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Trenched Plots Under Forest Canopies

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TRENCHED PLOTS UNDER FOREST CANOPIES

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TRENCHED PLOTS UNDER FOREST CANOPIES

INTRODUCTION

THE presence of abundant surface vegetation in forests of low and medium density in humid regions and its absence or much reduced quantity in dense and very dense stands in the same regions are well known. The differences under the two conditions have generally been attributed to the intensity and quality of the light that reaches the floor and to which the surface vegetation is exposed.

Until recently the explanation of vegetational differences beneath canopies of different densities has been formulated on a purely observational basis unsupported by experimentation. In this connection the investigation undertaken by Fricke (1904) is of particular significance as it is the first attempt to determine by experimentation the rôle of root competition for moisture in accounting for differences in the vegetation on the forest floor under different degrees of crown density. Fricke pointed out the significance of soil moisture in the region of his experiments in accounting for these differences. He expressed the opinion that the common idea of light and shade species is "a scientifically ungrounded dogma." Between the earlier overemphasis on crown competition for light as set forth by Heyer (1852) and the later overemphasis on root competition for soil moisture as set forth by Fricke, we are now arriving by experimentation at a much sounder basis in accounting for the differences in the surface vegetation under canopies of different densities and when subjected to different degrees of root competition.

The relative importance of light and soil moisture in particular is better known than that of other environmental factors. We are coming to believe that the nature and condition of the reproduction and other surface vegetation beneath living canopies are not due to any single factor such as light or soil moisture, but to a complex of factors.

INVESTIGATIONS BY FRICKE AND FABRICIUS

THERE are a number of publications, more particularly in recent years, dealing with light and moisture relationships within the forest, in their effect on the young growth under the canopy of the older trees. These have been reviewed by Toumey (1929), Craib (1929), Barr (1930), and others.

The work of Fricke (1904) is notable because of its pioneer, iconoclastic character which did excellent service in controverting the then dominating theory of the overwhelming importance of light in the growth of surface vegetation under the forest canopy and in championing the importance of root competition, particularly in its effect on soil moisture. This was no small task when, as Fabricius (1927) points out, Fricke went contrary to the established work of Heyer (1852) with its emphasis on light and shade species and contrary to the whole later theory and practice of silviculture which followed this study, including the work of Gayer, Burckhardt, Jankowsky, and Furst. Under these conditions Fricke may be forgiven the overemphasis which he placed on root competition for soil moisture as expressed in such statements as "All light species in the natural forests of a certain climate can grow well either in light or under canopy." Fricke was the first to surround areas, free of large trees but under their unbroken canopy, with a trench, thus severing all the roots of the larger trees and freeing the enclosed area from root competition. These areas were located in mature stands of Scotch pine and white fir and were surrounded by a trench 25 em. deep which was immediately filled in.

During the first summer after trenching a rank growth of woody and herbaceous vegetation came in on the trenched plots, while the untrenched check plots remained almost bare of vegetation. Germination and the growth of sown seeds of beech, fir, oak, and pine were better on the trenched plots than on the untrenched. The soil moisture was found to be higher on the trenched plots than on the untrenched ones. Cieslar (1909) later also found the soil moisture to be higher on trenched plots, but under the conditions of his experiment this increase in soil moisture was not in itself sufficient to induce germination.

Fabricius (1927) pointed out that what Fricke proved and others did not disprove was the distinctly stunting effect of the root competition of the older stand acting through the soil moisture and soil nutrients on the vigor of the young growth under its canopy. Fabricius (1927) laid out trenched and untrenched plots under a mature, well-closed spruce stand located near Munich. The trenching was as deep as the length of the spade blade. Seeds were sown on the worked up soil, but germination was very poor on both plots. Likewise, areas populated by young stunted spruce seedlings were trenched to a depth of 30 em. in July, 1921. By September, 1921, the seedlings on the trenched plot were dark green with round, bright buds, while those on the untrenched plot retained their faded color unchanged and their buds were poorly developed. There was a sharp difference at the trench, showing that the trench itself had no effect other than that of releasing the trenched area from root competition. Yearly height growth was measured from 1921 to 1926, and the seedlings on the trenched plot continued to grow much more rapidly than those on the untrenched (5.18 Cffi. as contrasted with 0.84 em. during the second year after trenching).

To prove that a deficiency of light (solar radiation) had no effect in retarding the growth of the seedlings under the canopy it would have to be shown that the trenched seedlings grew as rapidly as seedlings planted out in the open under otherwise similar conditions. To determine the relative rôles played by light and soil moisture Fabricius (1929) laid out new plots in two widely separated forests in Germany. 1'wo rows of plots, each consisting of many small circular areas (½ square meter), were laid out parallel to the edge of a mature spruce stand, one row near the edge, the other farther back under the stand. A row of small plots near the edge of the forest but free from its influence was also laid out. One out of eachthree of the circular plots in the two rows in the forest was surrounded by a trench 25 em. deep which was later refilled. Seeds of several tree species were so\vn on each of these plots so that each species \vas replicated eight times.

At the end of the second growing season results were so striking that photographs were taken and colored to show the much greener appearance of the trenched seedlings as contrasted \vith the untrenched. Numbers, heights, and dry weights were also obtained. The rows of circular plots out near the edge of the stand are here called the half shade plots, while those further back under the stand are called the full shade plots. The trenched plots, both in half shade and in full shade, were much more heavily vegetated than those not trenched, supporting eleven and thirteen species of surface vegetation respectively. Moisture determinations made at the end of July showed considerably more moisture in the trenched plots than in the untrenched. By comparing the trenched plots in half or full shade with those in full light the effect of light alone can be obtained. By comparing the trenched with the untrenched plots in half shade or full shade the effect of root competition alone can be obtained. The results indicate that water deficiency and light deficiency, due to the old stand, causes, each for itself, a very distinct effect in retarding the growth of the seedlings under the canopy. Which of these deficiencies causes the greater effect on growth depends upon the tree species and the absolute amount of the deficiency. One can distinguish light-demanding and shade-enduring species and, more orless, water-demanding species. Larch and pine, also beech, are adversely affected in half shade during the first two years, whereas fir and spruce are much less affected. In the first year oak and beech (because of their large seeds) and spruce and fir hardly respond at all to release from root competition. The most pronounced result the first year of trenching is the increased growth of the natural surface vegetation. Fabricius discusses his results in their application to the numerous silvicultural problems of the forest, such as growth in openings in the stand, growth of reproduction under standards, and the abundance and growth of surface vegetation, and concludes that "in all these phenomena root competition plays a very important role and, when the light is sufficient, is the limiting factor." His experiments are being continued.

THE INVESTIGATION HERE REPORTED

SITE CONSIDERATIONS

THE plots herein described are located on the Yale Demonstration and Research Forest near Keene in southern New Hampshire. The period covered by the investigation extends from 1922 to 1931.

The forest is located in the broad, rolling valley of the Ashuelot River and is surrounded by low, wooded mountains or hills. The region is characterized by a rainfall of 37.42 inches per year (1889-1930). The rainfall is very evenly distributed throughout the entire year, as is indicated by the following monthly averages in inches (1908-1930): January, 2.83; February, 2.83; March, 3.10; April, 3.08; May, 2.94; June, 3.03; July, 3.87; August, 3.77; September, 3.29; October, 3.29; November, 3.08; December, 2.97. Half of this rainfall (18.98 inches), therefore, falls during the growing season, April to September inclusive. Because of high temperatures and rapid loss of water from both soil and vegetation the months of July and August are the driest months of the year, and the vegetation often suffers as a result.

The mean annual temperature (1889-1930) is 45.2°F. The daily range of temperature is great, and no month of the summer season is entirely free from the danger of frost.

The soils of the valley are of sedimentary origin and are composed, in general, of fine to coarse sand, with a varying amount of disintegrated humus in the upper layers.

TRENCHED PLOTS UNDER FOREST CANOPIES

ESTABLISHMENT OF THE PLOTS

A number of trenched and untrenched plots of various types were established on the Yale Demonstration and Research Forest near Keene in southern New Hampshire in 1922, 1923, and 1924. These have been described by Toumey (1929). All of these plots have been abandoned with the exception of one known as Quadrat No. 5 with its check plot. As this quadrat is no longer to be retrenched and will, therefore, probably retrograde, it seemed wise to make a careful record of the condition of the vegetation. This was done in September, 1930, eight years after its establishment and five years after its second charting. Unless otherwise stated, all later descriptions and discussion refer to Quadrat No. 5.

In 1922 Quadrat No. 5 (9 X 9 feet) was laid out under the canopy of a 41-60-year-old white pine stand on practically level ground with a moderate cover of litter and with a very sparse vegetative cover. This quadrat or plot was surrounded by a trench one foot in width and three feet deep. The earth as it was removed from the trench was placed on canvas and later packed back into the trench where it was thoroughly tramped down, leveled off, and the litter spread over it. In the trenching process all of the roots leading into the plot were severed. Iron pipes were driven in at the four corners of the trenched plot and numbered according to the chart shown in Fig. 1. On either side of the trenched plot outside of the trench two check plots, each 4½ X 9 feet, were laid out. These plots were essentially the same as the trenched plot except for root competition with the surrounding white pine. Fig. 1 indicates the size (diameter breast high) and the position of the near-by trees with regard to the plots. The plots were surrounded by a fence. The trenched plot was retrenched in 1924, 1926, and 1928. It will not be retrenched in the future, but the roots of the canopy trees will be allowed to grow into the plot from all sides.

The position and size of the roots severed in the initial trenching were charted for each side of the plot (Toumey, 1929). The roots varied only slightly on the different sides of the plot, depending on the nearness of the surrounding trees. The total number of roots entering or leaving the plot was 825, distributed on the four sides as follows: 228, 175, 253, and 169. Considering all sides of the plot, 71.5 per cent of the roots were found in the upper foot of soil; 25.8 per cent, in the second; and 2.7 per cent, in the third. There was a relatively higher proportion of the larger roots at the greater depths.

The necessity for frequent retrenching of plots of this kind is shown by the fact that when the plot was retrenched in 1924, two years after its initial trenching, 126 roots had grown through the loose soil of the trench itself and had penetrated the trenched plot to an unknown distance, while over 400 had grown into the trench itself. In the 1926 retrenching it was found that 136 roots had grown through into the trenched plot since 1924. Of this number 72 per cent were in the upper foot of soil and none in the third foot. Fifteen of these roots, near the surface, were traced to their ends without undue disturbance of the plot and averaged 49.5 inches in length. They were mostly slender with few branches.

