Soil Acidity and Hemlock Reproduction In Relic Colonies In Indiana

J. E. Potzger and R. C. Friesner, Butler University

A voluminous literature on pH of soil and its relation to seedling growth and establishment is evidence of the importance ascribed to this factor by ecologists and foresters. It is also well known that cryptogams (2) and many herbaceous phanerogams (11) are limited to a definite optimum range of acidity. While trees as a whole may probably be less sensitive to an optimum range than herbs, they too, especially in the seedling stage, frequently show a marked preference for certain ranges in pH, showing less sensitiveness to deviation from the optimum towards greater acidity than towards alkalinity (8).

The present paper was not prompted by any immediate practical importance which its results might have, but is a phase of the extensive investigations the authors carried on in relic colonies of hemlock *(Tsuga canadensis)* at Trevlac, Brown County, and Pine Hills, Montgomery County, Indiana.

In Indiana, hemlock occupies a unique isolated position (3), usually along rims of rocky cliffs (Fig. 1). These cliffs form a line diagonally across the state from Jefferson, Clark, Floyd, and Crawford Counties on the southeast to Parke and Montgomery Counties on the northwest. These small isolated colonies of hemlock seem to hold their own near the broad-leaved competitors but are not able to expand into broad-leaved territory. In this respect, then, hemlocks in Indiana offer many interesting problems for the ecologist. Soil moisture and evaporation studies have been carried on at both of the above stations (3, 4, 5), and it was found that hemlocks occupy habitats with less soil moisture and are subject to greater water loss by transpiration than broad-leaved forests nearby.

Seedlings are abundant at both places, but young trees are limited in number, and, as previously stated, the forest does not extend its boundary. Seedlings are usually most abundant in beds of mosses and are totally absent among the broad-leaved trees on the plateau but a short distance from the cliff. This prompted the present investigation, to see if by transects of soil samples it could be discovered whether or not there existed an important relationship between pH of soil and abundance of seedlings.

Procedure

Soil samples were taken at the surface and at six-inch and twelve-inch depths. Transect lines were run from and to areas of abundant hemlock reproduction and mature stands, intermittently through areas where seedlings were wanting, and also from hemlock groves to broad-leaved forest.

A hole over a foot in depth was dug with a trenching spade, and samples of soil were taken from the side of the hole. Samples were taken at ten to twenty-five foot intervals. The soil was collected in small paper sacks, and reading of pH was made on the Youdon hydrogen-ion apparatus within a few days after collection. Three readings were made of each soil sample, and these three readings were averaged for the transects shown in our curves (Figs. 3, 4).

Observations

Trevlac, Brown County.—The numerous graphs from both stations tell the same story, i.e., seedling abundance is linked to a definite optimum degree of acidity of soil. In nearly every instance where the transect was from deciduous forest through hemlock groves and areas where seedlings were abundant, there is a decided fluctuation in acidity of the soil, it being most acid where hemlocks were present. This is well illustrated by Transects 1, 2, 3 for surface soil (Fig. 3). As a rule, there is more fluctuation in acidity in the surface soil than in the six- and twelve-inch soil (Transects 1, 2, 3). Apparently hemlock prefers an acidity range between 4.5 and 5.5, with an optimum of about pH 5.

Pine Hills, Montgomery County.—This is another interesting area of relics; both *Tsuga canadensis* and *Pinus Strobus* are present. Topo-

