Immediate and Long-Term Effects of Invasive Plant Species on Soil Characteristics

Irene Unger[1], Keith Goyne[2], Kristen Veum[3], Robert Kremer[2]

[1]Department of Biology & Environmental Science, Westminster College; [2]School of Natural Resources, University of Missouri; [3]USDA-ARS

Introduction:

Invasive species may:

i) utilize resources better than native species and/or

ii) successfully transform environmental conditions, including soil characteristics, in the introduced habitat.

Interactions between invasive plants and the soil microbial community may contribute to invasive species out-competing native species.

Root exudates from invasive species may stimulate the soil microbial community and, subsequently, increase nutrient cycling (Ehrenfeld 2003, Wolfe and Klironomos 2005, Koutik et al. 2007, Niu et al. 2007, Kao-Kniffin and Balser 2008).

Alternately, invasive species may benefit by escaping the constraints placed on them by soil microbes in their native range (i.e., enemy-release hypothesis) (Niu et al. 2007, Inderjit and van der Putten 2010, Schradin and Cipollini 2012).

It is unclear how long plant-mediated changes in soil biological, chemical and physical properties may persist. Legacy effects may be possible. Killing or removing above ground vegetation without the removal of roots or rhizomes of invasive plants may thwart ecological restoration efforts by continued influence on the soil microbial community (Elgersma et al. 2011).

Our objectives were to determine:

i) if invasive plant species alter soil physical, chemical or biological properties; and

ii) the long-term effects of invasive plant species on soil properties and subsequent implications on ecological restoration efforts

Study sites (from left to right): Green Area, PFCA and Tucker Prairie

Methods:

Invasive species of interest: sericea lespedeza (*Lespedeza cuneata*)

Study sites: four locations in Central Missouri, USA

i) Charles W. Green Conservation Area (Green Area) – an old-field with abundant sericea lespedeza

ii) Prairie Fork Conservation Area (PFCA) – two prairies reestablished using similar techniques (i.e., 3-5 years of cropping (corn or soybean) to eradicate undesirable plants followed by broadcast application of native plant seeds collected from near-by prairies to restore prairie assemblages) but at different times:

PFCA 2011 – seeded in 2011

PFCA 2013 – seeded in 2013

iii) Tucker Prairie Natural Area (Tucker Prairie) – a remnant prairie that has never been plowed

Study Sites: A) Green Conservation Area; B) Tucker Prairie Natural Area; C) Prairie Fork Conservation Area

Soil Collection:

At each site we collected four soil samples at two depths (0-5cm and 5-10cm).

Soils were intentionally collected underneath sericea lespedeza at the old field site (i.e., Green Area), while at the other 3 sites sericea lespedeza was intentionally avoided.

Samples were stored at 4°C or frozen until processed. Samples were moist sieved (2 mm mesh) prior to analyses. A portion of the moist sieved soils were air-dried for non-microbial analyses.

Methods cont.

Soil Analyses:

i) physical properties: color, texture, bulk density and water-stable aggregates

ii) chemical properties: pH, base cations, active-C, mineralizable-N, total organic C, total N, total soluble phenolics, and electrical conductivity

iii) biological properties: β-glucosidase and β-glucosaminidase for community function and PLFA for community structure

Statistical Analyses:

Analysis of Variance (ANOVA) followed by mean separation techniques were utilized to assess the observed differences between treatments.

Each soil metric was compared separately.

Results

Nearly every analysis differed significantly between the unplowed prairie reference site and the other three sites. Given this, Tucker Prairie data was removed and analyses were re-run. The restored sites generally did not differ from the invaded old-field. **Note**: for brevity, only surface soil (i.e., 0-5cm) data are reported.

Soil Physical Properties

Soils at Tucker Prairie have significantly lower bulk density and higher water stable aggregates (WSA) than all other sites (Table 1). The Green Area soils are more compacted than those at PFCA (Table 1).

Table 1: Select Soil Physical Properties

	Bulk Density	WSA (%)
Green Area	1.1	43.8
PFCA 11	1.2	40.2
PFCA 13	1.2	33.1
Tucker Prairie	0.8	69.6

Soil Chemical Properties & Microbial Properties

Initial results indicated significant differences between the sites for pH, and Na (Table 2). When Tucker Prairie was removed from the analyses, the only significant result that remained was pH. As with bulk density, the Green Area is significantly different than the PFCA sites for this variable (Table 2).

Table 2: Soil Chemical Properties

			NH_4Cl Extractable Bases Milliequivalents per 100 g						Mineralizable Nitrogen
0-5 cm	pH	EC	Ca	Mg	Na	K	Sum	CEC	(ppm)
Green Area	5.0	52.8	12.3	2.5	0.1	0.3	15.2	16.3	165.4
PFCA 11	5.6	50.3	16.1	3.1	0.1	0.4	19.7	18.4	139.4
PFCA 13	5.5	38.9	15.0	3.0	0.1	0.3	18.4	17.1	131.1
Tucker Prairie	4.8	39.9	12.2	2.9	0.2	0.4	15.7	18.9	174.6

Initial results indicated significant differences between the sites for TOC, TN, and active carbon (Table 3). However, when Tucker Prairie was removed from the analyses, the remaining sites did not differ. Tucker Prairie has greater C and N resources and greater associated microbial activity than the old field or the re-constructed prairies (Table 3). On the other hand, total soluble phenolics were least abundant in Tucker Prairie soils compared with the other three sites (Table 3).

