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Forest Lysimeter Studies Under Red Pine

HERBERT A. LUNT

Connecticut
Agricultural Experiment Station
New Haven

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CONTENTS

	PAGE
Introduction	221
Description and Installation	222
Collection and Analysis	224
Methods	224
Presentation of Results	225
Amount of leachate	225
Nitrate Nitrogen, conductivity and reaction	227
Total Nitrogen in the leachate	231
Total solids	233
Ash	234
Loss-on-ignition	234
Calcium	234
Magnesium	235
Potassium	235
Sulfur	235
Phosphorus	235
Silica	235
Iron	236
Results of moisture and chemical tests on the soil	236
Moisture distribution in the soil	236
Mixing of litter with sand	236
Discussion	237
Conclusions	244
Summary	245
Tables	247
References	268

FOREST LYSIMETER STUDIES UNDER RED PINE

HERBERT A. LUNT

IN THE REGION of podzolic soils there is no one portion of the forest soil profile of greater importance than the duff[1] layer. While unquestionably there is a mutual interdependence among soil type, forest type, and the type of duff that accumulates, in this particular study we are interested not in the origin of the duff but rather in its effect upon the soil. One way to learn what this effect may be is to determine what constituents are leached out of the duff and what proportion of the leached material is retained in the underlying mineral soil. This can be most readily and accurately measured by using lysimeters.

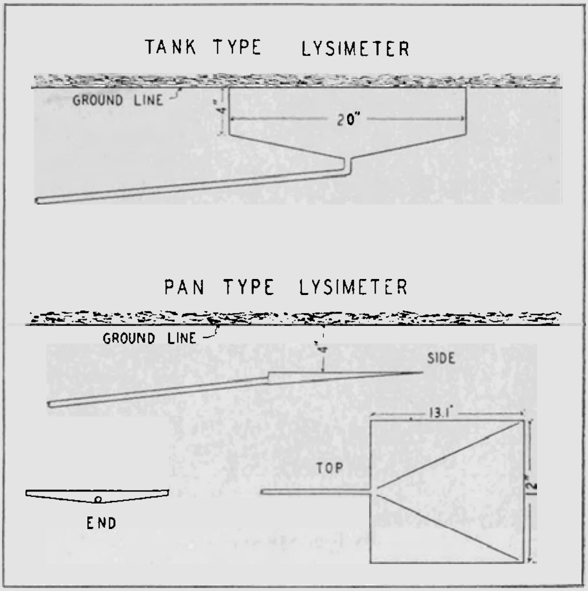

FIGURE 22. Sketch showing type of lysimeters used.

A. Tank type lysimeter in place.

B. Pan type lysimeter in place, and the top and end views of the pan itself. Those installed for collecting leachate from the litter only were placed on the ground line just under the litter.

Many studies have been carried on in lysimeters with cultivated soils planted to the usual farm crops. In recent years some attempts have been made to apply the lysimeter method to the study of uncropped or virgin soils. Such investigations are of value in ascertaining what materials pass through the natural mineral soil horizons without particular reference to crop production. The work reported in this bulletin falls in the latter category. Our purpose was to determine primarily the constituents leached out of the forest floor, herein referred to as litter[1]; and secondarily those leached out of the upper four inches of mineral soil.

DESCRIPTION AND INSTALLATION

The original set installed in April, 1932, consisted of six galvanized iron tanks twenty inches in diameter and four inches deep at the outside, with about a two-inch drop in the center (Figure 22 (A)). The outlet in the center was covered with a screen and the whole was then painted with asphaltum paint. Upon installation each tank was connected by a three-eighths inch tinned brass pipe to a central pit in which were placed large granite stock pots to receive the leachate.

FIGURE 23. Tank Lysimeters in place. The position of each tank is indicated by four sticks.

The place selected for installation was a uniform stand of red pine, *Pinus resinosa*, in a plantation belonging to the New Haven Water Company and located in the town of Woodbridge about eight miles from the Experiment Station. The plantation adjoins Lake Dawson, an artificial lake used as a public water supply. The trees, planted about 1915, were approximately 17 years old at the beginning of the experiment, and at that time had a d.b.h. of about five inches and an estimated height of 30 to 35 feet. The soil is classified as Hartford gravelly f.s.l. and consists of a brown A_1 0-2 or 3-inch, fine crumb structure, mellow in consistency; a chocolate brown A_2 2 or 3-inch to 7 or 8-inch mellow crumb structure; a reddish yellow brown B, of single grain structure 7 or 8 inches to 14

[1]The terms *duff* and *litter* as herein used apply to all of the unincorporated organic accumulation on top of the mineral soil.

inches containing some gravel, and underlain by coarse gravel and sand. The litter, about one inch thick, consists of pine needles only, without any sign of a humified or H layer. There is no ground cover.

The tanks were placed in position under the trees about half way between the trunk and the outer spread of the branches. Two tanks were filled with pure quartz sand and then covered with the natural litter cover. Two more were filled with the natural mineral soil which had been removed

FIGURE 24. Showing the open pit containing the receiving pots, and the glass jugs for the aliquot samples. The leachate was measured by means of the 2 liter graduated cylinder.

in a round block of the same size as the tanks and then put into the tanks in quarter sections with as little disturbance as possible. These two tanks were kept free of litter at all times. The remaining two tanks were filled with mineral soil in the same way and then covered with the natural litter cover. All tanks were placed flush with the surface of the mineral soil.

As the data accumulated during the first year it was recognized that this tank type of lysimeter, while giving us valuable information, was nevertheless restricted in the completeness of the information it could give, so it was decided to install an additional set of a different type, one in which the natural root competition would not be interfered with. It was felt that the main requirement of such a lysimeter should be that its installation involve a minimum of soil disturbance below as well as above the lysimeter. Therefore we designed a flat, square pan lysimeter, somewhat suggestive of a dust pan, measuring 12 by 13.1 inches (one-half the area of the tank type). (Figure 22 (B).) One end is straight and flat with no side wall; the opposite end drops about an inch in the center, with a side wall only as high as the level of the first end. The two other sides have side walls which taper from about one-half inch at the deep end to nothing at the shallow or flat end. The outlet, covered with screen, is at the lowest portion of the pan, being in the side rather than the bottom.

The method of installation consisted in digging a small temporary pit with one straight side, then placing the sharp straight edge of the lysimeter at the proper depth and gently forcing it into position, using crowbars as a means of leverage. The connecting pipe was then attached to the outlet nipple and the temporary pit was filled in. Six lysimeters were connected to one main pit as in the case of the tank lysimeters. Two were placed just under the litter, two under four inches of soil kept bare of litter, and two under four inches of soil with the natural litter covering. These were installed in the same plantation a short distance from the original set; and then a duplicate set was placed in a third position in the same forest, thus making, in all, six tank type and twelve pan type lysimeters.

COLLECTION AND ANALYSIS

After every rain of any consequence the leachate was measured, and a definite aliquot was placed in gallon glass jugs for ultimate analysis. Another portion was taken to the laboratory and tested immediately for nitrates, conductivity and reaction.

The year was divided into three periods, the first period running from April 10 (the date of the original installation) to July 15; the second, or fall period, ran from July 15 to November 20; and the third, or winter period, from November 20 to April 10. At the end of each period a composite of the aliquots saved was analyzed for nitrate, ammonia and organic nitrogen, total solids, ash, loss-on-ignition, calcium, potassium, sulfur and iron. In addition, there are incomplete data on phosphorus, magnesium and silica.

METHODS

Reaction: During the first two years reaction was determined colorimetrically by adding a drop of indicator to about a quarter-inch depth of leachate in a 30 cc. beaker. Beginning in 1935 all reactions were determined by the glass electrode.

Conductivity was found by the Kohlrausch method using a four dial decade Wheatstone bridge in place of the Kohlrausch slide.

Nitrate Nitrogen was determined by the phenoldisulfonic acid method. Discolored leachates were clarified by the use of copper sulfate, boneblack, calcium hydroxide and magnesium carbonate.

Ammonia Nitrogen: From 200 to 500 cc. of the leachate were distilled and the distillate nesslerized to determine this ingredient.

Organic Nitrogen: The residue in the Kjeldahl flask after distillation was acidified with H_2SO_4 concentrated almost to fumes, transferred to a large test tube and digested over a micro-burner after adding $CuSO_4$ and K_2SO_4. When clear, $KMnO_4$ was added to insure completeness of the digestion, and the cooled solution transferred to the original Kjeldahl flask and diluted. Then it was made basic with 20 percent Na_2CO_3, distilled and nesslerized.

