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RELATING SOIL CHEMISTRY AND PLANT RELATIONSHIPS IN WOODED DRAWS OF THE NORTHERN GREAT PLAINS

Marguerite E. Voorhees¹ and Daniel W. Uresk¹, ²

ABSTRACT—Soils of the green ash/chokecherry habitat type in northwestern South Dakota were evaluated for 22 properties to determine whether any could be correlated with density of chokecherry (Prunus virginiana) and snowberry (Symphoricarpos occidentalis). Surface soils were moderately fertile, with high levels of all elements except phosphorus and nitrogen. Soils were fine textured, with moderately high cation exchange capacity and saturation percentages. However, soils were nonsaline-nonalkaline with low amounts of exchangeable sodium. None of the soil properties showed good correlation with chokecherry and snowberry densities. Greatest correlations were found between each of the shrub species and grass.

Key words: wooded draws, green ash, shrubs, Prunus virginiana, Symphoricarpos occidentalis, grazing.

Wooded draws constitute a valuable habitat type in the northern Great Plains. They provide shelter from wind and weather and contain greater moisture than surrounding areas, resulting in an abundance of plant life and forage. An understanding of soil-plant relationships of these wooded draws has become more critical since these areas have been observed to be in decline (Boldt et al. 1978) for a variety of reasons (Girard et al. 1987).

Studies that correlate habitat type with soil properties are particularly useful in efforts to manage these systems. Knowledge gained from such studies might help managers determine the potential habitat type of a site after vegetation decimation. Efforts and limited resources could then be concentrated on sites with the greatest potential for rehabilitation.

This study was conducted to characterize the surface soil chemistry of the green ash/chokecherry (Fraxinus pennsylvanica/prunus virginiana) habitat type in northwestern South Dakota and to relate these soil properties as well as grass cover to density of chokecherry and snowberry (Symphoricarpos occidentalis). This habitat type is considered a topographic climax (Hansen, Hoffman, and Steinauer 1984, Hansen and Hoffman 1988) and is one of the most important in the northern Great Plains.

STUDY AREA

The study area is approximately 5 miles northwest of Bison, South Dakota, in Perkins County on lands administered by the USDA Forest Service, Custer National Forest. Geology of the area has been described by Hansen (1985). The topography is rolling to steep plains dissected by streams and drainageways. The climate of the area is characterized by warm summers and very cold winters. Annual precipitation averages 36 cm, with most received in the spring and summer.

The habitat types of the area have been described by Peterson (1987). The green ash/chokecherry habitat type was found on shallow to moderately deep, well-drained, Caballantry loam soils of upland ridges and the sides of steep drainageways with slopes of 15% to 40%.

METHODS

Collection of Samples

Soil samples were collected during the summer of 1986 from 24 green ash/chokecherry draws spaced over a 2769-ha pasture. The vegetation of the 24 wooded draws ranged from few trees and shrubs to a dense overstory and understory of trees and shrubs. Sampling was conducted

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at three locations in each draw. At each location (approximately 250 m² in area), three frames (20 x 50 cm) were randomly located. Stem densities of chokecherry at these locations ranged from low (0-2 stems/frame), to medium (3-6 stems/frame), and high (greater than 8 stems/frame). All stems were counted within a frame and the three values averaged for each location. Canopy cover of grass was estimated in each frame (Daubenmire 1959). One soil sample was collected within each frame to a depth of 10 cm. The three soil samples from each location were combined for chemical analysis, yielding a total of 72 samples.

Soil Analyses

Amounts of soil elements (P, K, Zn, Fe, Mn, Cu) were determined by using the ammonium bicarbonate-diethylenetriamine pentaacetic acid (AB-DTPA) extract (Soltanpour and Schwab 1977) and inductively coupled plasma atomic emission spectrometry (ICP-AES) (Jones 1977). The AB-DTPA procedure was developed and is used by the Colorado State University Soil Testing Laboratory. An equal amount of potassium is extracted as with the ammonium acetate test (Knudsen et al. 1982), and the same amount of iron is extracted as with the standard DTPA test (Havlín and Soltanpour 1981). Half as much phosphorus is extracted using AB-DTPA as in the sodium bicarbonate extract (Olsen et al. 1954), and slightly less zinc is extracted than in the standard DTPA test (Havlín and Soltanpour 1981). AB-DTPA extractable copper and manganese are highly correlated with DTPA-extractable levels of these elements ($r^2 = .75$ and .86, respectively) (Soltanpour and Schwab 1977).

The pH was measured with a pH meter that used a combination electrode on a saturated paste. Sodium adsorption ratio (SAR) was estimated from levels of soluble calcium, magnesium, and sodium measured in a saturation extract by means of ICP-AES. Total soluble salts were measured on the filtered extract with a solubridge.