Soil conditions. The soil is essentially uniform on both the trenched and untrenched plots. It is of sedimentary origin and is fairly homogeneous. Mechanical analyses of the different soil horizons have been made and have been recorded in detail by Craib (1929). Suffice it to say that, taken as a whole, the soil is a fine to a coarse sand with a variable amount of gravel intermingled. The variable gravel content has an effect on the water-holding capacity of the soil, which must be kept in mind. The reaction of the soil

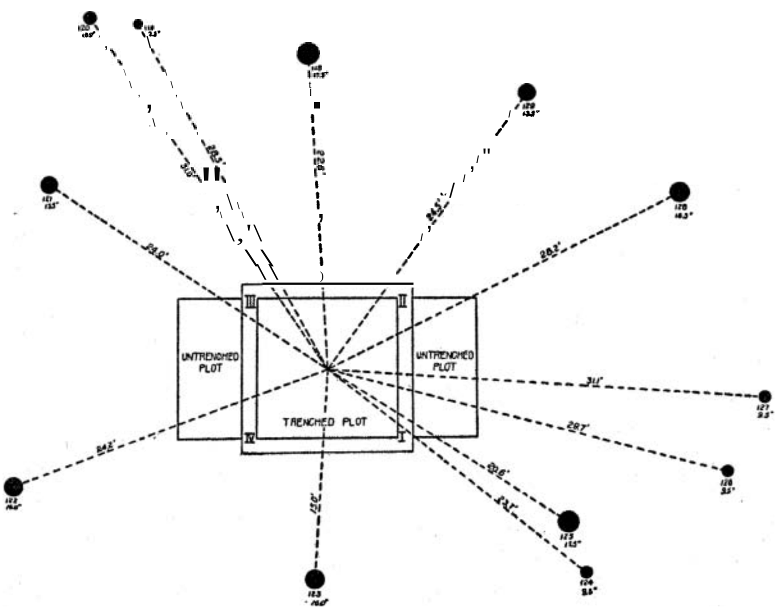

Fig. 1. Chart showing size (d.h.h. in inches) and distance (in feet) from the center of the plot of the surrounding white pine trees. The trenched plot (9 X 9 feet) is flanked on either side by the two untrenched plots (9 X 4½ feet).

is slightly acid, surface samples giving a pH value of 6.5. Organic matter, determined by ignition, varied from 7 per cent by weight in the surface sample to I.I per cent at a depth of 3 feet.

Light conditions. rrheplots were located in an open space between the boles of the 4I-6o-year-old white pine stand. The canopy was fairly uniform and moderately dense. The light conditions were as uniform on both plots as it is possible to secure under the checkered light conditions obtaining on the forest ft.oor. The average of a number of tests showed the photochemical light intensity at a height of 3 feet above the plots to be 7 per cent of full sunlight. T'hese tests were made by means of the Clements' photometer between 10 A. M. and 2 P. M. on bright clear days in midsummer.

Soil moisture conditions. Soil moisture determinations were made on the untrenched and trenched plots during the driest parts of two years at 6-inch intervals from the surface to a depth of 30 inches. The results of these extensive and careful determinations have been fully presented and discussed by Craib (1929) and Tourney (1929), and it is necessary here merely to indicate the chief results.

In both the trenched and untrenched plots there was usually a greater amount of available moisture present in the upper layers of soil than at increased depths.

During the driest periods of the year there was from two to nine times as much moisture available to plants in the ripper six inches of soil in the trenched plot as there was in the untrenched plot. This striking difference appears to be due wholly to the elimination of root competition in the trenched plot.

During the three driest months of the year, July, August, and September, the amount of soil moisture sometimes falls below the wilting coefficient on the untrenched plot, but never on the trenched plot. This fact is undoubtedly of great importance in accounting for the paucity of reproduction and secondary vegetation on the untrenched plot.

Soil moisture is abundant in the spring and late autumn, and trenching then exerts but little inft.uence on the amount of available moisture present in the soil.

PRESENTATION OF RESULTS

THE results obtained from the study of the vegetation on the plots in 1930 are here presented in the form of charts and tables. To make comparisons easier the charts made in 1922 and 1925 (Tourney, 1929) have been redrawn and symbols substituted for the numbers in order to conform with the 1930 charts. Some adjustment has also been necessary in the species listed and in the orientation of the charts to conform with the plan shown in Fig. 1. The numbering of the corner posts is uniform throughout all the charts and photographs, making detailed comparison easy. It is particularly desirable to compare the vertical photographs with the vegetation charts. The outlined areas in Figs. 2 and 3 are covered by the photographs shown in Figs. 8 and 12 and can be compared directly. The plots have been divided into foot squares to aid in charting, and these have been numbered in Figs. 4 and 6. The numbered squares in Figs. 18, 19, 20, and 21 correspond to those given in the charts. These foot squares have served as the unit in determining the frequency of distribution of the different species. Thus any species, e.g., white violet, occurring in 80 out of a total of 91 foot squares in the trenched plot had a frequency of distribution of 88.8 per cent (Table I).

Table II presents data on average maximum height and density of the vegetation on the trenched and untrenched plots. The maximum height of the vegetation (when present) on each foot square was averaged for the entire plot. The figure 8.4 inches for the trenched plot seems low, but only a few of the foot squares supported hemlocks 36 inches high and most of them supported only 2 or 3-inch herbaceous plants, hence the average is lower than a casual observation of the plot would seem to indicate. To secure the density of the ground cover the amount of surface covered by the low-lying vegetation was estimated, in terms of a fully vegetated area considered as 100 per cent cover. The density of the total vegetative cover includes the above low-lying vegetation plus the vertical projection of the seedlings and the taller goldenrods and asters.

No chart of the moss on the trenched plot was made in 1930 because of its extremely irregular distribution. Notes were taken, however, and show its abundance to be less than in 1925. (See plus signs in Table I.)

ANALYSIS OF THE VEGETATION ON THE PLOTS

In 1922. At the time of establishment the vegetation on the plots was very sparse (Fig. 8) and was composed chiefly of herbaceous species. Scattered irregularly over the plots was a moderate growth of pigeon wheat moss (Fig. 2). On the untrenched plot, grasses were by far the most abundant species, making up over 80 per cent of the vegetation (Table I). Much of this grass could be identified with certainty as *Danthonia spicata,*[1] but

[1] The nomenclature followed throughout is that of Gray's *New Manual of Botany*, 7th edition.

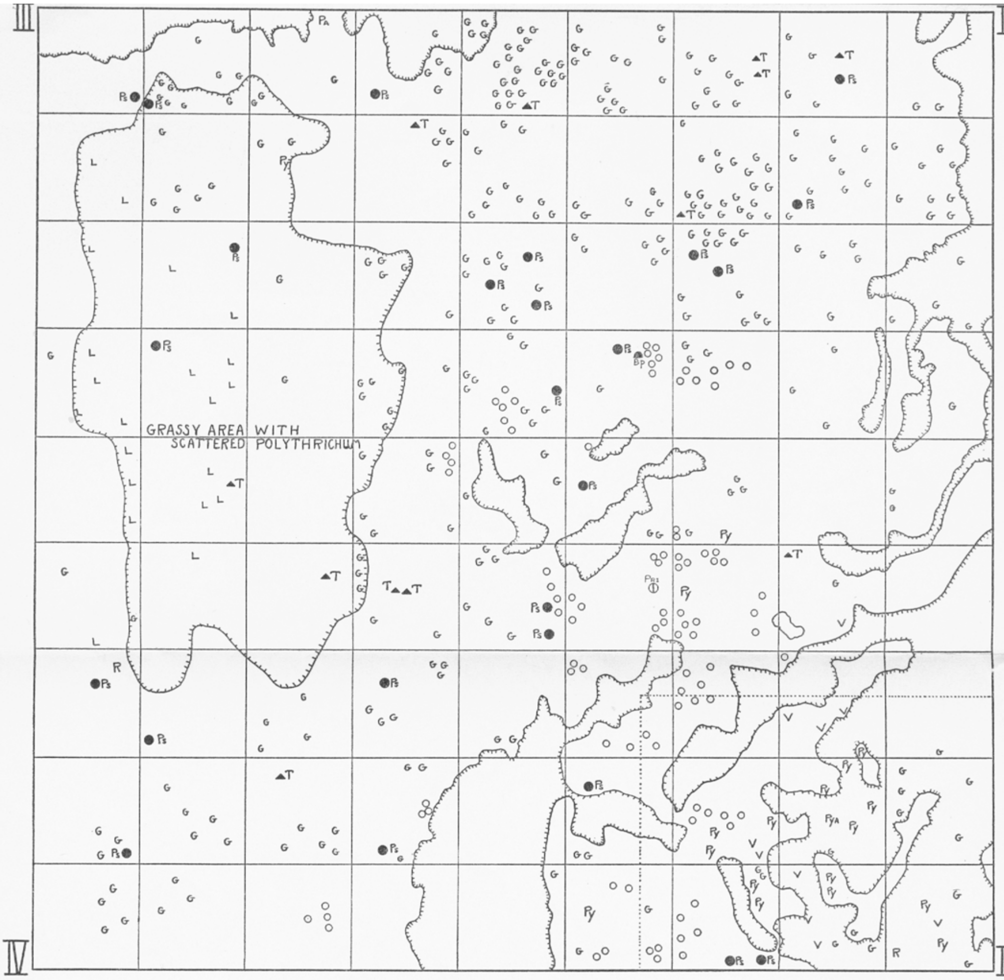

Fig. 2. Chart of the vegetation on the **trenched** plot when first established (August, 1922). The outlined areas indicate large patches of moss or grass. Isolated patches of moss are shown by small circles. The legend is as follows: O—*Polytrichum commune,* Bp—*Betula populifolia,* G—grasses, L—*Lobelia spicata,* Pa—*Pteris aquilina,* Pri—*Pinus rigida,* Ps—*Pinus Strobus,* Py—*Pyrola elliptica,* Pya—*Pyrola americana,* R—*Rubus hispidus,* T—*Tsuga canadensis,* V—*Vaccinium pennsylvanicum.* Common names are given in Table I.

