Short communication

Effects of invasive scotch broom on soil properties in a Pacific coastal prairie soil

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Abstract

Scotch broom (Cytisus scoparius) is a leguminous shrub, native to Europe that has invaded significant areas of the Pacific Northwest and rigorously competes with native vegetation. Mineral soils under scotch broom colonies and adjacent coastal prairie on the Mendocino Coast of Northern California were sampled to determine how soil properties and microbial processes have been affected. Soils under scotch broom were significantly more acidic and had greater organic matter content than prairie soils. The activities of two soil enzymes responsible for processing major detrital carbon and phosphorus pools were significantly higher under scotch broom. Organic matter accumulation with no change in C:N, a greater increase in phosphatase activity (123%) than in β-glucosidase (84%) under scotch broom, and a significant difference between soil C:P under scotch broom (619) and prairie vegetation (470) all suggest that the coupling of nutrient cycles has changed.

Keywords: Soil enzymes; Cytisus scoparius; Coastal prairie; Invasive plant; Soil C; Soil N; Soil P

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1. Introduction

Scotch broom (Cytisus scoparius Link), a woody legume native to Europe, has become a vigorous invader of temperate plant communities worldwide (Holm et al., 1997), including along the Pacific coast of North America. Originally introduced as an ornamental and later for erosion control and soil stabilization (Gilkey, 1957, Schwendiman, 1977 and McClintock, 1979), this shrub now poses a significant threat to plant communities from central California to British Columbia (Gilkey, 1957, Mountjoy, 1979, Rejmanek et al., 1991, Peterson and Prasad, 1998 and Isaacson, 2000).

Research on scotch broom has primarily focused on physiology and population dynamics (Bossard, 1991, Partridge, 1992, Nielsen et al., 1993, Parker, 2000 and Paynter et al., 2003) and the effects of scotch broom on soil properties are poorly understood. Several studies reported an increase in soil organic matter (SOM) and soil carbon, nitrogen and phosphorus (Dancer et al., 1977, Wheeler et al., 1987, Diquélou and Rozé, 1999 and Fogarty and Facelli, 1999), although reductions have also been found (Bellingham, 1998). Information on the effects of scotch broom on soil microbial processes and nutrient cycling is even more limited. Diquélou and Rozé (1999) reported increases in microbial biomass, ammonification, nitrification and the activity of a non-specific esterase under scotch broom invading grassland and abandoned cropland within its native range.

Because of general concern for the effects of invasive plants on nutrient cycles (Vitousek, 1990, Levine et al., 2002 and Mack et al., 2003) and the limited information specifically for scotch broom, this report presents preliminary findings that scotch broom significantly impacts both soil chemistry and belowground microbial processes in a Pacific coastal prairie grassland.

2. Materials and methods

2.1. Site description

The study site was on a coastal marine terrace in Mendocino County, California, where scotch broom has established discrete colonies within the grass-forb prairie matrix. The soils are fine- (Biazzi series) to coarse- (Hesser series) loamy, mixed, isomesic Ustic Humitopepts. Similar terraces along the Mendocino Coast have been previously described (Northup et al., 1995).

2.2. Sampling
In spring 2002, composite samples of four 0–5 cm cores were collected approximately 2 m within each of the five scotch broom colonies. Similar samples were taken from the adjacent prairie, 2 m from the edge of the corresponding scotch broom colony.

2.3. Analyses

2.3.1. Soil characteristics

Field-moist samples were sieved to pass 2 mm and dry weights determined after oven drying (105 °C, 24 h). Soil pH was measured potentiometrically in a 1:2.5 (w/v, soil:distilled water) slurry. Soil organic matter was measured by loss-on-ignition at 550 °C for 24 h. Soil carbon and nitrogen contents were measured on a Carlo Erba CHN analyzer. Inorganic and organic phosphorus were determined by the method of Saunders and Williams (1955).

2.3.2. Soil enzyme activities

β-Glucosidase and acid phosphatase activities were measured using the respective p-nitrophenyl ester substrates as previously described (Caldwell et al., 1999).

2.3.3. Data analysis

Soil properties and enzyme activities were calculated as micromoles p-nitrophenol (pnp) released per gram oven-dry weight per hour. Since the increased organic matter under scotch broom (Table 1) could decrease soil bulk density, biasing enzyme activities calculated on a soil weight basis, activities were also calculated on a SOM content basis. Differences in soil chemistry and enzyme activities from scotch broom and adjacent prairie soils were determined by a paired t-test.

Table 1.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Prairie</th>
<th>Scotch broom</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.3 ± 0.1</td>
<td>5.6 ± 0.2</td>
<td>0.0004</td>
</tr>
<tr>
<td>SOM (g kg⁻¹)</td>
<td>127 ± 19</td>
<td>158 ± 19</td>
<td>0.007</td>
</tr>
<tr>
<td>Total carbon (g kg⁻¹)</td>
<td>59.9 ± 0.93</td>
<td>73.4 ± 0.57</td>
<td>0.015</td>
</tr>
<tr>
<td>Total nitrogen (g kg⁻¹)</td>
<td>5.03 ± 0.6</td>
<td>6.33 ± 0.58</td>
<td>0.005</td>
</tr>
<tr>
<td>Inorganic phosphorus (mg kg⁻¹)</td>
<td>24.4 ± 1.4</td>
<td>20.1 ± 2.4</td>
<td>0.012</td>
</tr>
<tr>
<td>Organic phosphorus (mg kg⁻¹)</td>
<td>102 ± 10.1</td>
<td>97.7 ± 12.5</td>
<td>0.119</td>
</tr>
<tr>
<td>C:N</td>
<td>11.6 ± 0.42</td>
<td>11.9 ± 0.41</td>
<td>0.33</td>
</tr>
<tr>
<td>C:P</td>
<td>470 ± 76</td>
<td>619 ± 44</td>
<td>0.019</td>
</tr>
<tr>
<td>β-Glucosidase (µmol pnp g⁻¹ h⁻¹)</td>
<td>1.02 ± 0.38</td>
<td>1.88 ± 0.64</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(µmol pnp gSOM⁻¹ h⁻¹)</td>
<td>7.9 ± 2.1</td>
<td>11.7 ± 2.8</td>
</tr>
</tbody>
</table>
3. Results and discussion