Total solids, loss-on-ignition, SiO_2, calcium, potassium and *sulfur* were determined by the customary methods.

Soluble silica was determined by the colorimetric method of Němec, Lavik and Koppova, *Zeit. Anal. Chem.*, **83**: 428-445, 1931. Described by Wright (20).

Iron was found colorimetrically by the method of Griffin, *Technical Methods of Analysis*, p. 661.

Phosphorus was obtained by a modification of Truog's colorimetric method.

PRESENTATION OF RESULTS

In an earlier publication (14) the writer presented data on the amount of leachate collected, and the kind and amount of nitrogen which percolated through the soil during the first year and two periods of the second year. The results of the completed experiment under red pine are recorded here.

Amount of Leachate

Complete data on the leachate collected, expressed in percentage of the total rainfall, are given in Table 1. In the tank lysimeters there was a gradual increase during the progress of the experiment in the amount of leachate from the bare soil due, no doubt, to the increasing moisture content of the soil. It was noted in the field that the bare soil seemed to become increasingly wet, and at the same time more completely covered with moss. Removal of the moss was practically impossible without disturbing the soil. No doubt its presence lessened evaporation and possibly aided absorption so that one factor intensified the other.

The variation between duplicates, which in some cases is quite pronounced, can be ascribed to three more or less uncontrollable factors: Unevenness of the ground surface, a characteristic of forests from which plantations are not exempt; a slight settling of some of the tanks; and unequal precipitation because the tree crowns intercept the rainfall. The most striking differences occur in the case of Nos. 1 and 5, the latter delivering consistently more water than the former. Number 5 tank appeared to have settled somewhat and apparently received some run-off from adjacent areas. As stated in the previous article, we purposely allowed this condition to remain so that we might observe the differences resulting from such variation.

If we consider No. 1 as being more normal with respect to moisture absorption and percolation, we notice that it was consistent in delivering less water than did the litter-only tanks. This is as it should be, for the four inches of mineral soil are capable of retaining a considerable amount of water. Therefore the lysimeter containing soil delivered less water than one containing only sand.

Studies by the author (12) and others indicate that because of crown interception, on the average not more than 70 percent of the precipitation reaches the ground under conifers. In order to obtain data pertaining to the variation in the amount of water reaching the tanks, the soil was removed from tanks 1, 2, 4, and 5 in the fall of 1936 and the amount of rainfall caught by the open tanks was measured during the fall and winter months. The amounts in percentage of rainfall in the open are given in Table 2. The rain gauge in which precipitation was measured was located about one-half mile from the lysimeters. It so happened that 1936-37 was an unusually mild winter with very little snow, so that it was possible to obtain accurate rainfall data more or less applicable to any time of the year.

The data show considerable variation in the proportion of rainfall collected. Tank No. 5 delivered the largest amount as it did throughout the entire experiment. In this test a shallow trench was dug around each tank to prevent surface runoff from entering the tanks. Therefore, at least part of the difference in the amount of percolate collected from Nos. 1 and 5 was due to a difference in the amount of rain actually reaching the tanks.

We see in Table 1 no consistent differences in amount of percolate from Nos. 2 and 4, although in Table 2, Tank No. 4 appears to have a slight advantage in the amount received. Why the collection exceeded 100 percent of the rainfall in the 1/6—1/17 (January 6 to 17) period is not clear. It is interesting to note that the mean of all four tanks for the full period of the test was 73.2 percent, which is very close to the estimated 70 percent previously mentioned.

In the pan lysimeter data we see immediately the effect of root competition on the amount of leachate collected, even in the case of the litter only. In the earlier paper (14) the author predicted that, during very wet weather, nearly as much leachate would be collected from the pan lysimeters as from the tanks, allowing for the differences in areas. The data now on hand, however, fail to substantiate that prediction except in a very limited degree. On only a few occasions was there as high a percentage of rainfall recovery in the *pans* with soil as in the *tanks* with soil. These results demonstrate that tree roots are very efficient in taking the moisture out of the soil.

It will be observed that pans 8 and 17 quite consistently gave less leachate than did Nos. 12 and 14. After the conclusion of the experiment, examination of the pans revealed that the back end (i.e., the end farthest from the pit) of No. 8 had struck a rock during installation and was so bent out of shape as to interfere with its proper functioning. No. 17 was in normal position but there was some possibility of runoff away from the soil area over the pan. There is also the factor of crown interception previously mentioned.

Table 3 gives the amount of leachate in liters and in percentage of the yearly total which was collected for each period; and in addition it includes the precipitation in liter equivalents* for each period together

* By liter equivalent is meant the amount of rainfall, in liters, which fell over an area equal to that of the lysimeters: *viz.*, 314.2 sq. in. for the tanks, and 157.1 sq. in. for the pans.

with the percentage of the total for each period. The data show that during the first year the several treatments varied widely in the proportion of total leachate collected in each period in comparison with the proportion of precipitation for each period. Strangely enough, this variation was least in the case of the soil-and-litter tanks. In the second year the differences were less striking; while in the third year both the litter-only and the bare-soil tanks agreed almost exactly with the precipitation proportions, and the soil-and-litter tanks gave nearly similar results.

In the case of the pan lysimeters the most distinctive characteristic is the low proportion of leachate collected from the soil-and-litter pans during the first period of both years. This condition may be associated with the relation of moisture to the precipitation of colloids as suggested by Joffe (8). When a soil becomes dry, the colloids shrink and the individual particles become cemented into aggregates. This increases the non-capillary pore space and facilitates percolation. The soil was more moist during the first period and was more effective in retaining water and thus preventing percolation than it was during the second period. The second period includes the driest and hottest part of the summer and often a rather dry fall.

Lyon *et al.* (15) reported that the amount of percolate which they obtained during the second and third five-year periods was only about 78 percent of what it was during the first five years. In bare soil about two-thirds of the precipitation percolated through, while in a cropped soil less than half was obtained.

Nitrate Nitrogen, Conductivity and Reaction

Data relative to nitrate nitrogen, conductivity and reaction of the leachate are shown graphically in Figures 25, 26 and 27. The amount of nitrates from the litter fluctuated relatively little during the year, particularly after the first year, and always remained at a low level. In the *bare soil* the nitrates reached a high point in August of the first year, with a second lesser high in November. In the second year there was a moderate high in June and a second in early September, followed by a low concentration the remainder of the year. The maximum for the third year occurred in June, with a concentration between 5 and 8 p.p.m. carrying through to the first of December. In the lysimeters where both *soil and litter* were present there is little resemblance between the curves for the three years, with respect to nitrates. In the first year the concentration held up very well from the middle of August through the fall and well into December. The second year there was only a moderate amount of nitrate nitrogen all through late spring and summer and it fell off rapidly in September. The third year found the nitrates at a comparatively low level during the summer months and very low the remainder of the year.

As would be expected, the fluctuations which occurred in nitrate content were closely associated with rainfall. Every rainless period was accompanied by an increase in nitrates, as there were no roots to absorb them. The first significant rain washed most of the nitrates out of the soil and, if followed shortly by a second rain, the latter gave a leachate quite low in nitrates.

Conductivity followed the nitrate concentration very closely, indicating that, under the conditions of the experiment, the former is largely dependent upon the latter.