Table 3: Soil Chemical and Microbial Properties

0-5cm	TOC (%)	TN (%)	Active C g C/kg soil	Phenolics µM	β-glucosidase mg PNP/g soil/hr	β-glucsoaminidase mg PNP/g soil/hr
Green Area	2.58	0.23	0.70	18.58	0.16	0.08
PFCA 11	2.42	0.22	0.73	17.77	0.17	0.08
PFCA 13	2.25	0.21	0.73	22.85	0.14	0.08
Tucker Prairie	4.06	0.34	0.86	16.69	0.17	0.11

Soil Microbial Community Structure

Initial analyses revealed differences in mycorrhizae (MYC), actinobacteria (Actino.), $Gram^-$ bacteria, $Gram^+$ bacteria, and total microbial biomass between the sites (Table 4). Differences were also observed in the fungi:bacteria ratio (Fun/Bact), the stress ratio (i.e., ratio of cyclopropane fatty acids to unsaturated fatty acids), and the ratio of monounsaturated fatty acids to polyunsaturated fatty acids (MUFA/PUFA) (Table 5). Tucker Prairie soils had a much more robust microbial community than soils at the other three sites. When Tucker Prairie is removed from the analyses, only MUFA/PUFA remained significant.

Table 4: Soil Microbial Community Structure

	MYC	Fungi	Actino.	Gram-	Gram+	Anaerobe	Euk	Total
				(picomoles/g Soil)				
Green Area	8810	4998	21849	75060	44629	2758	20096	240048
PFCA 11	8463	4771	19107	60764	38360	2400	3412	188374
PFCA 13	7391	4120	19906	51871	36049	2214	3608	171858
Tucker Prairie	12287	7756	37251	122149	79316	3234	7652	366173

Table 5: Microbial Ratios

	G+/G-	Fun/Bact	Stress	MUFA/PUFA
Green Area	0.6	0.10	0.53	6.5
PFCA 11	0.6	0.11	0.47	13.2
PFCA 13	0.7	0.10	0.60	9.9
Tucker Prairie	0.7	0.08	0.96	9.2

Discussion

Two possible explanations for our data:

i) Tucker Prairie is not an appropriate reference site OR

ii) insufficient time has lapsed for soils at PFCA to return to true prairie conditions

Of these, the latter is more likely.

While Tucker Prairie does have unique features, such as a clay pan that restricts drainage (e.g., the water table is often perched just 30cm below ground on the flattest portion of the prairie), it is the best example of the prairie ecosystem that once covered northeast and central Missouri.

More importantly, other studies suggest that there is a lag time between vegetation community restoration and recovery of soil characteristics, including the soil microbial community. McKinley et al. (2005) suggested decades may be required to restore soil properties to that of virgin prairie. Jangid et al. (2010) noted that on restored prairie sites some members of the soil microbial community resembled those of native prairies, while others were unique to the restoration community. Finally, Grove et al. (2012) found support for the hypothesis that allelopathic invasive species may have a long-term and persistent effect on the soil microbial communities.

Clearly, additional investigations, including other sites in the mid-Missouri region are warranted. These studies should include research into the potential allelopathic nature of sericea lespedeza.

Acknowledgements:

This work was supported by a research grant from the Prairie Fork Charitable Endowment Trust. The authors also wish to recognize the contribution of several undergraduate students to sample collection and analysis.

Literature Cited:

* Ehrenfeld, J.G. (2003) Effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems 6:503–523.

* Elgersma, K.J., J.G. Ehrenfeld, S. Yu, and T. Vor (2011) Legacy effects overwhelm the short-term effects of exotic plant invasion and restoration on soil microbial community structure, enzyme activities, and nitrogen cycling. Oecologia 167:733–745.

* Grove, S., K.A. Haubensak, and I.M. Parker (2012) Direct and indirect effects of allelopathy in the soil legacy of an exotic plant invasion. Plant Ecol. 213:1869-1882.

* Inderjit and W.H. van der Putten (2010) Impacts of soil microbial communities on exotic plant invasions. Trends in Ecology and Evolution 25(9): 512–519.

* Jangid, K., M.A. Williams, A.J. Franzluebbers, J.M. Blair, D.C. Coleman, and W.B. Whitman (2010) Development of soil microbial communities during tallgrass prairie restoration. Soil Biol Biochem 42:302-312.

*Kao-Kniffin, J. and T.C. Balser (2008) Soil fertility and the impact of exotic invasion on microbial communities in Hawaiian forests. Microb Ecol 56:55–63.

*Koutika, L.S., S. Vanderhoeven, L. Chapuis-Lardy, N. Dassonville and P. Meerts (2007) Assessment of changes in soil organic matter after invasion by exotic plant species. Biol Fertil Soils 44:331–341.

*Mckinley, V.L., A.D. Peacok and D.C. White (2005) Microbial community PLFA and PHB responses to ecosystem restoration in tallgrass prairie soils. Soil Biol Biochem 37:1946-1958.

*Schradin, K., and D. Cipollini (2012) The sign and strength of plant-soil feedback for the invasive shrub, Lonicera maackii, varies in different soils. Forests 3: 903-922.

*Wolfe, B.E. and J.N. Klironomos (2005) Breaking new ground: Soil communities and exotic plant invasion. BioScience 55 (6): 477-487.