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Amount and Chemical Composition of the Organic Matter Contributed by Overstory and Understory Vegetation to Forest Soil

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AMOUNT AND CHEMICAL COMPOSITION OF THE ORGANIC MATTER CONTRIBUTED BY OVERSTORY AND UNDERSTORY VEGETATION TO FOREST SOIL

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1955

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AMOUNT AND CHEMICAL COMPOSITION OF THE ORGANIC MATTER CONTRIBUTED BY OVERSTORY AND UNDERSTORY VEGETATION TO FOREST SOIL

INTRODUCTION

INTEREST in forest litter on the North American continent has been centered primarily around effects upon such factors as fire hazard or seedbed conditions. Some investigators, however, have considered the possible harmful effects of indiscriminate destruction or removal of such litter on the productivity of forest sites. This has been particularly stressed in connection with the use or misuse of fire in forests (Heyward and Barnette 1934, Isaac and Hopkins 1935, Lunt 1937, Donahue 1942, Jemison 1943, Burns 1949).

In Europe, the situation has been somewhat different. There, due to the relatively small per capita area of forested land, standards of utilization have been very high. One of the forest products so used has been the litter. Dead branches and twigs were used for fuel, and leaf and needle litter collected for animal bedding or mulches for crops. In some cases, these products of the forest were as highly regarded as the wood itself.

The removal of forest litter year after year in some areas finally alarmed European foresters. Evidence became available that indicated site deterioration due to loss of litter. Starting at the beginning of the nineteenth century, foresters began writing about the evils of litter removal. Most of these earlier articles, however, were based largely on general observation, and it was not until 1876, when Dr. Ernst Ebermayer published "Die gesammte Lehre der Waldstreu mit Riicksicht auf die chemische Statik des Waldbaues," that a definitive work was available. This publication was based on a series of experiments started in Bavaria in the early 1860's where litter was removed, weighed, and partially analyzed from some areas, and adjacent areas were kept intact for controls. Research along such lines has been continued in Europe up to the present time (Ramann 1890, Rebel 1920, Nemec 1933, Wiedemann 1937, Anon. no date).

In America, interest in forest litter has been growing among foresters, ecologists and soil scientists. This litter is the parent material of humus in forest soils and has a major role in soil formation. It represents a storage of the chemical plant nutrients of a site, and can contain much of the nutrient capital of an area in a form unavailable to plants if decomposition is retarded. For these reasons and many others, the forest litter is of interest to biologists studying forest communities.

A number of investigations, which are reviewed in succeeding sections, have been made to determine the amount and chemical composition of the annual litter deposited by tree species in forested areas. However, relatively little work has been done to discover the possible importance of the litter of subordinate vegetation on such areas. This group of plants may make a more significant contribution to the total forest litter than is commonly believed.

The present investigation was undertaken to compare the quantity and chemical composition of the litter of subordinate vegetation in forests with that derived from the overstory of trees.

REVIEW OF LITERATURE

VARIATION IN CHEMICAL COMPOSITION OF PLANTS

BEFORE reviewing the research on the annual increment of organic matter to forest soils, it might be advisable to summarize briefly some of the work done in regard to differences in chemical composition of plants. In this way it may be easier to interpret some of the variations discussed later.

Without going into details, it can be stated that terrestrial plants generally absorb their nutrient ions from the soil solution and from the individual colloidal particles in the soil. This absorption is usually carried on, at least up to certain levels, in proportion to the availability of nutrients for absorption by the particular plant involved. Plants will even absorb elements such as gold and silver from the soil if such elements are available, although these minerals have no known nutritional value to plants. Generally, the greater the abundance of a given nutrient in the substratum, the higher will be the concentration of that nutrient in plants growing on the substratum (Will 1882, Krauss 1926, Auten 1930, Wittich 1933, Gast 1935, Mitchell and Chandler 1939, Romer 1940, Finn 1942, Finn and Tryon 1942, Wilde, Nalbandov, and Yu 1948). However, there is apparently a maximum level of nutrients beyond which there is no greatly increased uptake by plants (Mitchell and Chandler 1939).

It should not be concluded that plants absorb soil nutrients in a completely indiscriminate manner, dependent only on availability. There is information showing that species differ in ability to take up nutrients. For example, Mitchell and Finn (1935), in experimenting with increments of rock phosphate to forest soil, indicated that, within the range of their work, leaves of red maple[1] contain approximately twice as much phosphorus as the leaves of red oak. Chandler (1939) found that certain forest tree species influenced the characteristics of the soil on which they grew and concluded that the chemical variations were due to differences in the calcium content of the tree leaves.

Forest tree species have been divided into three general groups by Mitchell and Chandler (1939), according to requirement and content of nitrogen in foliage. Lutz and Chandler (1946) prepared a similar listing, based on calcium content of foliage, of the forest tree species in the eastern United States, combining the results of several investigators; they presented data which indicated that the nutrient content of the foliage of a given species tended to remain similar over an extended

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[1] Tree species are referred to in text and tables either by their common or scientific names; species in the understory vegetation are referred to by their scientific names. The reader will find a complete list of all species in the appendix.

geographical range. It has also been demonstrated that varietal differences within a species may be associated with variations in the chemical composition of the leaves (Boynton and Compton 1945). Numerous other examples of specific differences in foliar chemical content can be found in the literature.

In addition to species differences, there are other factors which may influence the chemical composition of foliage. It would appear reasonable to assume that a plant would require root and crown space commensurate with its inherent needs in order fully to utilize a normal amount of nutrients. In fruit trees it has been found that the condition of the roots and conducting tissue has an effect on the nutrient content of the foliage (Boynton and Compton 1945). It is quite possible that any injury or undue competition would influence the amount of nutrients in leaves, due to the metabolic changes thus induced. Therefore, the content of nutrient ions in leaves injured by insects or sprays differs from that of normal leaves (Boynton and Compton 1945).

The nutrient content of leaves appears to change with the age of the leaves. Working with deciduous species, Mitchell (1936) found that during the growing season the amount of nitrogen, phosphorus, and potassium, based on percentage of total dry weight, decreased quite rapidly but became relatively constant during the period before yellowing. Calcium, however, increased steadily throughout the entire growing season. If absolute amounts were used in place of percentages of dry weight, all these elements increased up to the time of yellowing, when a decrease was observable in nitrogen, phosphorus, and potassium, but not in calcium.

Chapman (1941), working with young rubber trees, found that there was a fairly constant decrease in percentage of nitrogen and phosphorus from the newly formed leaves of the uppermost whorl of a tree toward the lower and older whorls at the base, thus augmenting Mitchell's findings.

Alway, Maki, and Methley (1934), dealing with nine hardwood tree species in the Lake States, found that total ash, calcium and magnesium, expressed as a percentage of dry weight, increased throughout the growing season from June 1 to the time of leaf fall in October, whereas phosphorus, potassium, sulphur, and nitrogen decreased during the same period.

There is also evidence that there are differences in chemical content between leaves exposed to full light and those which develop in some degree of shade (Gutschick 1940)' Mitchell (1935) made this same point in reference to the technique of sampling leaves in connection with a system for determining the nutrient needs of shade trees.

Even diurnal variations occur in the chemical composition of leaves. Chapman (1941), who was concerned with leaf sampling to determine nutrient needs of rubber trees, believed that all samples for a given comparison should be taken within a relatively brief period during one day. Thomas (1945), on the other hand, stated that diurnal variations are too small to be appreciable over a 24-hour period.

Thus far the discussion has been limited to foliage of trees because their leaves usually constitute the major portion of the organic material deposited annually on forest soils. However, there is, even in intensively managed forests, a certain amount of wood and bark, chiefly from the smaller branches, incorporated in the forest floor each year. Since this factor enters the present research to a minimum extent, it will be noted only in passing. Investigations have shown that, as a rule, plant parts differ markedly in their content of ash, expressed as a percentage of dry weight. Theymay be arranged in order of decreasing ash content as follows: leaves> bark> branch wood>wood in stems of trees (Will 1882, Henry 19°8, Dengler 1935). In individual species and in the case of certain elements, this order may be altered, especially with respect to leaves and bark. Presumably most elements would follow the general trend expressed by ash content.

Councler (1886) found that the wood of fir was highest in ash, with spruce intermediate and larch lowest. With respect to the ash content of the bark, the species could be arranged in descending order as follows: spruce, larch, and fir. Busgen and Munch (1929) reported that the variation in ash content between wood of different ages, in identical environments, was greater than the variation in ash content between woods of the same age in different environments. In other words, age made more difference than site in determining the chemical composition of the wood.

The evidence cited above merely serves to bring out the extreme variability in the chemical content of the organic material deposited on the forest floor. Species, site, and age differences are probably the most important factors in determining these differences, but other factors may also play an important role.

AMOUNT OF ORGANIC DEBRIS IN FORESTS

The weight or bulk of the forest floor is of interest from the standpoint of seedbed conditions, influence on surface run-off of water, and as a source of fuel supply for fires. The amount of debris, however, is only one factor in determining the amount of plant nutrients in forest litter. Nevertheless, it is a logical starting point for research in this field, for without this measurement, chemical analysis of litter loses much of its value. Although it may be interesting to know the chemical composition of the leaves of the various species in a stand, it is impossible to arrive at quantitative results concerning the annual return of nutrient materials to the soil unless the total weight of the leaf fall per unit area is determined. Similarly, of course, data on the weight of the litter alone, without knowledge of its chemical composition, also leave much to be desired.

Annual Litter Fall

The following table summarizes, in chronological order, some of the principal investigations on this subject. In each case, the original data have, where necessary, been recalculated in terms of pounds per acre.

TABLE I. WEIGHT OF FOREST TREE LITTER ANNUALLY REACHING THE SOIL

Reference	*Forest type*	*Age (years)*	*Locality*	*Annual litter fall. lbs/acre dry weight*
Ebermayer (1876)	European beech	30–60	Bavaria	3,028
	European beech	60–90	Bavaria	3,031
	European beech	90	Bavaria	2,443
	Norway spruce	30–60	Bavaria	3,032
	Norway spruce	60–90	Bavaria	2,582
	Norway spruce	90	Bavaria	2,946
	Scots pine	25–50	Bavaria	2,629
	Scots pine	50–75	Bavaria	2,702
	Scots pine	75	Bavaria	3,272
Ebermayer (1890)	European beech	—	Bavaria	3,028
	Norway spruce	—	Bavaria	2,706
	Scots pine	—	Bavaria	2,867
Danckelmann (1887)	Scots pine	all	Prussia	1,710–2,970
Hursh (1928)	Mixed hardwood	—	Southern Appalachians	4,000 (estimated)
Alway and Zon (1930)	Jack pine Norway pine	50	Minnesota	2,006
	Norway pine	100	Minnesota	2,282
	Jack pine	30	Minnesota	2,152
	Norway pine White pine	250	Minnesota	1,994
	Jack pine	55	Minnesota	2,086
Sims (1932)	Pine–oak	—	Southern Appalachians	2,600–3,100
Morgan and Lunt (1931)	White pine Norway pine	27	Southern New England	2,000–3,000
Heyward and Barnette (1936)	Longleaf pine	—	Florida	2,755
	Slash pine	—	Florida	3,517
Romell (1939)	Norway spruce (including moss and blueberry understory)	—	Northern Sweden	1,377

TABLE I. WEIGHT OF FOREST TREE LITTER ANNUALLY REACHING THE SOIL *(continued)*

Reference	*Forest type*	*Age (years)*	*Locality*	*Annual litter fall. lbs/acre dry weight*
Kittredge (1940)	Canary pine	30	California	5,954
Auten (1941a)	Black locust	9	Ohio	2,600
	Sassafras	12	Ohio	2,600
Chandler (1941)	Mixed hardwood	30–70	New York	2,571–2,807
Mork (1942)	Norway spruce	40	Norway	2,970
	Norway spruce	60	Norway	1,695
	Norway spruce	140	Norway	1,319
	Norway spruce	200	Norway	717
	Birch	50	Norway	1,688
	Birch	100	Norway	719
Chandler (1944)	White pine Red pine Norway spruce Red spruce Eastern hemlock White cedar Balsam fir	—	Northeastern United States	2,463
Kittredge (1948)	Ceanothus-chamise	16	California	2,260
	Canyon live oak	55	California	1,819
	Manzanita	—	California	2,481

The weights of annual leaf fall given in the table above vary considerably, as might be expected with a wide range of species, age, site, and stocking. The effects of these factors will be discussed in subsequent sections. It may be pointed out that the data set forth represent averages of several years and, in most cases, several stands; they do not show the extreme variability in leaf fall from plot to plot and year to year, which is evident when the original data are examined. For example, Ebermayer (1876) reported the following data for a 36-year-old stand of pure Norway spruce on site class IV:

Year	*Yearly leaf fall, lbs/acre (air dry)*
1	5,652
2	3,447
3	2,422
4	2,154
5	2,834
6	1,936
7	2,938

The difference between the first and sixth years is nearly 200 percent.

Alway and Zon (1930) showed that a considerable difference existed between experimental sample plots during the same year and between years on the same plot, in the latter case, up to 24 percent. Kittredge (1948) found 100 percent difference in weight in successive years in the Ceanothus-chamise type in California.

Some of the variation noted above may be due to faulty technique in sampling. In order to collect litter it has been common practice to put down some type of artificial surface, such as burlap or screening, in order to separate the new leaf fall from that already on the forest floor. Another method consists of raking away all existing litter down to the mineral soil and then collecting the fresh litter when it falls. Either method disturbs natural conditions and the subsequent catch may not be an accurate measure of what falls. Because of the difficulty of accurately separating freshly fallen litter from old litter on the ground, it is nearly impossible to avoid this criticism. Methods have been devised by Kittredge (1944) and Cummings (1941) for estimating the amount of foliage on individual trees, but this is impractical in the problem under discussion.

In view of the fact that all investigations seem to point to a substantial variation in leaf fall within a given stand and from year to year, and since the magnitude of these variations is difficult to explain on sampling grounds alone, it seems certain that the amount of organic matter reaching the forest floor from year to year is not a constant value.

Influence of Stand Age on Litter Production

There is evidence to show that leaf fall decreases with increasing stand age. For example, the data from Mork (1942) in Table 1 indicate that in stands of both Norway spruce and European birch there is a decrease in weight of annual litter production as age increases, although the effect is confounded with elevation in this particular case. The following data for Scots pine, presented by Danckelmann (1887), illustrate the variation in amount of litter produced by stands of different ages:

Age (years)	*Annual leaf fall, lbs/acre (air dry)*
21- 40	2,184
41- 60	2,093
61- 80	2,002
81-100	1,820
100	1,729

The above table is indicative of the weight of leaf litter on medium to poor sites; the influence of age was less evident on good to medium sites.

The data from Ebermayer (1876) in Table 1 indicate a decrease in weight of annual leaf fall for European beech with increasing age, but the data for Scots pine show a reverse trend. Data reported by Alway and Zon (1930) also indicate that coniferous stands in the Lake States may have a diminishing annual leaf fall as they increase in age. Other authorities, such as Rebel (1920) and Kittredge (1948) agree that this trend is usually evident.

Influence of Site Quality on Litter Production

As might be expected, research has shown that variation in site quality has an influence on amount of litter fall in much the same fashion that site influences wood production. Ebermayer (1876) presented evidence showing that leaf size of European beech is reduced with decreasing site quality; in this case, site quality was inversely correlated with elevation above sea level. At an elevation of 133 meters above sea level, 1,000 beech leaves had an area of 3.414 square meters, while at 1,344 meters above sea level 1,000 leaves had an area of only 0.910 square meters. This change represents a reduction in average leaf size of over two-thirds.

Mork (1942) also presented data, compiled in Table 1, which indicated that increasing elevation, hence decreasing site index, reduced annual litter fall in both Norway spruce and European birch.

The following data are taken from Danckelmann (1887) and refer to normally stocked pure stands of Scots pine:

Age (years)	*Good to medium sites, litter fall, lbs/acre (air dry)*	*Medium to poor sites, litter fall, lbs/acre (air dry)*
21- 40	3,003	2,184
41- 60	2,912	2,093
61- 80	2,912	2,002
81-100	2,821	1,820
100	2,730	1,729

These data clearly show a difference in weight of litter fall between the two site groups and also bring out the interesting fact that age has more effect on litter weight on poor sites than on good sites.

In central New York, hardwood forests produced more leaf litter on good sites than was produced on poorer sites, although the difference was not large (Chandler 1941).

Ramann (1890) found that, on better sites, Scots pine had an average annual needle fall of about 2,421 pounds per acre and on poorer sites only about 1,615 pounds per acre. Rebel (1920) also indicated that leaf fall decreased with decreasing site index, as indicated by increased elevation above sea level.

In general, all investigators seem to agree that under comparable

TABLE 2. PERIODICITY OF LEAF FALL IN FOREST STANDS

Source	*Locality*	*Species*	*Age (years)*		*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*August*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
					Percentage of total											
					Dec.–Jan.	*Feb.–Mar.*										
Danckelmann (1877)	Prussia	Scots pine	55		4	1		3	3	7	6	6	41	24	5	
	Prussia	Scots pine	75		1	2		1	2	4	8	2	51	11	13	
Mork (1942)	Norway	Norway spruce	40	1940–1941	0.9	2.2	6.8	2.3	10.7	16.8	10.6	3.1	15.6	4.9	8.2	9.0
				1941–1942	2.1	1.8	6.7	2.6	9.1	17.7	13.6	4.0	9.6	23.1	6.4	3.3
New Hampshire Agric. Exp. Sta. (1932)	New Hampshire	Old conifers	—							8.1	6.5	6.2	16.2	53.7	9.2	
		Mixed hardwood	—							2.2	3.4	1.7	4.6	79.1	9.0	
		Gray birch	—							6.2	13.1	62.8	17.9			

conditions the amount of annual litter fall will be quite closely correlated with the general productivity of the site. Since the foliage is merely one part of the total organic matter produced on an area, this is a reasonable situation.

Periodicity of Litter Fall

Leaves or needles do not all fall from the trees at one time or even over a relatively short period of time. Individual species may show a difference in season and periodicity of leaf fall and the same species may not exhibit exactly the same tendencies from year to year, as is shown in Table 2. The data from the New Hampshire Agricultural Experiment Station are not for the entire year and therefore may not be completely appropriate for the present purpose; however, they do cover the months of greatest leaf fall.

It can be observed from the data that the general trend is for most of the leaf fall to occur in the autumn months. Conifers, however, tend to deposit litter on the soil throughout the year, The data on Norway spruce from Mork (1942) show two peaks in amount of litter fall, one in May and June and one in September and October. This is not evident in the other data, although Kittredge (1948) did mention a somewhat similar situation with longleaf pine in Florida.

Accumulation of Litter on the Forest Floor

As Kittredge (1948) pointed out, although annual litter fall is dependent on the density of the stand, species involved, site, age, etc., the accumulation of litter on the forest floor is dependent on all these influences, as well as all the other factors of environment which influence the decomposition of organic material. Thus temperature, humidity, and rainfall, through their effect on various soil organisms, play an important part in determining the amount of litter on the forest floor. Due to the great number of influencing agencies, the variations in accumulation of unincorporated organic matter are even more extreme than are the variations in annual leaf fall. At one extreme are the tropical regions of the world, where there is, for all practical purposes, no accumulation of debris in forests due to the extremely favorable conditions for decay. On the other hand, in the coniferous belt in subarctic or arctic regions, because of unfavorable conditions for decay, an organic layer of considerable thickness may accumulate from the annual increment of organic matter to forest soil. In the temperate zones, between the two above-mentioned extremes, there are many variations. The following table indicates, in outline form, some of the determinations of weight of the unincorporated organic matter under forest stands:

TABLE 3. TOTAL WEIGHT OF ORGANIC MATERIAL UNDER FOREST STANDS

Source	*Type*	*Age (years)*	*Locality*	*Dry Weight lbs/acre*
Heyward and Barnette (1936)	Slash pine	9	Mississippi	17,189
	Slash pine	9	Mississippi	19,500
	Slash pine	21	Georgia	41,677
	Slash pine	30	Georgia	32,074
	Longleaf pine	25	South Carolina	34,475
	Longleaf pine	25	Florida	19,878
	Longleaf pine	60	Mississippi	30,057
	Longleaf-slash	250	Georgia	22,375
Alway and Zon (1930)	Jack–Norway pine	50	Minnesota	33,541
	Norway pine	100	Minnesota	34,377
	Jack pine	30	Minnesota	16,953
	Norway pine (white)	250	Minnesota	23,958
	Jack pine	55	Minnesota	32,670
Auten (1941a)	Black locust	0–5	Illinois–Indiana	5,400
	Black locust	6–10	Illinois–Indiana	8,600
	Black locust	11–15	Illinois–Indiana	8,300
	Black locust	16–20	Illinois–Indiana	12,300
	Black locust	21–25	Illinois–Indiana	10,200
Sims (1932)	Mixed hardwood	—	Southern Appalachians	7,900
Kittredge (1940)	Monterey pine	30	California	53,582
	Maritime pine	30	California	31,311
	Canary pine	30	California	27,783
	Douglas fir	30	California	27,562
	Monterey cypress	30	California	27,342
	Redwood	30	California	24,696
Lunt (1932)	Norway pine	27	Connecticut	27,420
	White pine	27	Connecticut	21,590
	White pine	—	New Hampshire	118,678
	Spruce–hardwood	—	New Hampshire	110,810
	Hardwood	—	Connecticut	93,541
Gustafson (1935)	Black locust	—	Illinois	8,695

Variations in the weight of the forest floor, such as those reported in Table 3, reflect differences in the environmental factors affecting decay, differences in the weight of the litter annually reaching the soil, and also differences in the susceptibility of the litter of various species to decomposition. A detailed analysis of differences in susceptibility to decay may be found in the literature (Ramann 1898, Melin 1930, Watson 1930, Romell and Heiberg 1931, and Waksman and Cordon 1938).

In addition to the litter derived principally from leaf fall, large amounts of waste material may be left when the timber crop is harvested. Isaac and Hopkins (1937) mentioned a striking example of this in the Douglas fir region, where a calculated weight of slash amounting to 720,000 pounds per acre remained after cutting.

REVIEW OF LITERATURE

Comparison of Litter and Wood Production

Although the subject is not directly connected with the problem under consideration, it might be interesting to examine some of the findings concerning relative amounts of wood and leaves produced by forest vegetation.

Mork (1942) showed the following relationships:

Type	*Age (years)*		*Weight of litter as a percentage of the weight of wood produced annually*
Norway spruce	40	lowland site	35
Norway spruce	60		35
Norway spruce	140	mountain site	52
European birch	100		140
Scots pine	200		68

Ebermayer (1876) reported data showing that for beech, Norway spruce, and Scots pine stands in Bavaria of all ages up to 120 years, the average weight of the annual litter fall and the average weight of the annual wood growth are about equal.

It was estimated that in stands of Norway spruce in northern Sweden the average weight of the annual growth of spruce needles, moss, and blueberry bushes was over twice the weight of the annual wood production (Romell 1939).

It has been suggested that a good site annually produces as much organic matter as far as carbohydrate is concerned, when under forest, as it would if planted to agricultural crops such as wheat or potatoes (Liese 1943).

Amount of Litter Contributed by Subordinate Vegetation in Forests

There has been very little investigative work done on the litter produced in forests by subordinate vegetation, or non-tree species. Some chemical analyses, by species, have been carried out and will be reviewed in a following section, but there are few determinations of the weight of organic matter annually contributed by these plants to the soil.

