Butler University Botanical Studies

Volume 2 *Butler University Botanical Studies* Article 12

Studies in Forest Ecology

Ray C. Friesner
Butler University

John E. Potzger
Butler University

STUDIES IN FOREST ECOLOGY

I. Factors Concerned in Hemlock Reproduction in Indiana

By RAY C. FRIESNER AND J. E. POTZGER

INTRODUCTION

Casual observations made during botanical excursions to various parts of the state during the past twelve years have revealed a very scattered and unusual distribution in Indiana of the hemlock, *Tsuga canadensis*. As stated by Deam (4), this species is usually to be found in Indiana on north- or northwest-facing slopes. It is most commonly found on the steep slopes, canyon walls and rims of deep ravines, but may also be found in pure stands in some places such as at Turkey Run, in Parke county, where it is associated with beech and maple on plateau tops above canyon walls, and at Pine Hills, in Montgomery county, where it is associated with beech *(Fagus grandifolia)*, maple *(Acer saccharum* and *A. nigrum)* and white pine *(Pinus strobus)*. In the latter locality the hemlock is usually found on the steep slopes and canyon walls, but occurs in one second terrace groove with white pine, both species occurring with 100 per cent frequency in quadrat studies.

This disjunct distribution, together with the limitation of the hemlock in most of its stations to what appeared to be the most rigorous habitats, raised questions as to just what are the factors involved in hemlock reproduction in Indiana. The present paper is a record of the results of studies made during the year 1930 in an attempt to answer the question of reproductive factors. These studies include observations on seedling establishment as related to character of forest floor, soil moisture, evaporation, soil temperature and seedling mortality which were made at Trevlac, in Brown county, where there is a considerable number of hemlocks along the left (south) bank of Bean Blossom creek.

SEEDLING ESTABLISHMENT AND CHARACTER OF FOREST FLOOR

Thousands of seedlings, one, two and three years old, were to be found with ease. In almost every case seedlings were limited to the slopes or within a few feet back from the rims of the slopes. The most favorable germination places seemed to be beds of moss, but large numbers were found on free soil where the slope was not too steep to permit lodgment for the seeds, and on the flatter tops up to twenty-five or thirty feet back from the edge of the slope where there were either moss beds or small amounts of broken bits of forest litter. Seedlings were never found where the leaf litter attained any appreciable depth on the forest floor. Seed trees were sufficiently numerous that abundant seeds must have been blown to the plateau-like tops, but it seems from our observations that if the seeds found their way to the soil through the dense leaf litter and secured sufficient moisture, they were unable to lift their growing parts above the too-great depth of leaves and hence had to perish. One cannot escape the conviction as he observes the location of seedlings, that inability to penetrate the deep cover of leaf litter on the forest floor under the dense growth of beech, maple, oak *(Quercus alba, Q. rubra* and *Q. velutina)* and hickory *(Carya cordiformis* and *C. ovata)*, is of prime importance as a factor in hemlock reproduction on the more nearly level plateaus. Seedlings were always limited to those areas where the winds annually blow away the leaves and where there are sufficient mosses or broken forest debris in which the seeds may lodge until germination and establishment occur.