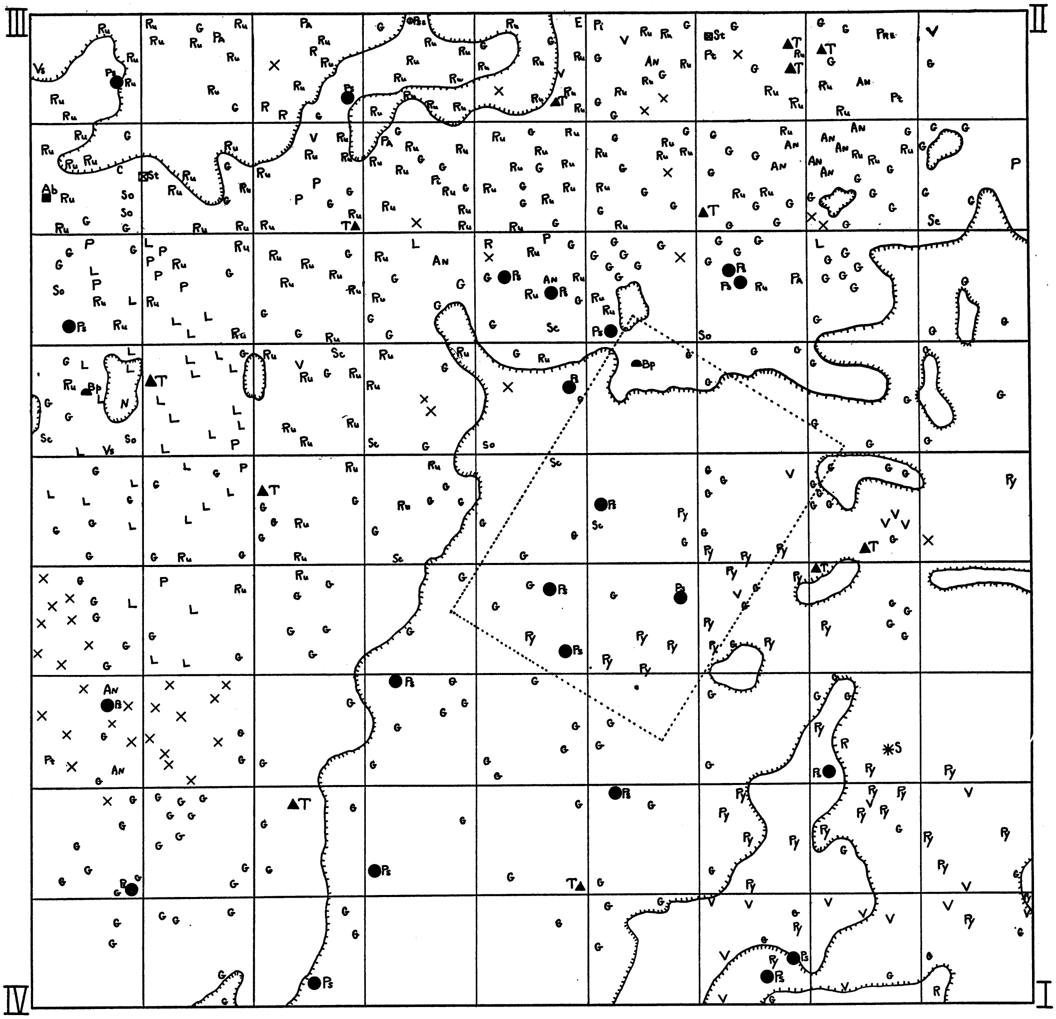

Fig. 3. Chart of the vegetation on the **trenched** plot 3 years after its establishment (August, 1925). The legend is as follows: X—*Viola blanda,* Ab—*Abies balsamea,* An—*Antennaria* spp., Bp—*Betula populifolia,* C—*Carex* spp., E—*Epipactis repens ophioides,* G—grasses, L—*Lobelia spicata,* N—*Nemopanthus mucronata,* P—*Potentilla canadensis,* Pa—*Pteris aquilina,* Pi—*Panicum implicatum,* Pre—*Prenanthes* spp., Ps—*Pinus Strobus,* Pse—*Prunus serotina,* Pt—*Populus tremuloides,* Py—*Pyrola elliptica,* R—*Rubus hispidus,* Ru—*Rumex acetosella,* S—*Spiræa latifolia,* Sc—*Stieronema ciliatum,* So—*Solidago canadensis,* St—*Spiræa tomentosa,* T—*Tsuga canadensis,* V—*Vaccinium pennsylvanicum,* Vs—*Viola sagittata.* Common names are given in Table I.

some of it, difficult of determination in a vegetative condition, was probably species of *Panicum* and *Stipa*. On part of the plot (Fig. 2) the grass was so abundant as to make it difficult to count the number of stalks, but the height and bulk of the vegetation were not great (Fig. 7).

The woody vegetation consisted of small (1 to 2 inches) 2-year-old seedlings of white pine (25), hemlock (12), pitch pine (1), and gray birch (1). The total number of species was 12; 8 herbaceous and 4 woody. The most important species arranged in the order of their abundance in 1922 were grass, white pine, lobelia, wintergreen, hemlock, and dwarf blueberry.

The vegetation was similar in species and distribution on the untrenched and trenched plots except that the density was slightly greater on the untrenched plots.

In 1923 *and* 1924. No detailed charting of the vegetation on the plots occurred until 1925, but observations and photographs give unmistakable evidence of the changes that occurred during the intervening time. A distinct difference between the trenched and untrenched plots was visible at the close of the first season after trenching (Fig. 9). In September, 1923, after a dry August, the vegetation on the trenched plot was much more abundant and more thrifty in appearance and showed increased size and abundance. In July, 1924, two years after trenching, the increase in abundance of the vegetation on the trenched plot was very striking in contrast with that on the untrenched plot (Fig. 10). Grasses were much more abundant, the moss was more luxuriant, and the first appearance of herbaceous and woody species, such as blackberry, five-finger, aster, and goldenrod, is noticeable in the photograph. The greater luxuriance of all species within the trenched plot is very evident. Wintergreen may be seen in vigorous flower in the lower right-hand corner of the plot (Fig. 10).

The greater abundance of the vegetation on the trenched plot as contrasted with the untrenched plot may be seen by comparing Fig. 11 and Fig. 12. On the other hand, there was little if any change in the vegetation on the untrenched plot from 1922 (Fig. 8) to 1924 (Fig. 11).

In 1925. In 1925, three years after its establishment, the trenched plot was recharted (Fig. 3) and its vegetation compared with that on the untrenched plot. The number of species on the untrenched plot had decreased from 12 to 7, the more xeric species persisting. The 2-year-old seedlings on the untrenched plot had been reduced to 5 per cent of their original number, those remaining being very unthrifty in appearance. A study of Figs. 13 and 14 will show the contrast between the vegetation on the trenched and untrenched plots.

TABLE I

ABUNDANCE AND FREQUENCY OF THE SPECIES FOUND ON THE TRENCHED AND UNTRENCHED PLOTS ARRANGED IN THE ORDER OF THEIR ABUNDANCE IN 1930

Herbaceous species Scientific name	*Common name*	*Symbol*	*Abundance (number and per cent of total)* Trenched 1922 *No.*	*%*	Trenched 1925 *No.*	*%*	Trenched 1930 *No.*	*%*	Untrenched 1930 *No.*	*%*	*Frequency (per cent)* Trenched 1922	Trenched 1925	Trenched 1930	Untrenched 1930
Viola blanda	White violet	X			76	12.8	764	41.2	39	15.6		19.8	88.8	23.3
Rubus hispidus	Blackberry	R	2	0.6	6	1.0	357	19.5	18	7.2	2.5	4.9	44.4	15.5
Potentilla canadensis	Five-finger	P			14	2.4	279	15.5	12	4.7		11.1	65.4	9.9
Stipa sp. Danthonia sp.	Grass	G	296	85.2	242	40.6	134	7.5	13	5.3	71.6	93.8	28.5	11.1
Pyrola elliptica	Wintergreen	Py	18	5.2	36	6.0	93	5.1	98	39.3	12.4	16.0	59.2	40.0
Solidago canadensis	Smooth goldenrod	So			6	1.0	61	3.3	2	0.9		6.2	14.8	2.2
Vaccinium pennsylvanicum	Dwarf blueberry	V	10	2.2	23	3.9	36	2.0	23	9.2	6.2	16.0	19.8	12.2
Trientalis americana	Star flower	Tr					36	2.0	6	2.6			28.5	6.6
Rumex acetosella	Sorrel	Ru			125	21.0	16	0.9	13	5.2		38.3	14.8	6.6
Antennaria sp.	Everlasting	An			13	2.2	13	0.7				8.6	7.4	
Aster undulatus	Blue aster	As					13	0.7	7	2.9			8.6	5.5
Solidago rugosa	Hairy goldenrod	Sr					9	0.5					6.2	
Epipactis repens ophioides	Rattlesnake plantain	E			1	0.2	6	0.3				1.2	4.9	1.1
Prenanthes sp.	Rattlesnake root	Pre			1	0.2	5	0.3				1.2	1.2	
Carex sp.	Sedge	C			1	0.2	4	0.2	6	2.6		1.2	2.5	4.4
Maianthemum canadense	Mayflower	M					2	0.1	2	0.9			1.2	2.2
Viola sagittata	Arrow-leaved violet	Vs			2	0.3	1	0.1				2.5	1.2	
Aster lateriflorus	White aster	Asl					1	0.1					1.2	
Pteris aquilina	Bracken fern	Pa	1	0.2	4	0.7			6	2.6	1.2	4.9		5.5
Lobelia spicata	Lobelia	L	21	6.4	35	5.9			1	0.5	11.1	12.4		1.1
Stieronema ciliatum		Sc			8	1.3						9.8		
Panicum implicatum	Woods panic grass	Pi			2	0.3						2.5		
Solidago arguta	Goldenrod	Soa							1	0.5				1.1
Pyrola americana	Wintergreen	Pya	1	0.2							1.2			
Polytrichum commune	Pigeon wheat moss	O		++		++++		++		+	++	++++	++	+
Total individuals			349	100.	595	100.	1830	100.	247	100.				
Total species			8		18		19		16					

TABLE I (cont.)

Woody species Scientific name	Common name	Symbol	Abundance (number and per cent of total) Trenched 1922 No.	%	Trenched 1925 No.	%	Trenched 1930 No.	%	Untrenched 1930 No.	%	Frequency (per cent) Trenched 1922	Trenched 1925	Trenched 1930	Untrenched 1930
Pinus Strobus	White pine	Ps	25	64.1	22	48.5	26	50.0	6	27.4	23.5	22.2	26.0	4.4
Tsuga canadensis	Hemlock	T	12	30.7	12	26.6	11	21.2	3	13.6	13.6	13.6	13.6	3.3
Pinus resinosa	Red pine	Pr							5	22.8				5.5
Betula populifolia	Gray birch	Bp	1	2.6	2	4.5	3	5.7	2	9.1	1.2	2.5	3.7	2.2
Populus tremuloides	Aspen	Pt			3	6.7	2	3.9				3.7	2.5	
Amelanchier canadensis	Shadbush	A					2	3.9	1	4.5			2.5	1.1
Spiræa tomentosa	Steeplebush	St			2	4.5	2	3.9				2.5	2.5	
Abies balsamea	Balsam fir	Ab			1	2.3	1	1.9				1.2	1.2	
Picea rubra	Red spruce	Pru					1	1.9					1.2	
Quercus borealis	Red oak	Q							1	4.5				1.1
Salix sp.	Willow	Sa					1	1.9					1.2	
Spiræa latifolia	Meadowsweet	S			1	2.3	1	1.9	2	9.1		1.2	1.2	2.2
Prunus serotina	Black cherry	Pse			1	2.3	1	1.9				1.2	1.2	
Lonicera sp.	Honeysuckle	Lo					1	1.9					1.2	
Viburnum cassinoides	Withe-rod	Vc							1	4.5				1.1
Acer rubrum	Red maple	Ar							1	4.5				1.1
Nemopanthus mucronata	Mountain holly	N			1	2.3						1.2		
Pinus rigida	Pitch pine	Pri	1	2.6							1.2			
Total individuals			39	100.	45	100.	52	100.	22	100.				
Total species			4		9		12		9					
Grand total individuals			388		640		1882		267					
Grand total species			12		27		31		25					

On the trenched plot a distinct increase in vegetation had taken place. Not only was there a great increase in the number of individual plants (338 in 1922 to 639 in 1925), but the number of species had more than doubled (12 in 1922 to 27 in 1925). Concomitant with this increase there also occurred a decrease in the numbers of certain species, particularly the grasses (compare Fig. 13 and Fig. 10), and their replacement by broad-leaved herbs and woody species. This succession will be discussed more fully later.

The conifer seedlings, although present, had not as yet become large enough to show above the surrounding vegetation in a photograph. The white pine seedlings had decreased from 25 in 1922 to 22 in 1925; the hemlock had held their own, while there had come in a few scattered individuals of aspen, steeplebush, balsam fir, meadowsweet, black cherry, and mountain holly (Table I). The pitch pine had disappeared. The moss had increased greatly in luxuriance and somewhat in abundance. No figures are available on the density or height of the vegetation for comparison with 1930.

