Final Grant Report (Awarded 2005)

To the Center for Invasive Plant Management

Changes to Native Forest Soils due to English Ivy Infestation

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Introduction

English ivy (*Hedera* spp.) is a well-known invasive species in forest communities of the Pacific Northwest and across North America. There have been a number of studies examining its physiological characteristics, competitiveness with regard to native plant species, its aboveground impacts to native vegetation, potential for spread, and strategies for removal. However, once English ivy is removed, native plant species installed in restoration efforts have not always been successful. The soil environment of formerly infested sites is often critical to restoration success, but studies are lacking on such soil characteristics. These could include soil characteristics present prior to infestation that facilitate English ivy invasion and/or potential lasting effects of the presence of English ivy on the soil environment.

This study examined a selected subset of the soil environmental characteristics associated with English ivy infestation. A comparative approach was utilized, with analyses of the soil environment from seven English ivy-infested locations compared to nearby comparable sites lacking English ivy. The chemistry of the upper rooting zone (of relevance to plants installed in restoration projects; 0-10 cm deep) and surface litter were examined in the summers of 2005 and 2006. Soil chemistry measurements included various forms of nitrogen, carbon, organic matter, pH, and soil moisture.

Results

Soil nitrogen, carbon, and organic matter content did not differ between ivy and non-ivy sites in soils sampled during 2005 (Table 1). Total nitrogen and carbon concentrations were clearly not different, but even though inorganic N forms also did not differ overall, this was not consistent across all locations. Some locations showed strong differences in ammonium, nitrate/nitrite, and total available N (ammonium plus nitrate/nitrite) between the ivy and non-ivy plots. Overall, soils were significantly more acidic (pH of 5.6 vs. 6.0) and had greater quantities of litter (by 10 – 20 tons / ha) in non-ivy locations.

Table 1. Results of soil chemistry analyses from summer 2005. Overall site parameter means are expressed ± 1 SD. Reported p-values are from blocked ANOVA tests examining differences between ivy and non-ivy sites (test power also provided).

Soil Parameter	Ivy Sites	Non-Ivy Sites	p-value	power	n
Total Nitrogen (%)	0.50 ± 0.16	0.51 ± 0.15	0.889	0.156	54
Total available N (mg/g soil)	0.014 ± 0.015	.014 ±.016	0.120	0.767	48
Nitrate/Nitrite -N (mg/g soil)	0.006 ± 0.007	.007 ±.008	0.148	0.515	48
Ammonium-N (mg/g soil)	0.008 ± 0.008	.006 ± .008	0.194	0.948	48
Total Carbon (%)	5.54 ± 2.30	5.14 ± 2.54	0.343	0.422	54
Organic Matter Content (%)	13.7 ± 2.4	12.4 ± 1.3	0.414	0.379	54
C:N ratio	11.6 ± 2.7	10.3 ± 2.7	0.231	0.507	54
pH	6.02 ± 0.42	5.65 ± 0.32	0.029	0.818	48
Soil Moisture (% dry weight)	20.1 ± 8.3	24.4 ± 7.8	0.302	0.450	48
Litter (tons/ha)	198 ± 45	298 ± 148	0.003	0.956	54

Although soil moisture overall (averaged over the entire summer) was not different between ivy and non-ivy sites (Table 1), transient effects of ivy infestation on soil moisture are evident after significant summer rainfall events. Increasingly higher levels of precipitation in a rainfall event prior to a sampling date were positively associated with reduced levels of soil moisture in ivy locations (Figure 1). During dry periods (weekly precipitation of zero), the presence of ivy is associated with greater soil moisture. These findings are potentially quite significant in a summer-dry climate, such as the Pacific Northwest.