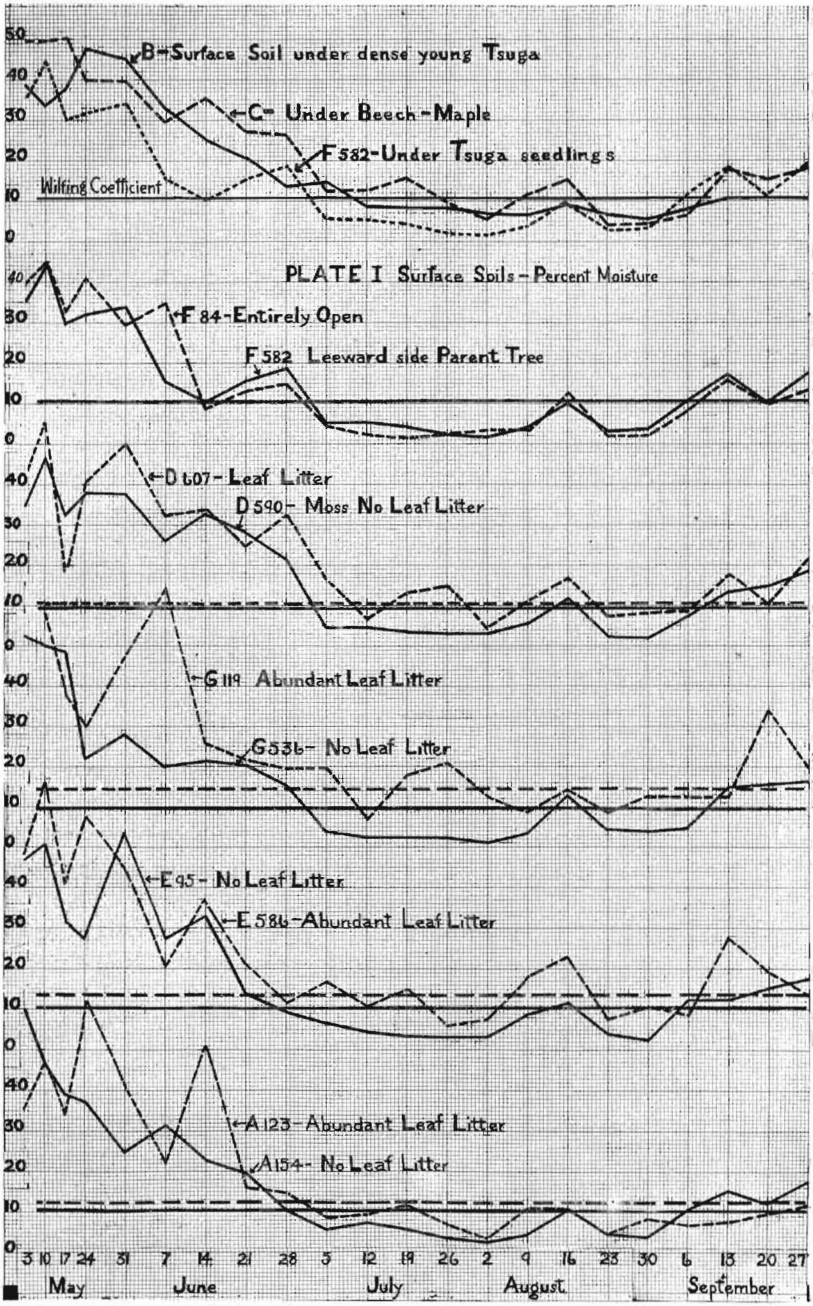
Lutz (6) has shown that in New England shade is a primary factor in establishment of hemlock seedlings. Seedlings came in only where there was shade during at least the hottest part of the day. Our stations were all shaded for at least a part of the day and the stations were so selected with respect to shade that it was eliminated as a factor from our studies. Our observations are in accord with those of Lutz regarding shade, but even when the shade factor is satisfactory we find that character of forest floor is the determining factor. As shown by Lutz (6), Marshall (7) and Frothingham (5), hemlock is able to withstand suppression by hardwoods for long periods of time, but our observations indicate that it does not compete in Indiana with the broad-leaved forest trees except on steep slopes and in occasional groves on plateau tops. Inability of seedling establishment on account of unsuitable forest floor plays a large part in determining this distribution.