During the first year the reaction was definitely more acid during the summer months when the nitrate content was high, but no such seasonal relationship was apparent during the second and third years. In general the numerous fluctuations in pH bore some relationship to the nitrate

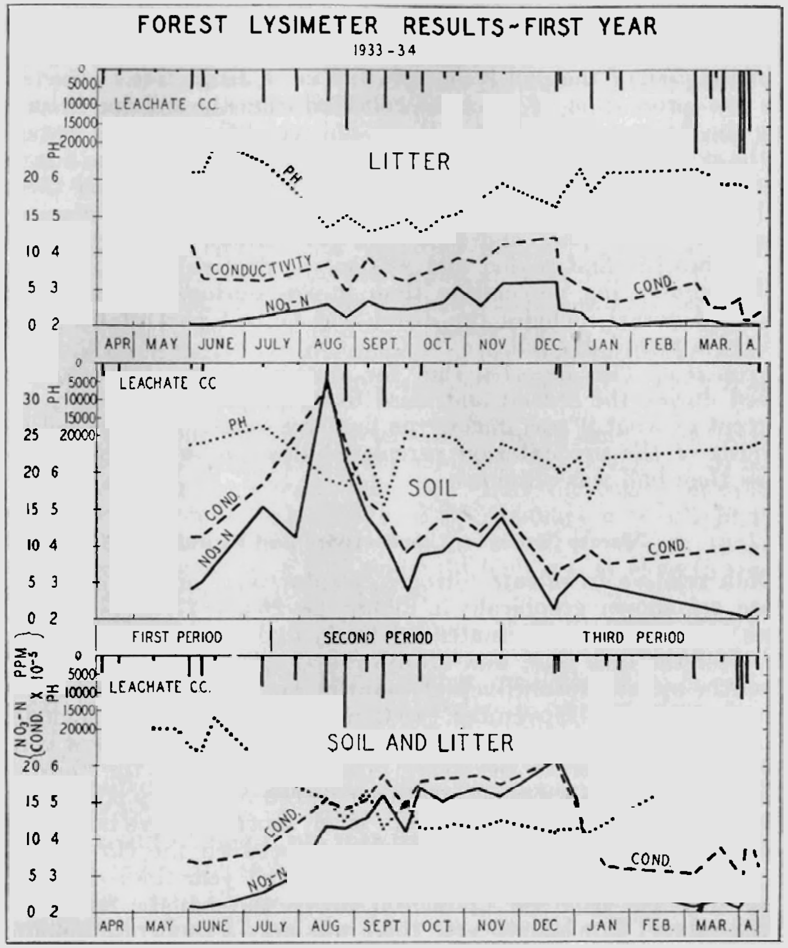

FIGURE 25. Current amount of leachate collected in the tank lysimeters during the first year, and its pH, conductivity, and nitrate nitrogen content.

content, an increase in nitric acid resulting in an increase in acidity. The correlation with rainfall is rather conspicuous and appears to be closer than it is with nitrates. The pH rose during rainless periods and dropped with nearly every significant rainfall.

In the pan lysimeters, the effects of root competition were very much in evidence, so much so that it was necessary greatly to expand the scale recording the amount of nitrates and leachate collected, in Figures 28 and 29,

in order to show any differences at all. Leachate from the *litter* pans contained its highest concentrations of nitrates about August 1, with relatively high amounts from late June till early September. In the second year the peak occurred in November. The *bare-soil* leachate exhibited a peak in August and again in April of the first year. Lack of leachate eliminated further data until June, at which time the greatest concentra-

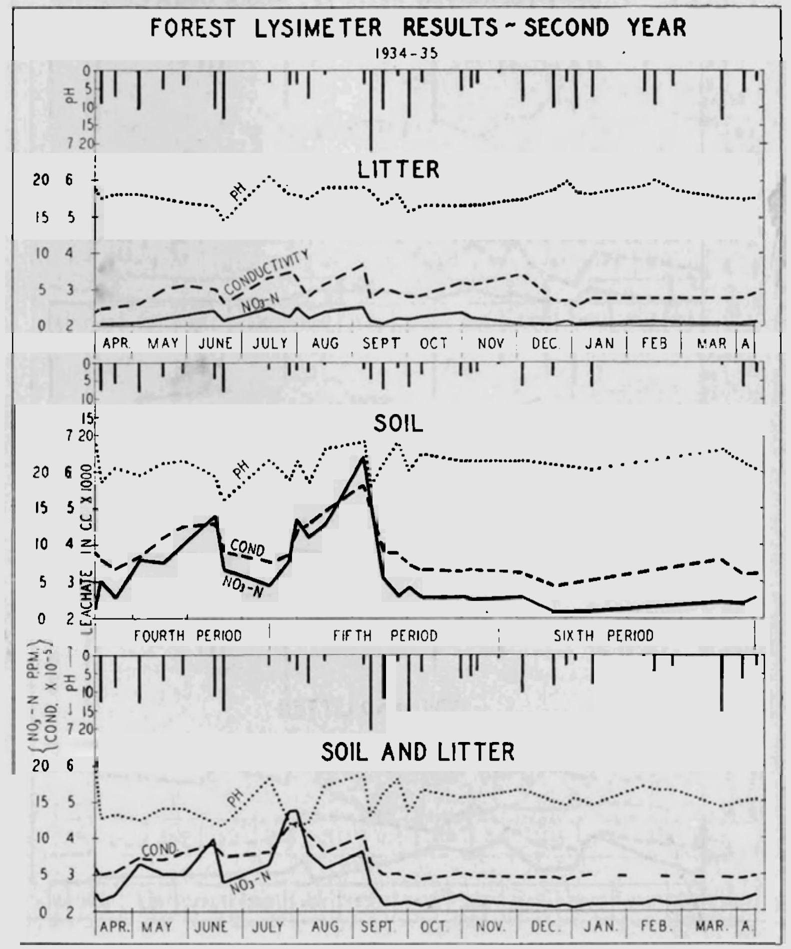

FIGURE 26. Current amount of leachate collected in the tank lysimeters during the second year, and its pH conductivity, and nitrate nitrogen content.

tion occurred for the second year's results. Except for minor fluctuations, the nitrates in the *soil-and-litter* leachate remained quite low throughout both years. Undoubtedly this low concentration is caused in part by the microoganisms using the nitrates in the process of litter decomposition, and in part by greater root activity.

Similar to its behavior in the tank lysimeters, conductivity followed the nitrates with moderate regularity.

The reaction of the leachate from the litter pans ranged in both years from pH 5.0 to pH 5.5 during the summer months and between 5.5 and 6.0 during the winter. The comparative uniformity of the pH of both the

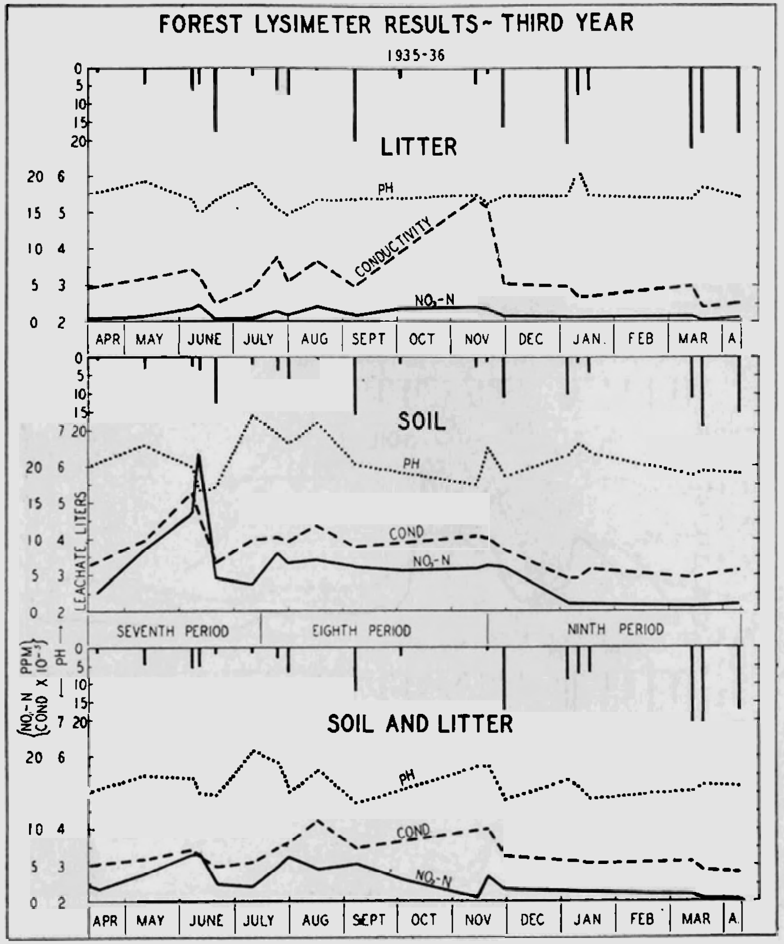

FIGURE 27. Current amount of leachate collected in the tank lysimeters during the third year, and its pH, conductivity, and nitrate nitrogen content.

bare-soil and the soil-plus-litter leachate, especially during the second year, is more apparent than real because of the small amount of leachate and consequently the limited data available.