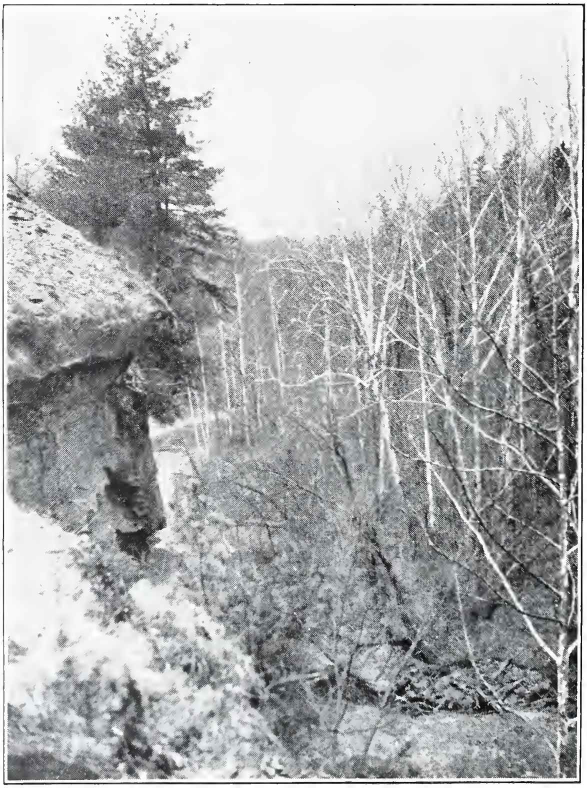

Fig. 1. White pine and hemlock along cliffs, Pine Hills, Montgomery County.

Fig. 2. Birdseye view of isolated colonies of hemlock and white pine along cliffs in Pine Hills, Montgomery County.

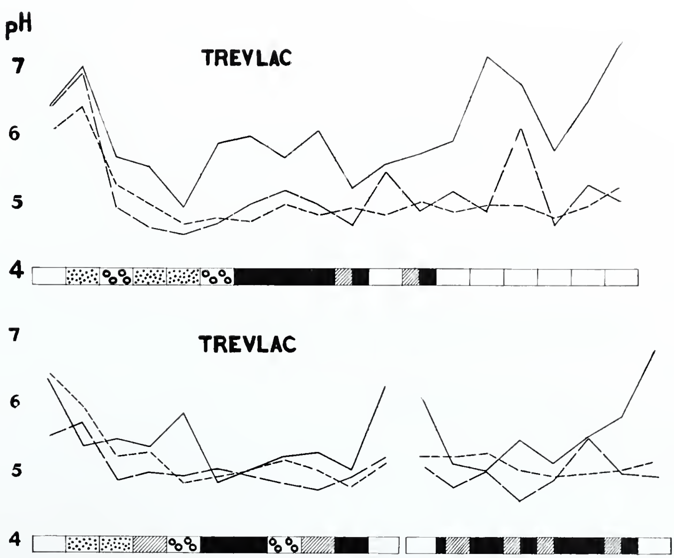

Fig. 3. Transects 1-3; soil samples from Trevlac, Brown County. Legend as in Fig. 4.

graphically the region is similar to Trevlac. It is a region of eccentric topographic features,—sudden and abrupt changes, grotesque rock formations, semi-xeric shallow soils, deeply alluviated narrow valleys, and flat narrow plateaus (9). Here, too, hemlock and pine cling closely to the edges of cliffs, at times making one wonder why their extent is so sharply delimited. Groves of evergreens seen in a panoramic view always indicate cliffs in the topography (Fig. 2).

The pH of the soil is similar to that at Trevlac (Transects 4-7, Fig. 4). Transect 7 was made on the cliffy wall known as Devil's Backbone. The open higher plateau was densely covered with *Danthonia spicata*, with no hemlock seedlings present and acidity less than in adjacent areas where seedlings were abundant or where moss covered the surface. The range of pH in this whole transect where seedlings of hemlock were present is remarkably uniform for all three depths of soil, i.e., close to 4.5. As soon as one reaches the floodplain deciduous forest where hemlock seedlings are absent, the pH rises in a sharp upward swing. Nowhere did we find hemlock or pine seedlings or young trees in the flood-

