

Abandoned agricultural fields: competition between native and exotic plant species for soil resources (awarded 2006)

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Introduction

As of 2005, over 30 million acres of abandoned agricultural land have been enrolled the federal Conservation Reserve Program (CRP), with the goal of restoring these fields to their original pre-cultivation state, either forest or prairie ecosystems (www.usda.gov). However while the number of abandoned agricultural fields is increasing, they are also commonly dominated by exotic grass species (Davis et al, 2005; McLachlan et al., 2006; Laungani, pers. obs.). In these CRP and CRP like systems both native grass species and native tree species are being displaced; and native species establishment is being severely impeded by these exotic grass species (Davis et al., 2005, pers. obs.). With such an extensive acreage designated for restoration through the CRP, it is critical to understand the mechanisms which underlie the establishment of all of these species (both native and exotic) in order to successfully achieve the goals of such a large scale restoration program. My research focuses on elucidating these fundamental mechanisms of co-existence and competition between plant species, which in turn considerably influence plant community structure in these fields. In an abandoned agricultural field setting, I will examine competitive interactions between the dominant grass species (both native and exotic) and the tree species (both deciduous and coniferous) which are re-colonizing these fields at different rates (Davis et al., 2005, Laungani, pers. obs).

A common exotic grass species in these fields is *Poa pratensis* (Kentucky bluegrass) and is considered a highly exploitative competitor (MacDougall and Turkington, 2005; Davis et al. 2005). *P. pratensis* is also widely planted in suburban areas as lawn grass, and so its potential for invasion into abandoned agricultural fields by accidental human transport of seed is high. The native grass species that are displaced in these fields by exotic colonizers include C₄ species such as *Schizachryium scoparium* (little bluestem) and *Andropogon gerardi* (big bluestem), while the tree species which are invading into these fields with variable success are *Pinus strobus* (eastern white pine) and *Quercus* sp (various oak species) (Davis et al, 2005; Laungani, pers. obs).

A LINK BETWEEN RESOURCE AVAILABILITY AND ABANDONED AGRICULTURAL FIELD COMMUNITY COMPOSITION: PRELIMINARY EVIDENCE

As is the case for many terrestrial ecosystems in general (Hu et al., 2001; Van der Krift and Berendse, 2001), nitrogen (N) is one of the main limiting nutrients for plants in these

fields (Wedin and Tilman, 1990; Tilman, 1997), and therefore, N availability to the plants has been shown to influence plant community composition (Wedin and Tilman, 1990; Knops et al, 2002; Siemann and Rogers, 2003). However the availability of N to the plants is the result of two opposing processes by the soil microbial community: 1) N production by the soil microbial community (in the forms of NH_4 and NO_3) and 2) microbial N uptake. Despite the fact that the soil microbial community mediates the availability of N to the plant community via the opposing processes of N production and microbial N uptake, there is little work examining how the plants may influence their own N supply through their interactions with the soil microbial community - particularly examining plant species effects on these two critical N cycling processes (Wedin and Tilman, 1990; Van der Krift and Berendse, 2001; Knops et al., 2002; 2004; Hawkes et al., 2005; Vinton and Goergen, 2006). There is still a paucity of work rigorously examining how competitive outcomes are impacted by plant-microbe-resource interactions (Bowman, et al, 2004; Suding et al, 2004), specifically how competing exotic plant species influence their own N supply through their interactions with those soil microbes which produce inorganic forms of N – ammonium and nitrate. The ultimate goal of this research is to elucidate how plant-microbe interactions can feedback to impact plant N supply rates and in turn competitive interactions for soil N between plant species.

Two experiments were established to examine the role of plant-microbe-resource interactions in determining the competitive ability of the exotic grass species. The first determined temporal patterns of N cycling and microbial functioning associated with different plant species. The second evaluated the importance of plant species specific microbial communities in the context of resource competition theory.

Results:

Experiment A: Temporal Variation in Gross Nitrogen Cycling Across Species

In this experiment we found no significant differences across species with regard to gross rates of N mineralization and microbial NH_4 consumption. However we did find significant differences across the species with regards to nitrate dynamics. We also found temporal variation in nitrate dynamics across species. Although these differences in gross nitrification disappear in June the exotic species *P. pratensis* maintained a high N supply rate (Figure 1, gray bars) across both time periods as compared to the other species. Although not statistically different in June *P. pratensis* had the lowest microbial NO_3 consumption which lead to higher net supply rate of nitrate associated with *P. pratensis*.