It is very interesting to compare the pan and tank leachates. Although the reaction of the litter leachate was approximately the same in both cases, that of the soil-and-litter *pans* was prevailingly less acid (pH

6.0 or above) than was that of the corresponding *tanks*. The most likely explanation for this difference lies in the greater moisture and nitrate content of the latter. Furthermore, the heavier leaching of the soil and

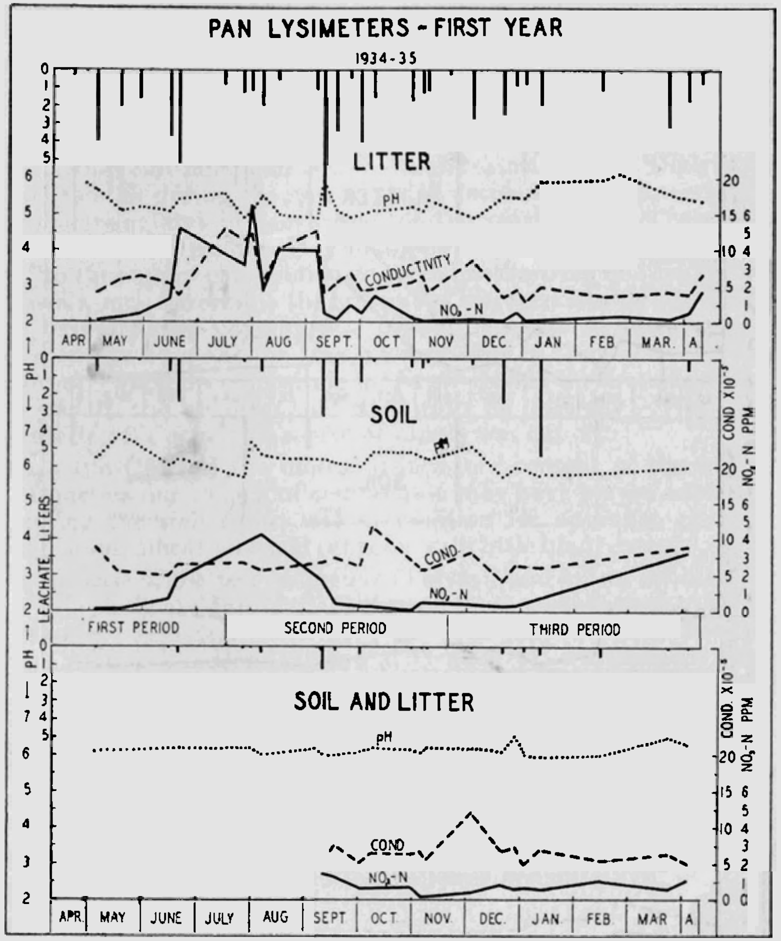

FIGURE 28. Current amount of leachate collected in the pan lysimeters during the first year, and its pH, conductivity, and nitrate nitrogen content.

litter in the tanks means a more complete removal of any acids present than does the smaller degree of leaching of the material lying over the pans.

Reference will be made again to the question of soil and leachate acidity.

Total Nitrogen in the Leachate

In the earlier article (14), it was reported that during the first year the tank lysimeters yielded nitrogen at the rate of 31 to 63 pounds to the acre. Of this about 88 percent was in the nitrate form in the tanks containing soil, and only 27 percent was nitrates in the litter-only tanks. During the second year (Table 4) the litter yielded 24.8 pounds of nitrogen, of which 40 percent was nitrate; the bare soil yielded 40.3 pounds with 84.6 percent as nitrates; while the soil and litter gave 47.7 pounds of

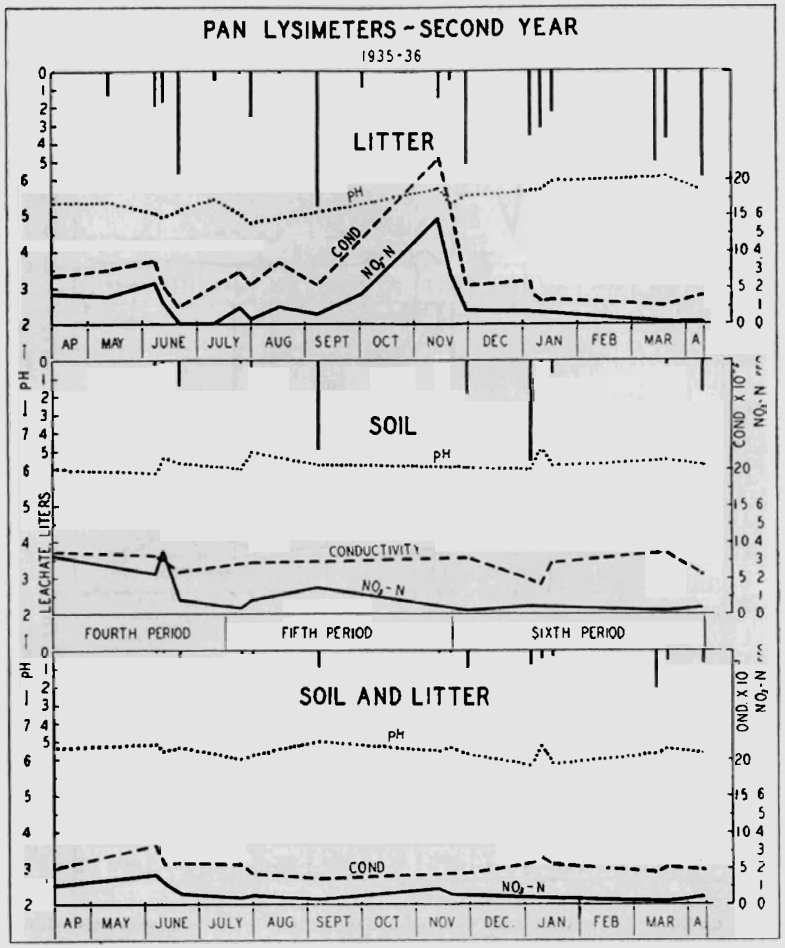

FIGURE 29. Current amount of leachate collected in the pan lysimeters during the second year, and its pH, conductivity, and nitrate nitrogen content.

which 76 percent was nitrate. In the third year (Table 5), the leachate yielded still less nitrogen, 17 pounds from the litter, of which 27 percent was nitrate; 27 pounds from the bare soil with 84 percent nitrate; and 20.5 pounds from the soil and litter with 74.6 percent nitrate nitrogen. There appears to have been a slight tendency during these three years for the nitrates to decrease and the ammonia to increase in percentage of the total

amount. In actual amount the nitrate nitrogen of the soil and litter lysimeter shows a very striking downward trend during the three years of the experiment. We see from Table 6 that the mean concentration of total nitrogen in mgs. per liter very definitely decreases in all cases from year to year. This applies to the pan lysimeters as well, although data from the latter are limited to two years.

Part of this decrease may be attributed to rainfall distribution. It may be observed that the largest proportion of the nitrogen was collected in the second period which included the warmest part of the summer when decomposition and microbial activity are greatest. From Table 3 we see that the rainfall during the *second period* decreased each succeeding year both in amount and in percentage of the year's total. Therefore, the distribution of the rainfall is a factor of considerable importance with respect to the supply of available nitrogen for the trees and, in the case of leachy soils, may determine the amount of nitrogen loss through leaching.

A second factor contributing to this decrease in nitrogen may be ascribed to the decay of the tree roots present in the soil at the time of installation. Their decomposition in the soil during the first year undoubtedly added to the nitrogen that went into the leachate. With no new roots entering the area, this source of supply was cut off.

As a third factor, the increased moisture content of the soil in the tank lysimeters due to lack of competition may have played some part by maintaining the soil in too wet a condition for optimum nitrification, although ammonification could continue with little hindrance (19, p. 784).

In the case of the pan lysimeters (Tables 7 and 8), we see that, except for the litter leachate during the first year, there was relatively little nitrogen obtained. In fact, it was generally less than the amount brought down by rain at Windsor (17) and at Geneva (6). Furthermore, the proportion that was in the form of nitrates was seldom in excess of 50 percent, in contrast to the tank lysimeters where it equalled or exceeded 75 percent in the bare-soil and soil-plus-litter tanks.

The lower rainfall of the first two periods of 1935-36 and consequently the smaller amount of leachate collected was largely responsible for the low nitrogen recovery in comparison with the preceding year. The concentration per liter also was lower during these periods, indicating that microbial activity was restricted by the lesser precipitation.

Total Solids

The amounts of total solids contained in the leachate are shown in Table 9. In every case the largest amount came from the litter, although its concentration per unit of volume of leachate was not always highest. In the tank lysimeters the amount of solids from the bare soil increased slightly from year to year, while that from the soil and litter decreased. Since the amount of leachate from the bare soil increased in about the same ratio as did the solids, the rate was more or less constant. In the soil-and-litter data no such relationship exists. The amount per cc was highest in the first year and lowest in the second. On the whole, the results indicate that at the sustained high moisture contents existing under the conditions of the experiment, the soil becomes increasingly impervious to the passage of solids through it. The small amount of solids from the soil and litter in the pan type can be attributed to the low quantity of leachate collected, for the concentration in p.p.m. differs little from that of the bare soil. By periods there is a general relationship between leachate collected and the amount of solids found.