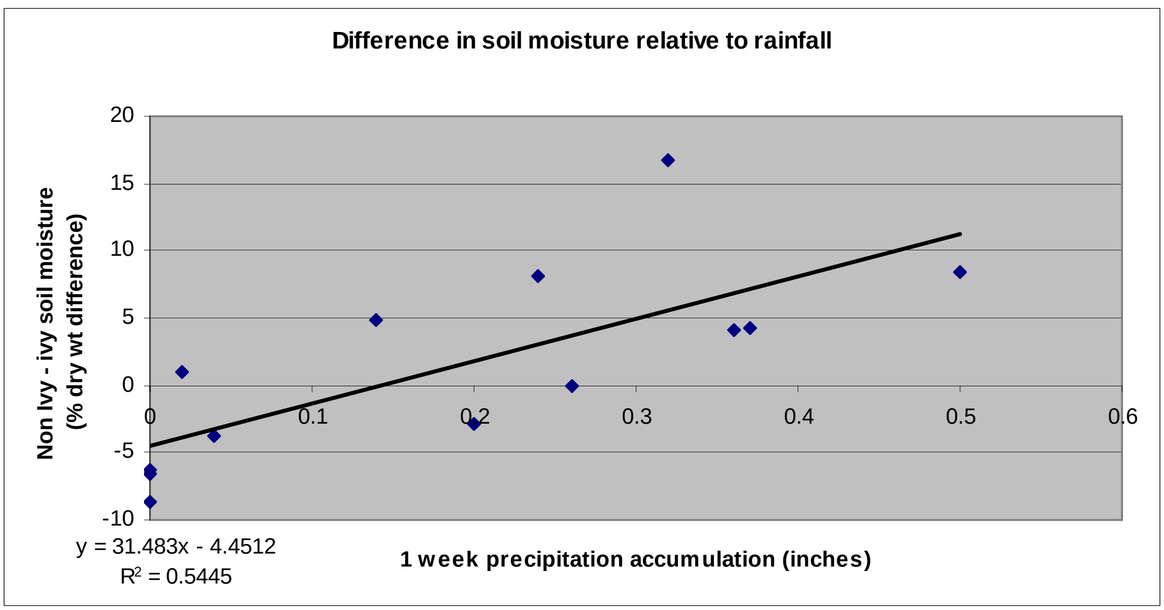

Figure 1. The relationship between weekly precipitation (7-day accumulation) prior to soil sampling and the difference in % soil moisture at ivy and non-ivy sites. The linear correlation was significant (p = .003).

Beyond soil chemistry, this study initially intended to examine potential effects of English ivy on soil biota. Analyses of soil biota (fungi, bacteria) from 2005 showed a very high degree of seasonal and spatial variability at both ivy and non-ivy sites. With such high variability it was clear that very large numbers of samples would be needed to characterize the soil biota of these sites. Thus, instead of direct biological measurements, we chose in 2006 to study soil nitrogen mineralization, a critical process mediated by soil microbiota. Nitrogen mineralization is a functional reflection of the quantity and activity of an important subset of soil microbiota.

Many of the soil parameters measured in 2005 showed a high degree of variability within each location. In order to characterize ivy versus non-ivy comparisons more completely, soil sampling was intensified (more sites) at fewer locations in the summer of 2006.

Initial statistical analyses show a significant difference in total available nitrogen, where non-ivy sites had more available N than ivy sites. The statistical test power in this comparison is relatively low, raising questions about the significance of the differences that were found. No differences were seen in either of the contributing types of available nitrogen (ammonium or nitrate/nitrite), net N-mineralization rates, or moisture levels. All measures of soil nitrogen and mineralization were associated with very high variability (in both space and time).

Table 2. Results of soil chemistry analyses from samples collected in summer 2006. Overall site parameter means are expressed ± 1 SD. Reported p-values are from blocked ANOVA tests examining differences between ivy and non-ivy sites (test power also provided).

Soil Parameter	Ivy Sites	Non-Ivy Sites	p-value	power	n
Total available N (mg/g soil)	0.023 ± 0.026	0.021 ± 0.020	0.096	0.470	21
Nitrate/Nitrite -N (mg/g soil)	0.012 ± 0.014	0.011 ± 0.012	0.312	0.246	21
Ammonium-N (mg/g soil)	0.011 ± 0.011	0.010 ± 0.009	0.256	0.284	21
Net N mineralization rates (mg/g soil/day)	0.0009 ± 0.0010	0.0012 ± 0.0016	0.361	0.219	21
Soil Moisture (% dry weight)	37.7 ± 11.7	30.0 ± 9.2	0.875	0.069	21

