergy crop, grown in degraded soils presents itself as a plausible option as yielding high economic return while remediating environmental problems associated with degraded soil. Perennial dedicated energy crops, such as miscanthus, are increasingly expected to replace petroleum, as conversion processes are developed and emerging legislation in the U.S. requires their use (Perlack et al., 2011). Factors affecting nitrogen (N) requirements, yield potential, and establishment of miscanthus in degraded soils are a few of the questions that need to be addressed in order to help farmers and legislators evaluate the long-term production capacity of this crop.

Soil degradation can occur by a number of natural and manmade causes. One U.S. Midwest soil vulnerable to degradation is found in areas called Central Claypan Areas (Major Land Resourse Area 113). Found throughout much of northeastern and central Missouri, claypan soils contain a very slowly permeable subsoil layer with large clay concentration referred to as the claypan. Due to their large shrink-swell clay content they generally limit or slow the downward movement of water through the soil in the fall, winter, and spring periods. Erosion has been accelerated on these soils by grain cropping practices and productivity of these sensitive soil areas is reduced. These soils have small and sometimes negative profitability due to suppressed grain yield or greater risk of crop failure (Massey et al., 2008). Water erosion, accelerated by modern agricultural practices, has resulted in significant topsoil loss (USDA NRCS, 2006). As a result, these soils suffer from a loss of organic matter. These soils also exhibit a pronounced enriched-clay horizon, which can hinder root growth and grain production. This horizon at or near the surface can inhibit germination, which in turn reduces yield. Yield within degraded fields often vary as much as 4:1 or more from less eroded to highly eroded areas (Kitchen et al., 1999). Productivity is markedly reduced because the physical and chemical characteristics of the subsoil are no longer well suited for crop root growth (Scrivner et al., 1985a; Thompson et al., 1991; Myers, 2007) and because plant available water is low in clay horizons (Jiang et al., 2008).

Miscanthus could prove to be a valuable crop grown on degraded soils that are less productive and economically marginal. The potential of miscanthus to remediate degraded soils and motivate farmers by a strong economic return, makes it a worthy candidate for further study. Perennial dedicated energy crops, such as miscanthus, seem to be finding their place as one of the many options for more sustainable energy. Yet, questions affecting miscanthus establishment and sustained growth remain unanswered. Yield in response to N rate has never been evaluated for miscanthus planted on degraded soils of the U.S. Midwest. This input variable is important to determine so that farmers achieve maximum yields while weighing the economic costs of this crop.

Objectives

1. Determine miscanthus growth and yield response to N fertilizer for marginal claypan soils.
2. Measure the impact of N fertilization on miscanthus chlorophyll content over the growing season.

Materials and Methods

This research is defined by two different N rate experiments. The first is an N rate experiment initiated on a mature miscanthus stand grown on a claypan soil in Boone County Missouri at the Jefferson Farm, adjacent to the University of Missouri South Farm (denoted as “Boone JF”). For this study, a block of miscanthus was planted in 2007 with plots overlaid for N rate treatments in 2012. A randomized complete block design was used to further divide the area into three main blocks (i.e., reps), each block was then divided into four separate main plots of 3.7 m x 13.7 m dimensions. Treatments of 0, 45, 90 and 134 kg ha^{-1} were hand applied once per growing season shortly after green-up (early May).

The second experiment is also an N rate experiment that is being conducted over the 2013- 2014 growing seasons at the University of Missouri South Farm Lone Tree field (denoted as “Boone LT”), and two producer fields, one in Cooper County and one in Moniteau County. Each of these sites were selected because they represent the unique characteristics of claypan soils.. Each of these sites were originally planted in the spring of 2012. These trials were organized using a randomized complete block design with four main blocks divided into six separate plots. These plot dimensions also varied between location and are as follows: Boone (LT), 3.8 m x 9.1 m; and

Cooper and Moniteau County, 3 m x 4 m. Nitrogen fertilizer treatments of 0, 34, 67 and 134 kg ha-^{1} were hand applied once per growing season shortly after green-up (early to mid-May). Chlorophyll readings using a Minolta SPAD meter were taken at four-week intervals throughout the growing season for all four trial sites. Measurements were taken on the middle of a leaf from the mid-canopy. At the end of the growing season plots were harvested for yield using a sickle-bar mower, weighed, and sub-sampled for moisture correction to a dry matter basis.

