Understanding Plant-Soil-Microbial Processes to Enhance Ecosystem Services in Low-Input Biofuel Feedstock Production: Increasing Inter-Specific and Intra-Specific Biodiversity

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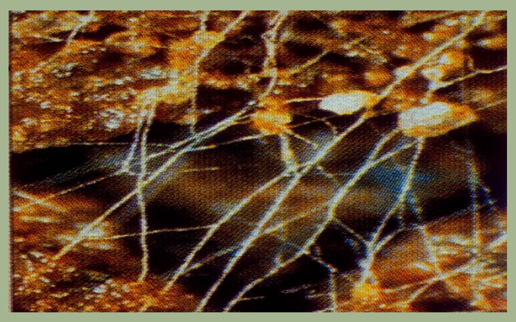
Introduction

The goal of this study is to understand how greater biodiversity (both within and between species diversity) of grassland plants could improve two processes that will be key contributors to the emerging clean energy economy: biomass production for energy and the capture and storage of greenhouse gases by plants and soils (biological carbon sequestration).

Switchgrass post harvest



Extra-radical AM hyphae

Perhaps the most promising approach in producing C-negative bioenergy (maximizing feedstock production while sequestering C) utilizes mixed-species perennial ecosystems. Research on restored prairie communities indicates that, for low-input systems, long-term yields can be greater with higher plant diversity than with low diversity communities or monocultures. Diverse grassland plantings are better equipped to deal with annual variations in climate and typically have fewer problems with pathogen buildup than monocultures. Also, including legumes in the mixture is a low-input alternative to N fertilization. However, growing a feedstock consisting of several different grass species might complicate efforts to convert plant cellulose into ethanol. Another source of complementarity to maximize biomass production and C sequestration that we are investigating is within species (intra-specific) genetic variation by combining multiple genotypes of switchgrass.

Field plots

Seven vegetative treatments include three switchgrass ecotypes originating from different latitudes with four mixtures of increasing biodiversity.

- KA Kanlow switchgrass (lowland cultivar origin central Oklahoma),
- CR Cave-in-Rock switchgrass (upland cultivar origin southern Illinois),
- SL Southlow Michigan Germplasm switchgrass (upland germplasm origin southern lower peninsula of Michigan),
- SG A mixture of the three switchgrass ecotypes (to increase genetic diversity while maintaining a pure switchgrass feedstock),
- CW A mixture of the three switchgrass ecotypes with a single ecotype of Canadian wild rye (a rapid-growing native prairie grass that is expected to speed switchgrass establishment by reducing weed competition),
- BB A mixture of the three switchgrass ecotypes with three big bluestem ecotypes (big bluestem is another native prairie grass that is more nutrient-use efficient than switchgrass),
- PR A mixture of four native prairie grasses (switchgrass, big bluestem, Canadian wild rye, and Indiangrass) with eight native prairie forbs.

Monocultures of switchgrass (intra-specific diversity)

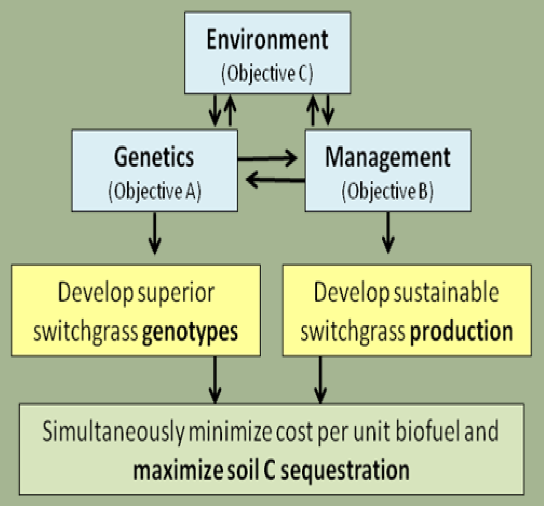
Switchgrass & big bluestem mix

Switchgrass & Canada wildrye mix

High diversity prairie mix (inter-specific diversity)

Overall project goals

Three complementary objectives of our overall research program are to assess the direct and interactive effects of **(A) genetics, (B) management, and (C) environment** while simultaneously optimizing aboveground production and belowground C storage in feedstock production. To accomplish these objectives, we are studying plant-soil-microbial processes in selected cultivars of switchgrass and other prairie grasses in established feedstock production trials located in Oklahoma and Illinois, in field diversity plots established by Argonne National Laboratory (ANL), and in greenhouse experiments at Oklahoma State University (OSU).



This presentation will focus on the management (biodiversity) and genetics aspects of our overall goals.

Sustainability of feedstock production practices may be improved if breeders can better identify plant traits that reduce fertilizer inputs and increase the crop's ability to sequester carbon in recalcitrant pools. Because mycorrhizal symbioses facilitate plant growth in infertile and droughty soil and also mediate soil C accrual, these plant-fungal associations need to be considered in the design of feedstock management practices.

Objectives and Hypotheses

Objective A: Assess the influence of plant diversity on AM fungal biomass, soil aggregation, and soil C inputs.

Hypothesis A: Due to complementarity of traits, increasing species (inter-specific) and genetic (intra-specific) diversity will optimize increase AM fungal biomass, optimize soil quality, and increase C inputs.