In northern Sweden it has been estimated that the annual growth of moss in 200 to 250 year old Norway spruce stands is approximately 3,811 pounds per acre (Romell 1939). This weight corresponds to the dry weight of about 148 cubic feet of wood per acre. Since the average production of stemwood in northern Sweden is only 138 cubic feet per acre, it is estimated that some forest areas may annually produce a greater weight of moss than stemwood. Under the same forest Romell estimated that the annual production of blueberry bushes is about 2,396 pounds

TABLE 4. PROXIMATE CHEMICAL COMPOSITION OF THE FOLIAGE OF TREE SPECIES IN NORTH AMERICA (VALUES ARE PERCENTAGES OF DRY WEIGHT)

Species	*Ash*	*N*	*Ca*	*P*	*K*	*Mg*	*S*	*Fe*	*Zn*	*B*	*Cu*	*Mn*	*Al*	*Na*	*References*
Abies balsamea		1.25	1.12	0.09	0.12	0.16									Chandler (1944)
Acacia angustissima	4.5		0.67	0.37	1.34	0.16									Russell (1947)
Acacia roemeriana	5.2		1.52	0.19	1.05	0.28									Russell (1947)
Acer rubrum	*5.31	0.42	1.26	0.11	0.40										Chandler (1941) *Lunt (1935)
Acer saccharum	†12.42	0.44	1.66	0.14	0.52	*0.28	*0.01	*0.022	*0.0054		*0.0012	*0.010		*0.14	Chandler (1941) †Alway, Kittredge and Methley (1933) *MacHargue and Roy (1932)
Aesculus californica	15.1		4.11	0.20	1.78										Russell (1947)
Aesculus glabra	14.44	1.60	4.37	0.29	0.92	0.31	0.15	0.034	0.0028		0.0007	0.012		0.11	MacHargue and Roy (1932)
Betula lenta		0.72	1.65	0.17	0.75										Chandler (1941)
Betula populifolia	7.53		0.99												Garstka (1932)
Carya cordiformis		0.68	3.41	0.12	0.44										Chandler (1941)
Carya ovata	9.82	0.72	2.16	0.12	1.37										Lunt (1935)
Castanea sativa	4.4														Russell (1947)
Catalpa speciosa	9.62	1.91	2.26	0.30	1.31	0.34	0.48	0.068	0.0050		0.0019	0.013		0.10	MacHargue and Roy (1932)
Celtis occidentalis	26.98	2.61	7.81	0.17	1.75	0.53	0.29	0.055	0.0032		0.0006	0.017			MacHargue and Roy (1932)
Celtis reticulata	15.8		4.91	0.19	1.38	0.46									Russell (1947)
Cladrastis lutea	13.27	2.24	3.68	0.78	1.88	0.29	0.11	0.025	0.0036		0.0012	0.007			MacHargue and Roy (1932)
Cornus florida	9.32	0.66	2.08	0.20	1.69	*0.51	*0.70	*0.024	*0.0028		*0.0007	*0.005	*0.12		Lunt (1935) *MacHargue and Roy (1932)
Diospyros texana	9.2		3.93	0.10	0.71	0.56									Russell (1947)
Diospyros virginiana	8.79	2.28	1.63	0.14	1.98	0.36	0.27	0.021	0.0036		0.0005	0.022		0.17	MacHargue and Roy (1932)
Fagus grandifolia	*6.65	0.64	1.04	0.10	0.65										Chandler (1941) *Lunt (1935)
Fraxinus americana		0.59	2.37	0.16	0.59										Chandler (1941)
Fraxinus excelsior	8.8														Russell (1947)
Fraxinus quadrangulata	8.43	2.10	1.98	0.42	1.26	0.30	0.11	0.025	0.0034		0.0013	0.008		0.29	MacHargue and Roy (1932)
Juglans nigra	13.07	1.74	3.23	0.46	1.98	0.50	0.01	0.040	0.0042		0.0011	0.019		0.15	MacHargue and Roy (1932)
Juniperus pinchotii	4.8		1.83	0.13	0.53	0.17									Russell (1947)
Juniperus utahensis	4.5		1.59	0.17		0.25									Russell (1947)
Juniperus virginiana		1.50	1.64	0.23	0.76	0.26	0.42	0.028	0.038	0.0018	0.0015	0.047	0.026	0.05	Van Camp (1948)
Liquidambar styraciflua	8.24	1.52	1.97	1.29	0.60	0.43	0.01	0.020	0.0027		0.0009	0.070		0.07	MacHargue and Roy (1932)
Liriodendron tulipifera	*10.67	0.51	2.56	0.11	0.95	*0.211	*0.37	*0.028	*0.0028		*0.0005	*0.009		*0.07	Chandler (1941) *MacHargue and Roy (1932)
Magnolia acuminata		0.58	1.71	0.28	0.76										Chandler (1941)
Magnolia macrophylla	9.45	1.74	2.38	0.18	1.33	0.33	0.20	0.023	0.0019		0.0006	0.029		0.09	MacHargue and Roy (1932)
Morus microphylla	16.0		4.65	0.17	1.98	0.53									MacHargue and Roy (1932)
Morus rubra	16.73	3.12	3.82	0.29	2.27	0.35	0.09	0.050	0.003		0.0007	0.025			Russell (1947)

Ostrya virginiana		1.10	2.34	0.10	0.42										Chandler (1941)
Picea excelsa		1.02	1.96	0.09	0.29	0.23		*0.005	*0.0062	*trace	*trace	*0.083	*0.01	*0.036	Chandler (1944) *Smith (1950a)
Picea rubens		0.89	0.79	0.10	0.35	0.20									Chandler (1944)
Pinus banksiana	*3.84	1.03	0.59	0.09	0.12		0.09								Alway and Zon (1930) *Alway, Kittredge and Methley (1933)
Pinus caribaea	3.23	0.51	0.38	0.04	0.05	0.11									Heyward and Barnette (1936)
Pinus palustris	3.67	0.50	0.44	0.04	0.05	0.11									Heyward and Barnette (1936)
Pinus resinosa	*4.27	0.88	0.53	0.06	0.10		0.08								Alway and Zon (1930) *Alway, Kittredge and Methley (1933)
Pinus rigida	2.19	*0.41	0.35												Garstka (1932) *Melin (1930)
Pinus Strobus	5.49	*0.54	0.73	*0.08	*0.17		*0.07								Garstka (1932) *Alway, Kittredge and Methley (1933)
Platanus occidentalis	9.00	2.07	2.19	0.16	1.25	0.30	0.08	0.26	*0.0042		0.0004	0.015		0.10	MacHargue and Roy (1932)
Populus tremuloides and Populus grandidentata		0.70	2.11	0.10	0.47										Chandler (1941)
Prunus avium		0.88	2.42	0.15	0.63										Chandler (1941)
Prunus serotina	*8.04	0.55	2.36	0.18	0.56	*0.53	*0.12	*0.029	*0.0027		*0.008	*0.023		*0.07	Chandler (1941) *MacHargue and Roy (1932)
Pyrus coronaria	7.92	2.16	1.84	0.34	1.79	0.25	0.19	0.018	0.0028		0.009	0.002		0.10	MacHargue and Roy (1932)
Quercus alba	*5.90	0.54	1.36	0.13	0.52										Chandler (1941) *Lunt (1935)
Quercus borealis	*3.94	0.62	1.38	0.11	0.66	†0.34		†0.04				†0.04	†0.11		Chandler (1941) *Alway, Kittredge and Methley (1933) †Plice (1943)
Quercus breviloba	5.6		1.87	0.10	0.67	0.22									Russell (1947)
Quercus douglasii	10.9		2.01	0.17	0.54										Russell (1947)
Quercus palustris	5.83	1.14	1.23	0.08	0.50	0.44	*0.22	0.04	*0.0116		*0.0006	0.08	0.10	*0.75	Plice (1943) *MacHargue and Roy (1932)
Quercus velutina	7.65	2.22	2.17	0.20	1.00	0.31	0.04	0.025	0.0066		0.0007	0.187		0.09	MacHargue and Roy (1932)
Quercus virginiana	6.0		1.53	0.11	0.67	0.021									Russell (1947)
Robinia pseudoacacia	*14.14	2.81	3.22	*0.20	*1.21	*0.41	*0.02	*0.033	*0.0050		*0.0007	*0.005		*0.06	Auten (1941) *MacHargue and Roy (1932)
Sassafras albidum		1.59	1.57												Auten (1941)
Thuja occidentalis		0.60	2.16	0.04	0.25	0.15									Chandler (1944)
Tilia americana	*10.66	1.09	3.23	0.15	0.52	†0.77	‡trace	†0.06	‡0.0054		‡0.0010	†0.02	†0.11	‡0.25	Chandler (1941) *Alway, Kittredge and Methley (1933) †Plice (1943) ‡MacHargue and Roy (1932)
Tsuga canadensis		1.05	0.68	0.07	0.27	0.14									Chandler (1944)
Ulmus americana	*10.99	0.77	2.06	0.15	0.44	*0.53	*0.07	*0.068	*0.0020		*0.007	*0.013		*0.11	Chandler (1941) *MacHargue and Roy (1932)

TABLE S. PROXIMATE CHEMICAL COMPOSITION OF THE FOLIAGE OF SUBORDINATE VEGETATION IN NORTH AMERICA (VALUES ARE PERCENTAGES OF DRY WEIGHT)

Species	*Ash*	*N*	*Ca*	*P*	*K*	*Mg*	S	*Fe*	*Zn*	*B*	*Cu*	*Mn*	*Al*	*Na*	*Reference*
Adiantum pedatum		0.83	0.98	c.14	1.54	0.28	0.24	.050	.021	.0014	.0012	.036	.020	.05	Van Camp (1948)
Amphicarpa bracteata		1.74	1.91	0.19	1.35	0·45	0·57	.093	.022	.0034	.0016	.015	.053	.05	Van Camp (1948)
Aralia nudicaulis		0.56	1.82	0.22	0·79	0.46	0·55	.c39	.027	.0032	.0007	.288	.014	.05	Van Camp (1948)
Arisaema triphyllum		2.18	1·41	0.22	2.86										Bard (1949)
Aster divaricatus		1.67	1.07	0.21	3.30										Bard (1949)
Atriplex canescens	15·5		1.73	0.14		0.16									Russell (1947)
Berberis trifoliata	3.2		0.67	0.16	0.81	0.15									Russell (1947)
Bumelia texana	6.6		3.04	0.12	0·57	0.24									Russell (1947)
Cassia roemeriana	11.6		5·16	0.17	1.25	0.30									Russell (1947)
Ceanothus cuneatus	6.1		1.75	0.15	0.66										Russell (1947)
Ceanothus divaricatus	5.1		1.32	0.13	0.66										Russell (1947)
Chrysothamnus viscidiflorus	6.0		2.00	0.11		026									Russell (1947)
Collinsonia canadensis		0·73	0.85	0.20	1.03	1.27	0.60	.037	.027	.0027	.0010	.025	.029	.05	Van Camp (1948)
Colubrina texensis	8.6		3.29	0.17	1.28	0.23									Russell (1947)
Comptonia peregrina		2.04	0·54	0.18	0·72	0.18	0.23	.021	.017	.0021	.0010	.118	.017	.05	Van Camp (1948)
Condalia obtusifolia	7.6		1.50	0.22	2·39	0.30									Russell (1947)
Cornus florida		1.01	3.03	0.19	0·94	0·43	0·77	.032	.023	.0032	.0017	.013	.053	.05	Van Camp (1948)
Corylus avellana	7.6														Russell (1947)
Dryopteris noveboracensis		0.88	0·93	0.18	0.90	0.56	0.60	.059	.022	.0022	.0007	.089	.016	.05	Van Camp (1948)
Dryopteris spinulosa		1.94	0·93	0.16	2.60										Bard (1949)
Eupatorium rugosum		2.30	1.41	0.26	3.83										Bard (1949)
Forestiera neomexicana	7.6		1.29	0.14	2.63	0.32									Russell (1947)
Galium circaezans		1.63	2.09	0.12	2·50										Bard (1949)
Galium triflorum		1.76	2.27	0.19	3.46										Bard (1949)
Gaultheria procumbens		1.38	1.06	0.12	1.23										Bard (1949)
Guaiacum coulteri	13·4														Russell (1947)
Hamamelis virginiana		0.66	1.59	0.20	0.76	0.24	0.38	.034	.015	.0059	.0015	.146	.022	.05	Van Camp (1948)
Hydrophyllum canadense		1.95	2.29	0.14	4.10										Bard (1949)
Ilex opaca	4.8	1.08	0·97	0.07	0.74	0·51	0·33	.027	.024		.0006	.054			MacHargue and Roy (1932)
Impatiens capensis		2.08	1.71	0.26	3.83										Bard (1949)
Impatiens pallida		1.30	1·73	0.27	4·00										Bard (1949)
Kalmia latifolia		0·45	1.14	0.18	0.58	0.18	0.32	.013	.015	.0026	.0008	.139	.019	.05	Van Camp (1948)
Kochia vestita	21.5		1.69	0.06		0·93									Russell (1947)
Leucaena retusa	6.4		2.82	0.13	1.30	0.22									Russell (1947)

Lindera benzoin		1.85	1.56	0.23	1.55	0.49	0.32	.050	.040	.0032	.0035	.223	.053	.05	Van Camp (1948)
Lycopodium clavatum		1.72	0.14	0.22	1.53										Bard (1949)
Lycopodium complanatum		1.35	.020	0.13	1.55										Bard (1949)
Lycopodium lucidulum		1.59	0.20	0.17	1.70										Bard (1949)
Lycopodium obscurum		1.58	0.16	0.14	1.20										Bard (1949)
Maianthemum canadense		1.61	1.46	0.26	2.68										Bard (1949)
Mimosa fragrans	7.1		2.38	0.17	1.14	0.32									Russell (1947)
Mitchella repens		1.05	1.78	0.16	1.90										Bard (1949)
Nolina texana	4.0		0.92	0.09	0.70	0.16									Russell (1947)
Parosela frutescens	6.7		2.27	0.14	1.21	0.24									Russell (1947)
Podophyllum peltatum		1.39	2.10	0.11	2.00										Bard (1949)
Polystichum acrostichoides		1.42	0.78	0.22	2.30										Bard (1949)
Polytrichum commune			0.23	0.24	0.31	0.12			.030			.08			Smith (1950)
Prosopis chilensis	8.2		3.04	0.19	1.32	0.30									Russell (1947)
Prosopis velutina	8.6														Russell (1947)
Rhamnus californica	7.1		1.35	0.22	1.64										Russell (1947)
Rhus coriaria	12.0														Russell (1947)
Rhus diversiloba	8.8		2.24	0.27	1.41										Russell (1947)
Rhus microphylla	8.9		2.40	0.16	1.95	0.40									Russell (1947)
Rhus trilobata	6.2		2.30	0.11	0.91	0.34									Russell (1947)
Rhus virens	4.8		1.67	0.11	0.73	0.23									Russell (1947)
Rubus hispidus		1.34	1.02	0.25	0.77	0.33	0.31	.077	.026	.0034	.0010	.128	.074	.05	Van Camp (1948)
Sambucus glauca	10.9		2.38	0.19	1.98										Russell (1947)
Sanguinaria canadensis		1.96	2.45	0.18	2.70										Bard (1949)
Smilacina racemosa		1.91	1.82	0.17	3.73										Bard (1949)
Solidago latifolia		1.92	1.27	0.20	3.07										Bard (1949)
Sophora secundiflora	5.2		2.00	0.15	0.89	0.21									Russell (1947)
Symphoricarpos rotundifolius	7.3		0.26			0.32									Russell (1947)
Thalictrum dioicum		1.31	1.63	0.30	2.60										Bard (1949)
Tiarella cordifolia		1.91	3.00	0.20	2.50										Bard (1949)
Trillium grandiflorum		1.97	3.27	0.25	3.17										Bard (1949)
Uvularia sessilifolia		0.84	0.85	0.20	0.87	0.21	0.44	.031	.020	.0023	.0011	.061	.026	.05	Van Camp (1948)
Viburnum acerifolium		1.06	1.64	0.24	0.89	0.54	0.44	.039	.028	.0044	.0014	.060	.064	.05	Van Camp (1948)
Yucca mohavensis	5.6														Russell (1947)

per acre. Thus, the combined weight of moss and blueberries may be 50 percent greater than the weight of stemwood produced annually in the spruce overstory. Romell also presented data from Elias Mork in Norway, indicatmg that in mixed coniferous forest the annual growth of moss is 4,356 to 4,900 pounds per acre. This value is in close agreement with Romell's findings.

Ebermayer (1876) discussed the subject of moss in forests at some length, stating that in Bavaria the thickness of the moss on forest floors is directly related to elevation above sea level. In the moist mountain forests there is much more moss than on the dry, sandier lowland areas. Generally, the weight of moss was greater in the "fresh" alder and spruce stands than in forests of species such as larch or pine, more adapted to dry sites. Ebermayer was of the opinion that if the canopy of stands is opened too much, the moss would be replaced by various grasses.

Other investigators mention the fact that subordinate vegetation, especially moss, is present in substantial quantities and some even stress its importance in soil formation or as a source of nutrients, but none gives any quantitative data as to weight (Ebermayer 1890, Rebel 1920, Stepanoff 1929, Mork 1942).

CHEMICAL COMPOSITION OF THE FOLIAGE OF FOREST VEGETATION

There has been a substantial amount of research in which the chemical composition of various parts of forest plants has been determined. Much of this work is fragmentary from the point of view of plant nutrient elements, however, because only a few elements were pertinent to the specific investigation. As a result, when summarizing previous information it is often necessary to combine data from more than one investigation to obtain more complete information on a certain species. Such combination, of course, does not lead to accuracy, due to different techniques of analysis and varying sites. The results therefore, are simply indicative of possible ranges.

The accompanying tables summarize the major investigative work done with native or introduced North American species. The analyses of the litter of subordinate vegetation are found in Table 5 and that of tree species in Table 4. In many cases the decision as to whether a given species was listed in Table 4 or 5 was admittedly arbitrary. No analyses of wood or woody material are included because such material is largely outside the scope of this problem.

The two tables are largely self explanatory, but a brief summary of ranges can be presented:

Element	*Tree species percentage of oven-dry weight*	*Subordinate vegetation percentage of oven-dry weight*
Ash	26.98 –2.19	21.5 –3.2
Nitrogen	3.12 –0.41	2.30 –0.45
Calcium	7.81 –0.35	5.16 –0.14
Phosphorus	0.78 –0.04	0.30 –0.06
Potassium	2.27 –0.05	4.1 –0.31
Magnesium	0.77 –0.021	1.27 –0.12
Sulphur	0.70 –0.01	0.77 –0.23
Iron	0.26 –0.005	0.093 –0.013
Zinc	0.038 –0.0019	0.040 –0.015
Boron	0.0018–trace	0.0059–0.0014
Copper	0.009 –trace	0.0035–0.0006
Manganese	0.187 –0.002	0.288 –0.013
Aluminum	0.12 –0.01	0.074 –0.014
Sodium	0.75 –0.05	0.05

PROCEDURE

LOCATION AND GENERAL DESCRIPTION OF THE EXPERIMENTAL AREA

THE area selected for investigation is located southwest of and immediately adjoining the town of Litchfield, Connecticut, in a tract which is part of the holdings of the White Memorial Foundation.

The area exhibits relatively little variation in topography, ranging from about 900 to 1,120 feet above sea level, according to the United States Geological Survey Map of 1903. However, due to the presence of Bantam Lake and adjacent swamps at an elevation of 896 feet, much of the low-lying land has a water table very near the surface. Consequently, a small difference in elevation may result in a considerable change in site quality.

The soils of the area, according to Morgan (1939), are primarily of the Charlton, Merrimac, and Litchfield soil series and vary from excessively sandy land of level topography to stony, hilly land of medium to heavy-textured, glacial-till soils. For a more detailed description of these soil series reference is made to the Connecticut Agricultural Experiment Station Bulletin 423.

The average precipitation, based on a 4o-year record at the weather station at Cream Hill in Litchfield County, is 46.75 inches per year, and is fairly evenly distributed throughout the twelve months. The average length of the growing season is 155 days. The average date for the last killing frost in the spring is May 6, and the first killing frost in the fall, October 8. The average temperature for the coldest month, January, is 24.IoF. and for the warmest month, July, 69.4°F. (D.S.D.A. 1941).

The forest vegetation does not represent a single clearly defined type, due to the occurrence of the experimental area in the transition zone between the central hardwood community (oak-hickory) and the northern hardwood community (beech-birch-maple) and the consequent mixing of the species of these two communities. There are also extensive pure stands of eastern white pine in the area, although at the present time such stands rarely occur farther south in Connecticut.

The species composition of the subordinate forest vegetation is indicated in the checklist in Table 6.

DESIGN OF THE EXPERIMENT

In order to ascertain the relative importance of the overstory and the subordinate vegetation as suppliers of organic material to the soil, it was considered advisable to carry out the experiment in at least two differing forest types and over a period of time covering two growing seasons.

PROCEDURE

The white pine type and the mixed hardwood type presented as great differences in species composition of the overstory as could be found in the region and, in addition, had the advantage of being present on the experimental area in adjacent stands. Therefore, these two types were selected for the experiment. The experiment was carried out during the growing seasons of 1948 and 1949.

The investigation had three levels of comparison: between understory and overstory; between white pine and hardwood forest types; and between the two growing seasons in which data were collected.

The layout on the ground was made in the following manner. A boundary line between a white pine stand and a hardwood stand was selected. Sixteenth-acre plots (52 feet x 52 feet) were laid out in duplicate in each stand 100 to 200 feet from the type boundary, to eliminate any influence from the adjoining stand. On each of the sixteenth-acre plots nine mechanically selected one-milacre plots were established on which to collect the understory material, and two milacre plots, also mechanically selected, were established for the collection of overstory material. The details of the collection will be given in a later section.

This design can be considered as a replicated split plot with additional replications within the blocks on the level of the first split. Data were analyzed by a technique appropriate to a three-level analysis of variance (Snedecor 1946).

DETAILED DESCRIPTION OF EXPERIMENTAL AREAS AND PLOTS

Soils, Location, Elevation, and Aspect of Blocks

Borings were made with a soil auger around the periphery of the four plots in each block in order to ascertain that the soil was of the same series on the entire block. A soil pit was opened to make a more detailed examination of the soil profile and to obtain samples for mechanical analysis.

The mechanical analysis was carried out in accordance with the method described by Bouyoucos (1936). The results showed relatively little difference in the texture of the surface soil of the four blocks. All were either sandy loams or loamy sands by either the American classification or the International classification (Laatsch 1938). However, the soils were not all similar in other properties, as indicated by the following description. For further details of the various soil series mentioned, reference is made to Lunt (1948).

Block I: This area is located on the north side of Plumb Hill, immediately west of the town of Litchfield. The topography slopes toward the east and north and the elevation is about 940 feet above sea level.

The soil is Ridgebury sandy loam, a poorly drained upland soil derived from glacial till. Granite and gneiss are the dominant parent materials and the soil is quite compact. The humus layer is classified as medium mull.

Block II: This block is located about 500 yards west of the Bantam River, one-half mile above the point where the river enters Bantam Lake. The area has an elevation of 920 feet and is level, although bordered on the west by a gradual rise. The soil is Scarboro loamy sand, a stratified glacio-fluvial soil, very poorly drained, with a gravelly substratum. It is derived from non-calcareous material, largely gneiss and schist. There is a compact layer seven or eight inches thick about two feet below the surface and this in turn is underlaid by loose silty loam. The humus layer is a granular mor.

Block **III:** The third block is located between Little Pond and Cranberry Pond, about one mile south of Litchfield. It is situated on a small rise and the land slopes gradually toward the west. The elevation is about 910 feet above sea level. The soil is of outwash origin on a glacial till base. The surface soil is Merrimac loamy sand, developed from well-drained, stratified, glacio-fluvial material derived from gneiss and schist. It is underlaid at a depth of two-and-a-half feet by compact glacial till, very similar to that encountered in the Paxton series. This forms a tight layer fairly typical of glacial till soils. The humus layer is a granular mor.