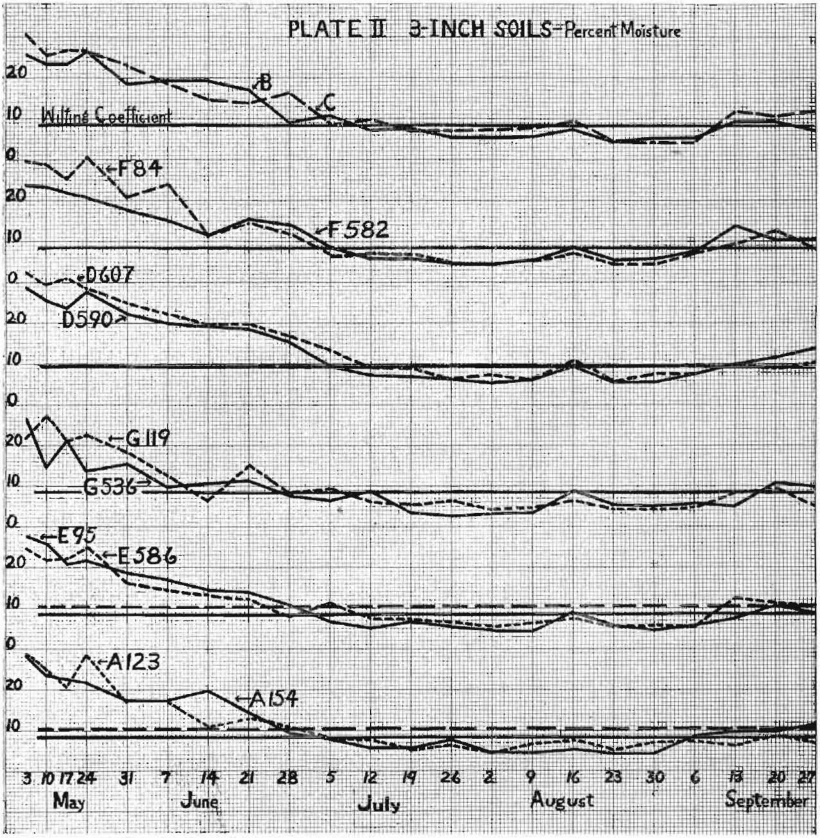
SOIL MOISTURE

It is a well-known fact that the root system of hemlock is very superficial, and from this one might conclude that available soil moisture should play a very important part in permitting or inhibiting seedling development. In order to determine whether soil moisture is a controlling factor in determining the particular type of distribution here exhibited, soil was taken weekly from May 3 to September 27, 1930, at twelve different stations, and its moisture content per unit of dry weight was determined. Eight of these stations were so situated that they were but a few feet on either side of the limits of seedling distribution. The seedling limits were very sharp and well marked and coincided in every case with the limits of abundant leaf litter on the forest floor. Seedlings were abundant wherever the wind had sufficient sweep to blow away the leaves. Such places were usually fairly well covered with a carpet of moss. Thus Stations A 154 and A 123 were approximately ten feet apart, each five feet on either side from the line of seedling limits, the former amongst abundant seedlings and the latter where there was a heavy layer of leaves on the floor and no hemlock seedlings were present. Stations D 590 and D 607, E 95 and E 586, and G 536 and G 119 were arranged in similar relationships with respect to the presence and absence of seedlings. Curves of soil moisture content show for almost every week throughout the summer a considerably higher moisture content for the soils covered with leaf litter (and without seedlings) than for soils without leaf litter and having abundant seedliugs. This is true for both surface and three-inch soils (Plates I and II).

One is forced to the conclusion, therefore, that character of forest floor is more important in limiting seedling establishment in our stations than moisture content of soil, since seedlings are in every case growing in drier soil and under conditions less favorable in respect to soil moisture than a few feet away where there is more available moisture but no chance to become established.

If Curve B (Plate I), which is drawn from moisture content of soils under a dense stand of hemlock ranging from one to six inches DBH., is compared with curves A 154, E 95, G 536, D 590, F 582 and F 84, all of which are from stations containing hemlock seedlings, it will be noted that for almost every week during the months of July and August the soils in which seedlings were growing were lower in moisture content than the soils about the more mature stand. This is true for surface soils, but less frequently so for three-inch soils (Plate II). Roots of one- and two-year hemlock seedlings rarely if ever penetrate the soil in these stations beyond the first inch, which in turn indicates that


B - Surface Soil under dense young Tsuga
C - Under Beech - Maple
F 582 - Under Tsuga seedlings
Wilting Coefficient
PLATE I Surface Soils - Percent Moisture
F 84 - Entirely Open
F 582 Leeward side Parent Tree
D 607 - Leaf Litter
D 590 - Moss No Leaf Litter
G 119 Abundant Leaf Litter
G 536 - No Leaf Litter
E 95 - No Leaf Litter
E 586 - Abundant Leaf Litter
A 123 - Abundant Leaf Litter
A 154 - No Leaf Litter
3 10 17 24 31 7 14 21 28 5 12 19 26 2 9 16 23 30 6 13 20 27
May June July August September



soil factors which influence seedling establishment would necessarily be those in the upper few inches of soil.