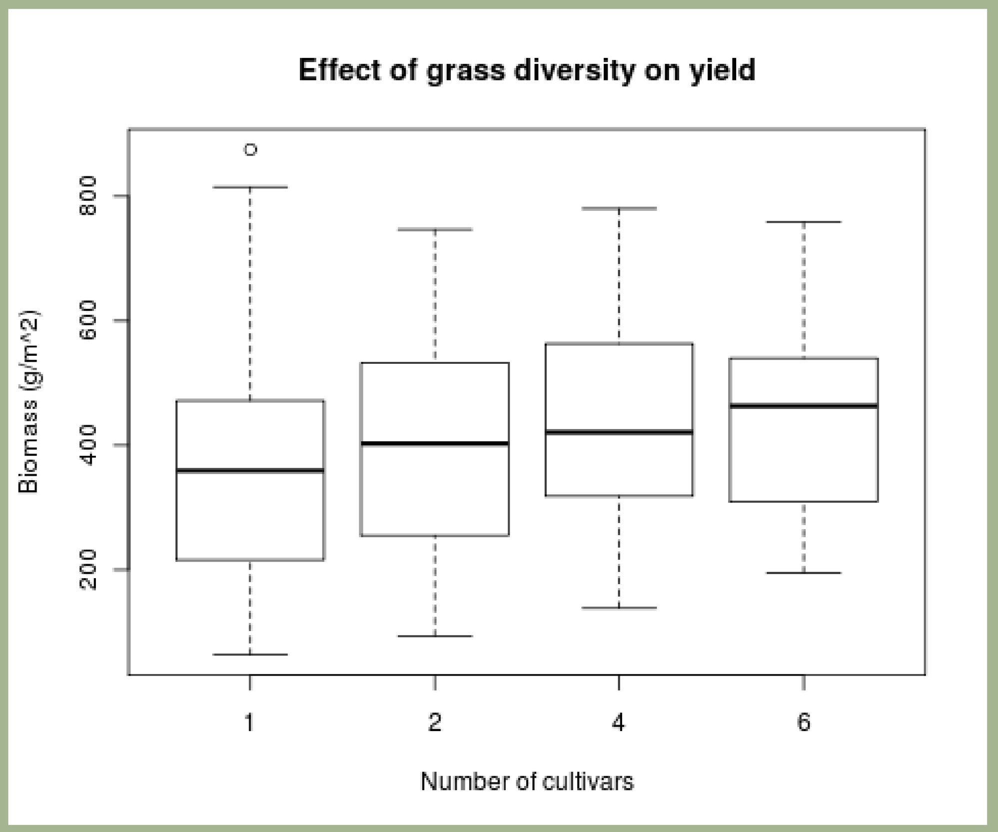
Objective B: Assess the importance of switchgrass genetics on mycorrhizal responsiveness and soil C inputs.

Hypothesis B: Switchgrass genotypes that produce a greater proportion of coarse roots (e.g., low specific root length) will support greater amounts of AM fungi in their roots and in the surrounding soil and have higher mycorrhizal responsiveness compared to genotypes with a greater proportion of fibrous roots (high specific root length).

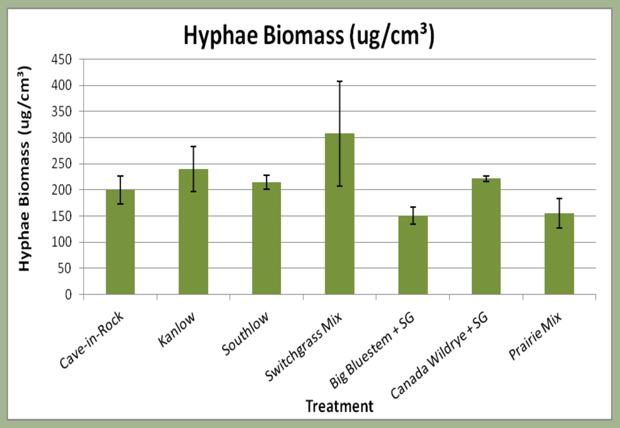
Our goal is to enhance aboveground ecosystem services such as wildlife habitat, while also increasing belowground services such as soil tilth and soil carbon sequestration, all without a loss in production.

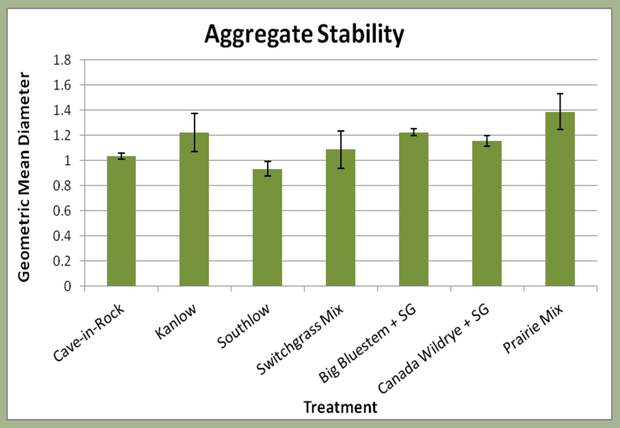
Preliminary Data

Increased plant diversity vs. low diversity communities or monocultures.



Aboveground biomass yields indicate high-diversity mixtures generally had productivity equal or greater than monocultures of switchgrass cultivars.





Belowground hyphal biomass yields and soil aggregate stability were generally equivalent between high-diversity mixtures and monocultures of switchgrass cultivars.

Switchgrass genetics may influence mycorrhizal responsiveness, root traits, and soil carbon.

Root production and morphology differs among switchgrass cultivars with potential effects on the rate of soil carbon sequestration.

Conclusions

Results of our study indicates that increased intra- or inter-specific diversity can improve aboveground ecosystem services, such as wildlife habitat, without decreasing belowground services such as soil tilth and soil carbon sequestration, with no loss in feedstock production.

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