The most important species arranged in the order of their abundance in 1925 were as follows: grass, sorrel, white violet, wintergreen, lobelia, dwarf blueberry, white pine, five-finger, everlasting, and hemlock.

In 1928. In 1928 we have the first photographic evidence that the conifers were large enough to be conspicuous above the rest of the vegetation (Fig. 15). The hemlocks were, however, little if any larger than the white pine, a condition much different from that in 1930. Aspen, willow, and gray birch were also visible.

In 1930. In 1930, eight years after establishment and five years after the previous charting, the plots were carefully recharted (Figs. 4, 5, and 6). The charting was done in mid-September after the dry summers of 1929 and 1930. The lateness of the season made it difficult to chart all of the early spring flowering plants with absolute accuracy, but the undisturbed character of the plot made possible the recovery of their dried remains in most cases. This applies to star flower, mayflower, and, possibly; bracken fern.

The plots were divided by strings into foot squares, and the position of each individual plant was indicated on a chart numbered to correspond to similar charts in 1922 and 1925. Table I shows the actual number of individuals of a given species, the per cent of the total number of individuals on the plot (abundance), and the per cent of the total number of foot squares on which the species were found (frequency).

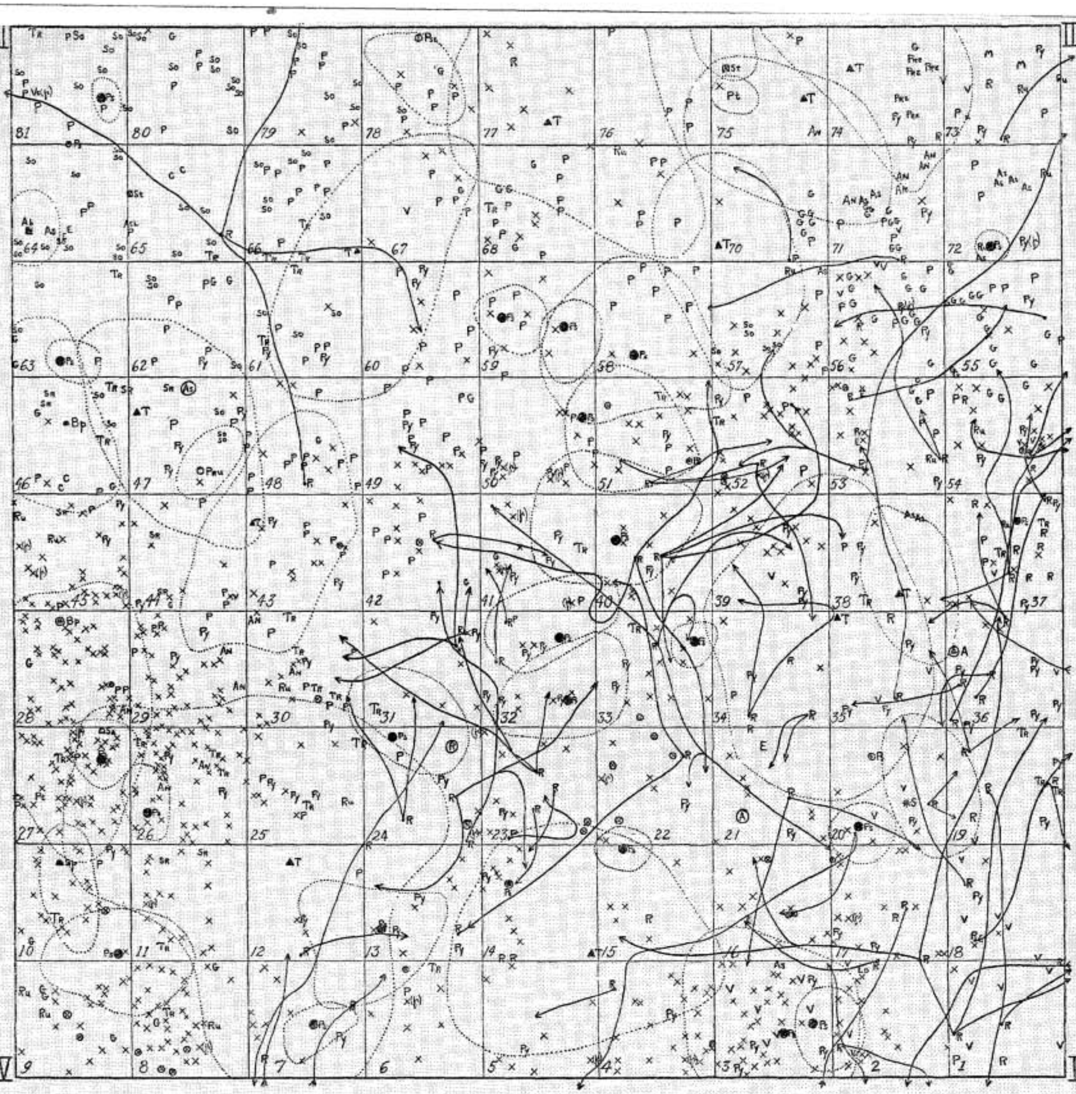

Fig. 4. Chart of the vegetation on the **trenched** plot 8 years after its establishment (September, 1930). A circle surrounding a symbol or letter indicates a seedling; (fr) indicates in fruit; the origin or point of rooting of *Rubus* runners is shown by a dot; their free ending by an arrow. The dotted lines indicate the crown spread of the tree species. The legend is as follows: X—*viola blanda*, A—*Amelanchier canadensis*, Ab—*Abies balsamea*, An—*Antennaria* spp., As—*Aster undulatus*, Asl—*Aster lateriflorus*, Bp—*Betula populifolia*, C—*Carex* spp., E—*Epipactis repens ophioides*, G—grasses, Lo—*Lonicera* spp., M—*Maianthemum canadense*, P—*Potentilla canadensis*, Pre—*Prenanthes* spp., Pru—*Picea rubra*, Ps—*Pinus Strobus*, Pse—*Prunus serotina*, Pt—*Populus tremuloides*, Py—*Pyrola elliptica*, R—*Rubus hispidus*, Ru—*Rumex acetosella*, S—*Spiræa latifolia*, Sa—*Salix* spp., So—*Solidago canadensis*, Sr—*Solidago rugosa*, St—*Spiræa tomentosa*, T—*Tsuga canadensis*, Tr—*Trientalis americana*, V—*Vaccinium pennsylvanicum*, Vs—*Viola sagittata*. Common names are given in Table I.

Untrenched plot.

The vegetation on the untrenched plot remained very sparse, probably essentially similar to its condition in 1922 and 1925. (Compare Fig. 18 with Fig. 11 and Fig. 8.) No chart of the vegetation on the untrenched plot for 1922 and 1925 is available, but assuming the vegetation similar on both plots at the time of establishment (1922), we find 388 individuals and 12 species as contrasted with 267 individuals and 25 species in 1930. Too much weight cannot be laid on the number of individuals in 1922, as these were largely (85 per cent) stalks of grass and \vere not counted on that part of the plot labeled "grassy area" (Fig. 2).

The significant point is the fact that in 1922 there were 12 species; in 1925, only 7 species (Toumey, 1929); and in 1930 the number had risen

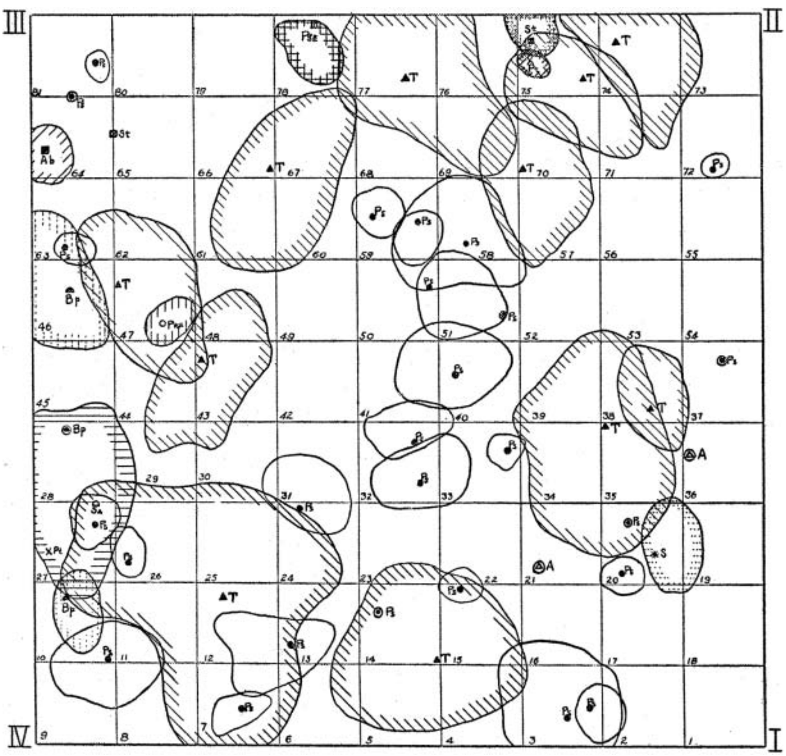

Fig. 5. Chart of the woody vegetation (except *Rubus*) on the **trenched plot** showing their crown spread (September, 1930). Seedlings are indicated by a circle around a symbol.

to 25 species. The large number of species which had become established on the trenched plot (31) had, undoubtedly, by means of seeds, runners, and rhizomes, spread to the adjacent untrenched plot. This large number of species was, however, represented by a limited number of individuals, most of which were small and poorly developed as compared with the same species on the trenched plot. Some of these species were white violet, five-finger, star flower, sorrel, aster, and sedge.

The small number of white pine (6) and hemlock (3) seedlings on the untrenched plot in 1930 as compared with the original trenched plot (1922) is probably due to the loss on the untrenched plot of most of the seedlings which had started two years before the establishment of the plot in 1922, whereas those on the trenched plot survived. Very little seeding in of conifers seems to have occurred since 1922 on either the trenched or untrenched plots, except five red pine on the untrenched plot.

Trenched plot.

The trenched plot in 1930 was covered with a dense mass of vegetation (Figs. 4 and 16) in striking contrast with the sparse vegetation on the untrenched plot (Fig. 17). This mass of vegetation was made up of many species (31) and a large number of individual plants (1,882). Of the species, 12 were of woody plants (40 per cent) and 19 were of herbaceous plants (60 per cent). These 12 woody species were represented by only 52 individual plants, whereas the 19 herbaceous species were represented by 1,830 individual plants, chiefly small plants of white violet (764 individuals). The woody plants, however, because of their large size, composed the greater bulk of the vegetation and determined the physiognomy of the vegetation on the plot (Fig. 17). This is in direct contrast with the condition in 1922 when the great bulk of the vegetation was herbaceous with almost no woody vegetation. In Table I the blackberry, because of its growth habit, is classed with the herbaceous plants instead of with the tree and shrub-forming woody species. The blackberry forms a considerable mass of vegetation which increases still more the bulk of woody vegetation.

In Table I the species making up the vegetation are arranged in the order of their abundance in 1930. The principal species were white violet, blackberry, five-finger, grass, and wintergreen among the herbaceous plants, and white pine and hemlock among the woody plants.