When the curves of soil moisture for both surface and three-inch soils (Plates I and II) are studied in reference to the wilting coefficient[1], it is found that the moisture content for every station at which hemlock seedlings were growing (Curves A 154, E 95, G 536, D 590, F 84 and F 582) is below the wilting coefficient for the entire months of July and August, except Curves G 536 and D 590 for the week of August 16. When a similar study is made of curves from stations covered with forest litter and containing no hemlock seedlings, but in each case near the corresponding stations with seedlings (*i. e.*, Curves A 123, E 586,

[1]Wilting coefficient was determined by the formula $W.C. = \frac{ME}{1.84}$

G 119 and D 607), it will be noted that the soil moisture does not nearly so often fall below the wilting coefficient during these two months.

The wilting coefficients of the soils of the different stations are presented in Table I, where it will be noted that in almost every instance the W. C. of surface soils is higher than that of three- and six-inch soils. This is undoubtedly related to the higher humus content of the surface soil at these stations. The soils three and six inches deep are especially devoid of humus.

TABLE I

WILTING COEFFICIENT OF SOILS AT EACH STATION. EACH VALUE REPRESENTS THE AVERAGE OF SOILS TAKEN DURING NINE DIFFERENT COLLECTINGS AT EACH STATION

Station	Surface Soil	3-inch Soil	6-Inch Soil
A 154	10.245	8.630	8.370
A 123	12.100	10.299	9.751
B	10.883	8.963	9.009
C	10.277	8.312	8.283
D 590	9.537	9.542	8.987
D 607	10.720	9.612	10.401
E 95	10.670	8.945	8.936
E 586	13.850	10.293	10.116
F 582	10.450	8.689	8.214
F 84	10.474	8.996	8.131
G 536	9.890	8.658	7.116
G 119	14.660	8.415	8.366

It will be noted that in every case (Table I: A 154, D 590, E 95 and G 536, compared respectively with A 123, D 607, E 586 and G 119), stations where hemlock seedlings are growing have a lower wilting coefficient than the nearby stations where leaf litter has inhibited seedling establishment. This is undoubtedly related to the lower humus content in areas where the seedlings are growing.

A comparison was also made between soils under more fully developed stands of hemlock and under beech-maple. Curves for Stations B (under dense stand of hemlock and on north-facing slope) and C (under beech-maple with admixture of gum *(Nyssa sylvatica)* and hickory and on south-facing slope) show that the soil is drier for fourteen of the twenty-two weeks under hemlock than under beech-maple, in spite of the fact that the physiographic features favored the soil of the hemlock station from the standpoint of moisture retention. It thus appears that hemlock stands are more xerophytic in respect to soil moisture than the broad-leaved forest types here present. Daubenmire (3) found the same conditions to exist in comparing hemlock and beech-maple at Turkey Run.

EVAPORATION

Evaporation studies were carried on by use of the Livingston porous clay atmometers. When stations A 154 and A 123 (Plate III), and D 590 and D 607 are compared, there is seen to be a slightly greater average weekly loss where seedlings are growing than where abundant leaf litter has prevented seedling establishment. But when stations E 95 and E 586 are compared, there is a greater average weekly evaporation where seedlings have been inhibited than where they are present.

Comparison of Stations B and C (Plate III) indicate a considerably higher average weekly evaporation in the hemlock stands than in the apparently more open beech-maple. Daubenmire (3) found that there was little difference between hemlock and beech-maple associations in respect to water evaporation at Turkey Run. Our results at Trevlac indicate a more xerophytic condition for hemlock. It should be noted that the hemlock stands studied by Daubenmire were much more mature than those under study at Trevlac and that the season during which our data were taken was unusually dry. A few comparative figures will suffice to bring out the marked difference:

AVERAGE WEEKLY EVAPORATION

Beech-Maple at Trevlac, 1930	80.9 cc
Beech-Maple at Turkey Run (3), 1929	50.4 cc
Beech-Maple at Sycamore Creek (2), 1929	56.7 cc
Beech-Maple at Sycamore Creek (1), 1928	46.3 cc
Hemlock at Turkey Run (3), 1929	52.2 cc
Hemlock at Trevlac, 1930	90.3 cc

SOIL TEMPERATURES

Soil temperatures taken three inches below soil surface and compared with air temperatures thirty-six inches above the surface showed an average from 0.2 to 1.5° F. greater difference between soil and air temperatures where leaf litter inhibited seedling establishment than where

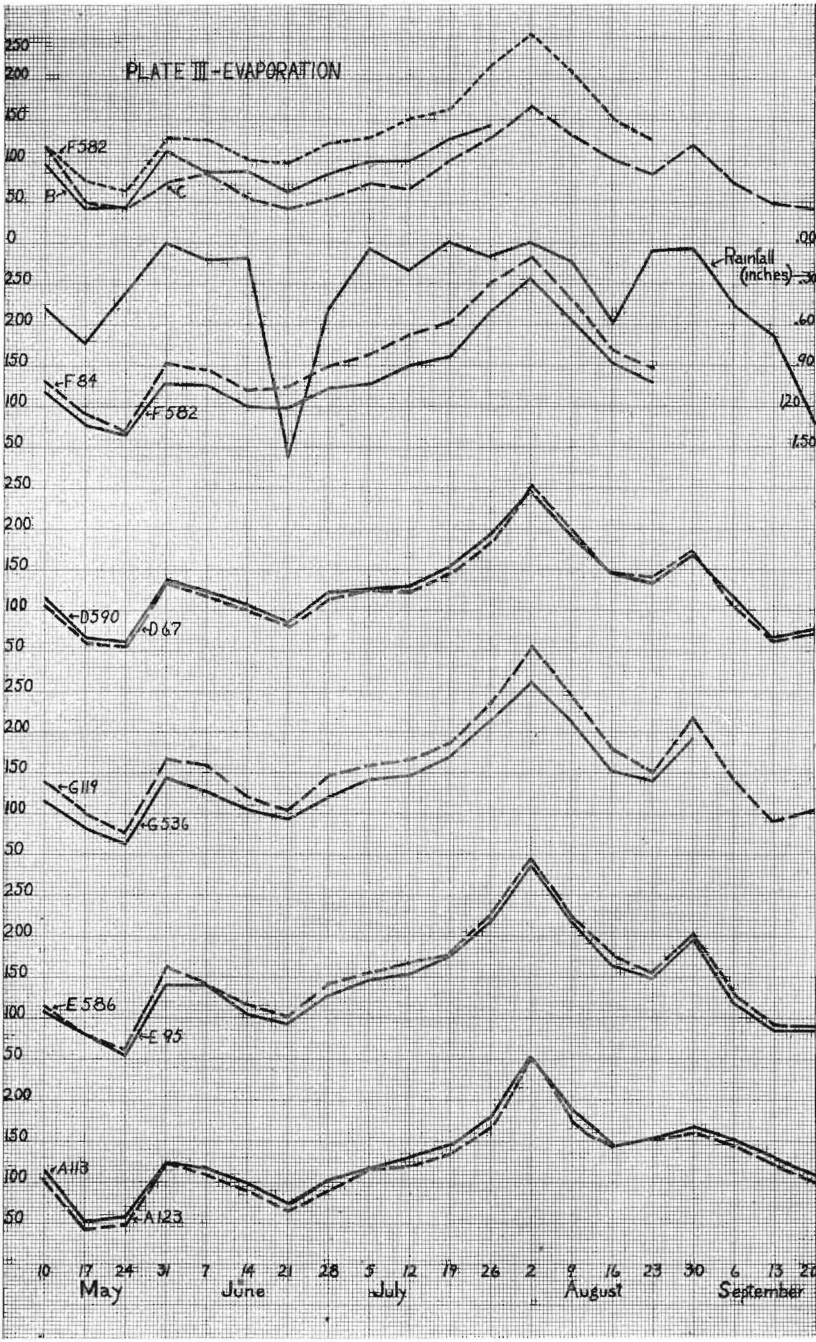


PLATE III - EVAPORATION
F582
B
C
Rainfall (inches)
F84
F582
D590
D67
G119
G536
E586
E95
A113
A123
May
June
July
August
September