Block IV: Block IV is located a few hundred yards south of Cranberry Pond, which is about one-and-a-half miles south of Litchfield. It is on the north slope of a hill and is at an elevation of about 980 feet above sea level. The soil is similar to that of Block **III;** it is a Merrimac sandy loam, underlaid at two-and-three-quarters feet by glacial till similar to that found in soils of the Paxton series. The humus layer is a granular mor.

Weather Conditions During the Growing Seasons of 1947, 1948, 1949

Temperature and precipitation data for the region were examined in volumes, 59,60, and 61 of *Climatological Data, New England,* published by the Weather Bureau of the United States Department of Commerce. The observations consulted were made at the Cream Hill Weather Station in Litchfield County, and indicated that the growing seasons, which probably would have had most effect on the experimental results, were somewhat warmer and drier than normal. The data, however, indicated no extreme differences between years that might have had a confounding effect on the experiment.

PROCEDURE

Checklist of Plant Species and Description of Stands on Individual Plots

The description of the sixteen individual plots is presented in several tables showing the species of subordinate vegetation and trees present on each area, the basal area of the trees by species, and the age and height of the trees. It can be observed that contrasting pine and hardwood often differ in age or total basal area, and that even the plots within one stand are not always similar in all respects. This situation is usually unavoidable however, in natural stands, if plot proximity is not sacrificed.

TABLE 6. OCCURRENCE OF SUBORDINATE VEGETATION SPECIES BY PLOTS

Species	*Plots*															
	*I-P-E**	*I-P-W*	*I-H-E*	*I-H-W*	*II-P-E*	*II-P-W*	*II-H-E*	*II-H-W*	*III-P-N*	*III-P-S*	*III-H-N*	*III-H-S*	*IV-P-E*	*IV-P-W*	*IV-H-E*	*IV-H-W*
Agrostis perennans	x															
Alnus rugosa	x	x											x	x		
Amelanchier laevis												x				x
Aralia nudicaulis							x				x	x	x	x		
Arisaema triphyllum	x	x	x	x	x	x	x	x								
Aster spp.	x	x	x	x				x								
Athyrium Filix-femina		x	x	x	x	x	x	x								
Athyrium thelypterioides	x							x								
Berberis thunbergii			x													
Brachyelytrum erectum					x	x	x	x								
Carex gracillima		x	x	x												
Carex laxiflora	x	x	x	x		x		x								
Carex pensylvanica				x			x	x			x			x	x	x
Carex spp.	x	x	x	x												
Carpinus caroliniana							x		x	x						
Chimaphila maculata									x							
Chimaphila umbellata									x							
Clematis virginiana	x	x	x	x	x	x	x									
Clintonia borealis														x		
Cornus alternifolia						x									x	
Corylus americana													x	x		
Corylus rostrata											x	x				
Cratagus spp.			x													
Cypripedium acaule									x	x						
Dennstaedtia punctilobula															x	x
Diervilla lonicera													x			
Dryopteris noveboracensis			x	x												
Dryopteris spinulosa	x	x	x	x	x	x		x								x
Fragaria virginiana		x		x												
Galium triflorum							x	x			x	x				
Gaultheria procumbens									x	x	x	x				x
Gaylussacia baccata																x
Geranium maculatum	x			x												
Hamamelis virginiana				x	x	x					x	x				
Ilex laevigata			x								x		x	x		x
Ilex verticillata		x	x	x	x	x	x	x							x	
Kalmia latifolia					x											
Lindera benzoin		x														
Lonicera canadensis						x	x									
Luzula campestris							x									

*Roman numeral indicates experimental block.
P denotes white pine cover type.
H denotes mixed hardwood cover type.
E, W, N, S indicate specific plot by cardinal direction from its replicate.

TABLE 6. OCCURRENCE OF SUBORDINATE VEGETATION SPECIES BY PLOTS (*continued*)

Species	*Plots*															
	I-P-E	*I-P-W*	*I-H-E*	*I-H-W*	*II-P-E*	*II-P-W*	*II-H-E*	*II-H-W*	*III-P-N*	*III-P-S*	*III-H-N*	*III-H-S*	*IV-P-E*	*IV-P-W*	*IV-H-E*	*IV-H-W*
Lycopodium clavatum									x	x						
Lycopodium complanatum					x	x	x	x								
Lycopodium lucidulum					x	x										
Lycopodium obscurum							x				x	x				x
Lysimachia producta															x	
Lysimachia quadrifolia			x	x						x					x	x
Maianthemum canadense	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Medeola virginiana				x			x	x			x	x				x
Melampyrum lineare									x	x						x
Mitchella repens	x	x	x	x	x	x	x	x			x	x	x			
Oakesia sessilifolia								x			x	x				
Onoclea sensibilis	x		x	x	x	x	x	x								
Osmunda cinnamomea	x	x		x	x	x	x	x							x	x
Ostrya virginiana														x		
Parthenocissus quinquefolia	x	x	x	x	x	x	x									
Polygonatum biflorum					x	x		x								
Polystichum acrostichoides	x	x	x	x	x										x	
Polytrichum commune	x	x							x	x						
Prenanthes alba						x										x
Prunus serotina	x	x	x	x				x								
Prunus virginiana																x
Pteridium aquilinum									x		x		x			
Pyrola elliptica									x							
Rhododendron nudiflorum	x										x	x				
Rhus toxicodendron	x	x	x	x	x	x	x							x		
Rubus allegheniensis															x	
Rubus hispidus	x	x	x	x	x	x	x						x			x
Rubus idaeus	x	x	x	x		x		x								
Rubus pubescens	x				x											
Sambucus canadensis	x															
Smilacina racemosa					x								x			
Smilax herbacea				x	x											
Solidago spp.	x	x	x	x				x								
Symplocarpus foetidus	x	x	x	x	x	x	x									
Thalictrum dioicum			x			x		x								
Trientalis borealis									x				x	x	x	
Trillium undulatum					x											
Vaccinium vacillans										x	x	x			x	
Viburnum acerifolium											x	x				
Viburnum alnifolium													x	x	x	x
Viburnum recognitum		x					x	x					x	x		

Total number of species: 81

TABLE 7. OCCURRENCE OF TREE SPECIES BY PLOTS

Species	*Plots*															
	I–P–E	*I–P–W*	*I–H–E*	*I–H–W*	*II–P–E*	*II–P–W*	*II–H–E*	*II–H–W*	*III–P–N*	*III–P–S*	*III–H–N*	*III–H–S*	*IV–P–E*	*IV–P–W*	*IV–H–E*	*IV–H–W*
Acer rubrum	x	x	x	x	x		x				x		x		x	x
Acer saccharum	x	x					x	x						x		
Betula lenta		x									x	x				x
Betula lutea						x										
Betula populifolia																x
Carya glabra								x								
Fraxinus americana						x										
Pinus Strobus	x	x	x		x	x			x	x	x	x	x	x	x	x
Populus grandidentata									x							
Populus tremuloides	x								x							
Prunus serotina				x					x				x	x		
Quercus alba					x						x	x			x	x
Quercus rubra				x	x			x	x	x	x	x			x	
Quercus velutina												x				
Tsuga canadensis				x	x						x	x				
Ulmus americana	x															
Total number of species: 16																

TABLE 8. AGE, AVERAGE TOTAL HEIGHT AND AVERAGE HEIGHT TO THE BASE OF THE LIVE CROWN OF DOMINANTS

Area	*Average age (years)*	*Average height of Dominants (feet)*	*Average height to base of Live Crown (feet)*
I–P	30	50	31
I–H	34	50	23
II–P	115	80	45
II–H	85	55	25
III–P	50	51	20
III–H	105	55	25
IV–P	45	55	25
IV–H	65	50	20

TABLE 9. BASAL AREA (SQUARE FEET) AND NUMBER OF STEMS PER ACRE BY PLOTS

Species	*Plots*															
	I–P–E	*I–P–W*	*I–H–E*	*I–H–W*	*II–P–E*	*II–P–W*	*II–H–E*	*II–H–W*	*III–P–N*	*III–P–S*	*III–H–N*	*III–H–S*	*IV–P–E*	*IV–P–W*	*IV–H–E*	*IV–H–W*
Acer rubrum		1.914	4.459	5.843	1.704		.492						.512		2.955	.600
Acer saccharum	1.732				.696	1.558	8.971	5.325						.110		
Betula lenta		.131									1.003	.674				.238
Betula lutea						.979										
Betula populifolia																.110
Carya glabra																.684
Fraxinus americana		.136				.110										
Pinus Strobus	6.103	7.940	1.396		8.436	14.017			6.940	4.903	.975	.340	12.953	16.180	.087	.218
Populus grandidentata									.106							
Populus tremuloides	.505								.115							
Prunus serotina									.142		.462			1.106		
Quercus alba											5.433	.601				2.838
Quercus rubra					.307	.159		.462	1.087	1.968	2.461	6.889				
Quercus velutina												.567				
Tsuga canadensis					1.610	1.414					.497	2.611				
Ulmus americana	.442															
Total basal area per one-sixteenth acre	8.782	10.121	5.855	5.843	12.753	18.237	9.463	5.787	8.390	6.871	10.831	11.682	13.465	17.396	3.042	4.688
Total basal area per acre	140.5	161.9	93.7	93.5	204.0	291.8	151.4	92.6	134.2	109.9	173.3	186.9	215.4	278.3	48.7	75.0
Number of stems per one-sixteenth acre	19	30	19	30	12	14	12	6	18	11	14	17	20	25	16	15
Number of stems per acre	304	480	304	480	192	224	192	96	288	176	224	272	320	400	256	240

METHOD OF COLLECTING MATERIAL

Understory

As indicated in the section on experimental design, the understory material was collected on nine milacre plots uniformly and mechanically located in each sixteenth-acre plot. These milacre plots were permanently located so that the collection could be made on the same plots during both the 1948 and 1949 growing seasons.

The foliage and stems of the subordinate vegetation was removed by hand with as little injury to any remaining parts as was possible under field conditions.

Species separation was carried out completely during the first season, but it was found that a minimum of 50 grams air-dry weight was needed in each sample to carry out the proposed work. Therefore, all species with less than this weight on the nine milacres within a sixteenth-acre plot were placed in a miscellaneous group and treated together. Similar division by species or groups of species was carried out during the second season (1949).

Since it was very desirable to collect the plant material in a ripened condition, but before any appreciable decomposition or leaching occurred, it had been anticipated that at least two collections should be made each season. This method was attempted in 1948 when one collection was made in July .and one in August and September. However, it was found that with the areas and species involved this was not necessary, since the material maturing before August furnished a very small portion of the total organic material derived from the subordinate vegetation. No evidence was found to show that more than one collection during the season would have affected the results appreciably.

Collecting the subordinate vegetation material from the total number of 144 milacre plots covered a period of about three weeks to one month, and as a result, the operation had to be started before all species had yellowed, and continued until certain species were somewhat past the ideal stage for collection. There was no way to avoid this situation, but the plots were picked in ascending order in 1948 (I, II, III, IV) and descending order in 1949 (IV, III, II, I) in an attempt to make the average values more comparable. The period of collection was the last several days of August and the first three weeks of September.

After the plant material was collected and sorted by species, it was spread out until air dry. The total air-dry weight was then determined and several randomly selected samples in the case of large collections, or the entire sample if small enough, were ground in a "Mikro-Samplmill", a hammer-type mill for grinding analytic samples. Grinding was carried to a point where the material would pass through a mesh with round perforations of .039 inch. The ground sample was then placed in a cardboard container of known weight, and the total weight (sample and container) was recorded. The material was then stored until analyzed.

Overstory

The annual litter from trees was collected on two mechanically selected milacre plots on each sixteenth-acre area. Milacre-sized rectangles of tobacco cloth were placed on the ground and fastened in place with heavy wire pins. Bushes that created too much of an obstacle were removed, but the tobacco cloth was spread over any small plants, and in this manner presented an irregular surface approximating natural conditions. The litter was free to blow on or off the cloth in the same manner it moved about on the natural forest floor. The mats were put in place on August 23, 1948, and were not disturbed until November 1949.

Collection of litter in 1948 was carried out on November 3. The litter was removed from the mats by hand and placed in burlap bags. The material was air dried and then weighed and randomly selected samples were sorted by species or groups of species. Each of the separates was then weighed and the proportional weights were applied to the whole sample. The litter was ground and stored in a manner similar to that employed in handling the understory material. A similar collection was made November 11, 1949.

During both seasons an effort was made to complete the collection of litter immediately after leaf fall had ceased, and before any pronounced leaching by rain could take place.

The collection for 1948 was not for a complete year and as a result might be expected to be somewhat less in volume than the 1949 collection, which covered a full twelve-month period. However, only a small amount of any variation between years could be attributed to this because almost all the litter fell during the fall months, especially in the hardwood stands. The mats were examined during the first week of August 1949 and found to be covered with very little material, although a period of at least nine months (since November 1948) had elapsed since the litter had been removed from them.

CHEMICAL ANALYSIS OF MATERIAL

A complete chemical analysis was desirable in order to have as much information as possible on the relative importance of the understory in supplying plant nutrients. However, due to the large number of individual samples and limitations of time, it was impossible to use standard gravimetric, volumetric, or colorimetric methods. As a result, most of the analytical work was done spectroscopically. For the determination of hydrogen ion concentration (pH) and nitrogen content, composite samples were made up for understory and overstory on each sixteenth-acre area for each season. This was accomplished by combining samples of the various species in proportion to their total air-dry weight on each area, and in this way creating a composite sample that was similar in composition to the natural mixture on the area.

Hydrogen ion Concentration

Air-dry samples of four grams were weighed out in duplicate for each determination and placed in glass beakers. Enough distilled water was added to give the mixture a fluidity sufficient to maintain constant contact with the electrodes of the pH meter. The amount of dilution necessary for this condition varied from six parts of water and one part of plant material, by weight, to eight parts of water and one part of plant material. Tests varying the dilution of individual samples by this amount showed no appreciable change in pH due to differences in dilution. The duplicate samples rarely differed more than one-hundredth part of a pH unit and the duplication was apparently unnecessary.

After the distilled water had been thoroughly mixed with the ground plant material, the mixture was allowed to stand for one hour and then the hydrogen ion concentration was measured with a Beckman pH meter. The results are shown in Table A of the appendix.

Nitrogen

Nitrogen determinations were made in duplicate on each composite sample, using the Kjeldahl method, as described in the official methods of the Association of Official Agricultural Chemists (1945). The actual weight of the plant material used in each determination was 2 grams air-dry weight. Moisture content determinations were made on other samples of the same materials by drying in an oven for 24 hours at 105°C. and then reweighing. The air-dry weight of the nitrogen samples was then recalculated to oven-dry weight and the nitrogen percentages were expressed on this basis. The data are presented in Table A of the appendix.

Other Elements

The remaining elements (potassium, calcium, magnesium, phosphorus, manganese, iron, aluminum, zinc, sodium, copper, and boron) were determined by spectrographic methods on the individual samples, rather than on the composite samples.

A sample of about 1.10 grams was weighed to the nearest 0.0001 gram in a previously dried crucible of known weight. The crucible and sample were placed in an oven for 24 hours at I05°C. and then reweighed. It was thus possible to obtain the precise oven-dry weight of the sample to the nearest 0.0001 gram and to calculate the moisture loss of the air-dry sample.

The crucibles and the oven-dry samples were then placed in a cold *mume* furnace and the temperature of the furnace slowly raised to 550°C., after which they were allowed to cool. This treatment completely ashed the plant material, leaving only a white residue. The residue was taken up in 20 percent hydrochloric acid and the solution placed in glass vials. This solution was the basic material from which the spectroscopic analysis was made by Mr. W. T. Mathis of the Connecticut Agricultural Experiment Station. Standard Applied Research Laboratories equipment with spark excitation was used. The data are presented in Table A of the appendix.

RESULTS AND DISCUSSION

THE results are presented in two ways: (1) the original data, which are presented by individual species, plot, forest type and year of collection, and are included in the appendix, and (2) summary tables (Tables 10 and 11) which present the data grouped by forest cover and type of vegetation.

The original data are included because these serve as a basis for portions of the discussion and any grouping desired can be obtained. In addition, the nutrient content of the various plant species may be of some interest. The other tables summarize the information in the manner most likely to interest foresters. In an effort to save space, further tables and the statistical analysis are omitted, but may be consulted in the original manuscript at the School of Forestry or the Graduate School of Yale University.

The discussion is based on the individual properties or individual nutrient elements. No attempt has been made to bring out every statistical variation, particularly when interactions of high order are involved. Rather, an attempt is made to discuss the more important trends.

TABLE 10. AVERAGE CHEMICAL COMPOSITION AND pH OF FOREST LITTER

	Pine Cover Type		*Hardwood Cover Type*	
	Lesser Vegetation	*Tree Species*	*Lesser Vegetation*	*Tree Species*
	Percentage, oven-dry weight			
K	1.07	.43	1.13	.48
Ca	.90	.70	.74	.81
Mg	.46	.34	.39	.40
P	.17	.13	.17	.14
Mn	.07	.13	.09	.17
Fe	.03	.02	.03	.02
Al	.06	.03	.05	.02
Zn	.013	.013	.012	.012
Na	.04	.03	.04	.03
N	1.46	.66	1.34	.76
Cu (ppm)	45	28	49	26
B (ppm)	24	23	22	27
pH	5.03	4.31	5.10	4.14

TOTAL WEIGHT OF FOREST LITTER

There were no significant differences between the averages of the blocks, although there was a range from 1,462.2 to 1,902.8 pounds/acre/year. This lack of significance may, in part, have been due to the lack of

TABLE II. AVERAGE WEIGHT OF LITTER AND TOTAL AMOUNT OF NUTRIENT ELEMENTS IN FOREST LITTER

	Pine Cover Type		*Hardwood Cover Type*	
	Lesser v.egetation	*Tree Species*	*Lesser Vegetation*	*Tree Species*
		Pounds/Acre/Tear		
Total Litter (oven dry)	231.4	1,248.5	27°·4	1,572.1
K	2.9	5·3	2.9	7·7
Ca	2.2	8·4	2.2	12·5
Mg	1.20	4.25	1.20	6·37
P	·35	1.62	·43	2·33
Mn	.II2	1.671	.234	2.998
Fe	.082	.281	.079	.329
Al	.161	.383	.125	·375
Zn	.031	.165	.035	.185
Na	.092	.328	.II2	.423
N	3·4	8.1	3.8	11.9
Cu	.0105	·°353	.0129	.0434
B	.0052	.0282	.0062	.0421

sensitivity of the experimental design. It might also indicate that although annual amounts of forest debris may vary locally, the production of litter is relatively constant on large areas over a period of several growing seasons. This would tend to be emphasized in the present experiment since the vegetation on each block was essentially similar and site quality did not vary widely.

It is to be noted that the values found for annual weights of litter correspond generally with the lower range of values found by other investigators and summarized in Table 1. Data for similar forest types and geographical locations are comparable.

The hardwood type, with an average annual litter of 1,842.5 pounds per acre, had a significantly higher value than did the pine cover type, which averaged 1,479,9 pounds per acre. This difference was apparent in all four localities in which the experiment was conducted, and during both the 1948 and 1949 growing seasons.

The average weight of litter in 1948 was significantly lower than in 1949. This was true in both forest types, but not on all blocks. Block I showed no difference between the two seasons. This variation from the average figures was entirely due to the variation in weight of overstory litter. Such seasonal variations are not unusual and have been noted by other investigators.

Under all circumstances the overstory litter was significantly greater in weight than that derived from understory plants. Considering all conditions of forest type, year of collection, and locality, the overstory litter averaged 1,410.3 pounds per acre per year, and the understory averaged 250.9 pounds per acre per year. In other words, the understory contributed about 15 percent of the total annual increment of organic matter to the soil.

The understory litter varied somewhat with the various localities. Blocks I and II showed significantly higher values than **III** and IV. This was probably due to two reasons. First, blocks I and II were located on sites that were not as dryas **III** and IV and would thus support more subordinate vegetation under tree canopies. In addition, portions of the stands on block I and II allowed more light to reach the forest floor, either because the crowns were high or the stands more open. This again would tend to promote understory plants. Examination of either the checklist of species in the plot description, or the plot data in the appendix, indicates that blocks I and II had a more varied floristic community and more mesic species than did blocks **III** and IV.

There was little or no variation of understory litter between forest types or years of collection, so the previously indicated variation in total amounts was due entirely to the variations in amount of debris from tree species.

The variation of overstory litter between forest types was probably attributable to inherent differences in the species. This trend is apparent in other work, although direct comparison is not convenient.

It is somewhat more difficult to assign a reason to the annual variation. However, the sampling of the overstory in 1948, as described in the section on procedure, was not for a full year. This might have affected the results, but should have resulted in a uniform difference, and such was not the case (block I showed no difference). As suggested previously, it is unlikely that this factor was important. It is possible that for some reason 1948 was a less favorable year for litter production than 1949.

Four general facts stand out in the data relating to total weight of litter:

(I.) Hardwood forest cover produces more litter than white pine cover.

(2.) The tree species produce more litter than does the subordinate vegetation.

(3.) The amount of subordinate vegetation is controlled more by available moisture on the site and by the nature of the canopy than it is by the species composition of the overstory or by seasonal variation.

(4.) Litter derived from the overstory may vary appreciably between different growing seasons.

RESULTS AND DISCUSSION

POTASSIUM

The outstanding feature in the potassium data is the fact the understory vegetation contained, on an average, twice (1.10 percent) the percentage of this element found in the litter of tree species (0.45 percent). The difference is highly significant from a statistical standpoint. Generally, this variation between overstory and understory held true for all blocks, in both forest types, and during the 1948 and 1949 growing seasons.

It would appear, upon examining both the original data as well as the various averages, that the litter of the tree species was remarkably uniform in potassium content. There was a variation from 0.30 to about 0.60 percent, but in no case is such variation statistically significant. Apparently differences in species, site and growing season, did not affect the potassium content of tree leaves significantly in this experiment. This situation appears somewhat at variance with previous work where wide ranges of potassium content in foliage have been found. Potassium is generally considered to be one of the elements whose availability in the soil is strongly reflected in nutrient content of tree foliage (Lutz and Chandler 1946).

The lesser vegetation, on the other hand, exhibited much more variation in potassium content. Values ranged from 3.88 percent *(Osmunda cinnamomea,* plot I-P-E 1948) to 0.40 percent *(Lycopodium obscurum,* plot IV-H-W 1949). On adjacent hardwood areas in block I during the 1948 season, *Rubus bispidus* varied from 0.50 to 1.14 percent potassium. *Mitcbella repens,* during 1948 on plot II-P-W, averaged 1.12 percent potassium, but in 1949, on the same plot, had only 0.53 percent potassium in the annual parts. Many of the statistical differences in the data can be attributed to this extreme variability in potassium in the subordinate forest plants.

Blocks I and II showed higher potassium values than did III and IV. This appears to be caused by a different species composition in the lesser vegetation. Blocks I and IV showed differences between 1948 and 1949; these are largely attributable to seasonal variation in potassium percentages of the lesser vegetation litter.

When the total weight of potassium in the litter is considered, one fact is outstanding. The understory litter, although averaging only 15 percent of the total weight of all annual debris, contained about 30 percent of the total potassium contributed to the soil annually by organic matter from plants. Although there were other variations, these can be directly traced to the variations in total weight of litter or potassium percentages.

The potassium percentages found in this work coincide roughly with the middle range of values for tree species determined by other investigators, but almost completely cover the range found in the foliage of subordinate vegetation.