The height of the vegetation in each foot square was measured and its density estimated. These figures have been averaged in Table II. The average maximum height on the trenched plot was 8.4 inches in contrast

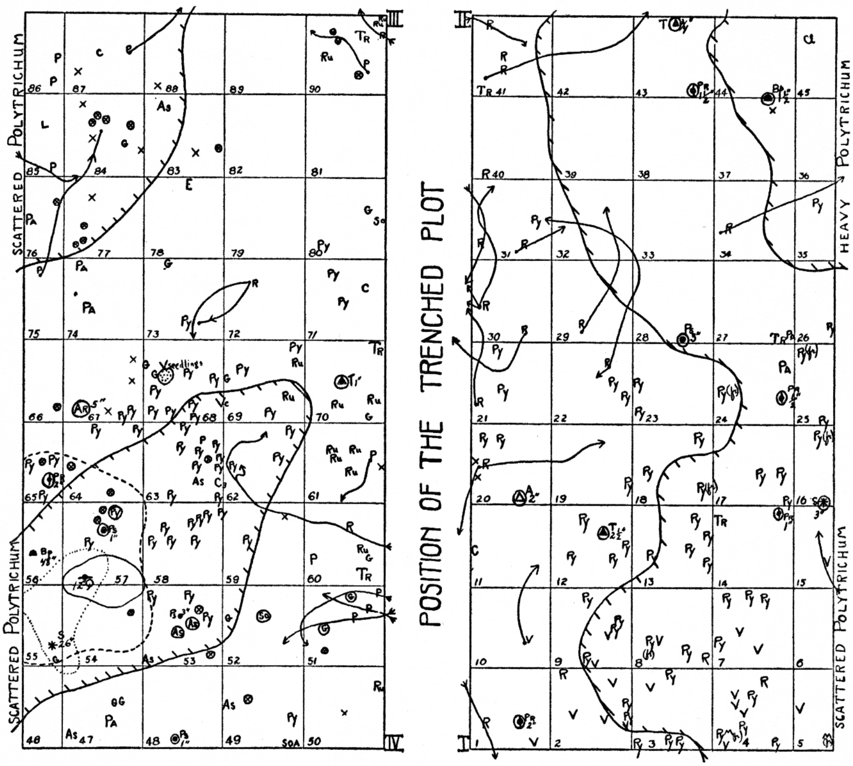

Fig. 6. Chart of the vegetation on the **untrenched** plots (September, 1930). The numbers I to IV indicate the position of the corner posts of the trenched plot. Legend as in Fig. 4. The height in inches of the tree species follows the symbol. The legend is as follows: X—*Viola blanda,* A—*Amelanchier canadensis,* Ar—*Acer rubrum,* As—*Aster undulatus,* Bp—*Betula populifolia,* C—*Carex* spp., G—grasses, L—*Lobelia spicata,* M—*Maianthemum canadense,* P—*Potentilla canadensis,* Pa—*Pteris aquilina,* Pr—*Pinus resinosa,* Ps—*Pinus Strobus,* Py—*Pyrola elliptica,* Q—*Quercus borealis,* R—*Rubus hispidus,* Ru—*Rumex acetosella,* S—*Spiræa latifolia,* So—*Solidago canadensis,* Soa—*Solidago arguta,* T—*Tsuga canadensis,* Tr—*Trientalis americana,* V—*Vaccinium pennsylvanicum,* Vc—*Viburnum cassinoides.* Common names are given in Table I.

with 2.5 inches on the untrenched plot. The hemlock trees, however (average 37.7 inches), gave the vegetation as a whole the appearance of much greater height.

TABLE II

AVERAGE MAXIMUM HEIGHT, DENSITY OF GROUND COVER, AND TOTAL DENSITY OF THE VEGETATION ON THE TRENCHED AND UNTRENCHED PLOTS (SEPTEMBER, 1930)

Plot	*Maximum height** (*inches*)	*Density of ground cover** (*per cent*)	*Density of total vegetative cover** (*per cent*)
Trenched	8.4	48.4	80.0
Untrenched	2.5	2.9	8.1

* See page 12 for explanation of these terms.

The density of the ground vegetation alone was 48.4 per cent on the trenched plot and 2.9 per cent on the untrenched plot. But when the crown spread of all of the young trees on the plot is considered the density rises to 80.0 per cent and 8.1 per cent respectively. The last figure is higher than would be expected, due to a few fairly large young trees of red oak and gray birch and of meadowsweet in squares 55, 56, and 57 (Fig. 6), where a small depression caused a concentration of the soil moisture.

The location and crown spread of the larger woody species are shown in Fig. 5. The extensive crown spread of the hemlock is also indicated by the data in Table III.

The hemlocks average 37.7 inches in height with a crown spread of 29 × 24 inches and a diameter of stem at the base of .51 inches. The white pines are not as vigorous, having an average height of 14.2 inches, a crown spread of 12 × 7 inches, and a diameter of .23 inches. Apparently the conditions of moisture, light, and soil nutrients are more favorable for the growth of hemlock than they are for the growth of pine. Some of the broad-leaved species, such as gray birch, spiræa, and willow, are quite large.

The growth rate of the white pine on the trenched plot as shown in Table IV is, however, very slow in contrast with the growth rate of others of the same age in the unshaded open areas near by. In 1930 these pines in the open grew 12.3 inches; in 1929, 14.0 inches; and in 1928, 13.8 inches, a growth rate over five times as rapid as that of the white pines on the trenched plot.

The most important factor in accounting for this difference in growth rate is probably the much greater light intensity in the open as compared with the trenched plot. The intensity of light needed for germination and survival is much less than that needed for rapid growth. Even if there

TABLE III

HEIGHT, CROWN SPREAD, AND DIAMETER OF STEM AT THE BASE OF THE WOODY VEGETATION (EXCEPT RUBUS) ON THE TRENCHED PLOT (SEPTEMBER, 1930)

Number of square	*Species*	*Height (inches)*	*Crown spread (inches)*	*Diameter (inches)*
3	White pine	17	11 × 5	.2
3	White pine	19	24 × 15	.3
7	White pine	8	9 × 4	.1
10	White pine	18	16 × 13	.3
13	White pine	8	14 × 10	.2
15	White pine	16	4 × 3	.2
20	White pine	10	4 × 5	.2
24	White pine	19	10 × 11	.3
26	White pine	11	9 × 3	.2
27	White pine	9	12 × 7	.2
32	White pine	20	16 × 8	.3
32	White pine	17	8 × 12	.3
33	White pine	9	4 × 6	.1
40	White pine	26	18 × 12	.3
50	White pine	23	12 × 16	.3
58	White pine	23	22 × 11	.4
59	White pine	10	8 × 4	.1
59	White pine	12	9 × 7	.2
63	White pine	11	6 × 4	.2
72	White pine	3		
81	White pine	10	5 × 3	.1
Averages and total	21	14.2	12 × 7	.23

TABLE III (cont.)

Number of square	*Species*	*Height (inches)*	*Crown spread (inches)*	*Diameter (inches)*
12	Hemlock	52	50 × 44	.7
14	Hemlock	41	32 × 29	.6
35	Hemlock	20	10 × 15	.2
43	Hemlock	21	26 × 19	.3
47	Hemlock	40	30 × 18	.4
66	Hemlock	45	26 × 18	.5
70	Hemlock	32	24 × 18	.5
74	Hemlock	38	32 × 34	.6
75	Hemlock	33	22 × 19	.5
77	Hemlock	55	32 × 28	.8
Averages and total	10	37.7	29 × 24	.51
64	Balsam	11	10 × 10	.2
47	Spruce	11	7 × 6	.1
27	Aspen	24		.2
75	Aspen	32	5 × 2	.1
10	Gray birch	15	14 × 8	.3
46	Gray birch	45	20 × 22	.4
20	Spiræa (S)	35	14 × 10	.3 and .1
75	Spiræa (St)	32	12 × 10	.1
27	Willow	50	24 × 20	.4
78	Cherry	20	12 × 10	.2

were sufficient moisture and nutrients in the trenched plot for rapid growth, the light might still be inadequate for such growth. This is borne out by the fact that the hemlock, a more shade-enduring species, is growing much more rapidly on the trenched plot and is able to thrive better than the pine. However, increased root competition between the crowded plants on the trenched plot itself is undoubtedly an important cause in the slower growth rate of the pines on the trenched plot as compared with those in the open. This same root competition within the plot is probably also responsible for the slowing down of the growth rate of the pine from 1927 to 1930 (Table IV).

The amount of vegetation growing under the crowns of the small hemlocks on the trenched plot is noticeably less than that growing elsewhere

TABLE IV

HEIGHT GROWTH IN INCHES OF THE WHITE PINES ON THE TRENCHED PLOT (SEPTEMBER, 1930)

	1930	*1929*	*1928*	*1927*	*1926*	*1925*
	1.6	2.4	2.8	3.0	2.5	2.7
	1.8	2.5	1.6			
	2.8	2.6	3.1	2.4		
	2.0	3.9	3.5	3.9	3.5	2.7
	2.1	2.0	2.5	2.2	1.6	
	.8	2.0	2.0	1.4		
	2.4	2.2	2.4	2.0		
	1.3	2.4	3.0	3.0	3.0	3.1
	1.3	1.6	.9	1.2	2.3	
	1.4	1.8	1.8	1.3	1.6	
	2.3	3.7	3.5	3.9	3.5	3.0
	2.6	2.4	2.0	2.4	3.5	
	2.7	3.7	4.1	4.1	3.5	2.5
	2.6	3.0	3.4	3.7	2.6	
	.5	1.3	3.3	3.6		
	2.8	3.7	3.1	3.9	2.8	2.6
Average	1.94	2.58	2.69	2.80	2.76	2.77

on the plot (Fig. 4). These hemlock crowns are dense and close to the ground so that low light intensity beneath them may be an important factor in determining the lack of vegetation, though soil moisture probably also plays a part.

Comparison of trenched and untrenched plots.

The average height of the hemlocks (37.7 inches) and the white pines (14.2 inches) on the trenched plot is in distinct contrast with the average height of the conifers on the untrenched plot (2.6 inches). Whether all the conifers on the untrenched plot are the same age as those on the trenched plot is not known, but it seems reasonable to suppose that some of them are. The trenched and untrenched plots were essentially similar in 1922, and there has been little change in the number of conifers on the trenched plot. If the trees are the same age, and examination seems to bear this out, the difference in growth is strikingly evident. If they are not of the same age, the seedlings present on the untrenched plot in 1922 must have died and others come in, while those on the trenched plot survived. In either case the superior survival and growth conditions on the trenched plot are evident.

Succession occurring on the trenched plot (1922-1930). A distinct succession is noticeable in the vegetation on the trenched plot, from soon after trenching up to the present. The two outstanding features of this succession are (1) the increasingly mesic character of the vegetation, and (2) the change from a predominance of herbaceous vegetation to a predominance of woody vegetation.

Some herbaceous species present in 1922 increased immediately following trenching only to give way in the succession to the woody vegetation. This is particularly true of the grasses which were fairly abundant in 1922, increased markedly in 1923 and. 1924 (Figs. 9 and 10), only to begin falling off in 1925 (Table I and Fig. 13), although still with a high frequency percentage, and in 1930 to be represented by about half as many stalks and with a low frequency percentage. Almost none are visible in the 1930 photographs and those that remain are not thrifty. Bracken fern and lobelia followed much the same course as the grasses.