Ash

The ash content (Table 10) ranged from about 20 to more than 450 pounds to the acre. There seems to be little consistency with regard to the amount obtained at different periods of the year or from different portions of the profile, although there is some tendency for the leachate to be less concentrated with respect to ash in the third, or winter period, of each year. This latter condition was largely a matter of dilution.

Loss-on-ignition

Loss-on-ignition (Table 11), obtained by difference between total solids and ash, was usually greatest from the litter lysimeters where there was no soil to absorb or precipitate out the organic matter. In all other cases variation in loss-on-ignition can be correlated with the amount of leachate obtained.

In the second part of Table 11 it is seen that loss-on-ignition constituted from 23 percent to 77 percent of the total solids, with little consistency with regard to time or kind of material.

Calcium

In common with most of the forest soils of the region, the soil studied contains a low amount of calcium, particularly in the available form. This condition, together with the relatively high acidity (pH 4.5) accounts for the comparatively low calcium removal shown in Table 12. Over a long period of time it was to be expected that the amount of calcium from the bare soil would gradually decrease since there was no provision for renewal of its supply. But where the litter was allowed to remain in place, the amount of calcium in the leachate should have remained more or less constant because of the continual renewal of its supply through falling needles. The data show that the amount of calcium from the litter alone was equal to or greater than that from the soil and litter.

On the whole, the greater the quantity of leachate collected, the larger the amount of calcium obtained. The most striking exception occurred in the bare-soil lysimeter during the second period of 1933-34 where 74.5 percent of the year's total of calcium was obtained in contrast to 54.5 percent of the total leachate.

There is some indication of a higher concentration during the second period of each year, although not in every case. In the bare soil, where the nitrate concentration was highest, there was some correlation between the calcium content and the removal of nitrates. In the soil-and-litter lysimeters the correlation was practically nil.

Magnesium

Analysis for magnesium was made only during the first two years, with the results shown in Table 13. It is noted that the concentration was quite low in comparison with calcium. The ratio of calcium to magnesium varied from about 2.5 to 10.7 with an average of 4.24. There was no consistent relationship with kind of material or time except with the pan lysimeters in which the ratio was higher, *i.e.*, more calcium, during the third period. The ratio for the bare-soil leachate was slightly wider than it was for the litter leachate.

Potassium

The amount of this element contained in the leachate varied from 12 to 31 pounds per acre per year from the tank soils, and from less than one to nearly 16 pounds from the pan soils (Table 14). Less potassium came from the bare soil than from either litter alone or soil and litter. This was due to the smaller amount of leachate collected, since the concentration per liter was just as high or higher in the soil leachate as in the other two lysimeters. The somewhat lower concentration of potassium in the pan leachate, as compared with that of the tanks, may be attributed to assimilation of potassium by the tree roots in the pans.

Sulfur

Sulfur passed into the drainage water at the rate of 12 to 35 pounds per acre per year in the tank lysimeters and up to 18 pounds in the pans (Table 15). This is considerably less than Joffe obtained from his A_1 horizon. Joffe's lysimeters are located in a more highly industrialized region with some factories not more than two or three miles distant. On the other hand, our lysimeters have no significant source of supply closer than seven or eight miles and even that is of minor consequence because of its direction with respect to the prevailing winds.

In his rain gauge tanks at Windsor, Morgan (17) collected, as a five-year average, 17 pounds of sulfur per acre. There is no reason to suspect that the amount brought down by rain in the vicinity of these lysimeters near New Haven should be very different.

Phosphorus

The incomplete data available, Table 16, show very small amounts of phosphorus in the leachate—in all cases less than a pound to the acre. By far the largest concentration was obtained in the litter leachate.

Silica

Lack of platinum ware prevented the securing of thoroughly reliable data on the silica content of the leachate. Indications are that the SiO_2 content was approximately of the same magnitude as potassium (Table 17). Soluble silica by the colorimetric method is more dependable for this purpose but was not used until the third year. The amounts for that year varied from 1 to 14 pounds in the tanks, and .05 to 3.7 in the pans.

As would be expected, the amount from the litter was smallest in both total amount and in concentration per liter.

Iron

Table 18 gives the iron content of the leachate. The amounts vary from .12 to 5.48 pounds in the tanks, and .04 to 4.31 in the pans. In these experiments there was little consistency with respect to either the source of the leachate or the time of the year. However, in the tanks the concentration per liter was least in the winter period in two out of the three years, and least in the pans in one of the two years. The litter yielded much more iron than was expected. According to Joffe (9) plants take up little iron and aluminum so that these elements do not enter into the cycle of absorption by the roots and deposition as needle fall as do the other essential elements. However, under the conditions of this experiment, some mineral matter must have been included in the litter layer where the acid humus decomposition products would have been very active upon it.

Results of Moisture and Chemical Tests on the Soil

Since the termination of the experiment we have made several samplings of the soil in the lysimeters and also nearby soil outside the lysimeters. The latter was designated as field soil. Samples taken in June (Table 19) show distinct differences in moisture and relative wetness. The field soil was lower in available nitrogen, and for some reason it contained less soluble iron and manganese.

A final sampling, made October 23 at the time the soil was removed from the tanks, gave the results as shown in Table 20. There were no significant differences between the samples, aside from the slight tendency of the field soil to have a lower content of aluminum and manganese.

Moisture Distribution in the Soil

In order to determine if there were any marked inequalities in the distribution of moisture in the tanks, samples were taken by one-inch depths from both the center and the side of the tank lysimeters and from both front and back of some of the pan lysimeters. Five days previous to sampling there had been a 2.65 inch rainfall. Moisture, moisture-equivalent and relative wetness, were determined on these samples with the results shown in Figure 30. Aside from the lower layers of Tank 1, where the results appear to be erratic, there was little difference in relative wetness of the various portions of the soil. In some cases the fourth layer was somewhat wetter; in others it was less moist.

Mixing of Litter with Sand

Inspection of the litter tanks in which the litter rested directly on pure quartz sand revealed that there had been an active mixing of the lower portion of the litter layer with the sand so that there was no sharp delimitation of one from the other. This is shown in Figure 31. Probably both mechanical infiltration and biological activity contributed to this

condition. We know that this process takes place in normal soils and is of considerable significance in forest soil. That it should take place in sand to the extent that it did was quite unexpected.