Experiment B: The Role of the Soil Microbial Community in Plant Competition and Resource Reduction

The results of this experiment supported our main experimental prediction that the soil microbial associated with the different species determine the level of N available to the

plant as compared to plant uptake (Figure 2) for *P. pratensis* and *S. scoparium*. The lack of treatment effect seen in *A. repens* replicates could be attributed to the fact that *A. repens* is known to thrive in very high N soil environments (Wedin and Tilman, 1990), and the sandy N poor soils utilized in this experiment may not have allowed for a species specific microbial community to establish although the grass was able to establish in the replicate pots. Species differences between *P. pratensis* and *S. scoparium* in soil N levels were observed in the non-sterile monocultures as previously shown by Wedin and Tilman (1991) (Figure 2 – plant + microbes). In the absence of the soil microbial community both *P. pratensis* and *S. scoparium* reduced soil N to the same level (Figure 2 – plant only). Although they were not statistically different, when the species specific microbial community was in isolation *P. pratensis* had an available N level that was almost double that of *S. scoparium*. (Figure 2 – microbe only).

Discussion

Our results indicate that plant species identity can significantly impact the functioning of the soil microbial community, particularly the processes which determine N availability to the plant community. The exotic species *P. pratensis*, which is increasing in dominance in many grassland ecosystems in North America, seems to impact the soil microbial community by increasing plant available levels of N by reducing microbial consumption of N. Our results also indicate that in the context of resource reduction theory that microbial functioning is critical in determining N availability to the plant community more so than plant uptake. If the mechanism behind resource reduction was plant uptake *alone* then when plant uptake was removed in the “microbe only” treatment, the species differences in N levels would have disappeared. However because those differences remained intact this implies that the soil microbial community is able to maintain specific levels of plant available N. The greenhouse experiment was a pilot study to see the potential for microbial based feedbacks in the context of resource reduction theory. A more comprehensive study was established in summer 2007 with bare soil controls and other soil measurements to ensure treatment effects.

Given this high level of microbial control over a critical, often times limiting resource, species identity can feedback via the soil microbial community to maintain required resource levels and in turn maintain population levels. In the case of the exotic species *P. pratensis* it is important that interactions with the soil microbial community be considered when examining its increasing abundance in the grassland ecosystems of North America.

Long-Term Goals

The long term goals of this research attempts to elucidate not only the impact of plant-microbe interactions on local competitive outcomes, but also allows for examination of species identity impacts on N cycling and in turn how changes in species composition, such as the introduction and spread of exotic species such as *P. pratensis* can impact whole ecosystem level processes such as N cycling. This work also is to be used as a springboard for further work examining the links between C and N cycling, and how changes in C via species replacement can impact N cycling.

Benefits of Seed Money

The funds received from CIPM were extremely helpful in conducting this research. The isotopic aspect of this research is very costly and so this grant allowed for analysis of all the needed samples and replicates. In addition the work also calls for a number of inorganic N samples to be taken and those can also become very costly. Without this seed money this research would not have been able to be conducted.

Advancing this research

In order to advance this research a larger species survey would be required. Also we would need to examine whether or not these gross N cycling dynamics change when two species are in competition or if the soil is amended with N or carbon. These would be able to elucidate what is impacting the soil microbial community specifically.