The objective of determining miscanthus stand response to N fertilizer rate on claypan soils is the same for both studies. In more productive soils it is thought that most of the N miscanthus uses during the growing season is recycled N from leaves grown the previous year. However, for claypan soils, N mineralization is insufficient during the establishment years and N fertilization will be necessary for optimal growth. A summary of the N treatments for 2012 to 2014 of Boone (LT), Cooper, and Moniteau County (Table 1), in addition to the N treatments at Boone (JF) and past N application history can be found below (Table 2.)

Statistical analysis was performed using PROC GLM in SAS to model yield in response to N rate. All measurements were analyzed assuming fixed main effects of N placement and random replication effects. When significant F-test results were found ($P < 0.05$), treatment means and pair-comparison differences were obtained using LSMEANS . For chlorophyll readings, the procedure PROC MIXED was used to determine effects and interactions of N rate and date of readings. When significant ($P < 0.05$) F-tests were found, treatment means were again found separated using LSMEANS and the Tukey mean separation procedure.

Results and Discussion

Nitrogen fertilization did not lead to increase yields in 2013 for all locations except Boone (LT) (Figure 1). While significant ($P < 0.04$), the increase was relatively modest ($\pm$22%) when comparing the zero rate treatment, which averaged 9.6 Mg ha^{-1} to the high treatment, which averaged 12.3 Mg ha^{-1} at 134 kg N ha^{-1}. In general, yield for all locations were markedly low due in part to two factors. One, this was the first harvest crop for three of the sites, so the stand was not mature. Two, a drought in the summer of 2012, during its establishment phase, also retarded establishment at Boone (LT) and possibly the Cooper and Moniteau sites. The 2013 growing season was also drier than average, though not nearly as hot and dry as 2012. Reduced vegetative growth may have reduced the overall N demand such that the lower N treatments were not N limited. An absence in response to N fertilization could also be due to the ability of miscanthus to recycle nutrients from previous year’s growth, along with its ability to repartition N into the most photosynthetic-active upper leaves throughout the growing season. In addition, sufficient N might have already been present such that additions by the treatments from this study were not needed for the miscanthus to maintain productivity. This applies particularly to Jefferson Farm, which had 56 kg N ha^{-1} applied to it every year from 2007 until 2010 with no biomass harvested. No response to N fertilization was seen even at the lowest N rates. Additional trial years will be needed to determine if miscanthus has an increased need for N at the other locations as it matures.

Significant effects were seen between SPAD chlorophyll readings by N treatments and date for both 2013 and 2014 (Figure 2). SPAD increased as N rate increased. Average SPAD readings were high in the early summer months (June), and decreased going into the later months (August and September). A possible explanation for this is that the miscanthus is fairly good at intercepting the readily available N from the treatments and mobilizing it into the most photosynthetically active portions of the plant during peak irradiance. However, as the season progresses, and those initial amounts decrease, the miscanthus may use N stored in its underground organ (e.g., rhizome). It's plausible that this reservoir supplements and allocates N so that the miscanthus can maintain a high productivity throughout the growing season.

In summary, higher N rates correlated with increased SPAD chlorophyll readings early in the growing season in both 2013 and 2014; however, those differences diminished by September. In addition, only one site in 2013 responded when N was applied at 134 kg ha^{-1}. Preliminary results appear to indicate that N does not affect the yield of miscanthus when grown on claypan soils.

Table 1. Boone (LT), Cooper and Moniteau fields miscanthus N fertilizer treatments from 2012 to 2014.

N Treatment	2012	2013	2014	Total in 3 yrs
	----------	---------- **kg ha^{-1}**	----------	----------
1	0	0	0	0
2	0	34	34	64
3	0	67	34	101
4	0	67	67	134
5	0	134	67	201
6	0	134	134	268

Table 2. Jefferson Farm miscanthus N (kg ha-[1]) treatments from 2007 to 2014.