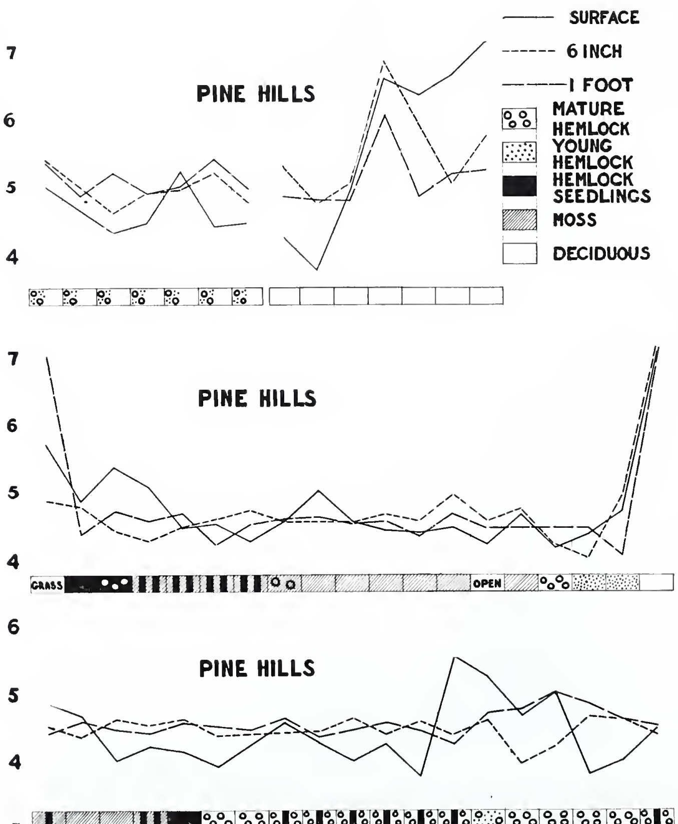

Fig. 4. Transects 4-7; soil samples from Pine Hills, Montgomery County.

plain, and seeds must fall in abundance into these areas from the steep cliffs above, where these trees overhang the cliffs (Fig. 1).

In Transect 4 we note the same tendency of range in pH, i.e., 4.5 to 5.5 where a transect passed through the densest hemlock and white pine groves on the slope and plateau north of Devil's Backbone. The six- and twelve-inch soils, are, again, marked by greater uniformity of acidity range than the surface soil.

Discussion

As one analyzes the hundreds of pH readings made on surface soil in the present study, he is impressed with the remarkable uniformity of acidity range where hemlock seedlings or mature trees are present. We realize that pH is but one of the factors exerting controlling influence, for we know from former investigations (3,5) that hemlock grow where evaporation is higher and soil moisture lower during the growing season than in adjacent areas of deciduous forest; we even suggested (3) that leaf litter may be an inhibiting factor because of its mechanical effect on seedlings, yet one cannot well ignore the prolific growth of seedlings in moss beds which are known for their acidifying influence on the soil. A glance at any of the transects where moss is indicated will show that the pH of the soil is strikingly of the same range as soil where seedlings were abundant.

Daubenmire (1), working in a similar relic colony at Turkey Run, Parke County, found conditions which parallel ours, viz., pH 4.5 to 5 where hemlock was abundant and 5.5 to 7 in deciduous forest. He also found a greater uniformity of lower acidity in the subsoil than in the surface soil. This one would expect, for surface soil is subject to greater diversity of influences which have a bearing on acidity, i.e., decomposition of leaf litter, leaching, etc. It is, however, the surface soil especially which is concerned in seed germination and seedling establishment.

Two features are obvious in the seven transects before us: first, the uniformity in pH range 4.5 to 5.5 where a transect passes through hemlock and moss-covered areas (Transects 2, 4, 5); and, secondly, the fluctuation between greater acidity in hemlock-controlled areas and less acidity in deciduous forest (Transects 2, 3, 6, 7), and this is much more significant if we consider that the two stations are separated by long distances and correlate in the same features with results from another area worked by Daubenmire (1).

