Effect of the Microbiotic Crust of the Antelope-Brush (Purshia tridentata) Shrub-Steppe on Soil Moisture

Lynne B. Atwood
Genoa Environmental Consulting
Box 20282, Smithers, BC, V0J 3P0, Canada
latwood@bulkley.net

Pam G. Krannitz
Canadian Wildlife Service, Pacific Wildlife Research Centre
5421 Robertson Rd., RR 1, Delta, BC, V4K 3N2, Canada

ABSTRACT

Microbiotic crusts moderated soil moisture conditions in the antelope-brush shrub-steppe of the South Okanagan and the influence was higher in areas with extensive amounts of crust. However, the life-forms in the crust played different roles.

Key words: antelope-brush, microbiotic crust, Purshia tridentata, shrub-steppe, soil moisture, South Okanagan.

The microbiotic crust is a complex mix of lichen, moss, liverworts, algae, fungi, and bacteria that colonize the soil surface in semiarid environments. Microbiotic crusts are also referred to as cryptobiotic (Belnap 1994), cryptogamic (Kleiner and Harper 1972), microfloral (Loope and Gifford 1972), or microphytic crusts (West 1990). Microbiotic crusts have been linked to 6 ecological functions: soil formation, soil surface stabilization, nutrient cycling, vascular plant germination and establishment, a source of food and shelter, and soil water relations (West 1990).

This study examined the role of the microbiotic crust on soil moisture and addressed 3 issues: (1) if the microbiotic crust influenced soil water content and loss; (2) if the soil moisture effect differed with microbiotic crust life-form; and (3) if the role of the microbiotic crust on soil water was more important than influences from other ecosystem components (Atwood 1998). The study area was the provincially Red-listed antelope-brush (Purshia tridentata) shrub-steppe in the South Okanagan.

METHODS

Eighty-eight 1-m² plots were established at 2 sites, Water Tower (WT) and Kennedy Bench (KB). The sites were chosen because they contained similar soil textures but different amounts of bare ground, variables that may influence soil moisture retention. The average cover of bare ground at KB was 4% compared with 22% at WT. Soil moisture was measured 1, 3, and 5 days after a rain event, in August and October, at a 15-cm² sample point in each plot. Half of the plots had sample points covered by microbiotic crust and half were bare. Two variables (crust and shrub) were tested in a 2 x 2 factorial design with 22 plots per combination (crust, shrub, crust x shrub, no crust or shrub [bare]).

Shrub cover was included in the experiment to account for the possible effects of hydraulic lift1 and shading on soil moisture. Data on soil texture, percent cover of each non-vascular and vascular plant life-form, and thickness of the moss in the microbiotic crust were collected from the entire 1-m² plot. Soil water content data were analyzed using analysis of variance (ANOVA), moisture loss over time was analyzed with Repeated Measures multivariate ANOVA (MANOVA), and Pearson's correlation coefficient (r) was used to identify associations between soil moisture and plot conditions. The percent cover data were arc-sine square root transformed prior to analysis.

RESULTS

SOIL MOISTURE CONTENT

After the 8-mm August rainfall the effect of microbiotic crust on soil moisture was similar at KB and WT. Soils beneath microbiotic crust at the sample point (crusted plots) received less rainwater initially, but retained moisture longer than bare soil (non-crusted plots) (Fig. 1). Soil water content was higher in crusted plots within 3 days of the rainfall and this trend was still evident 5 days after the rain. On day 5, soils covered by microbiotic crust contained almost twice the soil moisture of bare ground.

Rain showers were light and sporadic during the October data collection. For the first 3 sampling days soils covered by

1Hydraulic lift is the ability of deep rooted species to bring moisture to the upper soil layers where it can be used by shallow-rooted species (Caldwell 1990).
microbiotic crust contained more moisture than bare soils, but soil moisture conditions changed after a 2-mm rainfall on day 4. Soils covered by microbiotic crust absorbed little to none of the light shower, while soil moisture increased substantially in bare soils (Fig. 2). The 2-mm rain shower highlighted the differences in the water absorption patterns of the microbiotic crust life-forms. Soils beneath thick moss did not receive the light rain shower but soils beneath lichen crusts did (Table 1). Mosses in the microbiotic crust inhibited soil water percolation, but lichens did not.

Figure 1. Soil water content at 2 sites in crusted and non-crusted plots from day 1 to day 5 following a rain event in August (mean ±1 SE).

Figure 2. Soil water content at 2 sites in crusted and non-crusted plots from day 1 to day 5 following a rain event in October (mean ±1 SE).
SOIL WATER LOSS
In August, drying patterns differed between soils covered with microbiotic crust and those that were bare (KB [time x crust]: $F = 221.3, p = 0.0001, df = 1, 84$; WT [time x crust]: $F = 72.56, p = 0.0001, df = 1, 83$). The most rapid moisture loss occurred in the first 3 days after the rain event. On average, bare soils lost 86% of the soil moisture within 3 days of the rain, but soils covered by microbiotic crust lost an average of 44% soil moisture during this same period. Five days after the rain, crusted soils retained an average of 31% of the day 1 soil water, while bare soils retained only 9.5% of the moisture measured on day 1.