N Treatment	2007	2008	2009	2010	2011	2012	2013	2014	Total in 8 yrs
	----------	----------	----------	----------	**kg ha^{-1}**	----------	----------	----------	----------
1	56	56	56	56	0	0	0	0	224
2	56	56	56	56	0	45	0	45	314
3	56	56	56	56	0	90	0	90	404
4	56	56	56	56	0	134	0	134	492

Figure 1. Yield by location and N rate, showing LS mean differences of N rate when analysis of variance F-test was significant (0.05).

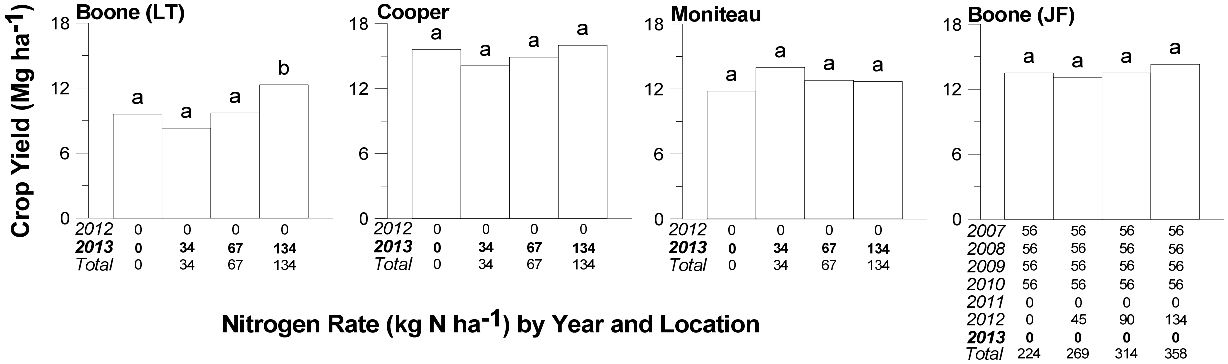
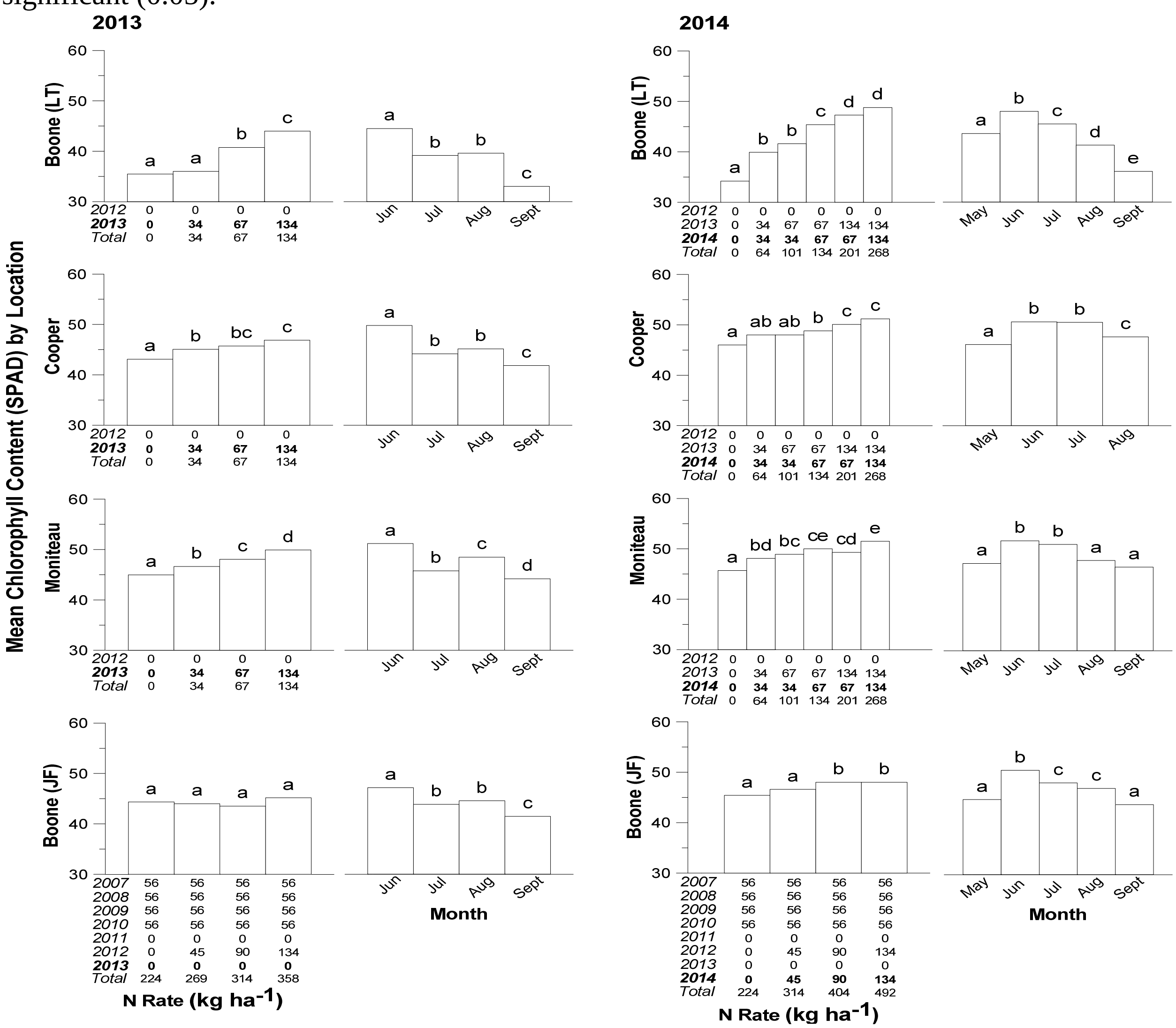


