Steven O. Link, Washington State University at Tri-Cities, Richland, Washington 99352

Bruce D. Ryan, Arizona State University, Tempe, Arizona 85287

Janelle L. Downs, Larry L. Cadwell, Pacific Northwest National Laboratory, Richland, Washington 99352

Jonathan A. Soll, The Nature Conservancy of Washington, Yakima, Washington 98908

Mary Ann Hawke, University of Washington, Seattle, Washington 98195

and

Jeanne Ponzetti, Oregon State University, Corvallis, Oregon 97331

Lichens and Mosses on Shrub-steppe Soils in Southeastern Washington

Abstract

The purpose of this study was to identify the lichens and mosses found on soils of the shrub-steppe at the Hanford Site in southeastern Washington. Twelve sites between 133 and 447 m and one at 807 m elevation were intensively sampled. Twenty-nine lichens and six moss species were identified. Three lichens were considered undescribed species. Based on comparison with other studies and herbarium records, we conclude the soil lichen flora of the Hanford Site is substantially different than that of the Great Basin or of the shrub-steppe in Idaho.

Introduction

Throughout much of the Intermountain West, a cryptogamic or microbiotic crust covers some or all of the interspace between vascular plants (Nash, 1996a). The crust is composed of water-stable surface soil aggregates bound by algae, fungi, lichens, and moss (Johansen, 1993; St. Clair and Johansen, 1993).

Soil cryptogams play several roles important to the structure of ecosystems in semi-arid regions (Metting 1991, St. Clair and Johansen 1993). Soil cryptogams can stabilize the soil, reducing wind and water erosion (Metting 1991; Johansen 1993; Eldridge and Greene 1994). They contribute nitrogen (Harper and Pendleton 1993; Jeffries et al. 1992; Evans and Ehleringer 1993) and organic carbon (Johansen et al. 1993) to the soil. Some researchers have found an increase in water infiltration into the soil with cryptogamic soil crusts (Brotherson and Rushforth, 1983). Intact cryptogamic crusts can also enhance seedling establishment in arid ecosystems (St. Clair et al. 1984).

The identification of the taxa of soil lichens and mosses of a particular location is an important first step in understanding their role in structuring ecosystems of the area. In the Columbia Basin, very little work has been done to relate lichen species to their environment, primarily because there has been very little collecting in the area (Ryan 1994). An early effort by Daubenmire (1970) lists 13 lichen species and seven moss species likely to be found in the *Artemisia tridentata-Agropyron* association in Washington. Some of the reported identifications were noted as questionable by Daubenmire (1970), with many of the lichens only known to the genus level. An exhaustive review (Ryan 1994) of work done on the lichens of the Columbia Basin of Washington found that collections have only been made in far eastern counties by Cooke (1955) and in Yakima and Grant counties. About 32 soil lichen species are recognized in the Columbia Basin (Ryan 1994). Recently, McCune and Rosentreter (1995) provided a field key to soil lichens of central and eastern Oregon; they recognize 74 species from alpine to lower elevation shrub-steppe ecosystems including acidic to basic soils. McCune and Rosentreter (1995) indicate that their key will also include most soil lichens in steppe communities in eastern Washington. No reports exist on the soil cryptogam floristics in the *Artemisia tridentata-Stipa comata* association (Daubenmire 1970) nor on the Hanford Site.

The objective of this study was to document the species that constitute the lichens and mosses of the lower elevation soils on the Hanford Site.

We compare our results on species number and composition with those of previous workers in semi-arid and arid regions of the Great Basin and in the semi-arid shrub-steppe. We discuss range extensions, the percent of species that fix nitrogen, and the effect of soil pH on species composition.