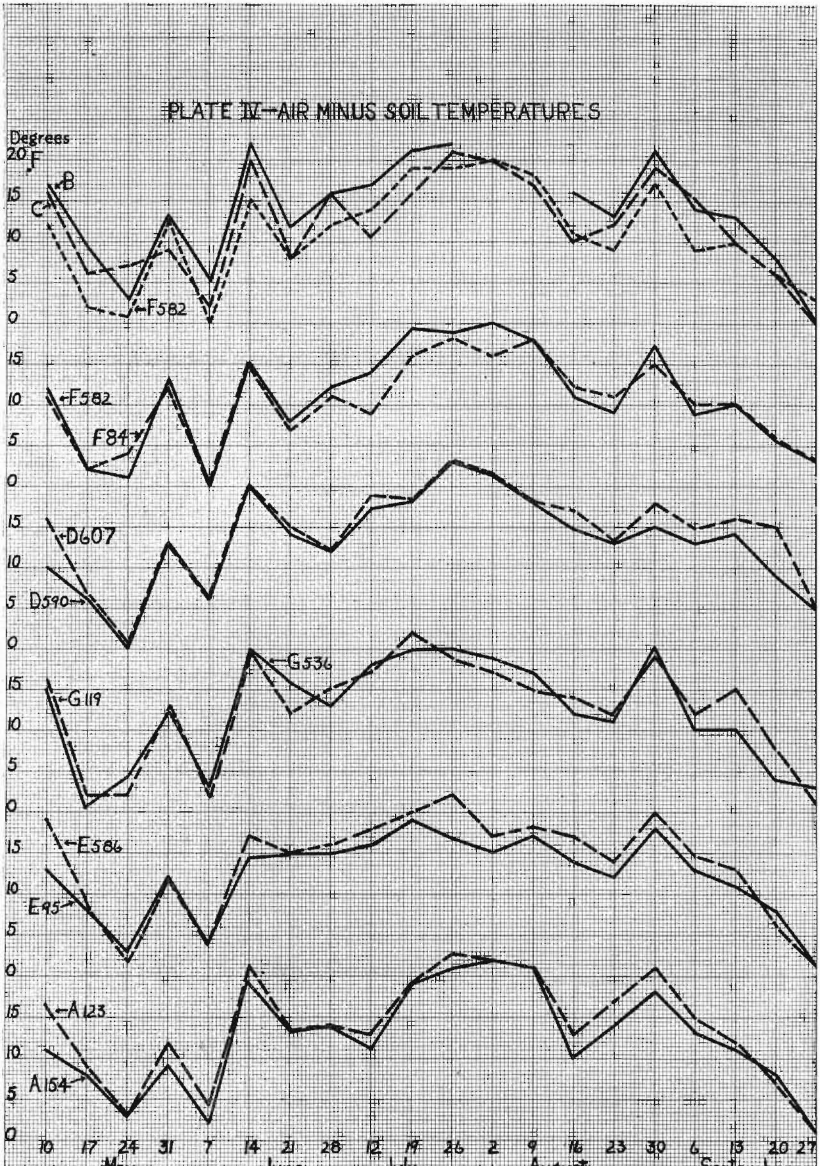


PLATE IV—AIR MINUS SOIL TEMPERATURES
Degrees F
B
C
F582
F582
F84
D607
D590
G536
G119
E586
E95
A123
A154
10
17
24
31
7
14
21
28
12
19
26
2
9
16
23
30
6
13
20
27
May
June
July
August
September

seedlings were abundant (Plate IV). This means (1) that where hemlock seedlings were abundant the soils are subject to greater fluctuation with changes in air temperature than where they were inhibited by leaf litter; (2) that where hemlock seedlings are abundant the soil is warmer on hot days and therefore subject to greater drying out due to heat. This is in accord with observations on soil moisture, where it was seen that the soil contains less moisture where seedlings are growing than where leaf litter has inhibited them (Plate I). All of this means that hemlock seedlings are growing under more rigorous conditions than are present only a few feet away where leaf litter inhibits their establishment.