CALCIUM

The calcium content in the foliage of different tree species varied widely. The mixed hardwood foliage on plot I-H-E in 1948 contained 1.66 percent, while the white pine litter on plot III-P-S in the same year contained only 0.38 percent. Generally, the pine litter seemed to have less calcium than the hardwood, although this was not as apparent on sites (blocks **III** and IV) which apparently supplied less calcium to all plants as it was on those areas relatively rich in this element (blocks I and II).

The plant material from the subordinate forest vegetation varied even more in calcium content than did the tree litter. The high for a single species (though a miscellaneous group on plot I-P-E was even higher) was 2.29 percent in the leaves of *Prunus serotina* on plot I-H-E in 1948, while the lowest amount was 0.17 percent in *Polytricbum commune* on plot III-P-S during the same year.

In comparing these ranges of calcium values in litter with previous determinations, as summarized in the *review of literature,* it would appear that the data in the present investigation were somewhat lower than average. Although this comparison is not exact, due to obvious differences in species and site, the litter of similar species was generally lower in calcium percentages than indicated by other workers.

As mentioned previously there was more calcium available to plants on blocks I and II than on **III** and IV. This was evident, not only in the average block values, but also when the data were broken down by cover type, year, and into overstory and understory components. In other words, the differences between blocks appear constant under all conditions, and the averages are not the result of some single factor. These differences may have been due to some extent to species differences between blocks. There may have been a greater preponderance of species which tend to accumulate calcium on blocks I and II than on **III** and IV. However, it is also possible that these particular plants may have been present in greater numbers on certain blocks, because the habitat, including more available calcium, allowed them to compete to better advantage.

In comparing similar species on the different blocks during the same growing season, it is apparent that the calcium percentages in litter from blocks I and II are highest. This is brought out in the following table:

TABLE 12. CALCIUM PERCENTAGES IN THE LITTER OF SEVERAL FOREST SPECIES

			Block		
		I	*II*	*III*	*IV*
			Percentage, oven-dry weight		
Pinus Strobus	1948	.59	.72	.43	.46
		.66	.72	.38	.60
	1949	.62	.61	.42	.45
		.76	.72	.51	.44
Dryopteris spinulosa	1948	1.29	1.00		.54
		1.07			
	1949	1.23	.78		.47
		1.26			
Osmunda cinnamomea	1948	1.22	.68		.57
			.82		
	1949	1.14	.76		.54
			1.15		
Carex pensylvanica	1948	.70	.58		.46
	1949	.46	.58		.30

It seems apparent that more calcium was available on certain areas than on others. The soils of all areas were derived from non-calcareous parent material, and while the soil of block I was till, the subsoil of the other areas was composed of similar material overlaid by relatively thin layers of outwash. The most important difference appears to be the fact that the soils of blocks I and II were somewhat more poorly drained than III and IV. Why this should affect available calcium is unknown.

There was some difference between growing seasons in calcium content of litter, but only on two areas. The pine stand on block IV showed a decided reduction in percentage of foliar calcium from 1948 to 1949. This reduction was apparently quite consistent for all species. The same situation existed in the hardwood stand on block I, especially in the litter of the subordinate vegetation. Just why these two areas should be so affected when other essentially similar areas were not is difficult to explain. Generally, the understory vegetation appeared to vary more in calcium content than did the tree species.

No significant differences occurred between the average calcium values for understory and overstory vegetation. Neither was there any significant difference between the pine and hardwood cover type averages. The litter of white pine, however, always contained less calcium than hardwoods on the same area. Generally, *Quercus* spp. did not appear to have as much foliar calcium as *Acer* spp.

Total amount of calcium in the annual litter generally tended to follow the trends of litter quantities, although modified somewhat by the difference in calcium percentages between years and areas. There was an average of 12.6 pounds of calcium per acre per year from all sources considered. Of this amount 2.2 pounds, or 17.5 percent, was derived from the litter of subordinate vegetation.

MAGNESIUM

Magnesium percentages in the litter of subordinate vegetation ranged from a high of 1.07 percent *(Polysticbum acrosticboides,* plot I-P-E 1949) to a low of .02 percent *(Polytricbum commune,* plot III-P-S 1949). A somewhat narrower range was found in the litter of tree species, from 0.73 percent (mixed hardwood, plot I-H-E 1949) to 0.20 percent *(Pinus Strobus,* plot III-P-S 1948). These data compare quite closely with those of other workers.

The various blocks showed significant differences in magnesium. The same general trend was exhibited with .magnesium as in the case of potassium and calcium. The average on block I was higher than blocks **III** and IV, and block II was significantly greater than block **III.** This was probably due to differences in the available magnesium on the various blocks, as well as to differences in the magnesium accumulating powers of the species on the several areas.

The following table shows the variation of individual plant species on different blocks:

TABLE 13. MAGNESIUM PERCENTAGES IN THE LITTER OF SEVERAL FOREST SPECIES

		Block			
		I	*II*	*III*	*IV*
		Percentage, oven-dry weight			
Pinus Strobus	1948	.31	.32	.24	.31
		.29	.30	.20	.32
	1949	.39	.30	.23	.29
		.32	.34	.24	.31
Dryopteris spinulosa	1948	.56	.68		.51
		.51			
		.56			
	1949	.78	.85		.69
		.77			
		.90			
Osmunda cinnamomea	1948	.59	.49		.39
			.48		
			.53		
	1949	.79	.60		.48
			.52		
			.58		
Carex pensylvanica	1948	.20	.21		.26
	1949	.34	.30		.17

The data also show a significant variation between the two growing seasons in which material was collected. During the 1949 season the magnesium content averaged 0.42 percent, whereas in 1948 the average was only 0.37 percent. This seasonal difference, although small, is statistically significant, and is evident not only in general annual averages but throughout the body of the data regardless of forest type, experimental area, or type of vegetation. No explanation is available within the scope of present information, but as previously discussed, similar annual variations have been commonly recorded.

Although the understory litter average (0.42 percent) was significantly higher than the average of the tree litter (0.37 percent), there were exceptions on certain areas. The data for block III show that, although the vegetation had less foliar magnesium than similar species on other blocks, certain understory species, particularly *Lycopodium clavatum* and *Polytrichum commune,* were exceptionally low in magnesium. The preponderance of these species actually caused the overstory average to be higher than the understory on this block.

In general, the litter of hardwood trees on all blocks had as high a magnesium content as that of the understory species but, except on block III, the pine litter was lower in magnesium than the litter of subordinate vegetation. The content of magnesium in the annual parts of the lesser vegetation also tended to vary more than in the case of tree species.

When the data on the annual total weight of magnesium are examined, several features appear. Hardwood litter contributes significantly more magnesium each year due to a combination of higher percentages of this element and greater weight per unit area. Blocks III and IV, which produced the least understory vegetation, also had lower magnesium percentages and this combination reduced the total magnesium appreciably. The understory, considering all blocks, contributed an average of 18.4 percent of all magnesium.

PHOSPHORUS

The percentages of phosphorus in forest litter are generally lower than those of the previously discussed elements. This is apparent from an examination of the data of the present experiment, or of the data of other investigators, as summarized in the *review of literature.*

In the litter of forest trees, values varied from 0.25 percent (*Quercus rubra,* plot III-P-S 1949) to 0.08 percent *(Pinus Strobus* and mixed hardwoods on the pine plots of block I 1948). The comparable range for lesser vegetation was 0.35 percent (miscellaneous group, plot III-P-S) to 0.08 percent *(Dryopteris noveboracensis,* plot I-H-W 1949). These values compare with the middle range of phosphorus contents in forest plants as determined by other workers.

The several blocks exhibited significantly different average phosphorus values. The differences previously found in other elements were reversed in the case of phosphorus. The two drier blocks, III and IV, had the higher values. This was apparent during both growing seasons and in pine and hardwood cover types. The normal assumption might be that more available phosphorus existed on these blocks. The following table brings out some interesting points in this respect:

TABLE 14. PHOSPHORUS PERCENTAGES IN THE LITTER OF SEVERAL FOREST SPECIES

		Block			
		I	*II*	*III*	*IV*
		Percentage, oven-dry weight			
Pinus Strobus	1948	.08	.10	.12	.09
		.08	.11	.12	.10
	1949	.11	.11	.15	.12
		.11	.10	.18	.12
Dryopteris spinulosa	1948	.23	.16		.14
		.22			
	1949	.12	.12		.25
		.18			
		.13			
Osmunda cinnamomea	1948	.23	.15		.14
			.20		
			.20		
	1949	.12	.11		.18
			.17		
			.13		
Carex pensylvanica	1948	.16	.15		.11
	1949	.11	.13		.18

There is no definite trend shown in Table 14. Although it is based on limited data, this indicates that the reason for block differences was not variation in available phosphorus. Rather it may have been differences in the phosphorus accumulating abilities of the plant communities occupying the areas. An examination of the species lists in the section on plot descriptions and of the original data in the appendix tends to confirm this view. Certain understory species on blocks I and II appeared to be low in phosphorus, but differences were more apparent in the overstory species. This was most evident in the hardwood cover type, and appeared to be primarily a difference between the oaks on blocks III and IV and the maples found on the moister soils of blocks I and II. The leaves of the oaks appeared, in this experiment, to contain more phosphorus than did maple leaves. Chandler (1941) did not find similar differences in New York.

No significant differences appeared in the averages of the two forest types or between the two growing seasons.

The understory litter, with an average value of 0.17 percent phosphorus, proved significantly higher in this respect than the litter of tree species, which averaged 0.14 percent. There may have been some tendency for phosphorus content to vary from one part of an individual stand to another, as shown by the significance of the replication interaction. This variation appeared to be primarily a function of the overstory. Generally, the tree litter seemed more variable in phosphorus content than did the litter of lesser vegetation. This might have indicated a greater sensitivity to phosphorus levels, or perhaps a lower ability to procure certain forms of phosphorus.

The understory contributed about 16.5 percent of the total annual increment of phosphorus to the surface of the soil. This amount was proportionately slightly greater than the weight of the litter from this source.

MANGANESE

Manganese percentages in the annual parts of lesser vegetation ranged from 0.01 percent (*Osmunda cinnamomea*, *Lycopodium* spp., and other species) to 0.62 percent (miscellaneous group, plot III–P–S 1948). In tree litter the range was from 0.03 percent (*Pinus Strobus* and mixed hardwood, largely maple, on plot I–P–E 1948) to 0.71 percent (*Quercus rubra*, plot III–P–S 1949). These values are somewhat higher than those of other investigators, but extreme variability of manganese percentages is also indicated in the previous work.

The various blocks showed significantly different manganese averages. The averages for blocks III and IV proved significantly higher than those for I and II, following the pattern exhibited by phosphorus.

This table indicates a strong possibility that there was more available manganese on blocks III and IV than on I and II. The other manganese data in the appendix also support this view.

No difference in manganese percentages was evident between the two cover types.

Data for the 1948 and 1949 growing seasons showed a significant difference in averages, values for the 1949 season being the higher. This variation was caused almost entirely by variation in the manganese content of the overstory vegetation, and was particularly evident on block III. No explanation of seasonal differences is attempted. Similar variations have been found in previous studies.

TABLE 15. MANGANESE PERCENTAGES IN THE LITTER OF SEVERAL FOREST SPECIES

		Block			
		I	*II*	*III*	*IV*
		Percentage, oven-dry weight			
Pinus Strobus	1948	.03	.04	.16	.06
		.06	.05	.18	.04
	1949	.05	.06	.31	.16
		.08	.07	.35	.05
Dryopteris spinulosa	1948	.02	.03		.12
		.04			
		.02			
	1949	.01	.02		.14
		.08			
		.02			
Osmunda cinnamomea	1948	.01	.14		.17
			.16		
			.08		
	1949	.04	.09		.21
			.10		
			.08		
Carex pensylvanica	1948	.09	.05		.07
	1949	.07	.04		.09

The leaves of tree species averaged 0.15 percent manganese, nearly twice the amount found in the litter of subordinate vegetation (0.08 percent). This difference was not as evident on the areas of lower manganese availability (blocks I and II) as it was on block III. On block IV, in the pine cover type, the understory foliage contained more manganese than the overstory.

It was evident that there was a very wide range among the forest plant species on the experimental areas in ability to procure manganese. Generally, the tree species, particularly the oaks, were more efficient than the understory vegetation in this respect. This was especially true when there were relatively large amounts of available manganese. Under conditions of less available supplies, the difference in composition between overstory and understory species was narrowed.

The litter of the understory contributed only about 7 or 8 percent of the annual increment of manganese to the forest floor.

IRON

Iron values in the annual parts of understory species ranged from 0.09 percent (miscellaneous group, plot I–P–W 1948) to 0.01 percent (*Kalmia latifolia*, plot II–P–E 1948). In the tree species represented by these data, the range was from 0.04 percent (*Pinus Strobus*, plot II–P–E 1949) to 0.01 (*Quercus alba*, *Quercus rubra*, *Acer rubrum*, and *Pinus*

Strobus). These values were somewhat lower than the data of other workers. As can be observed there was a rather narrow range in iron percentages compared with nutrient elements previously considered.

There is evidence that plant species in block IV averaged less foliar iron than those in the other blocks. This was largely due to the understory on this block. An examination of the data indicates that there was no single strikingly low value of this element, but rather a predominance of species that produced litter having about 0.02 percent iron. Since the evidence is not strong, and the tree species on the same block showed no similar trend, the difference appeared due to specific floristic composition rather than to difference in iron availability.

There was no difference between the two forest types or between the 1948 and 1949 growing seasons.

The understory litter, except on block IV, contained a significantly greater amount of iron than the foliage of the trees.

An average of the entire experimental area showed that the litter of subordinate vegetation, 15 percent of the annual total by weight, contained 20.8 percent of the iron returned to the soil by the plant debris.

ALUMINUM

The range in aluminum values for the understory vegetation was from 0.25 percent *(Lycopodium complanatum,* plot II–H–W 1948) to 0.01 percent in several species *(Kalmia latifoNa, Osmunda cinnamomea,* etc.). The range was much less in the litter of tree species, varying from 0.10 (mixed hardwood, plot IV–H–W 1949) to 0.01 in several species, including *Pinus Strobus, Acer rubrum,* and *Quercus* spp. The values for trees were quite similar to the data of other investigators. However, the range in subordinate vegetation was wider than previous data have indicated.

There was no significant difference between the various areas in average aluminum content in the litter, nor was there any difference between the averages for the two forest cover types.

The average aluminum percentage in the 1948 growing season was significantly higher than in 1949. This difference was largely due to high values in 1948 in the understory material on blocks II and **III.** An examination of the data on individual species in the appendix shows that the genus *Lycopodium* and such species as *Polytricbum commune, Mitcbella repens,* and certain of the ferns had very high aluminum percentages. On areas where these species made up a major portion of the annual growth, values were quite high. These same species also tended to show more variation in composition from one growing season to another.

The understory vegetation averaged 0.06 percent aluminum, three times greater than the overstory average.

Although the understory litter was only 15 percent of the total weight, its average annual contribution of aluminum to the soil on the experimental plots amounted to 28.8 percent of the total. On one area, block II, there was no significant difference between the amounts of aluminum from overstory and understory material, in spite of the much greater weight of overstory litter.

ZINC

The litter of subordinate vegetation varied in zinc content from 0.027 percent (miscellaneous species, plot II-H-W 1949) to 0.001 percent for several species in 1949. The forest tree litter varied from 0.026 percent (mixed hardwood, plot IV-H-W 1948) to 0.002 percent (*Quercus rubra*, plot II-H-N 1949). These ranges are quite comparable to those found in the *review of literature*.

The average percentages of zinc in the litter were fairly constant in most instances. Block III, however, seemed to be consistently lower than the other areas. This difference was evident in both hardwood and pine cover types, during both growing seasons, and for overstory and understory vegetation. It was, however, more pronounced in the understory data, particularly during the 1948 season.

An examination of the species data shows that the understory species on block III, particularly in the hardwood cover type, were predominantly plants with low zinc content. Among those particularly low in 1948 were *Gaultheria procumbens* and *Hamamelis virginiana*. However, it also appeared that the same species had a somewhat lower zinc percentage on block III than on other areas, indicating a lower available supply on this particular block.

Which of these two manifestations of low zinc availability was cause, and which effect, was not determined. The abundance of plant species with a tolerance for low zinc availability may have been due to original low supplies of zinc, creating a favorable competitive environment for this type of plant. On the other hand, it is possible that available zinc supplies have been reduced because the particular plants present on the area have not efficiently kept this element in the nutrient cycle. A more likely explanation however, probably rests on a combination of both, neither reason being solely cause or effect.

As a result of the general regularity of zinc percentages in litter, the total amounts of this element closely paralleled the total weights of litter. The variation in average zinc percentages between blocks was not enough to cause significant differences in total amounts of the nutrient.

RESULTS AND DISCUSSION

SODIUM

Sodium percentages in the litter of subordinate vegetation in this investigation ranged from 0.10 (*Dryopteris spinulosa*, plot I–P–E 1948) to 0.01 for a group of species such as *Osmunda cinnamomea*, *Prunus serotina*, *Lycopodium complanatum*, *Lycopodium lucidulum*, and *Kalmia latifolia.*

In tree species litter the range of sodium content was more restricted, varying from 0.06 percent to 0.01 percent. Mixed hardwoods, during 1948 on plot IV–H–W, had the highest value, and several species, or groups of species, also hardwoods and on blocks III and IV, were low during the 1949 season.

The understory values coincided quite closely with previous investigations, but generally the values for tree species appeared low. Several other research workers have indicated much higher sodium values, particularly among the oaks (see *review of literature*).

The differences between the various blocks in sodium percentages closely paralleled those previously considered for such elements as potassium and calcium. Blocks I and II had significantly higher sodium averages than III and IV. This difference was not as apparent in the understory as in the overstory.

The hardwood cover type had a significantly higher average than the pine type. There was no significant difference between seasonal averages, although individual species or groups of species may have varied greatly from one season to another.

All these differences are statistically significant, but are so small in actuality that there is probably no ecological significance.

One difference, however, was quite consistent throughout variations in area, cover type, and season. The understory litter was higher in sodium content than was that of the overstory. This resulted in an annual average amount of 21.4 percent of all sodium in the forest litter being derived from understory material.

COPPER

The content of copper in forest litter from subordinate vegetation varied from 104 parts per million (*Brachyelytrum erectum*, plot II–H–E 1948) to 22 parts per million (*Gaultheria procumbens*, plot IV–H–W 1948 and *Alnus rugosa*, plot IV–P–W 1949). In forest tree litter the range was from 72 parts per million (mixed hardwoods, plot II–H–E 1949) to 15 parts per million (*Pinus Strobus*, plot I–P–W 1948).

The data of other investigations, as summarized in the *review of literature*, supply little information concerning copper; however, the ranges indicated are roughly comparable to those in the present work.

Although the average copper content of the litter of the several blocks varied statistically, the actual differences were small. Block III was significantly higher than blocks I and IV, and block II had a higher average than block I. Such differences appeared most evident in the overstory of block I, where both pine and hardwood litter were quite low in copper. In block III it was the understory material which was high, particularly in the pine cover type. On examining the species data in the appendix, it is apparent that these differences were largely due to variation in floristic composition. For instance, in block III, individual species did not necessarily have a higher copper content than on other blocks, but a preponderance of all species present on this area were in the high-copper group.

There may have been some difference in copper availability on block I, where certain overstory species appeared to have somewhat less copper than similar species on other blocks. This effect was not evident in the subordinate vegetation, however, and so the argument loses some of its validity unless different rooting levels are considered to be important. There is little supporting evidence for such a consideration.

No difference was evident between averages of the copper content of the litter from the two cover types. Neither was there a significant difference between the averages for the two growing seasons, although block IV varied quite widely. This variation is one of the more interesting, though unexplainable, points in the copper data. The variation was almost entirely due to the understory in the hardwood type having very high values in 1949 compared to 1948 This was apparent for nearly all subordinate vegetation species on both plots in this type, but was not reflected in the tree species. As in previous considerations of seasonal variation of nutrient content in foliage, no adequate explanation is available.

The average copper content of the understory litter was almost twice that of the average content in the foliage of tree species. This general trend held true with few exceptions, under all conditions of cover type, growing season, and area. As a result, in this experiment, 22.9 percent of average amount of copper annually supplied to the forest floor was derived from the litter of subordinate forest vegetation. On one area (block I), however, there was actually no significant difference between the amounts of copper derived from understory and overstory.

BORON

The boron content in forest litter is relatively small and is most conveniently denoted in terms of parts per million.

In the present data, values ranged from 52 parts per million (miscellaneous species, plot I-P-E 1948) to 4 parts per million *(Braehyelytrum ereetum,* plot II-H-E 1948) in the subordinate vegetation, and from 38 parts per million (*Quercus rubra,* plot III-P-S 1949, and mixed hardwoods, plot III-H-S 1949) to 12 parts per million *(Pinus Strobus,* block I 1948) in tree species.

Any comparison with other data is extremely tenuous, due to differences in site, species, and method of analysis. In addition, boron is not one of the elements for which information is readily available. However, the ranges exhibited in this research were quite comparable to those from other investigations.

There was a very definite variation in boron content between individual species. No significant difference was found in average plot values for different locations, growing seasons, cover types, or classes of vegetation. Certain departures from this general observation were apparent when a more detailed breakdown of the data was made. For instance, in the hardwood cover type, tree species had a significantly higher boron content than did the subordinate vegetation, but a similar trend was not apparent in the pine cover type. The litter of hardwood trees was higher in boron than the litter of pines.

There were other variations which could nearly all be traced to varying floristic composition or to seasonal changes by individual plant species.

Due to the overall similarity in boron percentages, total weight of boron in forest litter very closely paralleled the weight of the litter itself.

NITROGEN

As previously indicated, no determinations of nitrogen were made on the litter of individual species. Rather, composite samples of the understory and of the overstory for each plot were utilized to ascertain percentages of this element.

In the understory, values ranged from 2.18 percent on plot I-P-E in 1948 to 1.02 percent on plot IV-H-E in the same growing season. Nitrogen percentages for overstory litter varied from 0.86 percent on plots III-H-S and IV-H-W in 1948 and plot III-H-S in 1949, to 0.54 on both pine plots in block IV in 1948. These determinations compare quite closely with the lower values of other investigations. It is significant that few of the species reported to have very high nitrogen contents by other workers are represented in the present data.

The differences between the various blocks followed the same trend exhibited by potassium, calcium, magnesium, and several other elements.

The vegetation on the two moister areas, blocks I and II, was somewhat higher in average nitrogen content than that on blocks III and IV. This difference was almost entirely due to the subordinate vegetation and quite possibly reflected the differing species composition of the understory between the moister and drier areas.

No differences appeared between the averages of the pine and hardwood cover types, or between the 1948 and 1949 growing seasons. However, when the data were examined in more detail, certain variations from these general conclusions were evident. Block I did show a significant difference between years, 1948 being higher. Here again, though, the difference was almost entirely due to variation in subordinate vegetion values.

When the averages for the two cover types were divided into understory and overstory data, it was evident that the hardwood overstory litter contained significantly more nitrogen than did the white pine needles. On the other hand, the subordinate vegetation under pine stands had significantly greater contents of nitrogen than did that under hardwood trees. This could have been caused by species variation, but this was unlikely for two reasons. First, floristic composition did not appear to vary appreciably under the two types of stands on the same block. Second, if there was variation, it had been usual, in the case of other elements, for the subordinate species under pine to contain lower amounts. However, it is possible that the difference indicated was caused by differential competition by the overstory for available nitrogen. A pine overstory may not compete as strongly for nitrogen, and thus leave more available to the subordinate vegetation than would a hardwood overstory under similar circumstances.