Organic matter was determined by wet oxidation with spontaneous heat of reaction. Potassium dichromate and concentrated sulfuric acid were used for organic matter, and results were determined calorimetrically. Nitrate nitrogen was determined by the chromototropic acid method. Levels of extractable Ca, Mg, and Na were measured by using ICP-AES on an ammonium acetate extract. Cation exchange capacity was determined by the sodium saturation method (Page 1982).
Statistical Analyses

Simple linear regression was used to relate soil chemistry variables to chokecherry and snowberry densities; the points were plotted to check for nonlinear relationships. Stepwise regression was used to test relationships between soil chemistry, canopy cover of grass, and density of each shrub. The regression model $Y = a + bx$ provided the best fit in relating chokecherry and snowberry densities with canopy cover of grass. Soil variables and densities of both shrubs were subjected to a nonhierarchical cluster analysis (ISODATA) to group the sites (Ball and Hall 1967). Stepwise discriminant analyses were used to estimate compactness of clusters and identify the key variables that accounted for their differences. However, cluster analyses and discriminant analyses and simple correlation plots did not provide any meaningful results.

RESULTS AND DISCUSSION

Nitrate nitrogen levels averaged 3.0 µg/g and ranged from 1.0 to 17.0 µg/g (Table 1). Soil organic matter ranged from about 4% to nearly 20%. These values compare well with values from surface soil samples from hardwood forest on fine-textured soils (Charley 1977). Organic matter levels ranged substantially higher than those from soils from similar sites in North Dakota (Hansen, Hoffman, and Bjugstad 1984), Montana, and South Dakota (Hansen and Hoffman 1988). Nitrate levels appeared adequate for growth of rangeland plants (Soltanpour et al. 1979).

Soils were near neutral in pH (Table 1) and similar to other sites in Montana, North Dakota, and South Dakota (Hansen, Hoffman, and Bjugstad 1984, Hansen and Hoffman 1988). Availability of nutrients at this pH is near maximum except for Fe, Mn, Zn, and Cu, which become less available above pH 7.0 (Brady 1974). Plants usually grow well between pH 5 and 8.5 (Donahue et al. 1977) if no other growth factor is limiting. Phosphorus and potassium content averaged 2.5 mg/kg and 321 mg/kg, respectively. Thus, phosphorus levels were low, whereas potassium, zinc, copper, and manganese levels were high (both generally and relative to similar sites in the northern High Plains [Hansen, Hoffman, and Bjugstad 1984, Hansen and Hoffman 1988]). Iron levels averaged 21.2 mg/kg and were fairly high.

The cation exchange capacity (CEC) was rather high at 45.2 meq/100 kg (Table 1). Clays in these soils are likely to have high adsorptive capacities since organic matter content and clay content did not fully account for the high CEC (Brady 1974). The sodium adsorption ratio (SAR) indicated minimal saturation of the exchange complex by sodium. Electrical conductivity was low at 0.6 mmhos/cm. These soils would be classed as nonsaline-nonalkaline with low electrical conductivity and exchangeable sodium percentage. The saturation percentage at 72.9 was somewhat higher than other nonsaline-nonalkaline soils in this classification (Richards 1954). The soil moisture percentage at 15 MPa, which is approximately equivalent to the wilting percentage, was 18%. These soils are thus relatively fine textured on average. Sand, silt, and clay averaged 33%, 41%, and 26%, respectively.

Soluble Ca, Mg, and Na were 4.5, 2.1, and 0.2 meq/l, respectively (Table 1). Extractable Ca, Mg, and Na averaged about 4311, 684, and 15 mg/kg, respectively. These corresponded to 10.8, 5.7, and 0.065 meq/100 g soil and exchangeable percentages of 23.8, 12.6, and 0.1, respectively. Thus, of these elements, Ca was predominant on the exchange complex, and exchangeable Na was very low. However, calcium was low relative to comparable sites of vegetation and landscapes (Hansen, Hoffman, and Bjugstad 1984, Hansen and Hoffman 1988).

Simple correlation coefficients for density of either chokecherry ($r = .26$ to $-.18$) or snowberry ($r = .36$ to $-.20$) with various soil properties were low (Table 2). Twelve soil properties were negatively associated with chokecherry density. Phosphorus showed the greatest positive relationship with chokecherry density ($r = .26$). Only four soil variables (pH, P, extractable Ca, and CEC) were negatively correlated with snowberry density. Magnesium showed the highest correlation with snowberry density ($r = .36$). Soil properties varied some for both species at the microsite level but were not statistically different ($p < .10$). For example, when density of chokecherry was high (no snowberry), phosphorus was somewhat greater than phosphorus on sites with high snowberry densities (no chokecherry), and thus, a positive correlation.

Stepwise multiple regression using all soil properties with either chokecherry or snowberry stem density did not provide meaningful results. However, a good relationship was found
for predicting chokecherry density using snowberry density and canopy cover of grass (Table 3). Predicting snowberry stem density using chokecherry density and grass cover similarly showed a good relationship \((r^2 = .50)\). When snowberry stem density was high, chokecherry stem density was low and vice versa (Fig. 1). Chokecherry density showed a good relationship \((r^2 = .48)\) with canopy cover of grass (Fig. 1). Stem densities of chokecherry were greatest when canopy cover of grass was low.

