Soil resistance under grazed intermediate wheatgrass

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Liebig, M. A., Hendrickson, J. R., Berdahl, J. D. and Kern, J. F. 2008. Soil resistance under grazed intermediate wheatgrass. Can. J. Soil Sci. 88: 833–836. Intermediate wheatgrass [Thinopyrum intermedium (Host) Barkw. & D.R. Dewey subsp. intermedium] is a productive, high-quality perennial forage that lacks persistence under grazing. A study was conducted to evaluate the effects of three grazing times on soil bulk density, soil pH, and soil organic C under intermediate wheatgrass. Treatment effects on the three soil attributes were negligible, implying grazing time did not negatively impact intermediate wheatgrass beyond a threshold whereby critical soil functions were impaired. Findings from this study are important in the context of sustainable forage and cropping system management, where maintaining or improving critical soil functions are essential for enhancing agroecosystem sustainability.

Key words: Seeded perennial forages, Northern Great Plains, soil organic C

Seeded perennial forages can be used to meet nutritional demands of livestock in the northern Great Plains of North America. Among the forages available, intermediate wheatgrass [Thinopyrum intermedium (Host) Barkw. & D.R. Dewey subsp. intermedium] has been found to be a high yielding, cool-season grass with excellent quality (Moore et al. 1995). Furthermore, intermediate wheatgrass has proven to be an adaptable forage, with applications in soil restoration and conservation efforts as well as use as pasture or hay (Stark et al. 1950; Robles and Burke 1998). Despite its adaptability, the use of intermediate wheatgrass has been limited because of its inadequate stand longevity under grazing stress (Hendrickson et al. 2005). Given this limitation, there is concern that management stressors (such as grazing) may negatively affect soil attributes within intermediate wheatgrass stands due to the absence of adequate soil cover and/or through invasion of undesirable plant species.

Given this context, we sought to determine the capacity of soil attributes to resist change under intermediate wheatgrass stands subject to different grazing times. Soil resistance, which is defined as the capacity of soil to continue to function without change throughout a disturbance (Seybold et al. 1999), was used as the metric by which the evaluation was conducted. Three soil attributes were selected as key indicators of soil resistance: soil bulk density (reflecting soil structural attributes, such as aggregation and porosity), soil pH (reflecting chemical attributes, and specifically the capacity of soil to buffer changes in reserve and exchangeable acidity), and soil organic C (reflecting biological soil quality, as well as direct and indirect contributions to water-holding capacity and aggregate stability).

METHODOLOGY

This evaluation was conducted at the USDA-ARS Northern Great Plains Research Laboratory at a field site approximately 6 km south of Mandan, North Dakota, USA (lat. 46°46'35"N, long. 100°54'20"W). The site was on gently rolling uplands (0 to 3% slope) with a silty loam overlying Wisconsin age till. The predominant soil at the study site was a Temvik-Wilton silt loam (fine-silty, mixed, superactive, frigid Typic and Pachic Haplustolls) (Soil Survey Staff 2008), which is similar to a Dark Brown Chernozem (Soil Classification Working Group 1998). Average annual precipitation at the study site from 1913 to 2003 was 410 mm and long-term growing season precipitation (April to September) was 330 mm. Average annual temperature was 4°C, though daily averages ranged from 21°C in the summer to —11°C in the winter. The average frost-free period at the site was 131 d.
A study was initiated in 1997 to evaluate grazing effects on intermediate wheatgrass. Details on study design and treatment descriptions can be found in Hendrickson et al. (2005). Briefly, three paddocks, each representing different grazing treatments, were established on previously fallowed land containing two strips of eight intermediate wheatgrass entries. The eight entries consisted of adapted cultivars and experimental populations, which were assigned randomly within each strip. Paddock size was 20 m x 18 m, and individual entry plots were 2 m x 9 m. Experimental treatments were replicated three times, for a total of 144 plots.

Intermediate wheatgrass entries were seeded in 1997 in a tilled seedbed at a rate of approximately 100 seeds m\(^{-1}\) of row with rows spaced 36-cm apart. Entries were hayed in mid-July of 1998 and 1999. In 2000, paddocks within a replicate were randomly assigned one of three grazing treatments: (1) early vegetative (grazing during the four- to six-leaf stage), (2) mid-culm (grazing when stems had approximately two palpable nodes), and (3) late boot (grazing during the late boot stage). Within each replicate, eight plots – each representing a different entry – were selected as ungrazed controls. Paddocks were grazed with two cross-bred yearling steers per paddock only once each season for 4 yr (2000 to 2003). Early vegetative treatments were grazed in late May or early June, mid-culm treatments in mid-June, and late boot treatments in late June or early July. The length of the grazing period varied from 4 to 13 d depending on the amount of biomass available. Grazing within each treatment was terminated when about 50% of the biomass was removed relative to ungrazed controls. In October of each year, all plots were mowed at a height of 15 cm to reduce standing residue. Mowed residue was left on the plots (Hendrickson et al. 2005).