The understory litter generally averaged 1.40 percent nitrogen, almost twice the average (0.71 percent) of the tree species. This difference was the most striking and constant fact to be derived from the nitrogen data, occurring under all conditions of growing season, area, or cover type. As a result, more than one quarter (26.5 percent) of the total average annual weight of nitrogen added to the forest floor from organic debris was derived from the annual parts of subordinate vegetation. On certain areas, however, for example block I of this experiment, there was no statistically significant difference between the annual amounts of nitrogen from overstory and understory. In the hardwood type of this same block, the understory contributed more nitrogen than the overstory, although this difference was not statistically proven.

RESULTS AND DISCUSSION

HYDROGEN ION CONCENTRATION

The determination of hydrogen ion concentration was made on composite samples of plant material identical to those used in obtaining the nitrogen content of forest litter. The details of the laboratory procedure used may be found in a previous section. The values obtained are expressed in the usual pH units.

Averages for individual plant parts ranged from a pH of 6.29 (plot I-P-E 1948) to 4.33 (plot III-H-S 1949) in the case of the subordinate vegetation. The litter of the tree species varied from a pH of 4.85 (plot I-P-E 1949) to 3.80 (plot I-H-W 1949).

No significant differences in average pH values were evident between blocks, cover types, or growing seasons.

The average pH of the understory litter was 5.06, and that of the overstory 4.23. This average difference proved significant, and similar differences were evident in more detailed grouping of the data. The higher pH of the understory under all conditions, appeared to be the most important feature of this phase of the investigation.

These results are not surprising in the light of the information given in previous sections. Generally, the understory material has had higher contents of basic elements (potassium, calcium, magnesium).

There was some variation between blocks when the understory litter alone was considered. The litter of block III was significantly more acid than that on the other blocks. This again was explainable on the grounds of nutrient element concentrations. The understory on this area has been shown to be lower in calcium, potassium, and magnesium, than on other locations, and higher in manganese, copper, and aluminum. This difference could quite possibly create more acid conditions.

SUMMARY AND CONCLUSIONS

FOREST litter is the parent material of the humus in forested areas, and as such is of primary importance in soil formation. The litter contributes a major portion of the annual increment of nutrient elements to forest soils. In addition, it has a profound influence on such important and diverse factors as seedbed conditions and fire hazard. For these and other reasons, forest litter is of interest to anyone making a study of, or attempting to manage, a forest stand.

There is an extensive literature dealing with many aspects of organic litter in forests. Much of this work is fragmentary, dealing only with phases of particular interest in the course of another investigation.

A review of the literature leaves an impression of great complexity and variation in amount and quality of forest litter, dependent on factors such as species composition, site, age, vigor and density of vegetation, and specific growing season.

This experiment was undertaken to investigate one aspect of the general problem. This concerned the relative importance of subordinate forest vegetation compared to tree species in producing litter. Both the quantity and quality of the litter was investigated.

The work was conducted on the property of the White Memorial Foundation in northwestern Connecticut. Here plots were laid out in two forest types on four different areas. On these plots the litter of the subordinate vegetation and the tree species was collected by species, or groups of species, over the course of two growing seasons. The litter weights, by area, were calculated and analyses carried out to determine the percentages of twelve nutrient elements and the hydrogen ion concentration.

Weight of Litter

Under all circumstances, the tree species produced more litter than did the subordinate vegetation on the same areas. In this experiment, the litter of subordinate vegetation averaged 15 percent of the total annual weight of litter. The hardwood cover type produced more litter (average of 1,842 pounds per acre per year) than the pine cover type (average 1,480 pounds per acre per year). It appeared that the amount of subordinate vegetation was more controlled by available moisture on an area and by the density of the overstory canopy than by the species composition of the canopy. It was also evident that the weight of the annual litter fall from tree species may vary appreciably from year to year. Such random seasonal variation was less evident in the subordinate vegetation.

Potassium

The most interesting fact in the potassium data was that the litter of subordinate vegetation contained an average percentage (1.10), twice that (0.45) found in the litter of tree species. As a result, 30 percent of the annual increment of potassium to forest soil from litter was derived from subordinate vegetation.

The litter of trees was relatively constant in potassium percentage, but the values in the litter of subordinate vegetation fluctuated widely, depending on species, area, and growing season.

Calcium

There was variation in calcium content between species in both understory and overstory litter, but greater differences were found in the subordinate vegetation.

It was probable that more available calcium was present on certain of the experimental areas than on others. This was evident, not only in area averages, but by direct single-species comparisons. Generally, the white pine litter appeared low in calcium compared either to hardwood litter or to the litter of subordinate vegetation. Otherwise there was no outstanding difference between tree species and subordinate vegetation litter.

Magnesium

Area averages in magnesium percentages of forest litter followed much the same pattern of variation shown by calcium. In addition, there were significant differences between the growing season averages, and between overstory and understory averages. Although the understory average was higher than that of the tree species, certain individual understory species, notably *Lycopodium clavatum* and *Polytrichum commune*, had very low magnesium percentages. The pine litter generally was lower in magnesium content than either hardwood tree litter or subordinate vegetation litter.

Phosphorus

Decided differences in average phosphorus values of litter were found on the several experimental areas. These differences were probably caused, not by different levels of phosphorus availability, but by species selectivity. The variations were most evident in the litter of tree species, primarily due to the high phosphorus values in oak litter compared to maple litter.

The litter of subordinate vegetation had a higher average phosphorus content than did the litter of the forest trees.

Manganese

Extreme variability was found in the amounts of manganese in forest litter. The dry sites probably supplied greater amounts of available manganese than the moist areas. Species selectivity in accumulating foliar manganese was very evident. Tree species, particularly oaks, were apparently more efficient in obtaining manganese than subordinate vegetation. This trend seemed most evident on areas of relatively high manganese availability. The litter of forest trees averaged 0.15 percent manganese, whereas the litter of subordinate vegetation averaged 0.08 percent.

Iron

The iron percentages in forest litter did not have as wide a range as the previously considered nutrient elements. However, species selectivity was still apparent in both overstory and understory. The litter of subordinate vegetation had a higher average iron content than did the forest tree litter.

Aluminum

The average aluminum percentages of litter did not differ appreciably from area to area, although species variation was evident. This was particularly true in the case of subordinate vegetation, where the annual parts of *Lycopodium* spp., *Polytrichum commune*, and *Mitchella repens* had relatively high aluminum contents. These same species also exhibited most variation from one growing season to the next. The litter of subordinate vegetation averaged 0.06 percent aluminum, three times the average percentage in tree litter.

Zinc

Although a range of zinc content in forest litter was found for different species, few differences in the general averages were significant. There was no significant variation between the zinc averages for the two growing seasons, the two cover types, or between understory and overstory litter. One experimental area probably supplied less available zinc than the others. This difference was accentuated by a concentration on this particular area of species of understory vegetation with lower than average zinc percentages; *Gaultheria procumbens* and *Hamamelis virginiana* were in this category.

Sodium

Sodium in forest litter exhibited the same general characteristics as potassium, calcium, and magnesium, although present in smaller quantities. It was apparent that sodium was more available on the moister sites. The litter of the hardwood cover type averaged more sodium than that of the pine cover type. The understory litter had a higher average sodium content than overstory litter. Although these differences were statistically significant, the absolute variations were very small,-probably of little ecological significance.

Copper

The copper content of forest litter was relatively small, although the litter of subordinate vegetation averaged nearly twice as much copper as did the litter of tree species. On one experimental area, there was considerable variation in the copper content of the understory litter during the two growing seasons. This difference was apparent in nearly all species of subordinate vegetation, but was not reflected in the tree species.

Boron

As in the case of copper, boron was not plentiful in forest litter, and was constant in average quantity under most conditions of the experiment. The boron concentration in the litter varied according to species, but no significant differences were found between averages for years, areas, or overstory and understory. The litter of hardwood trees contained more boron than white pine litter.

Nitrogen

Differences between experimental areas in nitrogen content of litter followed the pattern set by potassium, calcium, magnesium, and sodium. Nitrogen values were higher on the moister soils supporting more varied floristic communities. This difference appeared due primarily to the differing subordinate vegetation on these areas compared to drier sites. The litter of subordinate vegetation averaged 1.40 percent nitrogen over the whole experiment, whereas tree species litter had an average nitrogen content of 0.71 percent. The litter of hardwood trees contained more nitrogen than the pine litter, although in considering the litter of subordinate vegetation under these stands, the situation was reversed. This variation may have been caused by differential competition from the two overstories. On some areas, there was no statistical difference between absolute amounts of nitrogen derived from overstory and understory in spite of the greater weight of the litter from the overstory.

Hydrogen Ion Concentration

No significant differences were found between the averages for the litter of various experimental blocks, forest cover types, or growing seasons. The litter of subordinate vegetation was consistently less acidic under all conditions than the litter of the overstory. Although there was little difference in the litter of subordinate vegetation, the litter of the overstory showed white pine needles were slightly less acid than hardwood leaves.

There is strong evidence that the litter of subordinate vegetation in forest stands may play an important role in the general nutrient cycle. Due to higher concentrations of many nutrient elements in this portion of the forest litter, the influence of the litter of subordinate vegetation must be greater than its proportional weight would indicate. In considerations of forest soil fertility and humus layer conditions, it is evident that the importance of the understory vegetation should not be minimized, and surely cannot be ignored. The nutrient cycle in forest communities clearly involves the subordinate vegetation as well as the trees in the overstory. Too commonly forest stand composition is viewed only in terms of the tree species in the main canopy. From a biological point of view the subordinate vegetation is obviously a part, and, as the present investigation has shown, may be an important part, of the forest community. It should be recognized that so-called pure forest stands (in which at least 80 percent of the trees are of a single species) containing a rich understory vegetation are, biologically, not pure but mixed. Although the data presented are directly applicable only to the specific forest types and areas in which the experiment was conducted, there are indications that the effects of subordinate vegetation on soil conditions, especially fertility, are far reaching and deserve further study and investigation.

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APPENDIX

TABLE A. WEIGHT AND CHEMICAL COMPOSITION

Species	*Litter Weight, Oven Dry, Lbs. Per Acre*	*K Per Cent*	*K Lbs. Per Acre*	*Ca Per Cent*	*Ca Lbs. Per Acre*	*Mg Per Cent*	*Mg Lbs. Per Acre*	*P Per Cent*	*P Lbs. Per Acre*	*Mn Per Cent*	*Mn Lbs. Per Acre*
Osmunda cinnamomea	35.7	3.88	1.4	1.22	.4	.59	.21	.23	.08	.01	.004
Dryopteris spinulosa	59.8	3.75	2.2	1.29	1.7	.56	.21	.23	.14	.02	.012
Athyrium thelypterioides	52.0	3.70	1.9	1.13	.6	.56	.29	.25	.13	.02	.010
Polystichum acrostichoides	30.5	1.60	.5	.82	.3	.70	.21	.14	.04	.02	.006
Alnus rugosa	12.6	.96	.1	1.40	.2	.60	.08	.12	.02	.07	.009
Mitchella repens	87.2	1.00	.9	.96	.8	.70	.61	.10	.09	.02	.017
Miscellaneous species	14.2	2.97	.4	2.84	.4	.59	.08	.29	.04	.03	.004
Total, Plot I–P–E	292.0	2.53	7.4	1.51	4.4	.58	1.69	.18	.54	.03	.062
Athyrium Filix-femina	22.0	2.86	.6	1.13	.2	.50	.11	.23	.05	.04	.009
Dryopteris spinulosa	34.8	2.92	1.0	1.07	.4	.51	.18	.22	.08	.04	.014
Mitchella repens	94.9	1.24	1.2	1.38	1.3	.64	.61	.16	.15	.04	.038
Polystitchum acrostichoides	9.9	1.70	.2	.93	.1	.59	.06	.18	.02	.03	.003
Miscellaneous species	66.4	1.44	1.0	1.47	1.0	.52	.35	.22	.15	.06	.040
Total, Plot I–P–W	228.0	1.75	4.0	1.32	3.0	.57	1.31	.20	.45	.05	.104
Dryopteris spinulosa	32.0	2.60	.8	1.35	.4	.56	.18	.17	.05	.02	.006
Dryopteris noveboracensis	37.0	2.22	.8	1.41	.5	.50	.19	.18	.07	.09	.033
Athyrium Filix-femina	23.0	.63	.1	1.36	.3	.45	.10	.17	.04	.06	.014
Rubus idaeus	187.9	2.09	3.9	1.32	2.5	.54	1.01	.17	.32	.03	.056
Rubus hispidus	39.6	.79	.3	.84	.3	.45	.18	.14	.06	.08	.032
Prunus serotina	15.9	1.15	.2	2.29	.4	.73	.12	.16	.03	.08	.013
Carex laxiflora	107.1	.70	.7	.62	.7	.18	.19	.13	.14	.06	.064
Miscellaneous species	79.0	1.41	1.1	1.53	1.2	.49	.39	.18	.14	.04	.032
Total, Plot I–H–E	521.5	1.51	7.9	1.21	6.3	.45	2.36	.16	.85	.05	.250
Rubus idaeus	65.7	.43	.3	1.57	1.0	.44	.29	.24	.16	.07	.046
Rubus hispidus	80.4	.72	.6	1.13	.9	.54	.43	.18	.14	.14	.113
Prunus serotina	67.7	1.42	1.0	1.67	1.1	.73	.49	.21	.14	.16	.108
Maianthemum canadense	14.7	1.78	.3	1.29	.2	.44	.06	.28	.04	.22	.032
Dryopteris noveboracensis	28.5	1.98	.6	.98	.3	.54	.15	.18	.05	.15	.043
Athyrium Filix-femina	45.1	2.34	1.1	1.47	.7	.54	.24	.18	.08	.02	.009
Dryopteris spinulosa	36.5	2.66	1.0	1.45	.5	.62	.23	.17	.06	.02	.007
Carex pensylvanica	121.7	.66	.8	.70	.9	.20	.24	.16	.19	.09	.110
Miscellaneous species	77.4	1.20	.9	1.63	1.3	.47	.36	.20	.15	.09	.070
Total, Plot I–H–W	537.7	1.23	6.6	1.28	6.9	.46	2.49	.19	1.01	.10	.538
Lycopodium complanatum var. flabelliforme	113.6	.90	1.0	.33	.4	.16	.18	.15	.17	.02	.023
Lycopodium lucidulum	57.4	1.30	.7	.27	.2	.12	.07	.12	.07	.01	.006
Kalmia latifolia	12.7	.51	.1	1.01	.1	.33	.04	.10	.01	.08	.010
Mitchella repens	217.1	1.02	2.2	1.13	2.6	.60	1.30	.13	.28	.03	.065
Rubus pubescens	69.1	.52	.4	.82	.6	.36	.25	.16	.11	.08	.055
Miscellaneous species	74.8	1.40	1.0	1.20	.9	.48	.36	.19	.14	.07	.052
Total, Plot II–P–E	544.7	.99	5.4	.88	4.8	.40	2.20	.14	.78	.04	.211
Mitchella repens	142.2	1.12	1.6	1.37	1.9	.68	.97	.14	.20	.03	.043
Osmunda cinnamomea	81.8	2.21	1.8	.68	.6	.49	.40	.15	.12	.14	.114
Lycopodium complanatum var. flabelliforme	76.4	1.03	.8	.39	.3	.20	.15	.13	.10	.02	.015
Lycopodium lucidulum	28.6	1.37	.4	.28	.1	.10	.03	.14	.04	.01	.003
Dryopteris noveboracensis	33.3	2.14	.7	.75	.2	.45	.14	.13	.04	.08	.027
Athyrium Filix-femina	30.7	2.34	.7	1.26	.4	.59	.18	.18	.06	.02	.006
Dryopteris spinulosa	52.2	2.35	1.2	1.00	.5	.68	.35	.16	.08	.03	.016
Miscellaneous species	65.6	1.79	1.2	1.26	.8	.54	.35	.20	.13	.03	.020
Total, Plot II–P–W	510.8	1.64	8.4	.94	4.8	.50	2.57	.15	.77	.05	.244
Brachyelytrum erectum	13.1	2.12	.3	.34	.1	.03	—	.16	.02	.01	.001
Osmunda cinnamomea	18.5	2.90	.5	.82	.2	.48	.09	.20	.04	.16	.030
Viburnum recognitum	20.7	1.18	.2	1.53	.3	.77	.16	.19	.04	.08	.017
Carpinus caroliniana	15.9	.82	.1	1.08	.2	.48	.08	.19	.03	.19	.030
Lycopodium obscurum	28.0	.61	.2	.21	.1	.18	.05	.18	.05	.02	.006
Lycopodium complanatum var. flabelliforme	103.3	1.02	1.1	.44	.5	.33	.34	.18	.19	.02	.021
Miscellaneous species	30.3	1.78	.5	1.46	.4	.51	.15	.25	.08	.11	.033
Total, Plot II–H–E	229.8	1.26	2.9	.78	1.8	.38	.87	.20	.45	.06	.138
Prunus serotina	16.8	1.16	.2	1.66	.3	.66	.11	.24	.04	.07	.012
Osmunda cinnamomea	36.2	2.42	.9	.81	.3	.53	.19	.20	.07	.08	.029
Brachyelytrum erectum	30.7	2.00	.6	.91	.3	.47	.14	.20	.06	.02	.006
Lycopodium complanatum var. flabelliforme	47.4	1.16	.5	.30	.1	.22	.10	.19	.09	.02	.009
Carex pensylvanica	14.7	1.34	.2	.58	.1	.21	.03	.15	.02	.05	.007
Miscellaneous species	58.9	1.97	1.2	1.05	.6	.48	.28	.21	.12	.05	.029
Total, Plot II–H–W	204.7	1.76	3.6	.87	1.7	.42	.85	.20	.40	.04	.092
Lycopodium clavatum	43.1	.98	.4	.31	.1	.13	.06	.20	.09	.05	.022
Polytrichum commune	24.5	.60	.1	.26	.1	.10	.02	.22	.05	.04	.010
Miscellaneous species	6.9	.69	.1	.82	.1	.33	.02	.31	.02	.52	.036
Total, Plot III–P–N	74.5	.81	.6	.40	.3	.13	.10	.21	.16	.09	.068
Lycopodium clavatum	29.5	.86	.3	.18	.1	.05	.01	.18	.05	.08	.024
Polytrichum commune	51.6	.57	.3	.17	.1	.04	.02	.19	.10	.04	.021
Miscellaneous species	11.7	.70	.1	.80	.1	.29	.03	.35	.04	.62	.073
Total, Plot III–P–S	92.8	.75	.7	.32	.3	.06	.06	.20	.19	.13	.118
Gaultheria procumbens	36.7	.78	.3	.89	.3	.25	.09	.16	.06	.12	.044
Hamamelis virginiana	22.4	1.23	.3	1.01	.2	.24	.05	.30	.07	.25	.056
Aralia nudicalis	19.6	1.41	.3	1.06	.2	.24	.05	.28	.05	.41	.080
Miscellaneous species	29.3	1.70	.2	.68	.2	.46	.13	.14	.04	.10	.029
Total, Plot III–H–N	108.0	1.02	1.1	.83	.9	.30	.32	.20	.22	.19	.209

Fe Per Cent	*Fe Lbs. Per Acre*	*Al Per Cent*	*Al Lbs. Per Acre*	*Zn Per Cent*	*Zn Lbs. Per Acre*	*Na Per Cent*	*Na Lbs. Per Acre*	*Cu Parts Per Million*	*Cu Lbs. Per Acre*	*B Parts Per Million*	*B Lbs. Per Acre*	*N Per Cent*	*N Lbs. Per Acre*	*pH*
.02	.007	.01	.004	.001	.001	.01	.004	46	.00016	40	.00014			
.04	.024	.02	.012	.007	.004	.10	.060	54	.00323	44	.00263			
.03	.016	.02	.010	.006	.003	.03	.016	54	.00281	40	.00208			
.02	.006	.02	.006	.012	.004	.04	.012	36	.00110	22	.00067			
.02	.003	.02	.003	.010	.001	.02	.003	32	.00040	28	.00035			
.07	.061	.08	.070	.018	.016	.04	.035	33	.00288	28	.00244			
.08	.011	.10	.014	.011	.002	.05	.007	34	.00048	52	.00074			
.02	.128	.04	.119	.011	.031	.05	.137	38	.01106	31	.00905	2.18	6.4	6.29
.05	.011	.02	.004	.011	.002	.05	.011	70	.00154	45	.00099			
.03	.010	.02	.007	.010	.003	.05	.017	38	.00132	48	.00167			
.04	.038	.11	.104	.013	.012	.03	.028	27	.00256	21	.00199			
.03	.003	.06	.006	.005	.001	.03	.003	36	.00036	30	.00030			
.09	.060	.12	.080	.013	.009	.05	.033	37	.00246	39	.00259			
.05	.122	.09	.201	.012	.027	.04	.092	36	.00824	33	.00754	1.74	4.0	5.32
.02	.006	.02	.006	.015	.005	.05	.002	53	.00170	32	.00102			
.02	.007	.11	.041	.015	.006	.05	.019	41	.00152	22	.00081			
.02	.005	.01	.002	.009	.002	.03	.007	42	.00097	28	.00064			
.03	.056	.02	.038	.012	.023	.06	.113	54	.01015	42	.00789			
.02	.008	.02	.008	.013	.005	.02	.008	39	.00154	20	.00079			
.02	.003	.01	.002	.015	.002	.01	.002	34	.00054	30	.00048			
.05	.053	.04	.043	.013	.014	.02	.021	43	.00461	17	.00182			
.03	.024	.03	.024	.023	.018	.04	.032	45	.00356	28	.00221			
.03	.162	.03	.164	.014	.075	.04	.204	47	.02459	30	.01566	1.59	8.3	5.35
.03	.020	.02	.013	.009	.006	.05	.032	89	.00585	44	.00289			
.03	.024	.02	.016	.014	.011	.04	.032	42	.00338	32	.00257			
.02	.014	.01	.007	.008	.005	.03	.020	36	.00244	31	.00210			
.04	.006	.03	.004	.017	.002	.05	.007	24	.00035	26	.00038			
.02	.006	.11	.031	.014	.004	.05	.014	28	.00080	25	.00071			
.03	.014	.02	.009	.009	.004	.04	.018	36	.00162	38	.00171			
.02	.007	.02	.007	.006	.002	.07	.026	76	.00277	38	.00139			
.05	.061	.05	.061	.009	.011	.02	.024	45	.00548	22	.00268			
.07	.054	.08	.062	.023	.018	.05	.039	44	.00341	39	.00302			
.04	.206	.04	.210	.012	.063	.04	.212	49	.02610	32	.01745	1.62	8.7	5.40
.04	.045	.15	.170	.008	.009	.03	.034	98	.01113	17	.00193			
.05	.029	.09	.052	.005	.003	.03	.017	55	.00316	21	.00121			
.01	.001	.01	.001	.006	.008	.01	.001	35	.00044	17	.00022			
.03	.065	.09	.195	.014	.030	.04	.087	47	.01020	18	.00391			
.02	.014	.01	.007	.011	.008	.02	.014	51	.00352	18	.00124			
.03	.022	.03	.022	.026	.019	.08	.060	70	.00524	34	.00254			
.03	.176	.08	.447	.014	.077	.04	.213	62	.03369	20	.01105	1.52	8.3	5.15
.04	.057	.11	.156	.014	.020	.02	.028	26	.00370	20	.00284			
.03	0.25	.04	.033	.023	.019	.06	.049	63	.00515	29	.00237			
.03	.023	.14	.107	.007	.005	.01	.008	64	.00489	28	.00214			
.06	.017	.08	.023	.004	.001	.01	.003	37	.00106	26	.00074			
.02	.007	.08	.027	.012	.004	.02	.007	51	.00170	15	.00050			
.03	.009	.03	.009	.009	.003	.06	.018	45	.00138	29	.00089			
.03	.016	.03	.016	.019	.010	.05	.026	65	.00339	19	.00099			
.03	.020	.05	.033	.015	.010	.02	.013	44	.00289	26	.00171			
.03	.174	.08	.404	.014	.072	.03	.152	47	.02416	22	.01118	1.30	6.6	4.95
.02	.003	.01	.001	.004	.001	.05	.007	104	.00136	4	.00005			
.03	.006	.05	.009	.014	.003	.07	.013	66	.00122	30	.00056			
.02	.004	.03	.006	.018	.004	.05	.010	42	.00087	30	.00062			
.03	.005	.08	.013	.031	.005	.07	.011	64	.00102	43	.00068			
.02	.006	.17	.048	.003	.001	.03	.008	43	.00120	9	.00025			
.04	.041	.24	.248	.015	.015	.07	.072	53	.00547	38	00392			
.03	.009	.03	.009	.014	.004	.06	.018	55	.00167	31	.00094			
.03	.074	.14	.334	.014	.033	.06	.139	56	.01281	31	.00704	1.47	3.4	4.91
.02	.003	.02	.003	.006	.001	.03	.005	29	.00049	29	.00049			
.02	.007	.06	.022	.014	.005	.07	.025	38	.00137	29	.00105			
.05	.015	.03	.009	.023	.007	.12	.036	93	.00286	93	.00040			
.02	.009	.25	.119	.001	.001	.03	.014	44	.00209	22	.00104			
.03	.004	.03	.004	.004	.001	.06	.008	40	.00059	14	.00021			
.03	.018	.02	.012	.018	.011	.06	.035	33	.00194	26	.00153			
.03	.056	.08	.169	.013	.026	.06	.123	46	.00934	23	.00472	1.52	3.1	5.35
.04	.017	.17	.073	.002	.001	.03	.013	53	.00228	12	.00052			
.05	.012	.14	.034	.003	.001	.03	.007	52	.00127	11	.00027			
.05	.003	.06	.004	.033	.002	.08	.006	57	.00039	38	.00026			
.04	.032	.15	.111	.005	.004	.03	.026	53	.00394	14	.00105	1.11	0.8	4.81
.04	.012	.17	.050	.005	.001	.03	.008	69	.00204	5	.00015			
.07	.036	.21	.108	.003	.002	.03	.015	85	.00439	11	.00057			
.03	.004	.03	.004	.033	.004	.07	.008	37	.00043	31	.00036			
.06	.052	.17	.162	.008	.007	.03	.031	74	.00686	12	.00108	1.18	1.1	4.80
.02	.007	.03	.011	.001	.0004	.02	.007	42	.00154	21	.00077			
.03	.007	.02	.004	.001	.0002	.02	.004	34	.00076	50	.00011			
.03	.006	.02	.004	.003	.0006	.02	.004	71	.00139	29	.00057			
.03	.009	.06	.018	.012	.004	.03	.009	40	.00117	14	.00041			
.03	.029	.03	.037	.005	.005	.02	.024	45	.00486	17	.00186	1.12	1.2	4.70