Methods

The Hanford Site (Figure 1) in southeastern Washington has cool wet winters and hot dry summers. Precipitation is greatest in the fall and winter with an annual average of 160 mm at lower elevations (Thorp and Hinds 1977). Soils range from silts to sands (Table 1). Surface soil pH ranges from as high as 8.9 under the canopy of *Sarcobatus vermiculatus* to between 6.4 and 6.9 at higher elevations (Rickard and Vaughan 1988, Bolton et al. 1990, Bolton et al. 1993). Vegetation ranges from undisturbed shrub-steppe dominated by *Artemisia tridentata, Purshia tridentata, Grayia spinosa,* and common bunchgrasses such as *Pseudoroegneria spicata, Poa sandbergii,* and *Stipa comata* to disturbed sites dominated by *Bromus tectorum* (Table 1). Vascular plant

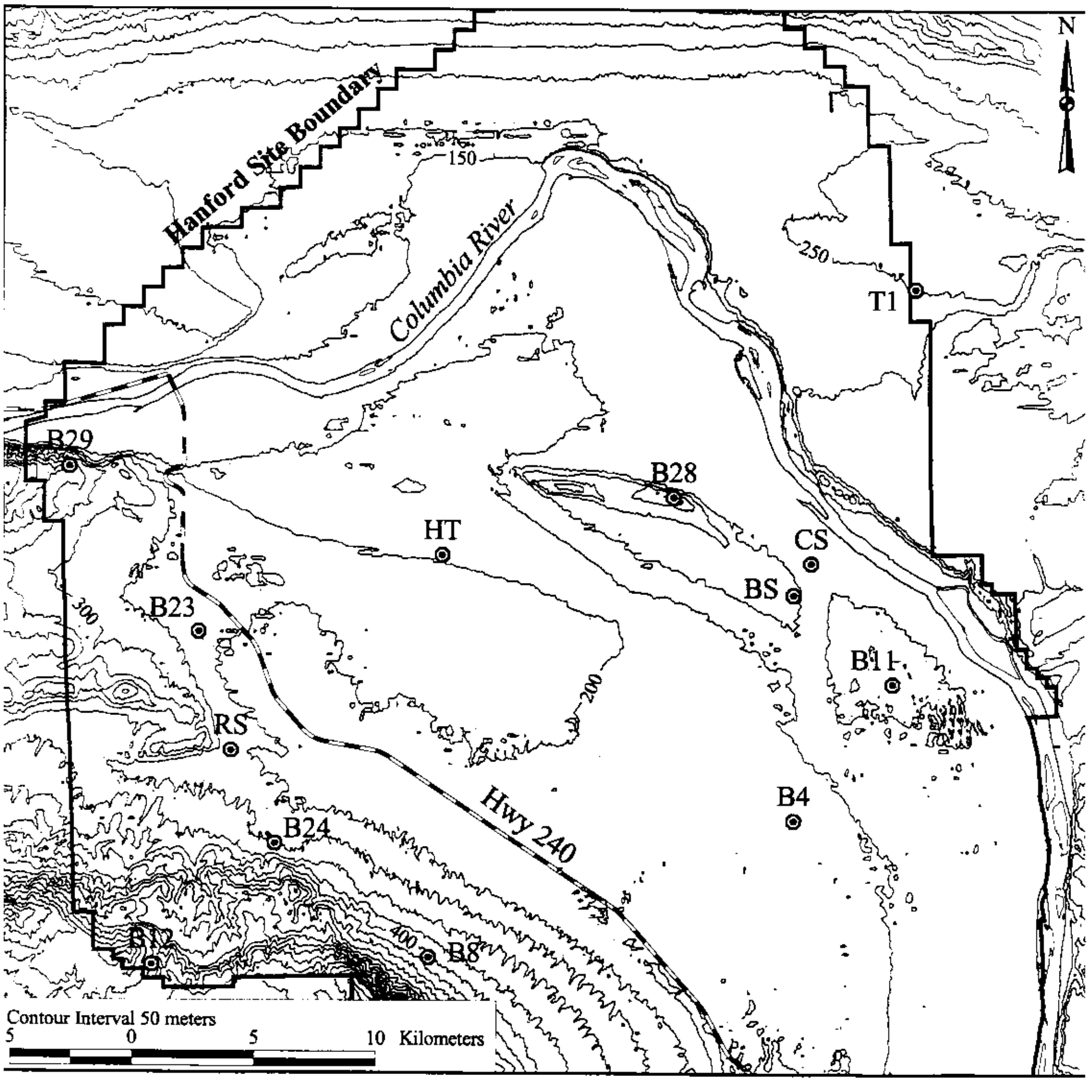

Figure 1. Map of the study sites on the Hanford Site in southeastern Washington. Study site information is presented in Table 1.

TABLE 1. Sample location information on the Hanford Site in Benton and Franklin counties, WA, USA.