Sorrel is peculiar in that it was absent in 1922, came in in great abundance later on, and was still quite abundant in 1925, but had practically disappeared by 1930. Even when abundant (1925) it tended to be limited in its distribution to the edges of the plot (frequency 38.3 per cent) as shown in Figs. 4 and 6. Its appearance and distribution seem to be related to the disturbance caused by trenching.

The white violet, absent in 1922, came in in great abundance in 1925 and 1930, a mesic species apparently, though it has spread somewhat to the untrenched plots. Though locally very abundant, a few plants were found in almost every foot square (frequency 88.8 per cent) (Fig. 21).

Some woody or semiwoody forms, as blackberry, wintergreen, five-finger, and dwarf blueberry, which were present originally, increased markedly later in the succession. This is particularly true of blackberry which increased from only two plants in 1922 to 357 plants in 1930 (Fig. 19). These plants formed a great tangle and a high density of vegetation (Fig. 16) with a frequency percentage of 44.4 per cent. Wintergreen and five-finger, though not possessing a high degree of density, were widely distributed (59.2 and 65.4 per cent). Wintergreen was also abundant and widely distributed on the untrenched plot (Fig. 18).

A number of herbaceous species appeared late in the succession but now form a considerable part of the vegetation. This is especially true of the asters and goldenrods (Fig. 20) which average 22 inches in height. Star flower also appeared late. Many of the species appearing late in the succession are mesic forms.

The woody species present in 1922 have remained about the same in number though now very much larger, while those on the untrenched plot have become much fe\ver in number and have shown very poor growth.

The most striking change that has taken place has been the coming in, particularly late in the succession, of a number of woody species, some of which are distinctly mesic in character, such as balsam (Fig. 20), willow, ' meadowsweet" and black cherry. These have all shown good growth (Table III).

RESULTS AND DISCUSSION OF OTI-IER TRENCHING EXPERIMENTS

A NUMBER of other trenching experiments have been carried out on the Yale Den10nstration and Research Forest at Keene, N. H. These have been discussed by 'Tourney (1929) and Craib (1929). In one experiment (sample plot I) white and red pines planted in 191'7 were overgrown by a dense stand of gray birch which in 1920 was made up of 9,776 trees per acre varying in diameter from 1 to 5 inches. rfhe soil was a coarse sand. The photochemical light intensity under the gray birch was about $\frac{1}{8}$ of full sunlight. Twenty pines were trenched by driving a sharp spade vertically to its full depth into the soil in a three-foot circle around each of the pines. This was repeated each year. Thus the pines grew relatively free from root competition with the surrounding gray birch. rrhe average annual height growth of the 20 trenched pines was 14 per cent greater the first year after trenching than that of the 5S untrenched pines. This increased growth continued during the 4 years of the experiment and was considerably greater than the growth of the same trees before trenching.

In another experiment (sample plot 10) plots 6 X 6 feet were laid out under a dense 30-year-old white pine stand. There \vas practically no ground vegetation under this stand. The photochemical light intensity was $\frac{1}{64}$ of full sunlight. One plot was surrounded by a 3-foot-deep trench, the other was left untrenched.The soil moisture was higher in the trenched plot than in the untrenched plot. Three years after trenching there were 20 species of plants gro\ving on the trenched plot and only 7 on the untrenched plot. There were 32 plants per square foot on the trenched plot and 4 per square foot on the untrenched. Removal of the litter from half of each plot had a very favorable effect on the germination of white pine seed and on the migration into the plot of the ground vegetation.

In a third experiment (sample plot 27) 9 X 9 foot plots were laid out in a 41-60-year-old white pine stand. One plot was trenched, the other left untrenched. At the end of two years there were 17 species present on the trenched plot and 8 species present on the untrenched plot. The number of individuals was considerably greater on the trenched plot (39 per square foot) than on the untrenched plot (8 per square foot).

It is only by the carrying out of many experiments under many different climatic and soil conditions and with different forest types that the whole truth regarding the relative importance of light and soil moisture in their effect on the surface vegetation can be determined. Such experiments have been carried out or are under way in several parts of the United States and Europe, and these will be referred to as far as they are known to the authors.

Baldwin (1930) has established 2 plots (each 2 milacres in extent) in a 75-year-old fully stocked stand of red spruce in northern New Hampshire. One plot was surrounded by a 2½-foot-deep trench in October, 1925, the other was left untrenched. The roots were all confined to the upper foot of soil, a condition differing materially from that of white pine stands at Keene in southern New Hampshire. Retrenching occurred in 1926 and 1928. The soil was fine sand overlaid by 9 inches of dark brown loam and a 4-inch layer of humus, high in acidity. The surface of the plots was sparsely vegetated with spruce and fir reproduction, *Polytrichum* moss, and a few herbs, *Coptis trifolia* being most abundant.

Practically no change has taken place on the untrenched plot in the 5 years since its establishment. A few seedlings have come in and the older ones have died. The trenched plot on the other hand supports a much richer flora now than before trenching. Many herbaceous and woody species have migrated into the trenched plot, mosses and *Lycopodium* are flourishing, and the conifer seedlings are thrifty, of good color, and beginning rapid height growth.

Barr (1930) established trenched plots on the same area in British Columbia in which Griffith worked, and his results may be summarized in his own words (*op. cit.*, page 34) : "Trenching improved conditions for germination in the humus soil, but results are not clear on the mineral soil." He makes no statement as to the effect of trenching on the surface vegetation.

The work of Griffith (1927) (cited by Barr) done in British Columbia consisted of plots, trenched and untrenched, laid out in a mature spruce-balsam stand on both raw humus and mineral soil. He found that two years after trenching there was no apparent effect on the germination of a natural seed supply on humus, whereas the number of seedlings on mineral soil was increased. Trenching greatly increased the abundance and thriftiness of the surface vegetation on the humus.

In the Knysna forests of South Africa, Phillips (1928) has determined the effect of canopies of *Acacia melanaxylon* (Tasmanian blackwood) of varying degrees of density on the growth of potted tree seedlings of various species. These potted seedlings were free from root competition with the canopy trees and were given ample water. The results varied from vigorous growth in 1/25 of full light (as measured by the Clements' photometer) to poor growth with no increment in 1/600 of full light. Where root competition was strong, reproduction was sparse and poorly developed under canopies of 1/10 to 1/40 of full light. Germination was good but establishment poor under conditions of root competition, whereas both germination and establishment were good where there was sufficient moisture. Although root competition is of great importance, a minimum intensity of light is also necessary for vigorous reproducti9n.

Hesselman (1929) in Sweden has established trenched plots of large size in very open Scotch pine stands on poor sandy soiL After two years these trenched plots show little effect on increasing the vigor and growth of the surface vegetation. It is believed, however, were the stands denser in which the trenched plots were established, the effect would be more apparent. Furthermore, the soil moisture in this Scotch pine stand, due to its low density, may be such that deficiency does not arise and, consequently, trenching to cut off root competition is ineffective in its influence on the vigor and growth of the vegetation on the forest floor. Poor root development due to low nitrogen content of the soil and the attacks of pseudo-mycorrhiza are probably also factors (Moore, 1930).

Pearson (1930a, 1930b) has established trenched plots in the western yellow pine forest type in Arizona, but the "unthrifty seedlings on trenched plots have failed to respond after four years." He explains this as due to the fact that, although "under certain conditions root competition may be the limiting factor," in the case of the plots under experiment as well as in the case of three fourths of the western yellow pine in Arizona, the species is growing below its optimum temperature conditions and the heat of solar radiation is necessary for growth. Hence, even though trenching may increase moisture content, an increased heat increment is like\vise necessary.

An interesting recent study bears on this problem of light and soil moisture relations in the forest, even though it does not involve trenching experiments. Daubenmire (1930), in attempting to determine why stands of beech-maple in western Indiana support an abundant surface vegetation on the forest floor and near-by hemlock stands are almost wholly bare of surface vegetation, found evaporation and light intensity much the same in both. He regards low soil moisture and high soil acidity in the hemlock stand as responsible for the lack of vegetation. This would appear to be a favorable situation for trenching experiments.

Shirley (1930) has recently established large numbers of trenched plots in the aspen and jack pine forests of Minnesota. These plots should in time yield valuable results.

SUMMARY

TRENCHED and untrenched plots were established in 1922 under a mature stand of white pine near Keene, N. H. Trenching severed all of the roots of the surrounding white pine, so the trenched plot was free from root competition with them in contrast with the untrenched plot. Light, needle cover, and vegetation were the same on both plots. Trenching was repeated in 1924, 1926, and 1928.

1. Over 800 roots from the surrounding pines were severed in the initial trenching process. Of this number, 71.5 per cent were located in the upper foot of soil, 25.8 per cent in the second foot, and 2.7 per cent in the third.
2. Between the retrenching of 1924 and that of 1926, 136 roots had grown through the trench into the trenched plot. Fifteen of these were found to have grown into the trenched plot an average distance of 49.5 inches.
3. The soil was a fine to a coarse sand, slightly acid in reaction, with a relatively low content of organic matter.
4. Chemical light intensity three feet above the surface of the plot was 7 per cent of full sunlight.
5. During the driest months of the year soil moisture was from two to nine times as great on the trenched as on the untrenched plot. Soil moisture occasionally fell below the wilting coefficient on the untrenched plot. It never fell below on the trenched plot.
6. In 1922 both plots were essentially alike in their sparse cover of vegetation. The vegetation was chiefly grass and moss with some tree seedlings.
7. One year after establishment (1923) showed a great increase in luxuri-

ance of the vegetation on the trenched plot. No essential change on the untrenched plot.

8. Two years after establishment (1924) showed still greater luxuriance of the vegetation on the trenched plot, with new species of broad-leaved herbs coming in. No essential change on the untrenched plot.
9. Three years after establishment (1925) both plots were recharted. The trenched plot increased in species from 12 in 1922 to 27 in 1925; in individuals, from 388 in 1922 to 639 in 1925.
10. Eight years after establishment (1930) both plots were recharted. The trenched plot had increased in species from 27 in 1925 to 31 in 1930; in individuals, from 639 in 1925 to 1,882 in 1930.
11. The untrenched plot had changed little in size or number of individuals from 1922 to 1930. In fact, it had decreased considerably during certain years.
12. On the untrenched plot there had been a decrease in number of species from 12 in 1922 to 7 in 1925, and an increase to 25 in 1930. This was due undoubtedly to an increased root competiti?n shortly after trenching, followed by a migration of the large number of species within the plot in later years to the adjacent untrenched plot. Most of the individuals on the untrenched plot were snlall and unthrifty, however.
13. The density of the vegetation on the trenched plot was 80 per cent, ,vhereas that on the untrenched plot was 8.1 per cent.
14. The hemlocks on the trenched plot averaged 37.7 inches in height, \vhereas the vegetation on the untrenched plot averaged 2.5 inches.
15. The great differences in abundance, size, and vigor of the vegetation on the trenched and untrenched plot appear to be due chiefly to increased moisture content on the trenched plot arising from the lack of root competition with the surrounding pines.
16. The hemlock grew better on the trenched plot than did the white pine, probably due to the soil nl0isture and light conditions being more favorable for the growth of the former.
17. A distinct succession occurred on the trenched plot from 1922 to 1930. The chief points in this succession are:
    a. An increased luxuriance-abundance, density, and number of species-during that period.
    b. The gradual change from a complete dominance of herbaceous vegetation to an increasing dominance of woody vegetation.
    c. The gradual coming in of mesic species such as violet, balsam fir, ,villow, etc.