Species	*Litter Weight, Oven Dry, Lbs. Per Acre*	*K Per Cent*	*K Lbs. Per Acre*	*Ca Per Cent*	*Ca Lbs. Per Acre*	*Mg Per Cent*	*Mg Lbs. Per Acre*	*P Per Cent*	*P Lbs. Per Acre*	*Mn Per Cent*	*Mn Lbs. Per Acre*
Lycopodium obscurum	49.2	.69	.3	.26	.1	.11	.05	.13	.06	.02	.010
Gaultheria procumbens	12.6	.80	.1	.88	.1	.28	.04	.17	.02	.08	.010
Hamamelis virginiana	25.7	1.16	.3	.89	.2	.25	.06	.27	.07	.24	.062
Miscellaneous species	6.6	1.51	.1	.80	.1	.34	.02	.26	.02	.26	.017
Total, Plot III–H–S	94.1	.85	.8	.53	.5	.18	.17	.18	.17	.12	.109
Alnus rugosa	29.4	.74	.2	1.14	.3	.56	.16	.19	.06	.14	.041
Maianthemum canadense	12.2	1.14	.1	1.30	.2	.62	.08	.18	.02	.18	.022
Miscellaneous species	33.4	.73	.2	.88	.3	.54	.18	.14	.05	.12	.040
Total, Plot IV–P–E	75.0	.67	.5	1.07	.8	.56	.42	.17	.13	.14	.103
Aralia nudicaulis	16.6	.61	.1	1.02	.2	.58	.10	.24	.04	.20	.033
Alnus rugosa	19.3	.56	.1	.98	.2	.60	.12	.18	.03	.12	.023
Miscellaneous species	27.1	.92	.2	1.00	.3	.61	.17	.20	.05	.08	.022
Total, Plot IV–P–W	63.0	.63	.4	1.11	.7	.62	.39	.19	.12	.12	.078
Carex pensylvanica	127.2	.80	1.0	.46	.6	.26	.33	.11	.14	.07	.089
Miscellaneous species	17.1	1.00	.2	.76	.1	.45	.08	.20	.03	.20	.034
Total, Plot IV–H–E	144.3	.83	1.2	.49	.7	.28	.41	.12	.17	.09	.123
Lycopodium obscurum	56.7	.70	.4	.30	.2	.24	.14	.12	.07	.02	.011
Osmunda cinnamomea	21.7	1.18	.3	.57	.1	.39	.08	.14	.03	.17	.037
Dryopteris spinulosa	31.8	.98	.3	.54	.2	.51	.16	.14	.04	.12	.038
Gaultheria procumbens	24.6	.66	.2	.94	.2	.49	.12	.10	.02	.10	.025
Gaylussacia baccata	19.3	.70	.1	.92	.2	.58	.11	.14	.03	.17	.033
Rhododendron nudiflorum	62.0	.94	.6	.97	.6	.70	.43	.19	.12	.24	.149
Miscellaneous species	48.7	.84	.4	.70	.3	.46	.22	.14	.07	.12	.058
Total, Plot IV–H–W	264.8	.87	2.3	.68	1.8	.48	1.26	.14	.38	.13	.351

Pinus Strobus	363.8	.40	1.5	.59	2.1	.31	1.13	.08	.29	.03	.109
Mixed hardwoods	666.0	.44	2.9	.86	5.7	.36	2.40	.08	.53	.03	.200
Total, Plot I–P–E	1,029.8	.43	4.4	.76	7.8	.34	3.35	.08	.82	.03	.309
Pinus Strobus	696.4	.39	2.7	.66	4.6	.29	2.02	.08	.56	.06	.418
Mixed hardwoods	441.7	.42	1.9	.85	3.8	.34	1.50	.10	.44	.04	.177
Total, Plot I–P–W	1,138.1	.40	4.6	.74	8.4	.31	3.52	.09	1.00	.05	.595
Acer rubrum	748.3	.40	3.0	.89	6.7	.34	2.54	.10	.75	.07	.524
Mixed hardwoods	140.7	.44	.6	1.66	2.3	.70	.98	.11	.15	.06	.084
Total, Plot I–H–E	889.0	.40	3.6	1.01	9.0	.40	3.52	.10	.90	.70	.608
Mixed hardwoods	1,061.6	.40	4.2	.94	10.0	.42	4.46	.10	1.06	.10	1.062
Total, Plot I–H–W	1,061.6	.40	4.2	.94	10.0	.42	4.46	.10	1.06	.10	1.062
Pinus Strobus	379.3	.44	1.7	.72	2.7	.32	1.21	.10	.38	.04	.152
Mixed hardwoods	438.8	.41	1.8	1.28	5.6	.50	2.19	.12	.53	.08	.351
Total, Plot II–P–E	818.1	.43	3.5	1.01	8.3	.42	3.40	.11	.91	.06	.503
Pinus Strobus	502.1	.40	2.0	.72	3.6	.30	1.51	.11	.55	.05	.251
Mixed hardwoods	465.0	.42	2.0	.81	3.8	.44	2.05	.14	.65	.10	.465
Total, Plot II–P–W	967.1	.41	4.0	.77	7.4	.37	3.56	.12	1.20	.07	.716
Acer saccharum	368.9	.34	1.3	1.16	4.3	.40	1.48	.09	.33	.10	.369
Acer rubrum	741.9	.37	2.7	.94	7.0	.44	3.26	.11	.82	.12	.890
Mixed hardwoods	789.8	.44	3.5	.98	7.7	.49	3.87	.12	.95	.09	.711
Total, Plot II–H–E	1,900.6	.39	7.5	1.00	19.0	.45	8.61	.11	2.10	.10	1.970
Acer saccharum	368.0	.42	1.5	1.02	3.8	.39	1.44	.10	.37	.06	.221
Mixed hardwoods	1,065.8	.44	4.7	.98	10.4	.40	4.26	.12	1.28	.07	.746
Total, Plot II–H–W	1,433.8	.43	6.2	.99	14.2	.40	5.70	.12	1.65	.07	.967
Pinus Strobus	730.4	.40	2.9	.43	3.1	.24	1.75	.12	.88	.16	1.169
Mixed hardwoods	383.6	.40	1.5	.70	2.7	.30	1.15	.22	.84	.23	.882
Total, Plot III–P–N	1,114.0	.40	4.4	.52	5.8	.26	2.90	.15	1.72	.18	2.051
Pinus Strobus	250.0	.31	.8	.38	1.0	.20	.50	.12	.30	.18	.450
Quercus rubra	700.6	.38	2.7	.65	4.6	.26	1.82	.23	1.61	.24	1.681
Total, Plot III–P–S	950.6	.37	3.5	.59	5.6	.24	2.32	.20	1.91	.22	2.131
Quercus rubra	231.7	.45	1.0	.68	1.6	.30	.70	.16	.37	.19	.440
Mixed hardwoods	818.5	.42	3.4	.64	5.2	.28	2.29	.18	1.47	.20	1.637
Total, Plot III–H–N	1,050.2	.42	4.4	.65	6.8	.28	2.99	.18	1.84	.20	2.077
Quercus rubra	328.2	.39	1.3	.58	1.9	.24	.79	.15	.49	.17	.558
Mixed hardwoods	649.7	.38	2.5	.62	4.0	.38	2.47	.18	1.17	.19	1.234
Total, Plot III–H–S	977.9	.39	3.8	.60	5.9	.33	3.26	.17	1.68	.18	1.792
Pinus Strobus	873.1	.36	3.1	.46	4.0	.31	2.71	.09	.79	.06	.524
Mixed hardwoods	248.8	.40	1.0	.82	2.0	.42	1.04	.16	.40	.14	.348
Total, Plot IV–P–E	1,121.9	.37	4.1	.53	6.0	.33	3.75	.11	1.19	.08	.872
Pinus Strobus	1,103.5	.36	4.0	.60	6.6	.32	3.53	.10	1.10	.04	.441
Mixed hardwoods	108.2	.48	.5	1.11	1.2	.49	.53	.13	.14	.08	.087
Total, Plot IV–P–W	1,211.7	.37	4.5	.64	7.8	.34	4.06	.10	1.24	.04	.528
Mixed hardwoods	1,098.4	.43	4.7	.62	6.8	.32	3.51	.16	1.76	.15	1.648
Total, Plot IV–H–E	1,098.4	.43	4.7	.62	6.8	.32	3.51	.16	1.76	.15	1.648
Quercus alba	442.7	.54	2.4	.88	3.9	.27	1.20	.16	.71	.18	.797
Mixed hardwoods	964.2	.56	5.4	.74	7.1	.36	3.47	.15	1.45	.16	1.543
Total, Plot IV–H–W	1,406.9	.55	7.8	.78	11.0	.33	4.67	.15	2.16	.17	2.340

Fe Per Cent	*Fe Lbs. Per Acre*	*Al Per Cent*	*Al Lbs. Per Acre*	*Zn Per Cent*	*Zn Lbs. Per Acre*	*Na Per Cent*	*Na Lbs. Per Acre*	*Cu Parts Per Million*	*Cu Lbs. Per Acre*	*B Parts Per Million*	*B Lbs. Per Acre*	*N Per Cent*	*N Lbs. Per Acre*	*pH*
.04	.020	.24	.118	.005	.002	.03	.015	63	.00310	10	.00049			
.02	.003	.03	.004	.001	.0001	.03	.004	42	.00053	19	.00024			
.03	.008	.02	.005	.001	.0003	.02	.005	43	.00111	50	.00129			
.03	.002	.06	.004	.007	.0005	.03	.002	43	.00028	33	.00022			
.04	.033	.14	.131	.003	.003	.03	.026	53	.00502	24	.00224	1.16	1.1	4.40
.02	.006	.03	.009	.014	.004	.02	.006	30	.00088	32	.00094			
.03	.004	.02	.002	.025	.003	.05	.006	30	.00037	26	.00032			
.03	.010	.03	.010	.017	.006	.04	.013	25	.00084	34	.00114			
.03	.020	.03	.021	.017	.013	.03	.025	28	.00209	32	.00240	1.52	1.1	4.90
.02	.003	.02	.003	.020	.003	.04	.007	32	.00053	34	.00056			
.03	.006	.03	.006	.013	.003	.02	.004	26	.00050	43	.00083			
.02	.005	.04	.011	.016	.004	.04	.011	41	.00111	30	.00081			
.02	.014	.03	.020	.016	.010	.03	.022	34	.00214	35	.00220	1.46	0.9	4.99
.02	.025	.02	.025	.013	.017	.04	.051	40	.00509	14	.00178			
.02	.003	.03	.005	.022	.004	.04	.007	35	.00060	26	.00044			
.02	.028	.02	.030	.015	.021	.04	.058	39	.00569	15	.00222	1.02	1.5	5.31
.02	.011	.09	.051	.009	.005	.03	.017	38	.00215	10	.00057			
.02	.004	.02	.004	.016	.003	.04	.009	48	.00104	16	.00035			
.02	.006	.04	.013	.022	.007	.04	.013	42	.00134	20	.00064			
.02	.005	.02	.005	.010	.002	.02	.005	22	.00054	16	.00039			
.02	.004	.04	.008	.010	.002	.02	.004	28	.00054	35	.00068			
.02	.012	.03	.019	.010	.006	.02	.012	28	.00174	28	.00174			
.02	.010	.03	.015	.014	.007	.03	.015	30	.00146	16	.00078			
.02	.052	.04	.115	.012	.032	.03	.075	33	.00881	19	.00515	1.18	3.1	5.11
OF 1948 FOREST OVERSTORY VEGETATION														
.02	.073	.02	.073	.012	.044	.02	.073	25	.00910	12	.00437			
.02	.133	.01	.067	.010	.067	.02	.133	18	.01199	24	.01598			
.02	.206	.01	.140	.011	.111	.02	.206	21	.02109	20	.02035	.72	7.4	4.39
.02	.139	.02	.139	.015	.104	.03	.209	15	0.1045	12	.00836			
.02	.088	.01	.044	.010	.044	.02	.088	21	.00927	26	.01148			
.02	.227	.02	.183	.013	.148	.03	.297	18	.02022	17	.01984	.65	7.4	4.20
.02	.150	.01	.075	.014	.105	.03	.224	18	.01347	27	.02020			
.02	.028	.03	.042	.011	.015	.02	.028	24	.00338	15	.00211			
.02	.178	.01	.117	.013	.120	.03	.252	20	.01785	25	.02231	.74	6.6	4.08
.02	.212	.02	.212	.012	.127	.04	.425	20	.02123	18	.01911			
.02	.212	.02	.212	.012	.127	.04	.425	20	.02123	18	.01911	.75	8.0	3.97
.02	.076	.02	.076	.016	.061	.04	.152	26	.00986	18	.00683			
.02	.088	.01	.044	.016	.070	.04	.175	18	.00790	32	.01404			
.02	.164	.01	.120	.016	.131	.04	.327	22	.01776	26	.02087	.70	5.7	4.39
.02	.100	.03	.151	.016	.080	.04	.201	32	.01607	16	.00803			
.02	.093	.02	.093	.012	.056	.03	.140	30	.01395	26	.01209			
.02	.193	.03	.244	.014	.136	.04	.341	31	.03002	21	.02012	.6	5.9	4.21
.02	.074	.02	.074	.008	.030	.02	.074	30	.01107	22	.00812			
.01	.074	.01	.074	.010	.074	.02	.148	22	.01632	24	.01781			
.02	.158	.02	.158	.016	.126	.04	.316	22	.01738	26	.02053			
.02	.306	.02	.306	.012	.230	.03	.538	24	.04477	24	.04646	.74	14.1	4.06
.02	.074	.02	.074	.010	.037	.03	.110	30	.01104	24	.00883			
.02	.213	.01	.107	.012	.128	.04	.426	31	.03304	24	.02558			
.02	.287	.01	.181	.012	.165	.04	.536	31	.04408	24	.03441	.66	9.5	3.95
.01	.073	.02	.146	.010	.073	.03	.219	30	.02191	18	.01315			
.02	.077	.02	.077	.012	.046	.03	.115	40	.01534	19	.00729			
.01	.150	.02	.223	.011	.119	.03	.334	33	.03725	18	.02044	.64	7.1	4.24
.02	.050	.03	.075	.008	.020	.02	.050	32	.00800	16	.00400			
.01	.070	.01	.070	.009	.063	.02	.140	37	.02592	30	.02102			
.01	.120	.02	.145	.009	.083	.02	.190	36	.03392	26	.02502	.65	6.2	4.40
.02	.046	.02	.046	.010	.023	.03	.070	32	.00741	30	.00695			
.02	.164	.02	.164	.011	.090	.03	.246	33	.02701	34	.02783			
.02	.210	.02	.210	.011	.113	.03	.316	33	.03442	33	.03478	.79	8.3	4.48
.02	.066	.02	.066	.008	.026	.02	.066	27	.00886	25	.00821			
.02	.130	.02	.130	.019	.123	.04	.260	30	.01949	30	.01949			
.02	.196	.02	.196	.015	.149	.03	.326	29	.02835	28	.02770	.86	8.4	4.46
.02	.175	.02	.175	.014	.122	.03	.262	27	.02357	15	.01310			
.02	.050	.05	.124	.014	.035	.03	.075	33	.00821	20	.00498			
.02	.225	.03	.299	.014	.157	.03	.337	28	.03178	16	.01808	.54	6.1	4.19
.02	.221	.03	.331	.014	.154	.04	.441	32	.03531	15	.01655			
.02	.022	.01	.011	.020	.022	.04	.043	35	.00379	29	.00314			
.02	.243	.03	.342	.015	.176	.04	.484	32	.03910	16	0.1979	.54	6.5	4.22
.02	.220	.02	.220	.012	.132	.03	.330	16	.01757	28	.03076			
.02	.220	.02	.220	.012	.132	.03	.330	16	.01757	28	.03076	.78	8.6	4.00
.01	.044	.01	.044	.008	.035	.02	.089	18	.00797	26	.01151			
.02	.193	.06	.579	.026	.251	.06	.579	20	.01928	20	.01928			
.02	.237	.04	.623	.020	.286	.05	.668	19	.02725	22	.03079	.86	12.1	4.30

TABLE B. WEIGHT AND CHEMICAL COMPOSITION

Species	*Litter Weight, Oven Dry, Lbs. Per Acre*	*K Per Cent*	*K Lbs. Per Acre*	*Ca Per Cent*	*Ca Lbs. Per Acre*	*Mg Per Cent*	*Mg Lbs. Per Acre*	*P Per Cent*	*P Lbs. Per Acre*	*Mn Per Cent*	*Mn Lbs. Per Acre*
Osmunda cinnamomea	35.2	1.34	.5	1.14	.4	.79	.28	.12	.04	.04	.014
Dryopteris spinulosa	30.3	1.28	.4	1.23	.4	.78	.24	.12	.04	.01	.003
Athyrium thelypterioides	57.6	1.40	.8	1.27	.7	.71	.41	.14	.08	.01	.006
Polystichum acrostichoides	17.2	2.42	.4	.67	.1	1.07	.18	.18	.03	.02	.003
Alnus rugosa	27.7	.99	.3	1.25	.3	.77	.21	.18	.05	.09	.025
Mitchella repens	66.2	1.18	.8	1.15	.8	1.01	.67	.14	.09	.03	.020
Miscellaneous species	45.7	.66	.3	.76	.3	.40	.18	.10	.05	.01	.005
Total, Plot I–P–E	279.9	1.25	3.5	1.07	3.0	.76	2.17	.14	.38	.03	.076
Athyrium Filix-femina	13.6	1.33	.2	1.44	.2	.78	.11	.16	.02	.02	.003
Dryopteris spinulosa	16.3	1.22	.2	1.26	.2	.77	.13	.18	.03	.08	.013
Mitchella repens	63.4	.82	.5	1.66	1.1	.66	.42	.12	.08	.04	.025
Polystichum acrostichoides	9.8	1.10	.1	.72	.1	.81	.08	.14	.01	.02	.002
Miscellaneous species	30.4	.72	.2	1.52	.5	.60	.18	.18	.05	.04	.012
Total, Plot I–P–W	133.5	.90	1.2	1.57	2.1	.69	.92	.14	.19	.04	.055
Dryopteris spinulosa	30.7	1.26	.4	.90	.3	.90	.28	.10	.03	.02	.006
Dryopteris noveboracensis	39.8	.65	.3	1.22	.5	.60	.24	.12	.05	.06	.024
Athyrium Filix-femina	30.7	1.13	.3	1.38	.4	.56	.17	.12	.04	.05	.015
Rubus idaeus	86.6	.50	.4	1.07	.9	.58	.50	.13	.11	.07	.061
Rubus hispidus	55.0	1.14	.6	.78	.4	.62	.34	.14	.08	.10	.055
Prunus serotina	10.0	1.44	.1	1.60	.2	.80	.08	.14	.01	.08	.008
Carex laxiflora	234.4	.48	1.1	.52	1.2	.31	.73	.10	.23	.04	.094
Miscellaneous species	75.2	.57	.4	1.14	.9	.60	.45	.12	.09	.04	.030
Total, Plot I–H–E	562.4	.64	3.6	.68	3.8	.50	2.79	.11	.64	.05	.293
Rubus idaeus	44.4	.45	.2	1.00	.4	.60	.27	.17	.08	.15	.067
Rubus hispidus	126.6	.50	.6	.90	1.1	.58	.73	.14	.18	.10	.127
Prunus serotina	36.0	.75	.3	1.67	.6	.78	.28	.14	.05	.09	.032
Maianthemum canadense	5.3	.88	.1	.94	.1	.46	.02	.18	.01	.12	.006
Dryopteris noveboracensis	23.3	.48	.1	1.06	.2	.51	.12	.08	.02	.06	.014
Athyrium Filix-femina	30.6	.86	.3	1.24	.4	.78	.24	.11	.03	.08	.024
Dryopteris spinulosa	16.3	.88	.1	1.24	.2	.80	.13	.13	.02	.06	.010
Carex pensylvanica	292.0	.68	2.0	.46	1.3	.34	.99	.11	.32	.07	.204
Miscellaneous species	103.8	.67	.7	1.02	1.1	.55	.57	.13	.13	.10	.104
Total, Plot I–H–W	678.3	.65	4.4	.80	5.4	.49	3.35	.12	.84	.09	.588
Lycopodium complanatum var. flabelliforme	98.9	1.09	1.1	.34	.3	.28	.28	.12	.12	.01	.010
Lycopodium lucidulum	39.4	1.49	.6	.29	.1	.28	.11	.12	.05	.01	.004
Kalmia latifolia	12.0	.69	.1	1.18	.1	.55	.07	.13	.02	.06	.007
Mitchella repens	274.9	1.04	2.9	1.12	3.1	.70	1.92	.13	.36	.03	.082
Rubus pubescens	56.8	.40	.2	.81	.5	.46	.26	.12	.07	.07	.040
Miscellaneous species	70.0	1.26	.9	.84	.6	.54	.38	.16	.11	.08	.056
Total, Plot II–P–E	552.0	1.05	5.8	.85	4.7	.55	3.02	.13	.73	.04	.199
Mitchella repens	156.4	.53	.8	1.22	1.9	.79	1.24	.14	.22	.02	.031
Osmunda cinnamomea	91.4	.82	.7	.76	.7	.60	.55	.11	.10	.09	.082
Lycopodium complanatum	146.8	.94	1.4	.28	.4	.35	.51	.10	.15	.02	.029
Lycopodium lucidulum	18.2	1.44	.3	.28	.1	.23	.04	.12	.02	.01	.002
Dryopteris novaboracensis	26.5	1.25	.3	.77	.2	.60	.16	.12	.03	.04	.011
Athyrium Filix-femina	19.8	1.81	.4	.90	.2	.58	.11	.12	.02	.01	.002
Dryopteris spinulosa	58.4	2.15	1.3	.78	.5	.85	.50	.12	.07	.02	.012
Miscellaneous species	46.6	1.74	.8	1.08	.5	.69	.32	.16	.07	.04	.019
Total, Plot II–P–W	564.1	1.06	6.0	.80	4.5	.61	3.43	.12	.68	.03	.188
Brachyelytrum erectum	17.3	2.22	.4	.49	.1	.22	.04	.14	.02	.02	.003
Osmunda cinnamomea	26.6	3.12	.8	1.15	.3	.52	.14	.17	.05	.10	.027
Viburnum recognitum	14.4	.86	.1	1.26	.3	.82	.12	.16	.02	.09	.013
Carpinus caroliniana	10.2	.74	.1	1.04	.1	.51	.05	.18	.02	.16	.016
Lycopodium obscurum	19.5	.76	.1	.22	.1	.20	.04	.15	.03	.01	.002
Lycopodium complanatum	73.0	1.01	.7	.31	.2	.22	.16	.14	.10	.01	.007
Miscellaneous species	26.3	1.47	.4	.77	.2	.55	.14	.14	.04	.08	.021
Total, Plot II–H–E	187.5	1.39	2.6	.69	1.3	.37	.69	.15	.28	.05	.089
Prunus serotina	13.0	1.18	.2	1.38	.2	.75	.10	.18	.02	.06	.008
Osmunda cinnamomea	37.5	1.80	.7	.80	.3	.58	.22	.13	.05	.08	.030
Brachyelytrum erectum	38.1	1.66	.6	.47	.2	.24	.09	.14	.05	.02	.008
Lycopodium complanatum	39.8	1.21	.5	.23	.1	.26	.10	.13	.05	.02	.008
Carex pensylvanica	25.6	1.47	.4	.58	.1	.30	.08	.13	.03	.04	.010
Miscellaneous species	19.2	1.35	.3	.77	.1	.67	.13	.16	.03	.07	.013
Total, Plot II–H–W	173.2	1.56	2.7	.58	1.0	.42	.72	.13	.23	.04	.077
Lycopodium clavatum	40.0	1.07	.4	.76	.3	.05	.02	.15	.06	.05	.020
Polytrichum commune	21.8	.64	.1	.46	.1	.03	.01	.14	.03	.05	.011
Miscellaneous species	7.3	.64	.1	.68	.1	.28	.02	.19	.01	.24	.018
Total, Plot III–P–N	69.1	.87	.6	.72	.5	.07	.05	.14	.10	.07	.049
Lycopodium clavatum	32.6	.86	.3	.35	.1	.04	.01	.14	.05	.08	.026
Polytrichum commune	43.9	.66	.3	.48	.2	.02	.01	.14	.06	.05	.022
Miscellaneous species	14.8	.77	.1	.61	.1	.35	.05	.18	.03	.27	.040
Total, Plot III–P–S	91.3	.55	.5	.44	.4	.08	.07	.15	.14	.10	.088
Gaultheria procumbens	19.3	.73	.1	.61	.1	.33	.06	.14	.03	.07	.014
Hamamelis virginiana	22.5	1.11	.2	.76	.2	.38	.09	.19	.04	.09	.020
Aralia nudicaulis	17.0	1.21	.2	.76	.1	.40	.07	.18	.03	.16	.027
Miscellaneous species	18.7	.85	.2	.70	.1	.42	.08	.17	.03	.13	.024
Total, Plot III–H–N	77.5	.90	.7	.65	.5	.39	.30	.17	.13	.11	.085