Figure 2. Leaf chlorophyll measure ments (SPAD) for year and location and month, showing LS mean differences of N rate (left) and date (right) when analysis of variance F-test was significant (0.05).



References

Jiang, P., S.H. Anderson, N.R. Kitchen, E.J. Sadler, and K.A. Sudduth. 2007. Landscape and conservation management effects on hydraulic properties of a claypan-soil toposequence. Soil Sci. Soc. Am. J. 71(3): 803-811.

Kitchen, N.R., K.A. Sudduth, and S.T. Drummond. 1999. Soil electrical conductivity as a crop productivity measure for claypan soils. J. Prod. Agric. 12:607-617.

Massey, R.E., D.B. Myers, N.R. Kitchen, and K.A. Sudduth. 2008. Profitability maps as input for site-specific management decision making. Agron. J. 100:52-59.

Mclaughlin S.B. and M.E. Walsh. Evaluating environmental consequences of producing herbaceous crops for bioenergy. Biomass and Bioenergy 1998;14(4):317–24.

Myers D.B., N.R. Kitchen, K.A. Sudduth, R.E. Sharp, and R.J. Miles. 2007 Soybean root distribution related to claypan soil properties and apparent soil electrical conductivity. Crop Science 47:1498-1509.

Perlack R.D. and B.J. Stokes (leads) (2011) U.S. Billion-Ton Update: Biomass Supply for a Bio-energy and Bioproducts Industry. U.S. Department of Energy, Oak Ridge National Laboratory, Oak Ridge, TN.

Scrivner, C.L., B.L. Conkling, and P.G. Koenig. 1985a. The effects of soil erosion upon soil productivity in Missouri farm fields. Missouri Agric. Exp. Stat. Pub. EC0950.

Thompson, A.L., C.J. Gantzer, and S.H. Anderson. 1991. Topsoil depth, fertility, water management, and weather influences on yield. Soil Sci. Soc. Am. J. 55:1085-1091.

USDA, 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. In: U.S. Department of Agriculture Handbook. United States Department of Agriculture, Natural Resources Conservation Service. 296 pp.

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PROGRAM CHAIR:

James L Camberato
Purdue University
915 W State St.
West Lafayette, IN 47907
(765) 496-9338
jcambera@purdue.edu

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International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
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