IS. Some species, important at first (grass, *Lobelia)*, had almost completely disappeared by 1930.

19. Some species, absent at first, came in later, but have now almost disappeared (sorrel).

20. Some species, absent at first, came in later in very large numbers and have remained (white violet, aster, goldenrod).

It appears from these investigations that the presence or absence of surface vegetation under living canopies is due to a complex of factors of which light 'is only one, but of which soil moisture is also one. In many cases soil moisture appears to be more effective in preventing the establishment of surface vegetation than light. It also appears that the rate of growth of species such as hemlock and white pine, when relieved from root competition when growing under canopies, have different relative rates of growth than when grown in the open. Under natural canopies hemlock makes the more rapid growth, while in the open the reverse is true. This indicates a difference in the light requisite for equal gro\vth.

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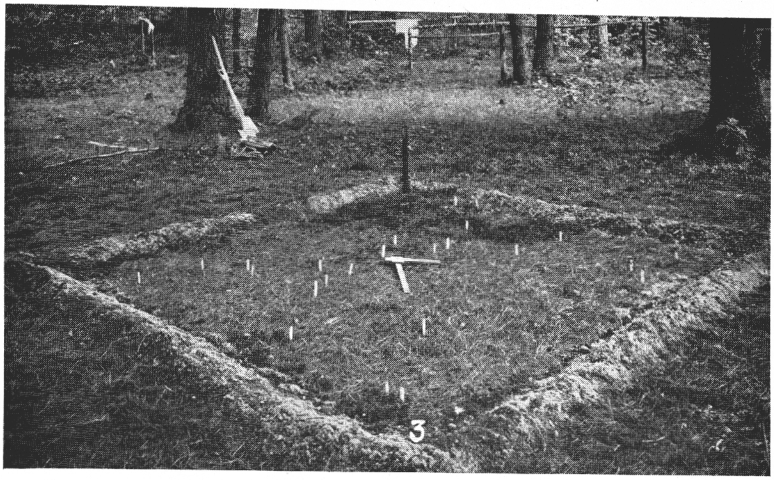


Fig. 7. **Trenched** plot soon after trenching (August, 1922). Corner 3 in the foreground. Moss and grasses make up most of the sparse vegetation. The labels indicate the position of white pine and hemlock seedlings.

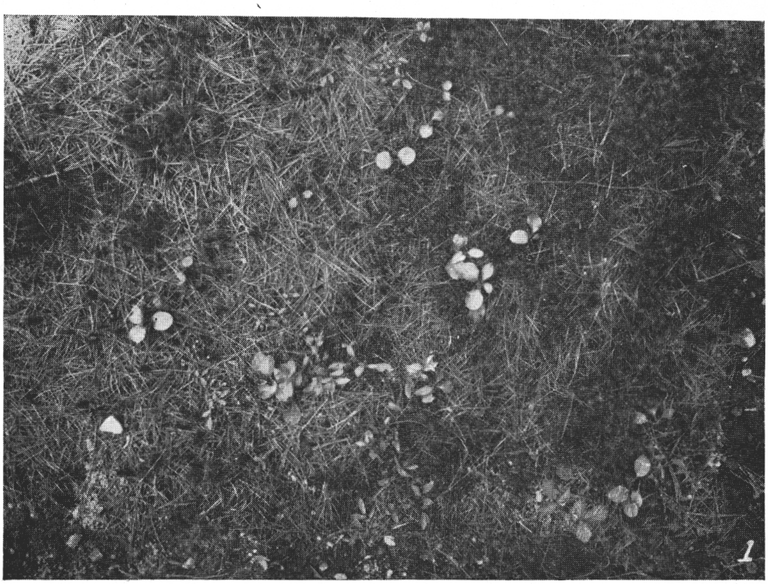
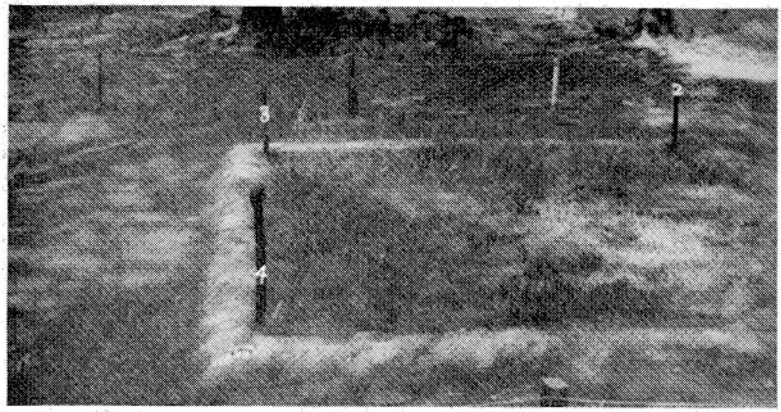


Fig. 8. Vertical view of vegetation on **trenched** plot at corner 1. Dotted lines in Fig. 2 indicate approximate area covered by the photograph. The sparse vegetation visible in the photograph is composed of pigeon wheat moss, blueberry, grass, blackberry, wintergreen, and a white pine seedling. (August 5, 1922.)



]'ig. 9. **Trenched** and **untrenched** plots one year after trenching (September, 1923). Nate the abundance and luxuriance of the grass ·and moss on the trenched plot compared with the ·untrenched plot. Corner 4 in the foi-eground.

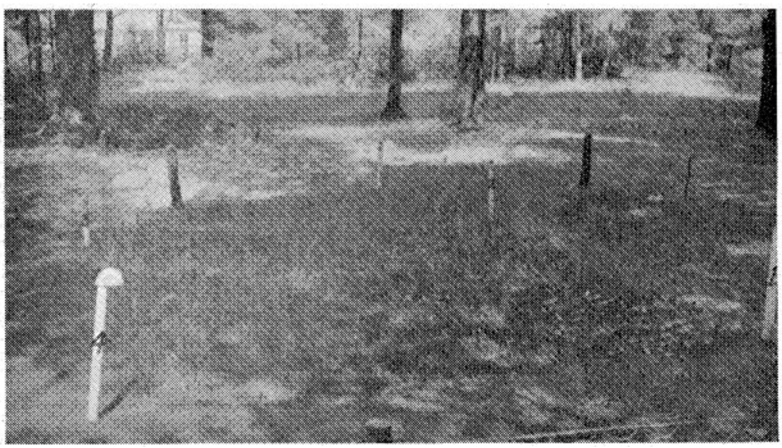


Fig. 10. **Trenched** plot and part of **untrenched** plot 2 years after trenching (July 30, 1924). The grass and moss have increased in abundance and luxuriance and the blackberry, goldenrod, and other species are coming in corners 4 (left) and 1 (right) in the foreground.

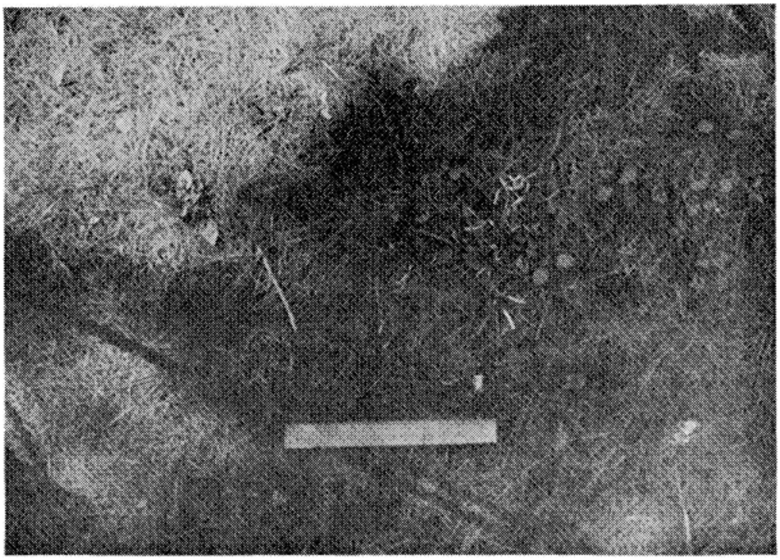


Fig. 11. Vertical view of **untrenched** plot showing sparse vegetation of blackberry, wintergreen, sedge, and aster. Compare with Figs. 8 and 12. (July, 1924.)

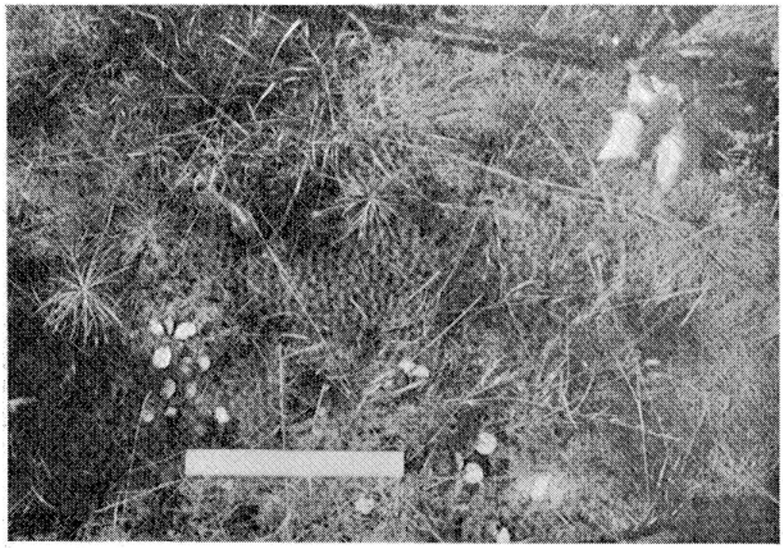


Fig. 12. Vertical view of vegetation on **trenched** plot. Dotted lines in Fig. 3 indicate approximate area covered by the photograph. Very abundant moss, grass (chiefly *Danthonia spicata*), gray birch, white pine, and wintergreen are visible. Compare with Figs. 11 and 19. (July, 1924.)

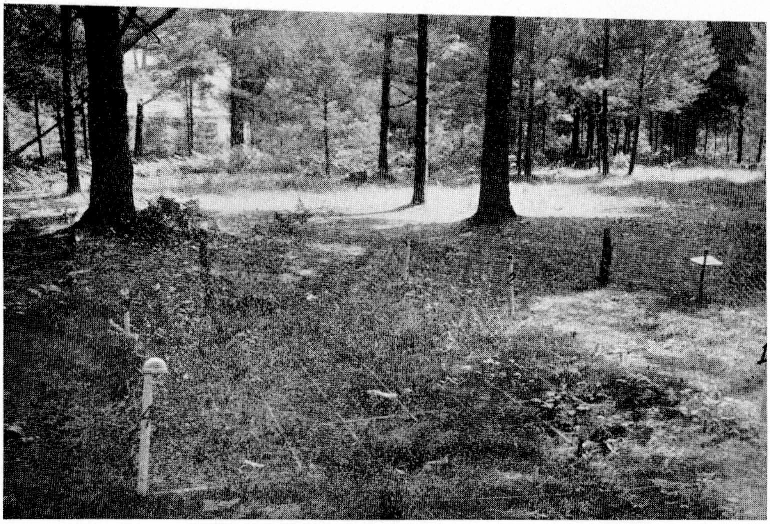


Fig. 13. **Trenched** and **untrenched** plots 3 years after trenching (July 23, 1925) with corners 4 (left) and 1 (right) in the foreground. Taken from same position as Fig. 10. Note increase in moss and in herbaceous species other than grasses.