The most outstanding example of fluctuation at Trevlac is the long transect shown in Transect 1. The line began in a deciduous forest halfway up a cliff and ended well up on the plateau in a sassafras-oak forest after having passed through a hemlock forest along the rim of the cliff. The reduced acidity in the six- and twelve-inch soils of the lower slopes is, no doubt, due to seepage from the cliffs which are partly of limestone makeup, while the subsoil on the plateau is probably more uniformly acid because of leaching. A tabulation of samples taken in deciduous forest, hemlock stands, and seedling beds tells the same story as the individual transects. Twenty-six samples in deciduous forest showed a range of pH 4.26 to 7.03 with a median range of 6.5;

twenty-eight samples from seedling beds showed a range of pH 3.96 to 6.14 with a median range of 5.08; twenty-six samples from mature stands of hemlock showed a range of pH 3.77 to 6.28 with a median range of 4.49.

In the Pine Hills area, Transects 5 and 6 are of considerable interest. The transect begins in the transition zone where pine, hemlock, and deciduous trees intermingle close to the canyon rim and continues well into the deciduous forest on the plateau beyond. As Transect 6 shows, there is a sudden decrease in acidity as the line crosses into the deciduous forest.

Now what does experimental evidence under controlled conditions show on the relationship between pH and seedlings of conifers?

Sundling, McIntyre, and Patrick (10) found that seedlings of conifers grew poorly in seedbed soil with a pH of 6.2 to 6.8. "In all cases the best seedlings were found in areas where the soil was most acid." Jack pine, white pine, red pine, and Norway spruce seedlings developed best in soil whose pH range was between 4 and 6. According to their Table 4, the following pH made for best general development and increase in weight: *Pinus Strobus*, 5.5; *P. resinosa*, 5.0; *Picea abies*, 4.6.

Wherry (12) found that of 23 eastern conifers more than half preferred acid soils. Kelly (6) reports that *Pinus rigida* in New Jersey is partial to soil ranging in acidity between 5.2 and 5.6, shunning more alkaline soils near the shore (his Table 2). Moore (8) working under experimental conditions found that seedlings of pitch, jack, and red pine had a decided acidity preference. We found at Pine Hills that white pine seedlings had an acidity preference similar to that of hemlock.

In which way does alkalinity influence the growth of seedlings? No doubt it has a bearing upon a number of factors dealing with normal functioning of the plant. Moore (8) found that when he added slaked lime to the soil, the roots of jack, pitch, and red pine became brown and shriveled. Sunding et al. (10) found in their series of decreasing acidity that lateral roots 0.5 to 5 cm. in length decreased in number in soil above 5.5 in *Pinus Strobus*, *P. resinosa*, *P. banksiana*, and *Picea abies*. In some cases the longer lateral roots were absent entirely. This must certainly influence absorption and reduce the extent of the root system.

Acidity also influences mycorrhiza on the roots, which in turn will affect absorption in the tree. According to Melin, quoted by Sunding et al. (10), optimum growth of mycorrhiza on pine and fir seedlings occurred at a pH 5 or a little lower. This will no doubt vary greatly, however, in different so-called ecological races of the same species, but it indicates that disturbances occur in absorption when seedlings of conifers must grow in soil lacking the optimum acidity.

For hemlock, our own field data thus reflect a similar definite optimum pH range for most efficient germination and seedling growth.

Summary

1. Comparative acidity studies were made in hemlock and deciduous forest.

2. Transect lines were run from hemlock to deciduous forest.

3. As a whole, soil where hemlock trees and seedlings grow is more acid than in deciduous forest.

4. The two stations studied yielded remarkably similar results.

5. Hemlock seedlings seem to prefer a pH 4.7 to 5.5.

6. Soil under beds of mosses has approximately the same range in pH as that where hemlock seedlings are abundant.

7. Acidity of soil is apparently one of the vital edaphic factors in hemlock reproduction in Indiana.

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