SEEDLING MORTALITY

Data above given have indicated that hemlock seedlings at Trevlac are growing under more rigorous conditions than are characteristic for the region as a whole. That is to say, they are growing where soil moisture is lowest, fluctuations of temperature are greatest, and in some stations where evaporation is greatest. It was therefore thought necessary to gather some accurate data on seedling mortality. Accordingly, on April 19, 1930, a number of linen tags were numbered and attached to stakes made from zinc-covered wire. These were placed beside seedlings and the exact positions and age of seedlings were recorded. On October 4, 1930, the "roll" was again taken. Results shown in Table II indicate that 88.7 per cent of the first year seedlings and 78.4 per cent of the second and third year seedlings perished. Of the entire number of seedlings tagged, 82.8 per cent perished. These results seem to be in general agreement with the conclusion that these hemlock seedlings were growing under rigorous conditions. Toumey and Neethling (8) found that hemlock seedlings are readily killed when there is a defi-

TABLE II

SUMMARY OF SEEDLING MORTALITY. SEEDLINGS TAGGED APRIL 19, 1930, AND AGAIN CHECKED ON OCTOBER 4, 1930

	1st Year	2d and 3d Year	Total
Tagged April 19, 1930	60	74	134
Dead October 4, 1930	53	58	111
Alive October 4, 1930	7	16	23
Per cent dead	88.3	78.4	82.8
Per cent alive	11.7	21.6	17.2

ciency of moisture in the upper stratum of soil. Further studies on seedling mortality are being carried out and data gathered over a longer period of time will be presented in a future paper.

CONCLUSIONS

1. Forest floor cover is one of the most vital factors involved in the establishment of hemlock seedlings in this study. The cover is so deep that seedlings are inhibited on the plateaus and more gentle slopes covered with the broad-leaved deciduous trees.

2. Seedlings become established on the steeper slopes wherever there is sufficient moss or other floor covering to give them lodgment, and in other areas where forest litter is not too deep.

3. Soil moisture studies show that seedlings are growing in every instance under more rigorous conditions than are present only a few feet away but where floor cover inhibited their establishment.

4. Soil temperature studies show that seedling areas are subjected to a greater amount of temperature fluctuation than neighboring areas without seedlings.

5. Evaporation studies sbow that areas with seedlings are sometimes subjected to greater water loss and sometimes less than neighboring areas without seedlings.

6. Wilting coefficient studies show that the wilting coefficient is higher in every case where seedlings are absent than where they are present. This is undoubtedly due to the greater humus content of the soil where floor litter is greater. Floor litter, and hence humus content, is much less in areas where seedlings are growing than where they are inhibited.

7. Wilting coefficient is higher for surface soils than for soils three and six inches deep. This is directly related to the humus content.

LITERATURE CITED

1. CAIN, STANLEY A., and R. C. FRIESNER. Some ecological factors in secondary succession: Upland hardwood. I. Evaporation studies. Butler Univ. Bot. Stud. 1: 1-16. 1929.
2. —— *Ibid.* III. Soil moisture and evaporation studies in the Sycamore Creek region. Unpublished data.
3. DAUBENMIRE, REXFORD. The relation of certain ecological factors to the inhibition of forest floor herbs under hemlock. Butler Univ. Bot. Stud. 1: 61-76. 1930.
4. DEAM, C. C. Trees of Indiana. Indiana Dept. Conservation Publication. 13. pp. 317. 1921.
5. FROTHINGHAM, E. H. The eastern hemlock. U. S. D. A. Bull. 152. 1915.
6. LUTZ, H. J. The trends and silvicultural significance of upland forest successions in southern New England. Yale Univ. School Forestry Bull. 22. 1928.
7. MARSHALL, ROBERT. The growth of hemlock before and after suppression. Harvard Univ. Forestry Bull. 11. 1927.
8. TOUMEY, J. W., and E. J. NEETHLING. Some effects of cover over coniferous seed beds in southern New England. Yale Univ. School Forestry Bull. 9. 1923.