Site	Elev. (m)	Soils	Dominant Vegetation
B11	160	Rupert sand	*Purshia tridentata*/Bunchgrass
B12	807	silty loam, loam, sand	*Artemisia tripartita*/Bunchgrass
B23	210	Warden silt loam	*A. tridentata/Grayia spinosa* Bunchgrass/*Bromus tectorum*
B24	261	Warden silt loam	*A. tridentata*/Bunchgrass/*B. tectorum*
B28	318	Kiona silt loam	*A. tridentata*/Bunchgrass/*B. tectorum*
B29	447	silty loam, loam, sand	*A. tridentata/G. spinosa* Bunchgrass/*B. tectorum*
B4	167	Ephrata sandy loam	*B. tectorum/Poa sandbergii*
B8	413	Ritzville silt loam	Bunchgrass
BS	159	Burbank loamy sand	*B. tectorum/Poa sandbergii*
CS	186	Burbank loamy sand	*A. tridentata/G. spinosa* Bunchgrass/*B. tectorum*
HT	133	Burbank loamy sand	*B. tectorum*
RS	209	Hezel sand	*Sarcobatus vermiculatus/P. sandbergii*
T1	268	silt, sand	*P. tridentata/A. tridentata/Stipa comata B. tectorum*

nomenclature primarily follows Hitchcock and Cronquist (1973).

Thirteen sites representative of a range of undisturbed to disturbed plant communities of the lower elevations (133 to 807 m above sea level) at Hanford were sampled (Table 1). Each site was examined by two to six people along a 100 meter transect and collectors were convinced they acquired the entire range of species in a site. Care was taken to prevent the samples from disintegrating because many of the samples were from sandy soils that were not stable.

In the laboratory, specimens were soaked in white glue and water for stabilization, then glued onto 3 x 5 inch cards. They were then cataloged, identified, and placed in lichen/bryophyte packets. Voucher specimens are retained in the herbaria of Arizona State University (lichens) and Washington State University at Tri-Cities (lichens and mosses).

Results

Twenty-nine soil lichens in 19 genera and six moss species in four genera have been identified (Table 2). Twelve (41%) lichen species are of the crustose growth form, eight (28%) are squamulose, seven (24%) are foliose, and two (7%) are fruticose (Table 2).

Three lichen species were previously undescribed. The undescribed *Arthonia* has black apothecia. The undescribed *Trapeliopsis sp.* #1 has a small thallus composed of gray white areoles with black apothecia and the undescribed *Trapeliopsis sp.* #2 has large thalli composed of gray white areoles with orbicular soralia. Two lichen species were identified only to genus level because they were sterile (Table 2). Five (17%) of the lichen species fix nitrogen (Table 2). Two of the six moss species were identified without the aid of fruiting structures and thus are only tentatively named.

Discussion

Our investigation of the floristics of soil cryptogams found on the Hanford Site is the most intensive survey to date in the shrub-steppe of Washington. We compare our results on species number and composition with those of previous workers

TABLE 2. Lichens and mosses occurring on soils of the Hanford Site and in common with other studies. Growth form (c = crustose, s = squamulose, fo = foliose, fr = fruticose), ability to fix nitrogen, and occurrence in other studies [1 - St. Clair et al. (1993), Great Basin (GB), Intermountain shrub-steppe (ISS); 2 - Pearson and Rope (1987); 3 - Rosentreter (1986); 4 - Kaltenecker (1997); 5 - McCune and Rosentreter (1995); 6 - Daubenmire (1970); 7 - Ryan (1994)] are indicated.