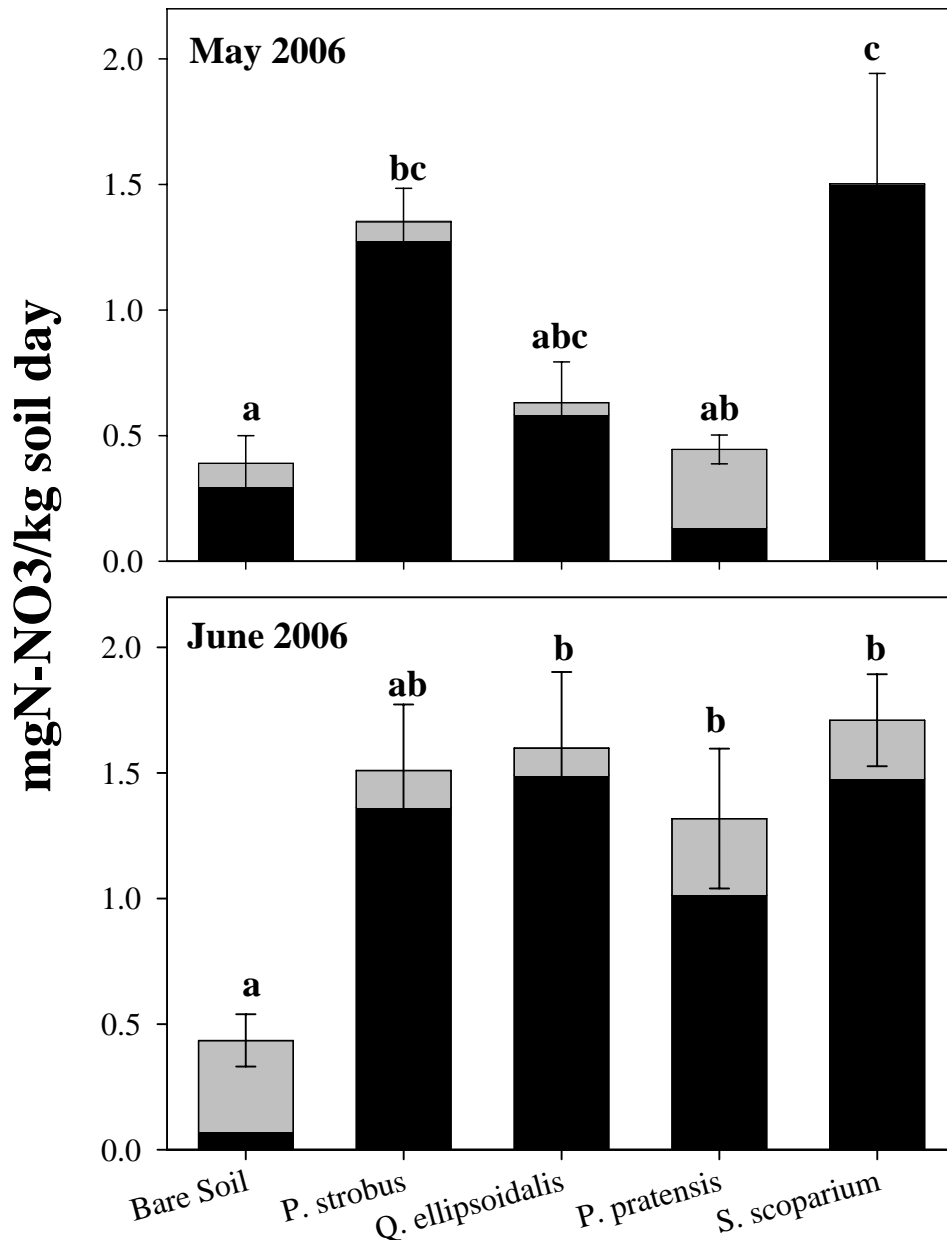


Figure 1: Temporal dynamics in gross nitrification associated with different species and a bare soil control in May 2006 (top) and June 2006 (bottom). Black bars represent rate of microbial nitrate consumption, gray bars represent rate of net nitrification (plant available nitrate production). Total bar height is the gross nitrification rate. Letters above bars indicate significant differences in gross nitrification rate (ANOVA, $P < 0.05$).