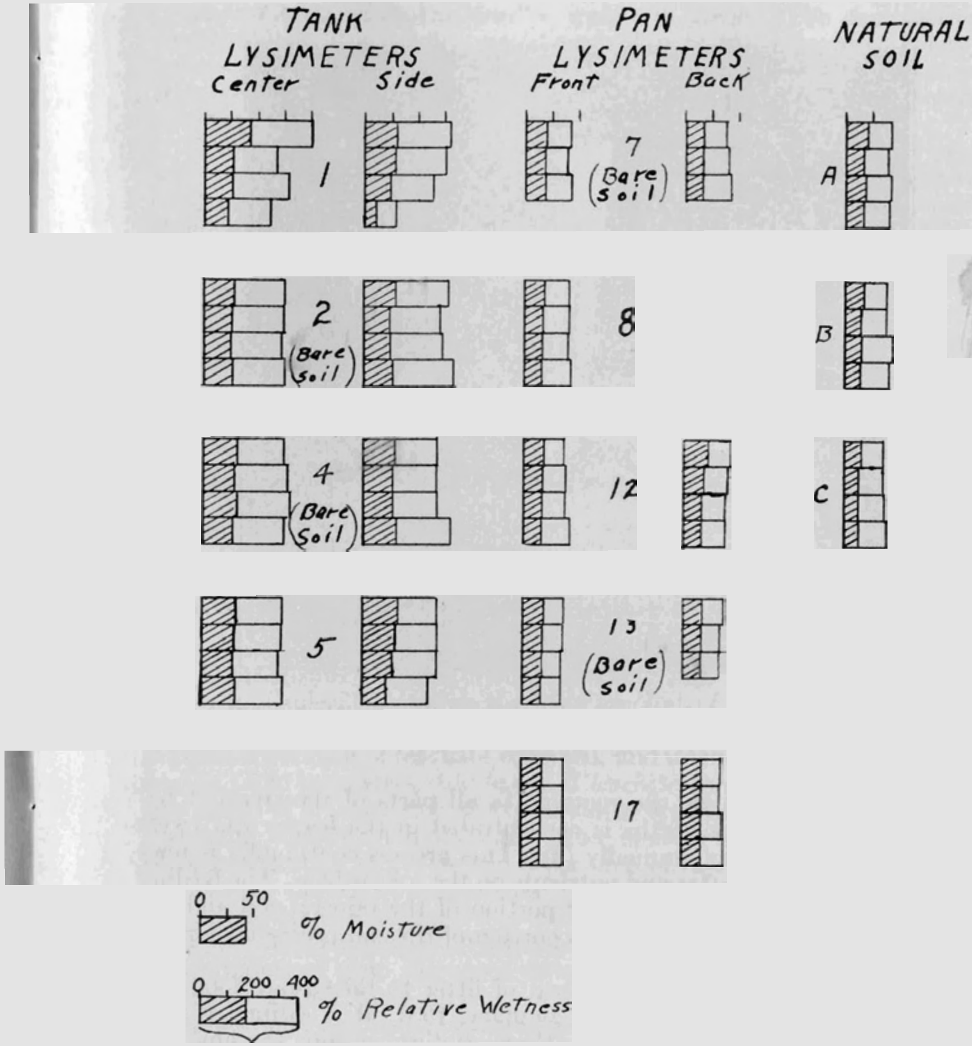

FIGURE 30. Moisture distribution in the lysimeters, October 23, 1936.

DISCUSSION

It must be borne in mind that this investigation was not designed to study the losses of soil constituents from the soil, as is the chief aim of most lysimeter experiments. The object was rather to determine the rôle of forest litter in tree nutrition and in the maintenance of soil fertility. The amount of the nitrate nitrogen, or calcium, or potassium, for example, which appeared in the leachate, may or may not have borne a relation to soil losses, for no data were obtained on the movement of these materials in the subsurface and subsoil.

Figure 31. One of the litter tanks, showing the intimate mixing of the lower litter with the top of the sand.

Nutrients taken up by the roots go to all parts of the tree but between two-thirds and four-fifths is concentrated in the leaves and twigs and is returned to the soil annually (3). This process continually renews the supply of organic matter and nutrients on the soil surface. The feeding roots of the tree permeate the upper portion of the mineral soil and the lower portion of the Ao. Hence, this portion of the soil profile is of great importance in forest tree nutrition.

From measurements of the amount of litter to the square foot and from analysis of samples collected in January, 1937, it is estimated that the portion of the profile involved in these studies contains the amounts shown in the following table:

	Estimated weight per acre lbs.	N %	N lbs./A.	Ca %	Ca lbs./A.	K %	K lbs./A.
Needles	4,000	1.470	58.8	.753	30.1	.379	15.2
Litter	14,800	.893	132.1	.765	113.2	.113	16.8
Soil	816,700	.276	2,254.0	.387	3160.0	—	—

The weight of needles was estimated from measurements obtained at the Rainbow Plantation at Windsor, making some allowance for differences in sites. It should be mentioned that the needles used in these analyses were collected from branches that had been pruned off the preceding summer while the needles were still green. The composition of freshly fallen, *dry* needles would undoubtedly run somewhat below the figures given. Red pine litter, which had accumulated on the ground at Rainbow and therefore had been subjected to weathering for a considerable period, analyzed 0.5 percent N and 0.45 percent Ca.

Now when we compare the amount of the several elements present with the amount obtained in the leachate, we observe that the maximum total annual nitrogen content of the percolate from the litter equalled about one-quarter of the total present in the litter. In the case of calcium, as much as one-half of the total was collected in the leachate, and with potassium, from one-seventh to one-fifth. The proportion obtained from the tanks containing soil was, naturally, very much less.

Apparently the nutrients contained in the litter are much more readily soluble than those in the mineral soil. This is shown not only by the analysis of the leachate, but also by rapid chemical tests which have been made. Samples collected in June, 1933, tested as follows:

	pH	Ca	P	K
Litter	4.4	2000 lbs./A	75 lbs./A	300 lbs./A
A_1	4.6	400 lbs./A	8 lbs./A	40 lbs./A

Comparisons between litter, bare soil, and soil plus litter are best shown in Table 21 in which the total amount of several constituents obtained during the full time of the experiment is given in pounds per acre, in pounds per inch of leachate collected, and in pounds per inch of rainfall. In the tank lysimeters, the *bare-soil leachate* contained the *greatest* concentration of all constituents except sulfur; and the soil-plus-litter leachate was more concentrated than the litter alone. On the basis of rainfall, the concentration of Ca, K and S per inch of rain was *less* in the *bare soil* than in the other two treatments. Where root competition occurred, as in the pan lysimeters, both the concentration and the total amounts of nutrients were less in the soil leachate than they were in the litter leachate, which indicates that the roots drew heavily upon the mineral soil and consequently left little surplus soluble material to be leached out. The difference between the concentration per inch of rain and the concentration per inch of leachate is least in the litter leachate from the tanks, and greatest in the soil and soil-plus-litter leachate from the pans. Of course, under field conditions, it is quite probable that the amount that is permanently removed from the soil in the drainage water is relatively small in this type of soil. This opinion is supported by the findings of Joffe (9,10) and Collison (4).

Few studies carried on elsewhere have been sufficiently similar in their set-up to permit comparisons with the results herein reported. None has data on forest floor alone and all, whether the ordinary tank type or the Russian type, include more than four inches of mineral soil. The nearest approach to the conditions of this experiment is the A_1 layer (18 cm deep) of Joffe's Russian-type lysimeters. In order to facilitate comparisons, his results for the years 1929-30 and 1930-31 are recorded in Table 22 side by side with the writer's data from the soil-and-litter pan lysimeters for the years 1934-35 and 1935-36. With considerably less rainfall, he obtained much more leachate, which was more acid and which contained a great deal more of all constituents listed.

The question arises—why? Part of the difference in the percolate obtained may be due to mechanical differences and operating efficiency of the two kinds of lysimeters. Joffe used round funnels while the writer used square pans. However, a more important factor is difference in the type of forest selected for study. Joffe's lysimeters were located under hardwoods which drop their leaves in the fall and consequently use little moisture from late fall until late spring. Pines, on the other hand, draw upon soil moisture throughout the year.

With respect to the concentration of the various constituents in the leachate, two factors undoubtedly enter the picture. The first is forest composition. All eight species of trees listed by Joffe as occurring on his lysimeter plot normally contain more ash than does pine. At least three of them—black locust, dogwood and hickory—are especially rich in ash. For example, Salisbury (18) reported the calcium content of the litter of several species as follows: Beech 2.46 percent, birch 2.30 percent, oak 1.70 percent, pine .99 percent. Alway, Maki and Methley (1) credit pine with a calcium content of 0.68 percent as compared with 1.89 percent for white oak, 2.05 percent for red oak, 2.12 percent for red maple, 2.51 percent for American elm, 4.03 percent for Norway maple, and 4.54 percent for basswood. Recent analysis by the writer has shown that red pine needles, when nearly ready to fall, have an ash content of about 2.0 percent, compared with 5.31 percent for leaves of red maple, 5.90 percent for white oak, 8.00 percent for sugar maple, 9.32 percent for dogwood and 9.80 percent for those of hickory (13).

The second factor may be a difference in native soil fertility. Joffe gives no data on soil composition or fertility value so that no direct comparisons can be made. However, it is entirely possible that his soil is more fertile than the writer's.

The greater amount of nitrogen obtained by Joffe may well be attributed to the presence of locust trees on his plot. Because of the symbiotic fixation of nitrogen in the nodules of its roots, locust leaves analyze higher in nitrogen than non-legume species, and the leachings from the leaves and underlying soil are richer in nitrogen.

Mention has been made of differences in reaction of the leachate. It is interesting to note that Joffe's soil tested pH 5.1 to 5.2 but his leachate had a reaction of pH 4.6 to 4.8, except as previously noted. He had no explanation for this difference. In our case we are faced with the opposite situation: pH of the litter 4.4, and of the soil 4.6, but with the leachate maintaining a reaction of 6.0 or better. Likewise, the leachate from the litter was considerably less acid than the litter itself. Nor was this situation confined to the pan lysimeters, for, except during the warm season when nitrates were high, definitely increasing the acidity at that time, the reaction of the leachate from the tanks was also invariably less acid than was the reaction of the soil. This is the relationship generally obtained in lysimeter work and can be attributed to the presence of strong

bases and weak acids in the soil. When such a medium is leached with a non-buffered liquid like water, the resulting leachate is invariably less acid than the medium. Frequency of leachings and the conditions obtained during the interval between leachings govern the reaction and the salt content of the leachate to a large extent. Morgan (17) has shown that there is a very definite relation between fertilizer treatment and the reaction of the leachate. But in every case, including the ammonium sulfate treatment, the reaction of the leachate was less acid than was that of the soil.