Fig. 14. Close up view of the boundary between **trenched** and **untrenched** plots. Corner 4 in the foreground, corner 3 in the background. Note distinct contrast between trenched and untrenched plots. Willow, goldenrod, aster, gray birch, violet, etc., visible on trenched plot. No conifers conspicuous as yet. (1925.)

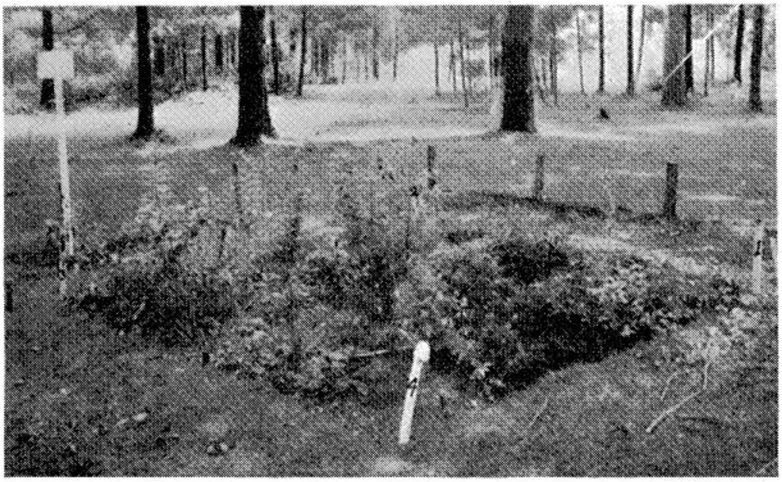


Fig. 15. Trenched and untrenched plots 6 years after trenching (1928). Corner 4 in foreground. Note increased size and diversity of the vegetation on the trenched plot. Hemlock and white pine becoming conspicuous.

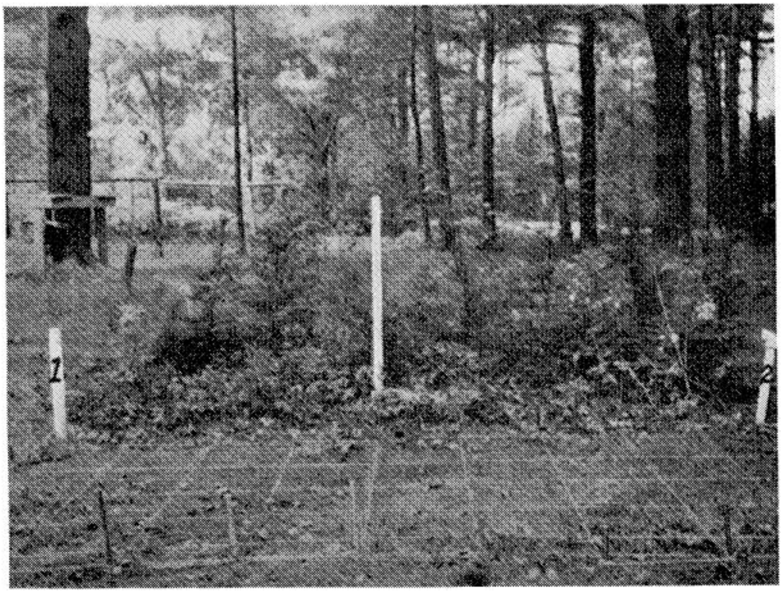


Fig. 16. General view of trenched plot looking over the untrenched plot. Eight years after trenching (September 22, 1930). Corners 1 (left) and 2 (right) in the foreground. The caliper is 36 inches long. Note the abundance of blackberry and the size and luxuriance of the hemlock trees. The sparseness of the vegetation on the untrenched plot is in distinct contrast with that on the trenched plot.

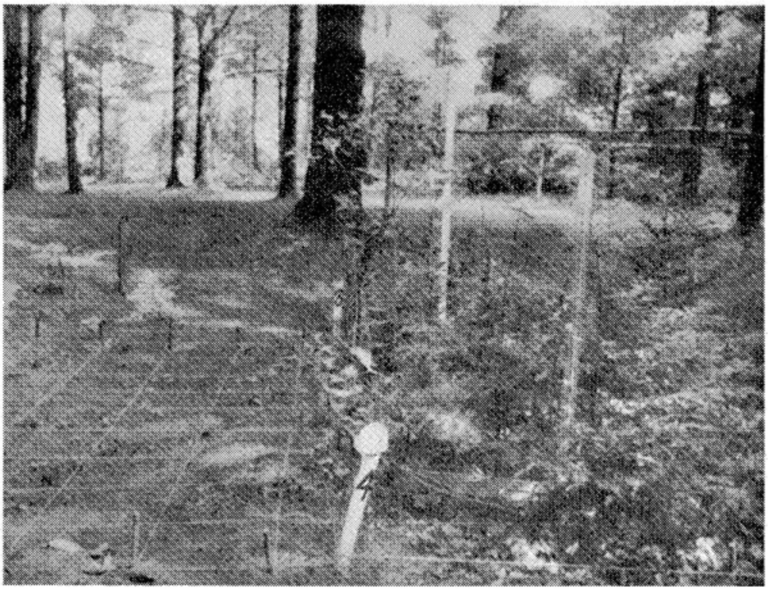


Fig. 17. Boundary between the **trenched** and **untrenched** plots (Septelnber 22, 1930). The caliper is 36 inches long. lIemlock, white pine, willow, gray birch, goldenrod, and violet can be identified in the photograph.

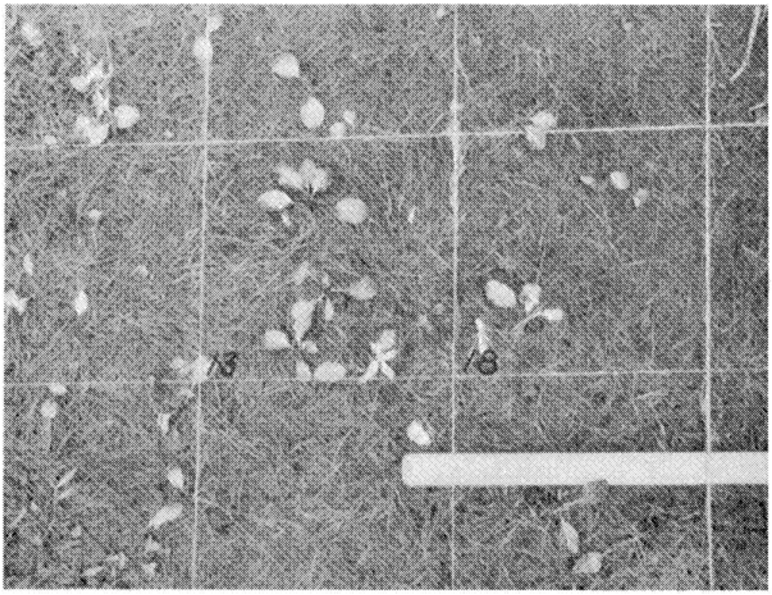


Fig. 18. Vertical vie'w of the vegetation on the **untrenched** plot (September 22, 1930). The numbered squares correspond to those given in Fig. 6. \Vintergreen, star flower, and blueberry are visible. Compare with Figs. 19, 20, and 2 I.

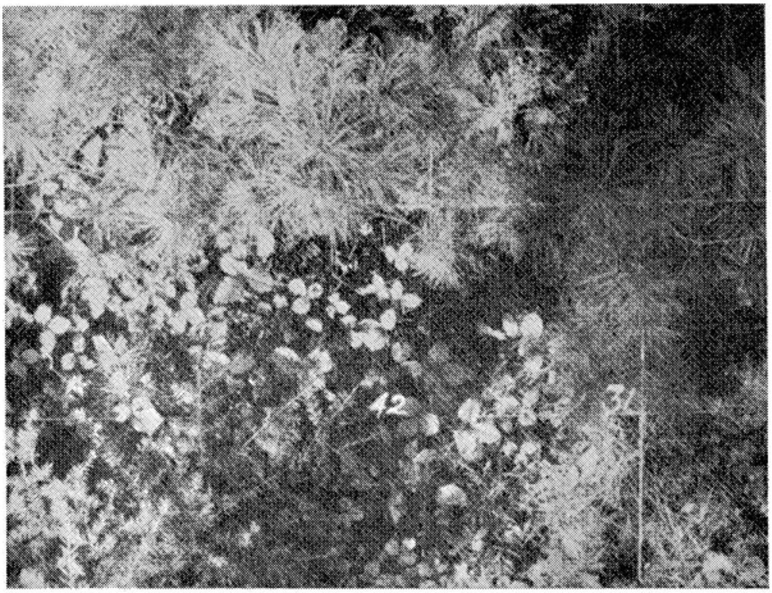


Fig. 19. Vertical view of the vegetation on the **trenched** plot (September 22, 1930). The numbered squares correspond to those given in Fig. 4. White pine, hemlock, blueberry, white violet, and wintergreen are visible.

Fig. 20. Vertical view of the vegetation on the **trenched** plot (September 22, 1930). Smooth goldenrod, arrow-leaved violet, steeplebush, white aster, and balsam fir are visible. The numbered squares correspond to those given in Fig. 4.

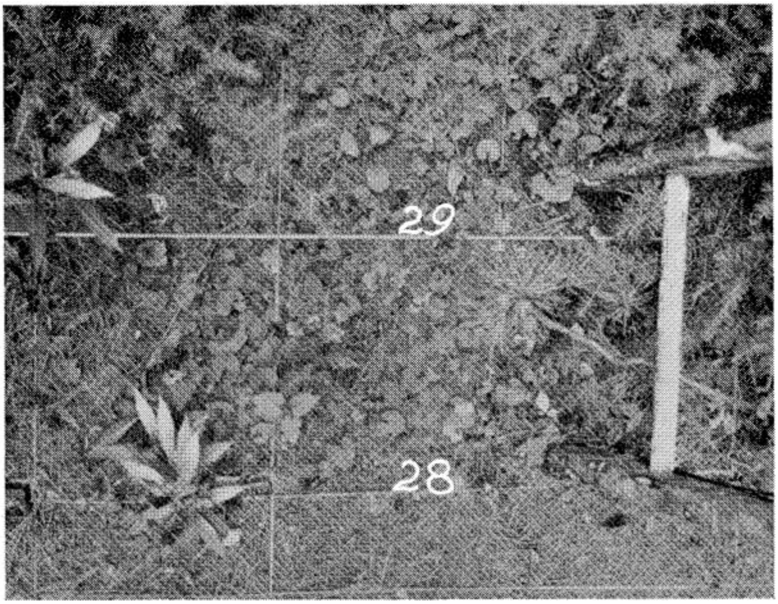


Fig. 21. Vertical view of the vegetation on the trenched plot (September 22, 1930). Showing the abundant growth of white violet. Hairy goldenrod, hemlock, a gray birch seedling, white pine, five-finger, and wintergreen can also be identified. The numbered squares correspond to those given in Fig. 4.

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