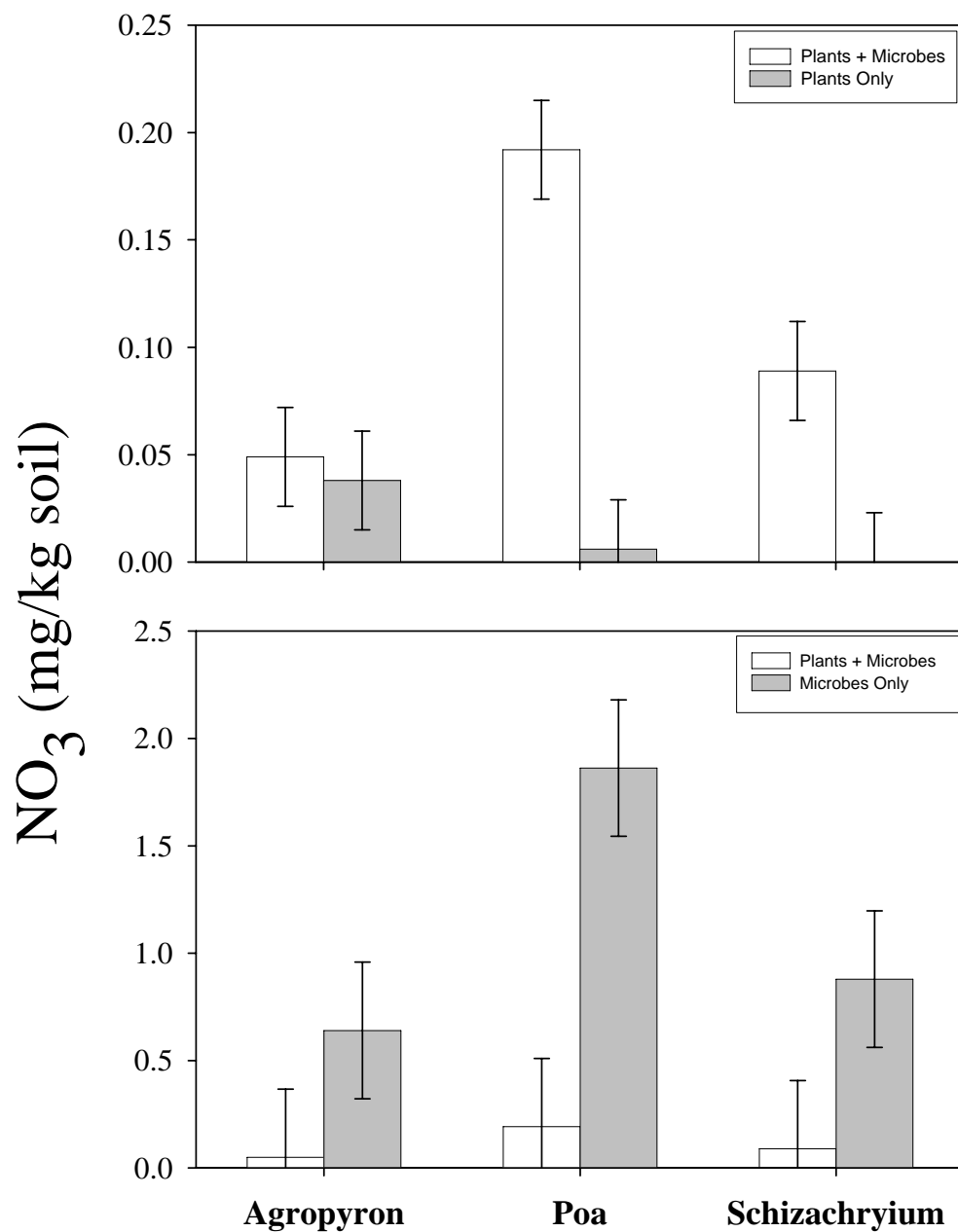


Figure 2: Extractable soil NO₃ levels across species. Open bars are non-sterile monocultures (plants + microbes). Gray bars represent plant only soil N levels (top) and microbe only soil N levels (bottom).

Literature Cited

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BUDGET (Specific expenditures under each category available upon request)

ITEM	COST
INORGANIC NITROGEN SAMPLE ANALYSIS	2,487.55
GREENHOUSE BENCH RENTAL	893.18
MISC CHEMICALS FOR 15N ANALYSIS	429.39
UC DAVIS ISOTOPIC 15N SAMPLE ANALYSIS	622.00
PRAIRIE MOON NURSERY SEED	12.00
MISC MATERIALS FOR 15N ANALYSIS	57.02
FORESTRY SUPPLIERS (FLAGS)	43.86
TOTAL DIRECT COSTS	4,545.00
TOTAL INDIRECT COSTS	455.00
TOTAL COSTS (DIRECT + INDIRECT)	5,000.00