	Growth Form	Nitrogen Fixer	1 GB	1 ISS	2	3	4	5	6	7
Lichens										
Acarospora geogena H. Magn.	c									
Acarospora schleicheri (Ach.) A. Massal.	s				•	•	•	•		•
Amandinea punctata (Hoffm.) Coppins & Scheid.	c				•			•		•
Arthonia sp. (undescribed)	c									
Arthonia glebosa Tuck.	c					•		•		•
Aspicilia sp. (*A. calcarea* group) sterile	c			•						
Aspicilia reptans (Looman) Wetmore	s			•			•	•		•
Caloplaca jungermanniae (Vahl) Th. Fr.	c							•		•
Caloplaca tominii Savicz	c		•			•	•	•		•
Candelariella terrigena Rasanen	c					•	•	•		•
Cladonia fimbriata (L.) Fr.	fr							•		•
Cladonia pyxidata (L.) Hoffm.	fr					•				•
Collema cf. *tenax* (Sw.) Ach.	fo	•	•	•	•	•	•	•	•	•
Diploschistes muscorum (Scop.) R.Sant	c						•	•		•
Endocarpon pusillum Hedw.	s		•				•	•		
Lecanora hagenii (Ach.) Ach.	c				•					
Lecanora muralis (Schreb.) Rabenh.	c				•	•	•	•		•
Leptochidium albociliatum (Desm.) M. Choisy	fo	•				•	•	•		•
Leptogium lichenoides (L.) Zahlbr.	fo	•					•	•		•
Massalongia carnosa (Dickson) Korber	fo	•				•	•	•		•
Peltigera rufescens (Weis) Humb.	fo	•				•		•		•
Physconia enteroxantha (Nyl.) Poelt	fo									•
Physconia isidiigera (Zahlbr.) Essl.	fo									
Placynthiella sp. (sterile)	c									•
Psora globifera (Ach.) Mass.	s		•		•		•	•	•	•
Psora luridella (Tuck.) Fink	s		•		•	•			•	•
Psora montana Timdal	s							•		•
Trapeliopsis sp. 1 (undescribed)	s									
Trapeliopsis sp. 2 (undescribed; aff. *wallrothii*)	s									
Mosses	NA	NA	NA	NA	NA			NA		NA
Bryum argenteum Hedw.						•	•		•	
Bryum cf *caespiticium* Hedw. (sterile)									•	
Ceratodon purpureus (Hedw.) Brid.						•	•		•	
Grimmia cf *montana* Bruch. (sterile)										
Tortula papillosissima (Coppey) Brotherus										
Tortula ruralis (Hedw.) Gaertn						•	•		•	

in semi-arid and arid regions of the Great Basin and in the semi-arid shrub-steppe. We discuss range extensions and the percent of species that fix nitrogen. Finally, we discuss the effect of soil pH on species composition.

Species Number and Composition

The recent review of terricolous lichens of the Intermountain Area by St. Clair et al. (1993) describes only 12 species in steppe habitats. Only three species, *Aspicilia reptans, Aspicilia* sp., and *Collema tenax*, occur in both the steppe described in St. Clair et al. (1993) and Hanford (Table 2). In addition, of the 12 species in steppe habitats described in St. Clair et al. (1993), 75% are squamulose or foliose and 25% are fruticose, while in the shrub-steppe at Hanford, 54 % are squamulose or foliose, 7% are fruticose, and 41% are crustose. The soil lichen flora of Hanford is more heavily weighted to the low-stature, crustose, growth form than the soil lichen flora of the steppe described in St. Clair et al. (1993). Only five species were common (Table 2) between our study and the list of 13 for the Great Basin in St. Clair et al. (1993). The 29 species observed in our study suggests that the shrub-steppe at Hanford is very rich in soil lichens compared with other areas of the Intermountain Area. In addition, because so few species are common between Hanford and those also listed in St. Clair et al. (1993) and the difference in growth form distribution, we conclude that the soil lichen flora of the lower Columbia Basin at Hanford is unlike that of the Intermountain Area described in St. Clair et al. (1993).

A survey of lichens at the Idaho National Engineering Laboratory in the shrub-steppe of southeastern Idaho (Pearson and Rope 1987) describes only 7 soil lichen taxa that are in common with those of Hanford (Table 2).

In a study of soil mosses and lichens in the shrub-steppe near Boise, Idaho, Rosentreter (1986) recognized 30 different lichen species. Of these, only 11 were also found at Hanford (Table 2). Rosentreter (1986) also identified six moss species, of which three are in common with those of Hanford (Table 2). In another study of soil mosses and lichens near Boise, Idaho, Kaltenecker (1997) recognized 36 different lichen species. Of these only 14 were also found at Hanford (Table 2). Kaltenecker (1997) recognized nine moss species, of which only three are in common with those of Hanford (Table 2).

On the basis of studies done by St. Clair et al. (1993), Pearson and Rope (1987), Rosentreter (1986), and Kaltenecker (1997) we conclude there is little similarity between the soil lichen and moss flora of Hanford and the soil lichen and moss floras of the Great Basin or of the Idaho shrub-steppe.