Soil samples were collected in May 1997 prior to planting and again in May 2004 after completion of the study. Sampling was conducted in a single day in both instances. In 1997, baseline soil cores were collected prior to planting from 10 points approximately 10 m apart along an east-west transect within the study area. Three samples were collected at each point using a 2.5-cm (i.d.) step-down probe from the 0- to 30-cm depth and composited. In 2004, soil cores were collected from the three grazing treatments as well as ungrazed controls within plots seeded to two intermediate wheatgrass entries (Oahe and Reliant). Sampling was restricted to the two entries due to limited resources. The entries chosen, however, were considered to be the most widely used intermediate wheatgrass varieties in the northern Great Plains. Samples were collected at depths of 0 to 5, 5 to 10, 10 to 20, and 20 to 30 cm using a 3.1-cm (i.d.) step-down probe. Six soil cores at 0 to 5 and 5 to 10 cm, and three soil cores at 10 to 20 and 20 to 30 cm were collected in each plot and composited by depth. Prior to processing, samples were saved in double-lined plastic bags and placed in cold storage at 5°C.

Soil cores collected during both samplings were dried at 35°C for 3 d and ground by hand to pass a 2.0-mm sieve. Identifiable plant material (>2.0-mm) was removed during sieving. Soil pH was estimated from a 1:1 soil-water mixture (Watson and Brown 1998). Total C was determined by dry combustion on air-dried soil ground with a roller mill to pass a 100-mesh sieve (Nelson and Sommers 1996). Organic C was considered the same as total C, as carbonates were not present in the depths sampled. Gravimetric data were converted to a volumetric basis for each sampling depth using field measured soil bulk density from the composited soil cores (Blake and Hartge 1986). All data were expressed on an oven-dry basis.

Data from 2004 were analyzed using an appropriate model in PROC MIXED (Littell et al. 1996). Grazing treatment and intermediate wheatgrass entry were considered fixed effects, while replicate was a random effect. No differences in soil attributes were found between entries, so results were reanalyzed to test for grazing effects only. Comparisons between grazing treatments were considered significantly different using a protected least significant difference (LSD) test at \( P < 0.05 \). Orthogonal contrasts were used to evaluate changes in soil bulk density, soil pH, and soil organic C between 1997 and 2004 for the 0- to 30-cm depth.

**FINDINGS**

Grazing effects on the three soil attributes were negligible, indicating soil conditions were resistant to change under intermediate wheatgrass. Soil bulk density was unaffected by grazing time at the 0- to 10-cm and 20- to 30-cm depths (Table 1). At 10 to 20 cm, soil bulk density was greater in the control and mid-culm treatments as compared with the early vegetative treatment, a result difficult to resolve, as grazing tends to affect soil physical properties in near-surface depths (Blackburn 1984). Overall, values for soil bulk density were not indicative of compaction levels that would impede root growth (Jones 1983).

Soil pH values across all grazing times and depths fell within slightly acid to neutral ranges (Table 1), implying an optimum pH for root growth and soil microbial activity (Smith and Doran 1996). Grazing time, however, did not affect soil pH at any depth.

Similar to soil pH, soil organic C was unaffected by grazing time at all depths (Table 1). Measurable effects of grazing on soil organic C in a relatively short timeframe (<10 yr) are difficult to resolve in grazing lands, and may only be observed under extreme conditions of extended drought or exceptionally high stocking rates, conditions not observed or undertaken in this study. A notable finding regarding soil organic C, however, was the extent by which management prior to the seeding of intermediate wheatgrass depleted soil C stocks in near-surface depths. Average soil organic C at the 0- to 5-cm depth was approximately 5 Mg C ha\(^{-1}\) lower than in a nearby native vegetation pasture under...
Table 1. Mean values of soil bulk density, soil pH, and soil organic C affected by grazing time at four depths in 2004. Changes in soil properties from 1997 to 2004 at 0 to 30 cm are presented in the right-most columns.