Soil chemistry under scotch broom was significantly different from that under coastal prairie, with a more acidic pH and greater accumulations of soil organic matter, soil carbon and soil nitrogen (Table 1). Although scotch broom is a nitrogen-fixing legume, nitrogen accumulation (26%) was similar to carbon accumulation (23%), resulting in no significant net change in soil C:N. Inorganic phosphorus was significantly lower under scotch broom, but organic phosphorus was not significantly different. However, because of the significant increase in organic matter under scotch broom, soil C:P was significantly lower under prairie (C:P = 470) than under scotch broom (C:P = 619).

Previous reports on scotch broom have cited increases in soil nitrogen (Dancer et al., 1977 and Wheeler et al., 1987), as well as carbon and nitrogen (Diquelou and Rozé, 1999; Fogarty and Facelli, 1999). Similar carbon and nitrogen accruals with little or no change in C:N have been reported for other woody legumes (Klemmedson, 1994 and Kaye et al., 2000). In contrast, trends for soil phosphorus can vary substantially. Fogarty and Facelli (1999) found higher soluble phosphorus concentrations under invasive broom in Australia. Klemmedson (1994) found a slight, but non-significant increase in soil phosphorus under New Mexican locust. Binkley et al. (2000) found different effects on different phosphorus fractions under Albizia facalteria.

The general accumulation of soil organic matter may be the result of reduced decomposition due to litter chemistry; e.g., legume tissues can be more lignified than grass detritus (Singh and Narang, 1991). The presence of condensed tannins in scotch broom (Frutos et al., 2002) may also limit decomposition (Cadisch and Giller, 1997), especially of organic nitrogen (Northup et al., 1995). At this site, the concentration of presumptive condensed tannins (Porter et al., 1986) was four times greater in scotch broom litter (7.2 A\textsubscript{550 nm} g\textsuperscript{-1}) than in grass litter (1.7 A\textsubscript{550 nm} g\textsuperscript{-1}).

Two soil enzymes responsible for key transformations in the processing of detrital material showed elevated activity under scotch broom on both a gram soil and gram SOM basis (Table 1). β-Glucosidase, which catalyses the final extracellular hydrolysis in the breakdown of cellulose to yield assimilable glucose, increased 84% on a soil weight basis and 48% on a SOM basis. Phosphatase, which releases inorganic phosphate from organic monophosphate esters, increased 123% on a soil weight basis and 81% on a SOM basis. The only other report of enzyme activities under scotch broom found higher activities of a non-specific esterase that represents general microbial activity (Diquelou and Rozé, 1999). The greater percent increase in phosphatase, relative to β-glucosidase, suggests a greater emphasis on P acquisition under scotch broom. One consequence of this is seen in the widening soil C:P
under scotch broom as phosphorus is preferentially removed, possibly in response to the
generally greater phosphorus demands of nitrogen fixing systems (Crews, 1993 and Vitousek
and Field, 1999).

4. Conclusions

Invasion by scotch broom significantly alters soil chemistry, soil enzyme activities and
possibly the relationships between biogeochemical cycles. Whether these changes are
ultimately beneficial or detrimental is currently unknown. Although once considered
beneficial to marginal soils, there is an increasing evidence that scotch broom can have a
significant, negative impact on native plant populations. A clearer understanding of the
mechanisms, magnitude and persistence of these altered soil characteristics and microbial
processes are needed to critically evaluate possible control and management strategies.

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References

Bellingham, 1998 P.J. Bellingham, Shrub succession and invasibility in a New Zealand

Binkley et al., 2000 D. Binkley, C. Giardina and M.A. Bashkin, Soil phosphorus pools and
supply under the influence of Eucalyptus saligna and Albizia facaltaria, For. Ecol. Manage.

Bossard, 1991 C.C. Bossard, The role of habitat disturbance, seed predation and ant dispersal
on establishment of the exotic shrub Cytisus scoparius in California, Am. Midl. Nat. 126

Cadisch and Giller, 1997 In: G. Cadisch and K.E. Giller, Editors, Driven by Nature: Plant

Caldwell et al., 1999 B.A. Caldwell, R.P. Griffiths and P. Sollins, Soil enzyme response to
1603–1608.

Crews, 1993 T.E. Crews, Phosphorus regulation of nitrogen fixation in a traditional Mexican

Dancer et al., 1977 W.S. Dancer, J.F. Handley and A.D. Bradshaw, Nitrogen accumulation in

Diquélou and Rozé, 1999 S. Diquélou and F. Rozé, Implantation du genet à balais, précédent


Partridge, 1992 T.R. Partridge, Successional interactions between bracken and broom on the


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