PLOT CONDITIONS
Soil moisture content and loss varied with environmental conditions surrounding the sample point. The plot conditions with the most consistent influence on soil water were the amount of microbiotic crust in the 1 m² surrounding the sample point, the dominant crust life-form, and life-form morphology.

Three days after the August rain event soil water content increased as the percent cover of microbiotic crust in the surrounding area increased, and the amount of water that was lost was reduced if the surrounding microbiotic crust contained thick moss (Table 2). Although moss inhibited initial percolation, it contributed to the water retention ability of the crust. The positive effect of a mossy microbiotic crust was so pronounced at KB that water content in bare soils was higher if surrounded by an extensive amount of moss (Table 2). General site conditions likely contributed to this effect as the positive relationship between microbiotic crust and moisture in bare soils was not seen at WT.

Plant litter and bare soil were the only other plot variables that consistently influenced soil water conditions. Three days after the rain, soil water content was higher in plots with large amounts of litter, and water content was very low if the sample point was surrounded by large amounts of bare ground (Table 2). Plant litter was more important for water retention in areas where the microbiotic crust was thin (WT), but the benefits were short lived and much of the soil water beneath the litter disappeared by day 5 (WT: grams of water lost between day 3 and day 5 increased with litter cover; $r = 0.38, p = 0.0003, n = 87$).

WT and KB contained the same average percent cover of microbiotic crust and the influence of the crust on moisture conditions was similar. Despite receiving the same amount of

Table 1. The correlation between soil moisture content of KB soils covered by a microbiotic crust and the percent cover of moss, lichen and thickness of the moss in the 1 m² surrounding the sample point.

<table>
<thead>
<tr>
<th>Association between soil moisture content in crusted soils and</th>
<th>Kennedy Bench – October, Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>% cover of moss in the microbiotic crust</td>
<td>$r$</td>
</tr>
<tr>
<td>% cover of lichen in the microbiotic crust</td>
<td>$r$</td>
</tr>
</tbody>
</table>

Table 2. The correlation between soil water content or the grams of water lost and conditions in the 1 m² surrounding the sample point for Kennedy Bench and Water Tower.

<table>
<thead>
<tr>
<th>Correlation with plot variables</th>
<th>Kennedy Bench</th>
<th>Water Tower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Association between day 3 soil water content and % cover of microbiotic crust in the 1-m² plot</td>
<td>$r$</td>
<td>$p$</td>
</tr>
<tr>
<td>Association between the grams of soil water lost between day 1 and day 3 and % cover of moss in the 1-m² plot</td>
<td>$-0.54$</td>
<td>$0.0001$</td>
</tr>
<tr>
<td>% cover of moss in the 1-m² plot</td>
<td>$-0.45$</td>
<td>$0.0001$</td>
</tr>
<tr>
<td>Association between soil water content on day 3 in non-crusted (bare) plots and % cover of microbiotic crust in the 1-m² plot</td>
<td>$0.32$</td>
<td>$0.03$</td>
</tr>
<tr>
<td>% cover of moss in the 1-m² plot</td>
<td>$0.5$</td>
<td>$0.0006$</td>
</tr>
<tr>
<td>Association between soil water content on day 3 and % cover of litter</td>
<td>$0.27$</td>
<td>$0.01$</td>
</tr>
<tr>
<td>% cover of bare ground</td>
<td>$-0.73$</td>
<td>$0.0001$</td>
</tr>
</tbody>
</table>
rainfall, one day after the August rain, non-crusted soils at KB contained almost twice the moisture of similar areas at WT (Fig. 1). The influence of surrounding plot characteristics likely contributed to this day 1 difference. KB contained 36% more plant litter, 82% less bare ground, and mosses that averaged twice the height of WT mosses; characteristics found to benefit soil water. It is likely the sparsely covered soils at WT dried rapidly, losing a large amount of the rain water before the day 1 collection.

**DISCUSSION**

Microbiotic crusts moderated soil moisture conditions in the antelope-brush shrub-steppe of the South Okanagan and the influence was higher in areas with extensive amounts of crust. However, the life-forms in the crust played different roles. Lichens were related to increased soil water absorption, while mosses were associated with prolonged soil moisture retention. In areas of sparse or thin crust, plant litter moderated moisture conditions, but the effect at conserving soil moisture was short lived. The cover of plant litter at WT averaged 57%, but over one-half of the moisture received during the August rainfall was lost before the day 1 collection. The extensive amount of bare ground on the site and the thin mosses could not retain the soil water.

The prolonged retention of soil moisture in semiarid environments is critical for seedling survival, plant growth, reproduction, and plant persistence (Dasberg 1971, MacMahon and Schimpt 1981, Lesica and Shelly 1992, Gutterman 1993). An extensive, diverse, and well-developed microbiotic crust would contribute to the colonization process of antelope-brush communities; however, crust development takes time. Restoration efforts that increase the recruitment of microbiotic crust species would accelerate development of both the nonvascular and vascular plant communities of the Red-listed, antelope-brush shrub-steppe.

**ACKNOWLEDGEMENTS**

We thank the landowners of the South Okanagan who allowed access to their land during this study and the Habitat Conservation Trust Fund, Endangered Species Recovery Fund, Environment Canada, and UBC Graduate Fellowship program for contributing to this project.

**REFERENCES**