Overall, soil properties were not highly correlated with either chokecherry or snowberry stem density. Each shrub was more influenced by the density of the other or the amount of grass cover. Factors such as other shrubs, trees, disease, fire, soil compaction, and grazing may also influence stem density of both chokecherry and snowberry (Boldt et al. 1978, Severson and Boldt 1978, Uresk and Painter 1985, Uresk and Boldt 1986, Uresk 1987), but these factors were not considered in the present study.

**SUMMARY**

Surface soils of the green ash/chokecherry woodland in northwestern South Dakota near Bison were found to be moderately fertile with fairly high levels of nutrients except phosphorus, which was low, and nitrogen, which was moderately low. Organic matter ranged from about 4% to 20%. These soils were fine textured with moderately high cation exchange capacity and saturation percentages. They were classed as nonsaline-nonalkaline with low amounts of exchangeable sodium.

Soil properties showed low correlation relationships with chokecherry or snowberry stem density. A good relationship was found between the two species of shrubs and grass. Additional factors such as density of other shrubs or trees, disease, fire, soil compaction, and grazing may also influence densities of chokecherry or snowberry and interact with soil surface properties.

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**Table 2. Simple correlation coefficients for densities of chokecherry and snowberry with chemical properties of soil of green ash/chokecherry habitat type near Bison, South Dakota \(n = 72\).**

<table>
<thead>
<tr>
<th>Soil Property</th>
<th>Chokecherry</th>
<th>Snowberry</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>0.19*</td>
<td>-0.20*</td>
</tr>
<tr>
<td>EC</td>
<td>-0.16</td>
<td>0.28**</td>
</tr>
<tr>
<td>Organic matter</td>
<td>-0.17</td>
<td>0.15</td>
</tr>
<tr>
<td>NO₃-N</td>
<td>-0.03*</td>
<td>0.10</td>
</tr>
<tr>
<td>P</td>
<td>0.28**</td>
<td>-0.06</td>
</tr>
<tr>
<td>K</td>
<td>0.14</td>
<td>0.18</td>
</tr>
<tr>
<td>Ca</td>
<td>-0.13</td>
<td>0.23**</td>
</tr>
<tr>
<td>Mg</td>
<td>0.17</td>
<td>0.36**</td>
</tr>
<tr>
<td>Na</td>
<td>0.09</td>
<td>0.30**</td>
</tr>
<tr>
<td>Ca</td>
<td>-0.18</td>
<td>0.25**</td>
</tr>
<tr>
<td>Zn</td>
<td>0.17</td>
<td>0.23**</td>
</tr>
<tr>
<td>Mn</td>
<td>0.03</td>
<td>0.23**</td>
</tr>
<tr>
<td>Cu</td>
<td>0.07</td>
<td>0.09</td>
</tr>
<tr>
<td>Fe</td>
<td>-0.11</td>
<td>0.03</td>
</tr>
<tr>
<td>SAR</td>
<td>-0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Saturation</td>
<td>-0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Ext. Ca</td>
<td>0.02</td>
<td>-0.16</td>
</tr>
<tr>
<td>Ext. Mg</td>
<td>0.01</td>
<td>0.23**</td>
</tr>
<tr>
<td>Ext. Na</td>
<td>-0.13</td>
<td>0.17</td>
</tr>
<tr>
<td>CEC (meq/100 kg)</td>
<td>0.04</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

* Significant at \(\alpha = .05\).
** Significant at \(\alpha = .01\).
* Extractable cations
Table 3. Coefficients (a, b, and c), standard error of the estimate (SE), and correlation (r²) describing relationships of chokecherry (C), snowberry (S), and grass (G) in green ash/chokecherry habitat type (n = 72).

<table>
<thead>
<tr>
<th>Density (Y)</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>SE</th>
<th>r²</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chokecherry</td>
<td>9.651</td>
<td>-0.4885</td>
<td>-0.082C</td>
<td>1.54</td>
<td>0.72</td>
<td>S</td>
</tr>
<tr>
<td>Snowberry</td>
<td>11.694</td>
<td>-1.076C</td>
<td>-0.076C</td>
<td>2.66</td>
<td>0.50</td>
<td>S</td>
</tr>
<tr>
<td>Snowberry</td>
<td>11.755</td>
<td>-6.266C</td>
<td>0.197</td>
<td>2.51</td>
<td>0.55</td>
<td>E</td>
</tr>
<tr>
<td>Chokecherry</td>
<td>9.323</td>
<td>-0.555G</td>
<td>0.620</td>
<td>2.53</td>
<td>0.48</td>
<td>E</td>
</tr>
</tbody>
</table>

1S = stepwise regression (Y = \( a + bx + cx \)); E = exponential regression (Y = \( a + bx \)).

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LITERATURE CITED


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