Fe Per Cent	*Fe Lbs. Per Acre*	*Al Per Cent*	*Al Lbs. Per Acre*	*Zn Per Cent*	*Zn Lbs. Per Acre*	*Na Per Cent*	*Na Lbs. Per Acre*	*Cu Parts Per Million*	*Cu Lbs. Per Acre*	*B Parts Per Million*	*B Lbs. Per Acre*	*N Per Cent*	*N Lbs. Per Acre*	*pH*
.02	.007	.04	.014	.014	.005	.04	.014	34	.00120	14	.00049			
.03	.009	.02	.006	.012	.004	.06	.018	26	.00079	22	.00067			
.02	.012	.02	.012	.010	.006	.04	.023	44	.00253	22	.00127			
.03	.005	.05	.009	.005	.001	.03	.005	63	.00108	22	.00038			
.03	.008	.03	.008	.007	.002	.02	.006	26	.00072	28	.00078			
.08	.053	.12	.079	.015	.010	.03	.020	46	.00305	25	.00166			
.04	.018	.04	.018	.010	.005	.04	.018	40	.00183	16	.00073			
.04	.112	.05	.146	.012	.033	.04	.104	40	.01120	21	.00598	1.80	5.0	5.48
.05	.007	.06	.008	.014	.002	.07	.010	48	.00065	36	.00049			
.03	.005	.03	.005	.018	.003	.06	.010	40	.00065	25	.00041			
.04	.025	.07	.044	.016	.010	.04	.025	37	.00235	21	.00133			
.03	.003	.06	.006	.010	.001	.04	.004	43	.00042	19	.00019			
.04	.012	.04	.012	.010	.003	.04	.012	49	.00149	25	.00076			
.04	.052	.06	.075	.014	.019	.05	.061	42	.00556	24	.00318	1.75	2.3	4.60
.02	.006	.02	.006	.010	.003	.06	.006	38	.00117	24	.00074			
.02	.008	.06	.024	.016	.006	.05	.020	26	.00103	20	.00080			
.03	.009	.03	.009	.008	.002	.06	.018	33	.00101	23	.00071			
.02	.017	.02	.017	.014	.012	.03	.026	32	.00277	20	.00173			
.02	.011	.02	.011	.014	.008	.05	.028	29	.00160	20	.00110			
.02	.002	.02	.002	.020	.002	.05	.005	26	.00026	24	.00024			
.04	.094	.03	.070	.013	.030	.04	.094	56	.01312	12	.00281			
.04	.030	.05	.038	.018	.014	.05	.038	32	.00241	23	.00173			
.03	.177	.03	.177	.014	.077	.04	.235	42	.02337	18	.00986	1.50	8.4	5.36
.02	.009	.02	.009	.020	.009	.04	.018	41	.00182	21	.00093			
.02	.025	.02	.025	.010	.013	.04	.051	31	.00392	19	.00241			
.02	.007	.02	.007	.014	.005	.04	.014	27	.00097	24	.00086			
.03	.002	.03	.002	.018	.001	.04	.002	52	.00028	21	.00011			
.02	.005	.06	.014	.012	.003	.04	.009	24	.00056	14	.00033			
.02	.006	.02	.006	.008	.024	.04	.012	38	.00116	20	.00061			
.02	.003	.03	.005	.017	.003	.06	.010	32	.00052	26	.00042			
.03	.088	.03	.088	.010	.029	.04	.117	42	.01226	13	.00380			
.02	.021	.04	.042	.019	.020	.04	.042	36	.00374	20	.00208			
.02	.166	.03	.198	.016	.107	.04	.275	37	.02523	17	.01155	1.37	9.3	5.35
.04	.040	.08	.079	.010	.010	.04	.040	46	.00455	20	.00198			
.04	.016	.08	.032	.008	.003	.04	.016	36	.00142	16	.00063			
.02	.002	.01	.001	.014	.002	.04	.005	29	.00035	24	.00029			
.03	.082	.08	.220	.014	.038	.04	.110	40	.01100	18	.00495			
.02	.011	.02	.011	.016	.009	.04	.023	44	.00250	20	.00114			
.03	.021	.04	.028	.016	.011	.06	.042	49	.00343	24	.00168			
.03	.172	.07	.371	.013	.073	.04	.236	42	.02325	19	.01067	1.38	7.6	5.15
.03	.047	.08	.125	.016	.025	.05	.078	36	.00563	20	.00313			
.02	.018	.06	.055	.013	.012	.06	.055	34	.00311	14	.00218			
.03	.044	.08	.117	.010	.015	.03	.044	49	.00719	20	.00294			
.05	.009	.07	.013	.009	.016	.04	.007	42	.00076	22	.00040			
.02	.005	.05	.013	.013	.003	.04	.011	31	.00082	23	.00061			
.02	.004	.02	.004	.009	.002	.04	.008	32	.00063	30	.00059			
.02	.012	.02	.012	.016	.009	.05	.029	31	.00181	16	.00093			
.04	.019	.06	.028	.018	.008	.04	.019	48	.00224	26	.00121			
.03	.158	.07	.367	.016	.090	.04	.251	39	.02219	20	.01109	1.24	7.0	4.85
.04	.007	.03	.005	.016	.003	.08	.014	56	.00097	10	.00017			
.02	.005	.06	.016	.014	.004	.06	.016	50	.00133	19	.00051			
.02	.003	.02	.003	.018	.003	.04	.006	30	.00043	25	.00036			
.02	.002	.06	.006	.007	.001	.02	.002	31	.00032	30	.00031			
.03	.006	.06	.012	.006	.001	.02	.004	48	.00094	12	.00023			
.03	.022	.08	.058	.006	.004	.03	.022	42	.00307	22	.00161			
.04	.011	.02	.005	.027	.007	.08	.021	63	.00166	21	.00055			
.03	.056	.06	.105	.012	.023	.05	.085	47	.00872	20	.00374	1.60	3.0	4.99
.02	.003	.02	.003	.024	.003	.06	.008	25	.00033	31	.00040			
.02	.008	.06	.023	.015	.006	.05	.019	44	.00165	15	.00056			
.04	.015	.02	.008	.016	.006	.07	.027	61	.00232	10	.00038			
.02	.008	.05	.020	.006	.002	.02	.008	50	.00199	19	.00076			
.05	.013	.04	.010	.012	.003	.05	.013	66	.00169	13	.00033			
.03	.006	.03	.006	.018	.003	.05	.010	42	.00081	20	.00038			
.03	.053	.04	.070	.013	.023	.05	.085	51	.00879	16	.00281	1.43	2.5	5.26
.03	.012	.06	.024	.008	.003	.03	.012	54	.00216	11	.00044			
.06	.013	.07	.015	.015	.003	.05	.011	51	.00111	26	.00057			
.03	.002	.02	.001	.025	.002	.07	.005	35	.00026	27	.00020			
.04	.027	.06	.040	.012	.008	.04	.028	51	.00353	18	.00121	1.12	0.8	4.72
.02	.007	.05	.016	.007	.002	.04	.013	48	.00156	18	.00059			
.06	.026	.06	.026	.013	.006	.05	.022	60	.00263	21	.00092			
.02	.003	.05	.007	.013	.002	.07	.010	41	.00061	20	.00030			
.04	.036	.05	.049	.011	.010	.05	.045	53	.00480	20	.00181	1.20	1.1	4.70
.02	.004	.02	.004	.012	.002	.05	.010	31	.00060	21	.00041			
.02	.005	.01	.002	.012	.003	.05	.011	32	.00072	34	.00077			
.02	.003	.02	.003	.014	.002	.05	.009	41	.00070	18	.00031			
.03	.006	.04	.007	.013	.002	.05	.009	40	.00075	25	.00047			
.02	.018	.02	.016	.012	.009	.05	.039	36	.00277	25	.00196	1.18	0.9	4.71

Species	*Litter Weight, Oven Dry, Lbs. Per Acre*	*K Per Cent*	*K Lbs. Per Acre*	*Ca Per Cent*	*Ca Lbs. Per Acre*	*Mg Per Cent*	*Mg Lbs. Per Acre*	*P Per Cent*	*P Lbs. Per Acre*	*Mn Per Cent*	*Mn Lbs. Per Acre*
Lycopodium obscurum	26.4	.79	.2	.36	.1	.21	.06	.10	.03	.01	.003
Gaultheria procumbens	6.2	.72	.1	.54	.1	.31	.02	.11	.01	.05	.003
Hamamelis virginiana	19.5	1.05	.2	.72	.1	.30	.06	.19	.04	.14	.027
Miscellaneous species	7.2	1.15	.1	.61	.1	.39	.03	.17	.01	.09	.006
Total, Plot III–H–S	59.3	1.01	.6	.67	.4	.29	.17	.15	.09	.07	.039
Alnus rugosa	25.7	.76	.2	.77	.2	.51	.13	.18	.05	.11	.028
Maianthemum canadense	17.2	1.12	.2	.74	.1	.43	.07	.18	.03	.08	.014
Miscellaneous species	30.7	1.02	.3	.74	.2	.51	.16	.16	.05	.08	.025
Total, Plot IV–P–E	73.6	.95	.7	.68	.5	.49	.36	.18	.13	.09	.067
Aralia nudicaulis	16.0	.72	.1	.75	.1	.62	.10	.23	.04	.17	.027
Alnus rugosa	17.1	.60	.1	.70	.1	.62	.11	.19	.03	.09	.015
Miscellaneous species	25.7	.97	.2	.86	.2	.58	.15	.24	.06	.15	.039
Total, Plot IV–P–W	58.8	.68	.4	.68	.4	.61	.36	.22	.13	.14	.081
Carex pensylvanica	121.4	1.37	1.7	.30	.4	.17	.21	.18	.22	.09	.109
Miscellaneous species	28.5	1.85	.5	.80	.2	.40	.11	.24	.07	.23	.066
Total, Plot IV–H–E	149.9	1.47	2.2	.40	.6	.21	.32	.19	.29	.12	.175
Lycopodium obscurum	15.9	.40	.1	.32	.1	.26	.04	.19	.03	.03	.005
Osmunda cinnamomea	33.2	2.24	.7	.54	.2	.49	.16	.18	.06	.21	.070
Dryoptersis spinulosa	82.6	2.33	1.9	.47	.4	.69	.57	.25	.21	.14	.116
Gaultheria procumbens	16.8	.78	.1	.78	.1	.48	.08	.16	.03	.08	.013
Gaylussacia baccata	15.9	.78	.1	.75	.1	.52	.08	.17	.03	.09	.014
Rhododendron nudiflorum	105.4	.58	.6	.88	.9	.87	.92	.24	.25	.27	.285
Miscellaneous species	63.4	.62	.4	.71	.5	.43	.27	.21	.13	.14	.089
Total, Plot IV–H–W	333.2	1.17	3.9	.69	2.3	.64	2.12	.22	.74	.18	.592

WEIGHT AND CHEMICAL COMPOSITION

Pinus Strobus	475.2	.50	2.4	.62	2.9	.39	1.85	.11	.52	.05	.238
Mixed hardwoods	486.1	.61	3.0	1.45	7.0	.61	2.97	.10	.49	.03	.146
Total, Plot I–P–E	961.3	.56	5.4	1.03	9.9	.50	4.82	.11	1.01	.04	.384
Pinus Strobus	659.4	.50	3.3	.76	5.0	.32	2.11	.11	.73	.08	.528
Mixed hardwoods	572.0	.46	2.6	.84	4.8	.48	2.75	.10	.57	.11	.629
Total, Plot I–P–W	1,231.4	.48	5.9	.80	9.8	.39	4.86	.11	1.30	.09	1.157
Acer rubrum	888.0	.54	4.8	1.09	9.7	.58	5.15	.11	.98	.07	.622
Mixed hardwoods	90.3	.60	.5	1.17	1.1	.73	.66	.12	.11	.05	.045
Total, Plot I–H–E	978.3	.54	5.3	1.10	10.8	.59	5.81	.11	1.09	.07	.667
Mixed hardwoods	1,174.5	.57	6.7	.92	10.8	.50	5.87	.12	1.41	.11	1.292
Total, Plot I–H–W	1,174.5	.57	6.7	.92	10.8	.50	5.87	.12	1.41	.11	1.292
Pinus Strobus	606.7	.40	2.4	.61	3.7	.30	1.82	.11	.67	.06	.364
Mixed hardwoods	707.1	.53	3.7	1.06	7.5	.53	3.75	.18	1.27	.09	.636
Total, Plot II–P–E	1,313.8	.46	6.1	.85	11.2	.42	5.57	.15	1.94	.08	1.000
Pinus Strobus	881.4	.49	4.3	.72	6.3	.34	3.00	.10	.88	.07	.617
Mixed hardwoods	554.1	.47	2.6	.98	5.4	.52	2.88	.12	.66	.10	.554
Total, Plot II–P–W	1,435.5	.48	6.9	.82	11.7	.41	5.88	.11	1.54	.08	1.171
Acer saccharum	541.7	.50	2.7	1.00	5.4	.48	2.60	.11	.60	.10	.542
Acer rubrum	1,192.4	.40	4.8	.91	10.9	.52	6.20	.13	1.55	.21	2.504
Mixed hardwoods	612.7	.39	2.4	.94	5.8	.50	3.06	.12	.74	.16	.980
Total, Plot II–H–E	2,346.8	.42	9.9	.94	22.1	.51	11.86	.12	2.89	.17	4.026
Acer saccharum	567.8	.57	3.2	1.41	8.0	.51	2.90	.12	.68	.06	.340
Mixed hardwoods	1,471.3	.59	8.7	1.03	15.2	.53	7.80	.11	1.62	.08	1.177
Total, Plot II–H–W	2,039.1	.58	11.9	1.14	23.2	.52	10.70	.11	2.30	.07	1.517
Pinus Strobus	1,517.6	.39	5.9	.42	6.4	.23	3.49	.15	2.28	.31	4.705
Mixed hardwoods	447.9	.55	2.5	.76	3.4	.33	1.48	.22	.99	.40	1.792
Total, Plot III–P–N	1,965.5	.43	8.4	.50	9.8	.25	4.97	.17	3.27	.33	6.497
Pinus Strobus	147.2	.43	.6	.51	.8	.24	.35	.18	.26	.35	.515
Quercus rubra	820.7	.41	3.4	.63	5.2	.26	2.13	.25	2.05	.71	5.827
Total, Plot III–P–S	967.9	.41	4.0	.62	6.0	.26	2.48	.24	2.31	.66	6.342
Quercus rubra	530.3	.40	2.1	.59	3.1	.30	1.59	.21	1.11	.61	3.235
Mixed hardwoods	2,094.2	.54	11.3	.63	13.2	.35	7.33	.19	3.98	.31	6.492
Total, Plot III–H–N	2,624.5	.51	13.4	.62	16.3	.34	8.92	.19	5.09	.37	9.727
Quercus rubra	1,033.3	.57	5.9	.63	6.5	.39	4.03	.20	2.07	.43	4.443
Mixed hardwoods	1,075.6	.52	5.6	.57	6.1	.38	4.09	.19	2.04	.30	3.227
Total, Plot III–H–S	2,108.9	.55	11.5	.60	12.6	.39	8.12	.19	4.11	.36	7.670
Pinus Strobus	1,430.2	.40	5.7	.45	6.4	.29	4.15	.12	1.72	.06	.858
Mixed hardwoods	573.2	.57	3.3	.74	4.2	.44	2.52	.16	.92	.12	.688
Total, Plot IV–P–E	2,003.4	.45	9.0	.53	10.6	.33	6.67	.13	2.64	.08	1.546
Pinus Strobus	1,657.5	.37	6.1	.44	7.3	.31	5.14	.12	1.99	.05	.829
Mixed hardwoods	89.0	.57	.5	.81	.7	.66	.59	.18	.16	.11	.098
Total, Plot IV–P–W	1,746.5	.38	6.6	.46	8.0	.33	5.73	.12	2.17	.05	.927
Mixed hardwoods	1,668.3	.53	8.8	.52	8.7	.33	5.51	.18	3.00	.28	4.671
Total, Plot IV–H–E	1,668.3	.53	8.8	.52	8.7	.33	5.51	.18	3.00	.28	4.671
Quercus alba	903.5	.51	4.6	.54	4.9	.30	2.71	.18	1.63	.31	2.801
Mixed hardwoods	1,490.9	.57	8.5	.52	7.8	.38	5.67	.18	2.68	.21	3.131
Total, Plot IV–H–W	2,394.4	.55	13.1	.53	12.7	.35	8.38	.18	4.31	.25	5.932