Preliminary Conclusions and Implications for Future Research:

These studies show that the soil chemistry of sites infested with English ivy differs in some ways from that of native forest sites without English ivy. Moisture levels following precipitation events were greater in native plant areas. Infrequent precipitation and low soil moisture levels are characteristic of the summer dry climate in the Pacific Northwest. Such drought conditions often constrain the success of planted native species in restoration efforts following invasive plant removal. In addition to direct effects of moisture on plants, soil moisture also limits the activity of microbiota responsible for nutrient cycling. Indeed, our data show a strong positive correlation between soil moisture and net nitrogen mineralization (Fig. 2). Given the negative effects of English ivy presence on soil moisture immediately after precipitation events, it is conceivable that nitrogen mineralization may be limited in ivy infestation sites during those brief, favorable moisture times of the summer. Lack of overall mineralization differences in this study may have resulted from measurements taking place over an extended (1-month) time period using techniques that did not allow for transient available moisture and consequent time-limited mineralization. Future research using stable isotopes and transient measures of nitrogen transformation would be helpful in characterizing the important dynamics of this relationship.

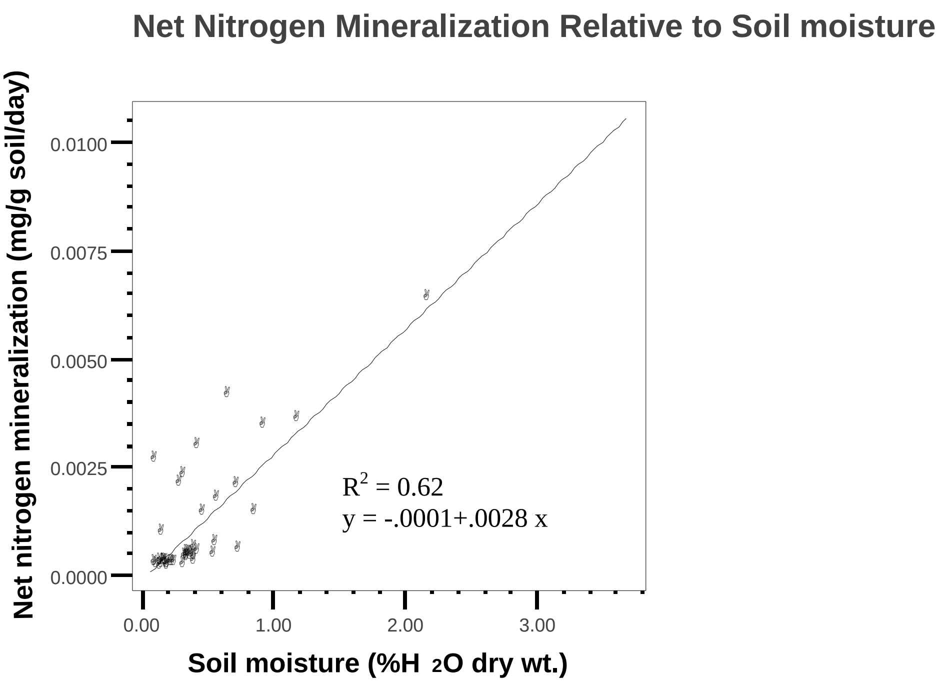

Figure 2. Relationship between soil moisture and net nitrogen mineralization. The linear regression was significant ($p = 0.05$).

The presence of English ivy was associated with less acidic soils, though the ecological significance of changes from pH 5.6 to 6.0 is uncertain. Most plant nutrients show little chemical change in availability across that range, but soil biota are known to be sensitive to relatively small changes in pH.

Available nitrogen may be higher in native sites, though the current results of these data were mixed, and further studies will need to occur to clarify these results. Alterations in the quantities of available nitrogen or the rate of its production (i.e., mineralization) can have significant consequences for plant growth and survival in most Pacific Northwest forest soils, which tend to be nutrient poor. Further studies could be undertaken to more clearly quantify these differences in order to assess the ecological and biological significances of such differences.