In order to check upon the field results pertaining to his problem, samples of litter, of dead needles from branches pruned the previous summer, and of the upper four inches of mineral soil were collected in January, 1937, for study in the laboratory. After cutting the needles and the litter in a food chopper and passing the mineral soil through a three-sixteenth inch hardware cloth, samples were placed in Büchner funnels and leached with successive additions of distilled water. The Büchners held 40 to 45 grams (dry weight) of needles and of litter and were leached with approximately 500 cc of water each time in the first test, and 250 to 300 cc in the second and third tests. Approximately 270 grams of the mineral soil were leached each time with 125 to 150 cc of water.

In the first test the pH of the leachate from the needles and the litter changed quite markedly toward a less acid condition, as shown in the following table:

Table 23. Reaction of Leachate in pH
Samples in Buchner Funnels Leached with Distilled Water

		Needles	Litter	Soil	Distilled water (unboiled)
Original Material		4.4	4.8	4.7	
No. and Date of Leaching					
1st	Jan. 19	4.83	5.15	5.45	5.60
2nd	Jan. 20	4.60	5.28	5.36	
3rd	Jan. 20	5.18	5.31	5.10	5.60
4th	Jan. 22	5.45	5.53	5.40	
5th	Jan. 22	5.70	5.90	5.10	5.80
6th	Jan. 25	5.60	5.63	5.18	
7th	Jan. 25	6.00	5.98	5.30	5.76
8th	Jan. 25	5.98	5.90	5.30	

In a second test seven successive leachings were made the first day, followed by two leachings each day for a week. Beginning the second day, the conductivity as well as the reaction of the leachate was determined. Simultaneously a third test was conducted in which leachings were made once a day and both reaction and conductivity determined. The results are shown in Figures 32 and 33. The first figure shows an initial drop and then an increase in pH of the *needle* leachate, with a general trend upward throughout the test. The *litter* leachate increased irregularly the first day, followed by a drop and then a general rise. Considering each day's leachings, we see that the 22-hour interval between the completion of one day's leachings and the beginning of the next resulted in a drop in pH followed by a distinct rise in the second leaching. The pH changes of the *soil* leachate showed a general upward trend; then a drop; and again an upward swing. In every case the relation between the first and second leaching for each day was exactly the reverse of what took place in the case of the *litter* leachate. It would appear that during the interval be-

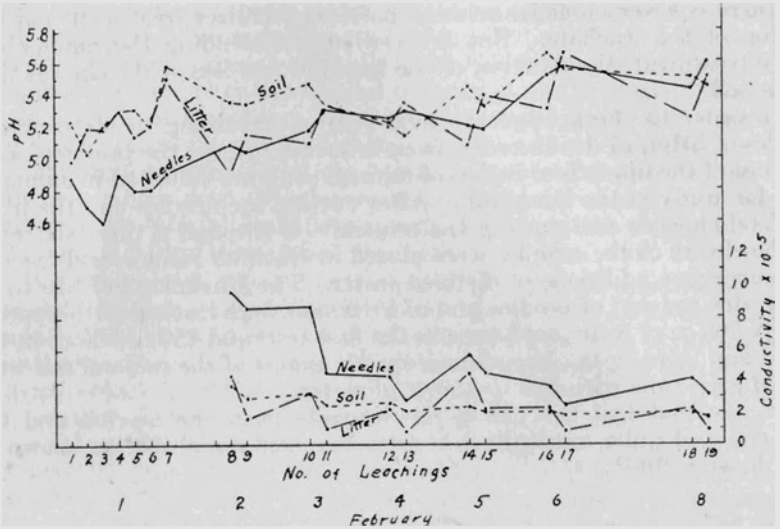

Figure 32. Reaction and conductivity of successive distilled water leachings of needles, litter and soil in the laboratory. Two or more leachings were made daily.

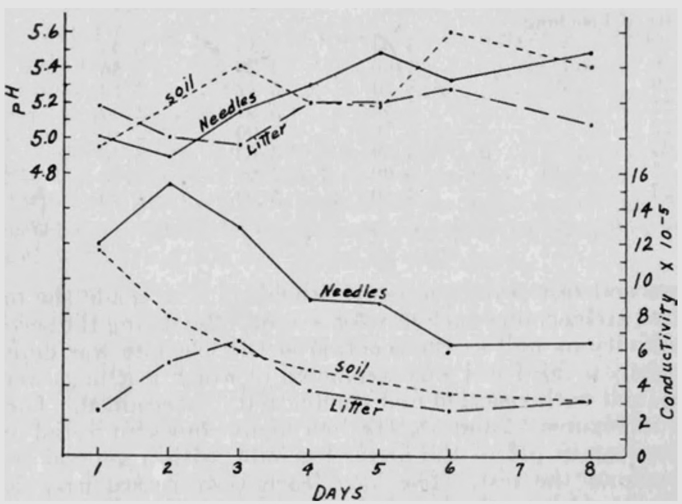

Figure 33. Reaction and conductivity of successive distilled water leachings of needles, litter and soil in the laboratory. Leachings were made daily.

tween leachings additional basic materials became soluble and the first of the two leachings removed most of this basic material, leaving less of it for the second. In the case of the litter, on the other hand, there was an accumulation of soluble acids, probably both organic and mineral, the latter principally sulfuric. The lower curves show the accumulation and removal of electrolytes as revealed by the conductivity measurements.

In the third experiment (Figure 33), the single daily leachings show a general though somewhat irregular upward trend in the pH of the needle leachate and soil leachate. The conductivity curves are interesting in that the peak of the salt extraction occurred the second day in the case of the needles and on the third day in the case of the litter. On the other hand, the soil leachate decreased steadily in electrolyte content, thus indicating that because of its mineral nature and because its organic matter constituents were already well broken down, microbiological activity was less in evidence than it was in the case of the litter and the needles. It should be stated that in the first of these three tests, leaching was done with the aid of suction, using filter paper in the bottom of the Büchner funnels. In the case of the litter, the paper became so badly clogged that the material was transferred to another Büchner containing a layer of coarse sand. In the second and third experiments, a thin layer of coarse sand was used in place of filter paper and filtration was done entirely by gravity. This meant that considerable moisture remained in the materials, particularly in the soil during the interval between leachings.

These laboratory tests are valuable in revealing what takes place in the field but cannot be as carefully measured there because of irregularities in amount and frequency of precipitation, changes in temperature, etc.

Atkinson and McKibbin (2), using samples of the H layer ("raw humus") from podzol profiles, leached them once every two weeks for a period of 14 weeks. They obtained a progressive decrease in acidity and in total solids. Their studies confirm the findings of Heimath (7) that free sulfuric acid is present in considerable amounts and is responsible, in no small degree, for the extreme acidity of the forest floor and its percolate.

The Russian-type lysimeters installed in an orchard by Collison (4) are not comparable to the writer's lysimeters in the forest. Nevertheless, his data from the 12 shallow funnels, placed at 12 inches from the surface, are worthy of consideration. He explains the extreme variation in amounts of leachate collected, 5 to 62 liters, as due, partly at least, to run-off. Where the funnels under the B horizon delivered more leachate than the A horizon, it was ascribed partly to the presence of root channels and partly to the suction effect of the funnels. Both factors are uncertain quantities in fairly deep lysimeters, but it is doubtful if either had much part in influencing water movement in the writer's lysimeters, which were only four inches deep.

Collison's findings, that the conductivity followed the nitrate content, agree with our results. Owing to the higher state of fertility of his orchard soil, both the conductivity and the nitrate concentration of his leachate were considerably higher than were those from our forest soil.

In the usual tank-type lysimeter containing agricultural soil, nitrates constitute almost all of the nitrogen present in the leachate (5) although, of course, the use of certain fertilizers may increase greatly the proportion of ammonia obtained (17).