<table>
<thead>
<tr>
<th>Soil property/depth (cm)</th>
<th>Early vegetative</th>
<th>Mid-culm</th>
<th>Late boot</th>
<th>Control</th>
<th>P value/LSD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil bulk density (Mg m⁻³)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>1.04 (0.03)'</td>
<td>1.04 (0.05)</td>
<td>1.10 (0.04)</td>
<td>1.04 (0.06)</td>
<td>0.18/NS</td>
</tr>
<tr>
<td>5 to 10</td>
<td>1.15 (0.04)</td>
<td>1.21 (0.04)</td>
<td>1.19 (0.05)</td>
<td>1.18 (0.05)</td>
<td>0.17/NS</td>
</tr>
<tr>
<td>10 to 20</td>
<td>1.13 (0.06)</td>
<td>1.22 (0.06)</td>
<td>1.19 (0.03)</td>
<td>1.26 (0.07)</td>
<td>0.01/0.07</td>
</tr>
<tr>
<td>20 to 30</td>
<td>1.21 (0.06)</td>
<td>1.20 (0.02)</td>
<td>1.21 (0.04)</td>
<td>1.22 (0.04)</td>
<td>0.88/NS</td>
</tr>
<tr>
<td>Soil pH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>6.43 (0.24)</td>
<td>6.58 (0.31)</td>
<td>6.64 (0.24)</td>
<td>6.43 (0.16)</td>
<td>0.49/NS</td>
</tr>
<tr>
<td>5 to 10</td>
<td>6.34 (0.14)</td>
<td>6.51 (0.24)</td>
<td>6.49 (0.25)</td>
<td>6.41 (0.15)</td>
<td>0.59/NS</td>
</tr>
<tr>
<td>10 to 20</td>
<td>6.67 (0.15)</td>
<td>6.95 (0.29)</td>
<td>6.77 (0.17)</td>
<td>6.77 (0.25)</td>
<td>0.21/NS</td>
</tr>
<tr>
<td>20 to 30</td>
<td>6.92 (0.19)</td>
<td>7.10 (0.27)</td>
<td>7.11 (0.26)</td>
<td>6.93 (0.20)</td>
<td>0.53/NS</td>
</tr>
<tr>
<td>Soil organic C (Mg C ha⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 5</td>
<td>18.5 (1.2)</td>
<td>17.0 (0.5)</td>
<td>17.7 (3.1)</td>
<td>18.9 (1.6)</td>
<td>0.80/NS</td>
</tr>
<tr>
<td>5 to 10</td>
<td>17.6 (1.4)</td>
<td>18.2 (0.4)</td>
<td>17.5 (0.6)</td>
<td>17.9 (1.5)</td>
<td>0.82/NS</td>
</tr>
<tr>
<td>10 to 20</td>
<td>30.1 (3.0)</td>
<td>31.1 (1.5)</td>
<td>30.0 (2.7)</td>
<td>32.3 (2.6)</td>
<td>0.64/NS</td>
</tr>
<tr>
<td>20 to 30</td>
<td>21.9 (4.3)</td>
<td>22.5 (3.0)</td>
<td>23.1 (4.7)</td>
<td>22.4 (4.4)</td>
<td>0.99/NS</td>
</tr>
</tbody>
</table>

*Least significant difference at *P* < 0.05. NS, not significant.

Values in parentheses represent standard error of the mean.

DISCUSSION

Resistance of soil attributes to management effects is largely controlled by inherent features of the soil. The soil type on which the experiment was conducted was highly resistant to change, as the soil possessed high soil organic matter content (relative to degraded cropland), medium soil texture (280 g kg⁻¹ sand, 530 g kg⁻¹ silt, and 190 g kg⁻¹ clay in the surface 30 cm), and a prevalence of 2:1 clay minerals. These inherent attributes would be expected to buffer changes to the soil imposed by management. Additionally, the management treatments applied in this study were likely intense enough neither in space nor time to induce change in the attributes measured. Despite this, an evaluation was necessary to determine if time of grazing would negatively impact intermediate wheatgrass to a point where deleterious effects on the soil became apparent. Results from this study suggest basic soil attributes do not change under grazed intermediate wheatgrass in the short-term and, in fact, may slightly improve (in the case of soil organic C accrual). Follow-up studies may seek to concentrate on quantifying the extent by which soil attributes do change under more intensive grazing regimes or other management perturbations, and how those changes affect critical hydrological and nutrient cycling functions.

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