Fe Per Cent	Fe Lbs. Per Acre	Al Per Cent	Al Lbs. Per Acre	Zn Per Cent	Zn Lbs. Per Acre	Na Per Cent	Na Lbs. Per Acre	Cu Parts Per Million	Cu Lbs. Per Acre	B Parts Per Million	B Lbs. Per Acre	N Per Cent	N Lbs. Per Acre	pH
.04	.011	.10	.026	.009	.002	.03	.008	44	.00116	16	.00042			
.02	.001	.02	.001	.015	.001	.04	.002	36	.00022	16	.00010			
.02	.004	.01	.002	.011	.002	.05	.010	46	.00090	18	.00035			
.03	.002	.04	.003	.014	.001	.04	.003	46	.00033	20	.00014			
.03	.018	.05	.032	.010	.006	.04	.023	44	.00261	17	.00101	1.21	0.7	4.33
.02	.005	.03	.008	.013	.003	.04	.010	25	.00064	33	.00085			
.03	.005	.03	.005	.019	.003	.06	.010	55	.00095	19	.00033			
.02	.006	.03	.009	.014	.004	.05	.015	36	.00111	28	.00086			
.02	.016	.03	.022	.014	.010	.05	.035	37	.00270	28	.00204	1.45	1.1	4.70
.02	.003	.01	.002	.015	.002	.03	.005	73	.00117	26	.00042			
.02	.003	.03	.005	.012	.002	.02	.003	22	.00038	39	.00067			
.03	.008	.03	.008	.018	.005	.05	.013	52	.00134	31	.00080			
.02	.014	.02	.015	.015	.009	.04	.021	49	.00289	32	.00189	1.44	0.8	5.00
.03	.036	.03	.036	.007	.008	.04	.049	93	.01129	9	.00109			
.03	.009	.04	.011	.017	.005	.06	.017	88	.00251	27	.00077			
.03	.045	.03	.047	.009	.013	.04	.066	92	.01380	12	.00186	1.20	1.8	5.70
.02	.003	.15	.024	.014	.002	.03	.005	87	.00138	11	.00017			
.02	.007	.06	.020	.014	.005	.06	.020	59	.00196	18	.00060			
.02	.017	.04	.033	.016	.013	.06	.050	84	.00694	24	.00198			
.02	.003	.02	.003	.012	.002	.02	.003	35	.00059	72	.00121			
.02	.003	.03	.005	.008	.001	.02	.003	40	.00064	49	.00078			
.03	.032	.04	.042	.013	.014	.02	.021	64	.00675	35	.00369			
.03	.019	.06	.038	.015	.010	.03	.019	91	.00577	27	.00171			
.03	.084	.05	.165	.014	.047	.04	.121	72	.02403	30	.01014	1.25	4.2	5.30
OF 1949 FOREST OVERSTORY VEGETATION														
.03	.143	.03	.143	.015	.071	.02	.095	25	.01188	18	.00855			
.03	.146	.01	.049	.015	.073	.04	.194	27	.01312	33	.01604			
.03	.289	.02	.192	.015	.144	.03	.289	26	.02500	26	.02459	.78	7.5	4.85
.02	.132	.03	.198	.014	.092	.02	.132	22	.01451	16	.01055			
.02	.114	.02	.114	.012	.069	.02	.114	18	.01030	20	.01144			
.02	.246	.03	.312	.013	.161	.02	.246	20	.02481	18	.02199	.59	7.3	4.01
.02	.178	.02	.178	.019	.169	.05	.444	29	.02575	26	.02309			
.03	.027	.02	.018	.015	.014	.05	.045	25	.00226	26	.00235			
.02	.205	.02	.196	.019	.183	.05	.489	29	.02801	26	.02544	.76	7.4	4.02
.02	.235	.01	.117	.016	.188	.04	.470	17	.01997	26	.03054			
.02	.235	.01	.117	.016	.188	.04	.470	17	.01997	26	.03054	.68	8.0	3.80
.04	.243	.04	.243	.012	.073	.02	.121	34	.02063	16	.00971			
.03	.212	.02	.141	.014	.099	.02	.141	35	.02475	30	.02121			
.03	.455	.03	.384	.013	.172	.02	.262	35	.04538	24	.03092	.73	9.6	4.49
.03	.264	.04	.353	.019	.167	.04	.353	33	.02909	19	.01675			
.03	.166	.02	.111	.023	.127	.05	.277	29	.01607	35	.01939			
.03	.430	.03	.464	.020	.294	.04	.630	31	.04516	25	.03614	.76	10.9	4.52
.02	.108	.01	.054	.008	.043	.02	.108	22	.01192	30	.01625			
.03	.358	.02	.238	.009	.107	.02	.238	38	.04531	25	.02981			
.02	.123	.01	.061	.008	.049	.01	.061	72	.04411	25	.01532			
.03	.589	.02	.353	.008	.199	.02	.407	43	.10134	26	.06138	.66	15.5	4.00
.03	.170	.01	.057	.011	.062	.02	.114	21	.01192	28	.01590			
.03	.441	.02	.294	.011	.162	.02	.294	21	.03090	19	.02795			
.03	.611	.02	.351	.011	.224	.02	.408	21	.04282	22	.04385	.74	15.1	4.10
.02	.304	.04	.607	.017	.258	.02	.304	31	.04705	18	.02732			
.02	.089	.02	.089	.013	.058	.02	.089	35	.01568	30	.01344			
.02	.393	.04	.696	.016	.316	.02	.393	32	.06273	21	.04076	.64	12.6	4.06
.02	.029	.04	.059	.006	.009	.02	.029	17	.00250	29	.00427			
.02	.164	.02	.164	.005	.041	.01	.082	21	.01723	38	.03119			
.02	.193	.02	.223	.005	.050	.01	.111	20	.01973	37	.03546	.78	7.5	4.58
.02	.106	.01	.053	.002	.011	.01	.053	38	.02015	30	.01591			
.02	.419	.02	.419	.008	.168	.02	.419	32	.06701	30	.06283			
.02	.525	.02	.472	.007	.179	.02	.472	33	.08716	30	.07874	.70	18.4	4.34
.02	.207	.02	.207	.009	.093	.01	.103	49	.05063	31	.03203			
.03	.323	.03	.323	.020	.215	.03	.323	38	.04087	38	.04087			
.03	.530	.03	.530	.015	.308	.02	.426	43	.09150	35	.07290	.86	18.1	4.53
.02	.286	.04	.572	.012	.172	.02	.286	34	.04863	22	.03146			
.03	.172	.02	.115	.011	.063	.03	.172	32	.01834	41	.02350			
.02	.458	.03	.687	.012	.235	.02	.458	33	.06697	27	.05496	.57	11.4	4.10
.03	.497	.04	.663	.012	.199	.02	.332	25	.04144	24	.03978			
.02	.018	.02	.018	.008	.007	.01	.009	20	.00178	32	.00285			
.03	.515	.04	.681	.012	.206	.02	.341	25	.04322	24	.04263	.59	10.3	4.12
.02	.334	.02	.334	.005	.083	.01	.167	22	.03670	29	.04838			
.02	.334	.02	.334	.005	.083	.01	.167	22	.03670	29	.04838	.82	13.7	4.00
.01	.090	.01	.090	.004	.036	.01	.090	16	.01446	34	.03072			
.02	.298	.10	1.491	.016	.239	.03	.447	25	.03727	24	.03578			
.02	.388	.07	1.581	.011	.275	.02	.537	22	.05173	28	.06650	.76	18.2	4.20

APPENDIX

TABLE C. CHECKLIST OF COMMON AND SCIENTIFIC NAMES OF PLANTS USED IN THE TEXT

The primary references used in compiling the following lists were Fernald, 1950; Rehder, 1940; Tryon, Fassett, Dunlop, and Diemer, 1940; Roland, 1945; Bailey, 1949; and Rehder, 1949.

List 1. Subordinate vegetation referred to in text by scientific names.

Scientific Name	*Common Name*
Adiantum pedatum L.	American maidenhair
Agrostis perennans (Walt.) Tuckerm.	Bent grass
Alnus rugosa (Du Roi) Spreng.	Smooth alder
Amelanchier laevis Wieg.	Serviceberry
Amphicarpa bracteata (L.) Fern. (*A. monoica* (L.) Ell.)	Hog peanut
Aralia nudicaulis L.	Wild sarsaparilla
Arisaema triphyllum (L.) Schott	Jack-in-the-pulpit
Aster spp. L.	Aster
Aster divaricatus L.	Aster
Athyrium Filix-femina (L.) Roth var. *Michauxii* (Spreng.) Farw.	Lady fern
Athyrium thelypterioides (Michx.) Desv.	Silvery spleenwort
Atriplex canescens James	Saltbush
Berberis trifoliata Hartw. = *Mahonia trifoliolata*	Barberry
Berberis Thunbergii DC.	Japanese barberry
Brachyelytrum erectum (Schreb.) Beauv.	Common wood grass
Bumelia texana Buckl. = *Bumelia lanuginosa* (Michx.) Pers.	Chittam wood
Carex spp. L.	Sedge
Carex gracillima Schwein.	Sedge
Carex laxiflora Lam.	Sedge
Carex pensylvanica Lam.	Sedge
Cassia roemeriana Scheele	Romer's Cassia
Ceanothus cuneatus (Hock) Nutt.	Wedgeleaf ceanothus
Ceanothus divaricatus Nutt.	Whitebark soapbloom
Chimaphila maculata (L.) Pursh	Pipsissewa
Chimaphila umbellata (L.) Bart. var. *cisatlantica* Blake	Prince's-pine
Chrysothamnus viscidiflorus (Hook) Nutt.	Yellowbrush
Clematis virginiana L.	Clematis
Clintonia borealis (Ait.) Raf.	Clintonia
Collinsonia canadensis L.	Stone root
Colubrina texensis A. Gray	Hog plum
Comptonia peregrina (L.) Coult.	Sweet-fern
Condalia obtusifolia (Hook.) Weberb.	Lote
Cornus alternifolia L. f.	Pagoda dogwood
Cornus florida L.	Flowering dogwood
Corylus americana Walt.	American hazelnut
Corylus avellana L.	European filbert
Corylus rostrata Ait. = *Corylus cornuta* Marsh.	Beaked hazelnut

APPENDIX

TABLE C. CHECKLIST OF COMMON AND SCIENTIFIC NAMES OF PLANTS USED IN THE TEXT (*continued*)

Scientific Name	*Common Name*
Cypripedium acaule Ait.	Pink lady's-slipper
Dennstaedtia punctilobula (Michx.) Moore	Hay-scented fern
Diervilla Lonicera Mill.	Bush honeysuckle
Dryopteris noveboracensis (L.) Gray	New York fern
Dryopteris spinulosa (O. F. Muell.) Watt	Spinulose wood fern
Forestiera neo-mexicana A. Gray	Adelia
Fragaria virginiana Duchesne	Wild strawberry
Galium circaezans Michx.	Wild licorice
Galium triflorum Michx.	Sweet scented bedstraw
Gaultheria procumbens L.	Spotted wintergreen
Gaylussacia baccata (Wang.) K. Koch.	Black huckleberry
Geranium maculatum L.	Cranesbill
Hamamelis virginiana L.	Witch hazel
Hydrophyllum canadense L.	Waterleaf
Ilex laevigata (Pursh) Gray	Winterberry
Ilex opaca Ait.	American holly
Impatiens capensis Meerb.	
Impatiens pallida Nutt.	Pale touch-me-not
Kalmia latifolia L.	Mountain laurel
Kochia vestita (S. Wats.) Rydb.	Brown sage
Leucaena retusa Benth.	Leucaena
Lindera Benzoin (L.) Blume	Spice bush
Lonicera canadensis Bartr.	Fly honeysuckle
Luzula campestris (L.) DC.	Wood rush
Lycopodium clavatum L.	Running clubmoss
Lycopodium complanatum (L.) var. *flabelliforme* Fern.	Running pine
Lycopodium lucidulum Michx.	Shining club moss
Lycopodium obscurum L.	Club moss
Lysimachia producta (Gray) Fern.	Loosestrife
Lysimachia quadrifolia L.	Loosestrife
Maianthemum canadense Desf.	False lily-of-the-valley
Medeola virginiana L.	Indian cucumber-root
Melampyrum lineare Desr. var. *americana* (Michx.) Beauverd	Cow wheat
Mimosa fragrans A. Gray	Mimosa
Mitchella repens L.	Partridge berry
Nolina texana S. Watson = *Dasylirion texanum* Schelle	Bunch grass
Onoclea sensibilis L.	Sensitive fern
Osmunda cinnamomea L.	Cinnamon fern
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper
Podophyllum peltatum L.	May apple
Polygonatum biflorum (Walt.) Ell.	Solomon's seal
Polystichum acrostichoides (Michx.) Schott	Christmas fern
Polytrichum commune Hedw.	Polytrichum moss
Prenanthes alba L.	Rattlesnake root

APPENDIX

TABLE C. CHECKLIST OF COMMON AND SCIENTIFIC NAMES OF PLANTS USED IN THE TEXT (*continued*)

Scientific Name	*Common Name*
Prosopis chilensis (Molina) Stuntz.	Mesquite
Prosopis chilensis (Molina) Stuntz. var. *velutina* (Wooton) Standl.	Mesquite
Prunus virginiana L.	Choke cherry
Pteridium aquilinum (L.) Kuhn.	Bracken fern
Pyrola elliptica Nutt.	Shinleaf
Rhamnus californica Esch.	Coffee berry
Rhododendron nudiflorum (L.) Torr.	Pinxter-flower
Rhus coriaria L.	
Rhus diversiloba Torr. and Gray	Poison oak
Rhus microphylla Engelm.	Sumac
Rhus Toxicodendron L.	Poison ivy
Rhus trilobata Nutt. = *Rhus aromatica* Ait.	Ill-scented sumac
Rhus virens Linol.	Evergreen sumac
Rubus allegheniensis Porter	Blackberry
Rubus hispidus L.	Groundberry
Rubus idaeus L.	Red raspberry
Rubus pubescens Raf.	Dewberry
Sambucus canadensis L.	American elder
Sambucus glauca Gray = *Sambucus canadensis* L.	American elder
Sanguinaria canadensis L.	Bloodroot
Smilacina racemosa (L.) Desf.	False-Solomon's-seal
Smilax herbacea L.	Greenbrier
Solidago spp. L.	Goldenrod
Solidago latifolia L. = *Solidago flexicaulis* L.	Goldenrod
Sophora secundiflora Lag.	Mescal bean
Symphoricarpos rotundifolius A. Gray	Roundleaf snowberry
Symplocarpus foetidus (L.) Nutt.	Skunk cabbage
Thalictrum dioicum L.	Meadow rue
Tiarella cordifolia L.	Foam flower
Trientalis borealis Raf. (*T. americana* (Pers.) Pursh.)	Trientalis
Trillium grandiflorum (Michx.) Salisb.	Wakerobin
Trillium undulatum Willd.	Wakerobin
Uvularia sessilifolia L. (*Oakesia sessilifolia* (L.) S. Wats.)	Bellwort
Vaccinium vacillans Torr. = *Vaccinium pallidum* Ait.	Dryland blueberry
Viburnum acerifolium L.	Dockmackie
Viburnum alnifolium Marsh.	Hobblebush
Viburnum recognitum Fern.	Arrow wood

TABLE C. CHECKLIST OF COMMON AND SCIENTIFIC NAMES OF PLANTS USED IN THE TEXT (*continued*)

List 2. Tree species referred to in text by scientific names.

Scientific Name	*Common Name*
Abies alba Miller	Silver fir
Abies balsamea (L.) Mill.	Balsam fir
Acacia angustissima (Mill.) Ktze.	Poirio guajillo
Acer rubrum L.	Red maple
Acer saccharum Marsh.	Sugar maple
Aesculus californica Nutt.	California buckeye
Aesculus glabra Willd.	Ohio buckeye
Betula lenta L.	Black birch
Betula lutea Michx. f.	Yellow birch
Betula pendula Roth. = *Betula alba* L.	European white birch
Betula populifolia Marsh.	Gray birch
Carpinus caroliniana Walt.	American hornbeam
Carya cordiformis (Wang.) K. Koch.	Bitternut hickory
Carya glabra (Mill.) Sweet.	Pignut hickory
Carya ovata (Mill.) K. Koch.	Shagbark hickory
Castanea sativa Mill.	Spanish chestnut
Catalpa speciosa Warder	Western catalpa
Celtis occidentalis L.	Hackberry
Celtis reticulata Torrey	Hackberry
Cladrastis lutea (Michx. f.) K. Koch.	Yellow-wood
Cratagus spp. L.	Hawthorn
Cupressus macrocarpa Hartw.	Monterey cypress
Diospyros texana Scheele	Black persimmon
Diospyros virginiana L.	Persimmon
Fagus grandifolia Ehrh.	American beech
Fagus sylvatica L.	European beech
Fraxinus americana L.	White ash
Fraxinus excelsior L.	European ash
Fraxinus quadrangulata Michx.	Blue ash
Juglans nigra L.	Black walnut
Juniperus pinchotii Sudw.	Pinchot juniper
Juniperus utahensis Engelm.	Utah juniper
Juniperus virginiana L.	Eastern redcedar
Larix decidua Mill.	European larch
Liquidambar Styraciflua L.	Sweet gum
Liriodendron Tulipifera L.	Yellow poplar
Magnolia acuminata L.	Cucumbertree
Magnolia macrophylla Michx.	Bigleaf magnolia
Morus microphylla Buckl.	Small leafed mulberry
Morus rubra L.	Red mulberry
Ostrya virginiana (Mill.) K. Koch.	Hophornbeam
Picea Abies (L.) Karst.	Norway spruce
Picea rubens Sarg.	Red spruce
Pinus Banksiana Lamb.	Jack pine
Pinus canariensis C. Smith	Canary pine

TABLE C. CHECKLIST OF COMMON AND SCIENTIFIC NAMES OF PLANTS USED IN THE TEXT (*continued*)

Scientific Name	*Common Name*
Pinus caribaea Morelet	Slash pine
Pinus palustris Mill.	Longleaf pine
Pinus pinaster Ait.	Maritime pine
Pinus radiata D. Don.	Monterey pine
Pinus resinosa Ait.	Red pine
Pinus rigida Mill.	Pitch pine
Pinus Strobus L.	Eastern white pine
Pinus sylvestris L.	Scots pine
Platanus occidentalis L.	American plane
Populus grandidentata Michx.	Largetoothed aspen
Populus tremuloides Michx.	Quaking aspen
Prunus Avium L.	Sweet cherry
Prunus serotina Ehrh.	Black cherry
Pseudotsuga taxifolia Britt.	Douglas fir
Pyrus coronaria L.	Garland crabapple
Quercus alba L.	White oak
Quercus rubra L. = *Quercus borealis* var. *maxima* (Marsh.) Ashe	Red oak
Quercus breviloba Sarg. = *Quercus durandii* Buckl.	Durand oak
Quercus chrysolepis Liebm.	Canyon live oak
Quercus douglasii Hook and Arh. = *Quercus novo-mexicana* Ryd.	Blue oak
Quercus palustris Muenchh.	Pin oak
Quercus velutina Lam.	Black oak
Quercus virginiana Mill.	Live oak
Robinia Pseudo-Acacia L.	Black locust
Sassafras albidum (Nutt.) Nees	Sassafras
Sequoia sempervirens (Lamb.) Endl.	Redwood
Thuja occidentalis L.	Northern white cedar
Tilia americana L.	Basswood

APPENDIX

TABLE C. CHECKLIST OF COMMON AND SCIENTIFIC NAMES OF PLANTS USED IN THE TEXT
(*continued*)

List 3. Tree species referred to in text by common names.

Common Name	*Scientific Name*
Ash, white	*Fraxinus americana* L.
Aspen, largetoothed	*Populus grandidentata* Michx.
Aspen, quaking	*Populus tremuloides* Michx.
Basswood	*Tilia americana* L.
Beech, American	*Fagus grandifolia* Ehrh.
Beech, European	*Fagus sylvatica* L.
Birch, black	*Betula lenta* L.
Birch, European white	*Betula pendula* Roth. = *Betula alba* L.
Birch, gray	*Betula populifolia* Marsh.
Cedar, eastern red	*Juniperus virginiana* L.
Cedar, northern white	*Thuja occidentalis* L.
Cherry, black	*Prunus serotina* Ehrh.
Cypress, Monterey	*Cupressus macrocarpa* Hartw.
Elm, American	*Ulmus americana* L.
Fir, balsam	*Abies balsamea* (L.) Mill.
Fir, Douglas	*Pseudotsuga taxifolia* Britt.
Hemlock, eastern	*Tsuga canadensis* (L.) Carr
Larch, European	*Larix decidua* Mill.
Locust, black	*Robinia Pseudo-Acacia* L.
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, canyon live	*Quercus chrysolepis* Liebm.
Oak, red	*Quercus rubra* L. = *Quercus borealis* var. *maxima* (Marsh.) Ashe
Oak, pin	*Quercus palustris* Muenchh.
Oak, white	*Quercus alba* L.
Plane, American	*Platanus occidentalis* L.
Pine, canary	*Pinus canariensis* C. Smith
Pine, eastern white	*Pinus Strobus* L.
Pine, jack	*Pinus Banksiana* Lamb
Pine, longleaf	*Pinus palustris* Mill.
Pine, maritime	*Pinus pinaster* Ait.
Pine, Monterey	*Pinus radiata* D. Don.
Pine, pitch	*Pinus rigida* Mill.
Pine, red	*Pinus resinosa* Ait.
Pine, Scots	*Pinus sylvestris* L.
Pine, slash	*Pinus caribaea* Morelet
Redwood	*Sequoia sempervirens* (Lamb.) End.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Spruce, Norway	*Picea abies* (L.) Karst.
Spruce, red	*Picea rubens* Sarg.
Walnut, black	*Juglans nigra* L.

ILLUSTRATIONS

FIGURE 1

Plot II–H–E. Upper—summer 1949; Lower—fall 1949. These two photographs illustrate the amount of organic material annually deposited on the forest floor in a typical hardwood stand.

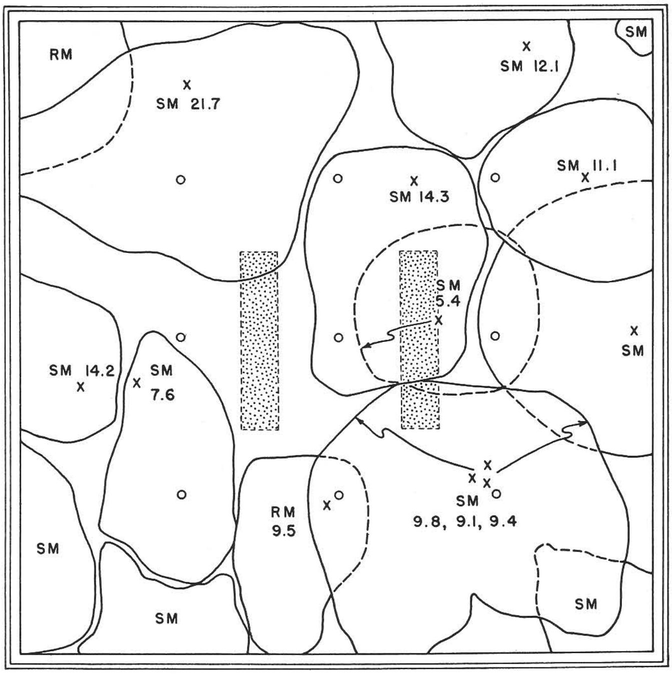
FIGURE 2

Plot II–H–E. Crown canopy diagram illustrating the location of the sampling areas with respect to the tree crowns.

PLOT II HE — CROWN CANOPY MAP

0′ 6.5′

SCALE



LEGEND

X — base of tree.

O — center milacre understory plots.

- - - - — subordinate crown boundary.

——— — crown boundary.

▨ — milacre mat used to collect tree leaves.

TREE SPECIES

RM — *Acer rubrum* L.

SM — *Acer saccharum* Marsh.

NOTE — The numbers indicate the diameters at breast height of trees.

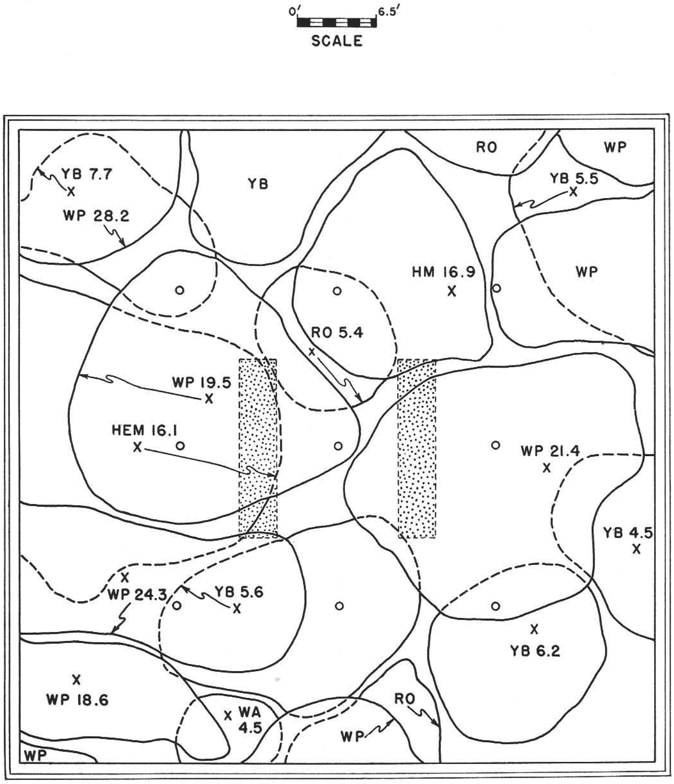
FIGURE 3

Plot II–P–W. Upper—summer 1949; Lower—fall 1949. These two photographs illustrate the amount of organic material annually deposited on the forest floor in a typical pine stand.

FIGURE 4

Plot II–P–W. Crown canopy diagram illustrating the location of the sampling areas with respect to the tree crowns.

PLOT II PW—CROWN CANOPY MAP



LEGEND

X — base of tree.

O — center milacre understory plots.

------ — subordinate crown boundary.

——— — crown boundary.

▨ — milacre mat used to collect tree leaves.

TREE SPECIES

HM — *Acer saccharum* Marsh.

WA — *Fraxinus americana* L.

RO — *Quercus rubra* L.

YB — *Betula lutea* Michx.

WP — *Pinus strobus* L.

HEM — *Tsuga canadensis* (L.) Carr.

NOTE — The numbers indicate the diameters at breast height of the trees.

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