Litter levels were higher under native plant cover. Generally, through a dry summer season greater litter accumulation would help hold water in the soil. However, during periods of no weekly precipitation, soil moisture in ivy infested sites (with less litter mass) was greater. In this case, the dense ground cover canopy of live ivy foliage likely acts to suppress soil water loss more than the greater quantity of litter in the non-ivy sites. In the summer, ivy is shaded in the forest understory and likely has low transpiration rates, which apparently do not deplete soil moisture to a great degree relative to the suppression of evaporative water loss directly from the soil by the ivy canopy.

Litter is also a source for nutrient input into the soil as it is broken down. Lower levels of litter in ivy sites may impact many other soil nutrient cycles that in time can impact the health of established native plants, as well as the survival of new plants. Litter chemical qualities, decomposition rates, and seasonal variation in litter levels would beneficial to investigate in future studies.

It is clear that the presence of English ivy can alter some aspects of the soil chemical environment of Pacific Northwest forest soils. Other aspects of the soil chemical environment were not different in association with ivy. Many of the soil chemical parameters measured were highly variable in space and time and this variability some times made it difficult to generalize about the effects of ivy presence. It appears that in some instances the effects of English ivy on soil chemistry are highly site-specific, likely dependent upon the specific vegetation association and abiotic conditions that each site presents.

The relationships found in this study need to be examined in controlled experiments as well as more extensive field studies. It will be important to develop an understanding of the factors controlling the high degree of variability in it and time associated with English ivy impacts on soil parameters. The ecological significance of temporally variable impacts (such as soil moisture) needs to be explored. Further, the impacts of ivy on soil properties should be studied to see if the differences found in this study continue to change the longer ivy is on a site. The time course for changes in soil properties following ivy removal also needs to be examined. There is still much we need to know to develop a better understanding of how English ivy infestations are related to soil properties and its effects on eradication and restoration efforts.

On-going Analysis & Dissemination

Data subsets with interesting preliminary correlations are being analyzed (e.g., sites with higher carbon; seasonal subsets) but the consequent restrictions in sample size may limit the power of any associations found. Soil pH and volatile organics for 2006 samples are being analyzed in the laboratory and added into the overall analysis.

A complete account of background, methodology, results, and implications will be written up in a detailed thesis for the College of Forest Resources at the University of Washington. Highlights of the most important results and their implications will also be published locally for land managers, restorationists, and regional invasive species biologists. These should contribute to the knowledge base that informs ivy removal, restoration decisions, and future research.

Importance of Grant

This grant was imperative throughout the study, from sample collection and processing to laboratory chemical analyses. Without these funds, such chemical analyses would not have been possible. Initial measurements of soil biota revealed such variability that it became evident we had insufficient human and monetary resources for the sampling required to characterize soil biota and their dynamics. Instead, with CIPM approval, funds and efforts were redirected at further chemical analyses that reflected soil biotic activity important for higher plant nutrition.

The research supported by this grant was a critical component of the course of study for a Master's degree undertaken by Anna Heckman in the College of Forest Resources at the University of Washington.

Itemized budget

Supplier(s)	Items	Cost
Biotic analysis		$ 874.00
Soil Food Web Inc	4 samples Bacteria and fungal analysis 4 samples Bacteria, fungal, and protozoa analysis	
Laboratory Supplies		$ 468.67
Exter analytical VWR Scientific	Grade 5 helium, copper/ cadmium column, KCL, Phenolate, sodium nitroprusside chemicals, pH standards,	
Field Supplies & Equipment		$ 696.04
Home Depot General grocer Seattle Urban nature project UPS Forestry Suppliers	Paper bags, 1 gal Plastic Ziploc, 1 quart plastic Ziploc, drying parchment, 70 ft 200 gauge PVC pipe, and 14 caps. Rolling pin (soil crusher), trowel, measuring tape CD of vegetation zone maps. Overnight shipment of biotic analysis samples (X 4) Soil corer	
	Total expenditures	$ 2,038.71
	Total overhead	$ 203.87
	Returned unused funds *	$ 1,398.41
	Total	$ 3,640.99

* Unused funds were originally targeted at soil biota analyses which were to be done in contract by an external laboratory. Initial soil biotic analyses showed such a high degree of spatial variability that that aspect of the research was refocused on chemical transformation measures (net nitrogen mineralization) that reflect soil biota activity.