Our lichen species list has more in common with the 74 species occurring on soils in central and eastern Oregon (McCune and Rosentreter 1995) than with lichen floras of the Great Basin (St. Clair et al. 1993). Of the lichens identified to species at Hanford, six (Table 2) are not found in McCune and Rosentreter (1995). The large number of species recognized by McCune and Rosentreter (1995) is a result of inclusion of habitats at high to low elevation and of basic to acidic soils. In contrast, the 29 species in our study were found only at low elevations (133 m to 807 m).

In Washington, in areas generally comparable to the Hanford Site, Daubenmire (1970) recognized 13 representative species and genera of soil lichens and mosses, of which only seven species were found in our study (Table 2). A possible reason for this difference is soil substrate. The soils examined in our study ranged from, primarily sands to silts (Table 1) while Daubenmire (1970) describes lichens and mosses found mostly on loamy or stony loam soils.

Range Extensions and the Percent of Species that Fix Nitrogen

An exhaustive survey of herbaria for lichens of Washington revealed all, but five species (Table 2) found in our study (Ryan 1994). We report *Acarospora geogena* and *Endocarpon pusillum* as new records for Washington. The three undescribed species (Table 2) in our report were not reported in Ryan (1994). Some of the undescribed lichen species found at Hanford potentially have been recognized by others (McCune and Rosentreter 1995, Kaltenecker 1997). Giving specific epithets to them will require further analysis by soil lichen taxonomists.

Our findings have extended the known range of the *Cladonia* species to Benton and Franklin counties. *Cladonia fimbriata* has been collected throughout the Pacific Northwest, although less commonly in semi-arid interior regions (Hammer 1995). *Cladonia pyxidata* has not been reported in the semi-arid interior regions of the Pacific Northwest (Hammer 1995). Our findings are in contrast to the report that *Cladonia* is not represented by a single species in the soil crust communities of the Great Basin or Colorado Plateau (St. Clair et al. 1993).

We found five species (17% of the soil lichen flora) capable of fixing nitrogen at Hanford (Table 2). St. Clair et al. (1993) report only one nitrogen-fixing soil lichen (Table 2) out of 34 species (3%) found in the Intermountain Area. Approximately ten percent of lichens fix atmospheric nitrogen (Nash 1996b). With 17% of soil lichens capable of fixing nitrogen, the soil lichen flora of Hanford appears relatively rich in nitrogen fixing species.

Soil pH

Lichen species composition is influenced by soil pH (Hale 1974, Nash 1996a). Lichens can be used to compute a soil pH index because many species favor acidic soils, while other species favor basic soils (McCune and Rosentreter 1995). McCune and Rosentreter (1995) list ten common species of acidic soils and ten of basic soils. Six of our species (*Acarospora schleicheri*, *Arthonia glebosa*, *Aspicilia reptans*, *Diploschistes muscorum*, *Leptochidium albociliatum*, *Placynthiella* sp.) fall into the acidic soil grouping while only two (*Caloplaca tominii*, *Collema* cf. *tenax*) are in common with the ten listed for basic soils. This confirms observations that the surface soils of the Fitzner-Eberhardt Arid Lands Ecology Reserve on the Hanford Site are slightly acidic with pH values as low as 6.5 (Rickard and Vaughan 1988; Bolton et al. 1990; Bolton et al. 1993; Johansen et al. 1993). Because six out of eight common species at Hanford fall into the acidic soil grouping of McCune and Rosentreter (1995) we suggest that most of the surface soils sampled in our study are slightly acidic. The suggested acidic nature of the surface soils at the Hanford Site is a potential cause for the large differences between species composition of the Hanford Site and the species composition of the Great Basin (St. Clair et al. 1993) that is dominated by basic soils. The differences may be attributed to the sensitivity of species to Al^{3+} (Kershaw 1985) and nutrient levels that are affected by pH (Nash 1996a) such as phosphorus (Bidwell, 1974).

Conclusion

Based on the large differences between our results and those of previous workers we have described a rather unique soil lichen flora for the Hanford Site. Given the limited number of sites and habitats sampled in our study we expect that more species will be recognized with expanded sampling. The soil cryptogam identifications for the Hanford Site in this study have added significantly to our biodiversity knowledge base.

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