CONCLUSIONS

These studies have shown that in the course of the year, natural precipitation in a red pine plantation caused the removal from the litter of from 7 to 31 pounds of nitrogen, 29 to 53 pounds of calcium, 14 to 31 pounds of potassium, 18 to 35 pounds of sulfur, lesser amounts of magnesium and small amounts of iron, phosphorus and silica. The larger amount in each instance refers to the maximum obtained in the tank lysimeters where root competition was eliminated; the smaller figure represents the minimum amount from the pan lysimeters with normal root competition. The mean annual amounts of the four main constituents leached from the pan-litter lysimeters were: Nitrogen, 16 pounds; calcium, 30; potassium, 15; and sulfur, 18. In years of deficient rainfall these amounts would be less, of course. From the analysis of freshly fallen pine needles, it is estimated that the amount of material deposited on the soil each year in a plantation of the age of this one approximates 55 to 60 pounds of nitrogen, 30 of calcium and 15 of potassium, to which must be added the amounts brought down by rainfall and that resulting from decomposing roots and animal remains. It is impossible to strike a balance sheet with any degree of accuracy, but the figures given indicate that there is a fairly close balance between deposition and removal.

In the case of the tank lysimeters the amounts of nitrogen, calcium and potassium which came from the litter constituted a significant portion of the total amount present in the litter as determined by analysis.

Leachate from the bare soil yielded during the course of a year from 1.5 to 40 pounds of nitrogen, from 9 to 47 pounds of calcium, 3 to 19 of potassium, 8 to 20 pounds of sulfur and small amounts of other materials. While these amounts were, on the whole, less than that which came from the litter, the concentration in mgs. per liter was as great or greater than that from the litter.

Excepting nitrogen obtained during the first year in the tank lysimeters, the amount of constituents obtained from the soil-and-litter lysimeters was, in general, no greater than that from the litter alone, and the concentration was not greatly different. Such data indicate that the soil absorbed or fixed much of the material coming from the litter; otherwise, the amounts from the soil and litter would equal the sum of that from the litter and the bare soil.

The greatest amount of nitrogen was obtained in the second period; *i.e.*, between July 15 and November 20, presumably as a result of the generally higher air temperature effect upon the activity of soil microörganisms. This was not true of calcium, potassium or any other constituent for which analysis was made.

The initial leachings of the tank soils contained a higher concentration of all constituents except nitrogen than did the subsequent leachings. Artificial leaching of soil in the laboratory gave similar results. Since under natural conditions there are always roots present to draw upon the moisture and plant nutrients liberated by the decomposing litter, losses through percolation are practically nil. This is particularly true of evergreen species. Greater losses would occur on steep slopes where a rapid run-off would carry away soluble plant food. We know, however, that there is a downward movement of nutrients in the soil, the best example being calcium which is almost always in greater concentrations in the lower portions of the profile than at the surface. The downward movement of constituents is apt to be greatest in the North where there is a short growing season and a minimum of growth activity in winter. A forest soil may be likened to an agricultural soil which is kept in crop continuously —pasture or alfalfa, for example—but with the added advantage of lessened evaporation because of the shade and retarded wind movement.

We can conclude from these studies that good growing conditions are most likely to be maintained through rapid liberation and consumption of nutrients contained in the litter. Anything that retards these processes leads to a higher acidity of the humic material with its accompanying unfavorable effects.

SUMMARY

Six tank-type lysimeters and 12 of the pan-type were maintained in a red pine plantation three and two years respectively, for the purpose of determining the kind and amount of materials which leach out of: (1) the forest floor (herein referred to as litter), (2) the upper four inches of mineral soil, and (3) the litter and soil together in their natural position. Nitrates, conductivity and reaction were determined following each significant rainfall. The other constituents were determined on composite aliquots three times a year: July 15, November 20 and April 10.

Tank Lysimeters (no root competition)

The largest amount of leachate was collected from the litter tank and the least from the bare soil. The amount ranged from 16 to 120 percent of the rainfall in the open. Variation between duplicates was ascribed partly to unevenness of the ground surface and slight settling in one case, and partly to unequal crown interception of the rainfall. On the average only 73 percent of the rainfall reached the ground.

Nitrogen in the leachate varied from 17 to 63 pounds to the acre per year with the largest portion of it usually in the second period. More than 75 percent was in the form of nitrates in the soil and soil-plus-litter tanks, and 40 percent or less was nitrate nitrogen in the litter tanks. The mean concentration of nitrogen in mgs. per liter decreased from year to year.

Conductivity was closely associated with the nitrate content.

The pH of the leachate increased during dry periods and dropped with nearly every significant rainfall. The bare soil leachate was least acid and that from the soil and litter most acid.

The amount of total solids per acre per year ranged from 761 to 1007 pounds from the litter, 384 to 422 from the soil, and 421 to 666 from the soil and litter. Ash varied from 188 to 455 pounds. Loss-on-ignition ranged from 190 to 632. The latter constituted from 40 to 60 percent of the total solids.

The calcium content of both litter and soil is low, the leachate containing from 38 to 60 pounds per acre per year. The magnesium content ranged from about one-half to one-fifth of the calcium.

From 12 to 31 pounds of potassium and 12 to 35 pounds of sulfur were found in the leachate. Phosphorus amounted to less than one pound per acre. Only small amounts of silica and iron were obtained, with little consistency as to source of the leachate or period of the year.

Pan Lysimeters (with normal root competition)

The withdrawal of soil moisture by the tree roots permitted only a small amount of percolation, especially from the soil-and-litter pans. The mean yearly percolate from soil and litter amounted to 6.6 liters as compared with 188 liters for the corresponding tank lysimeters.

Nitrates constituted only 50 percent or less of the total nitrogen content. Organic nitrogen equalled 36 to 57 percent in the soil and soil-plus-litter pans, and 44 to 49 percent in the litter pans. In general, the concentration of nitrogen per liter of leachate was as high as in the tanks.

Reaction of the litter leachate was about the same as in the tank lysimeters, but that from the soil-and-litter pan was prevailingly less acid than that from the corresponding tanks.

The concentration of all other constituents except potassium was approximately the same as it was in the tank leachate, so that the low amounts obtained were due primarily to the small amount of leachate. In the case of potassium, the concentrations per liter ran somewhat under those from the tanks.

The Experiment as a Whole

Rapid soil tests on the tank soils at the conclusion of the experiment showed no significant differences among the several tanks.

Inspection of the litter tanks showed there had been an active mixing of the lower portion of the litter layer with the quartz sand in the tank.

The maximum annual amount of nitrogen obtained in the litter leachate was equal to about one-fourth of the total N present in the litter. For calcium, the figure is one-half; for potassium, one-seventh to one-fifth.

In the tanks the bare soil leachate contained the greatest concentration of all constituents except sulfur. In the pans the litter leachate was most concentrated.

Lack of agreement with the results obtained by Joffe in his shallowest lysimeter may be ascribed to differences in construction and operating efficiency of the funnels and pans, difference in forest cover and, possibly, in native soil fertility.

Successive leachings of dry needles, litter and soil in the laboratory showed a generally progressive decrease in acidity of the leachate. Conductivity of the soil leachate decreased regularly with each successive leaching. Conductivity of the litter and of the needles increased for one or two leachings and then decreased progressively for the remainder of the leachings.

The amount of material deposited on the surface each year in a red pine plantation, 20 to 30 years old, approximates 55 to 60 pounds of nitrogen, 30 of calcium and 15 of potassium, to which must be added the amounts brought down by rainfall and that originating from decomposing roots and animal remains.

The presence of roots, which draw heavily upon the moisture and nutrient content of the soil, indicates that losses through percolation are of little consequence in the nutrient economy of the forest soil.

It is concluded that good growing conditions and a healthy soil condition are most likely to be maintained through rapid liberation and consumption of the nutrients contained in the litter. Any hindrance to these processes leads to a higher acidity of the humic material with its accompanying unfavorable effects.

Table 1. Leachate Collected in Percentage of Rainfall in the Open

		1933–34 Period				1934–35 Period				1935–36 Period			
Rainfall inches		1st 9.81	2d 18.22	3d 17.22	Av. 45.25*	1st 15.45	2d 17.24	3d 18.16	Av. 50.85*	1st 8.12	2d 10.17	3d 26.16	Av. 44.45*
	No.					**Tank Lysimeters**							
Litter	3	59.3	65.4	165.5	102.1	74.0	92.1	86.9	84.7	76.8	72.9	76.9	75.9
	6	50.9	63.7	147.8	93.0	86.9	101.8	88.3	92.5	98.0	98.6	93.6	95.6
	Av.	55.1	64.4	156.6	97.5	80.5	97.0	87.6	88.6	87.4	85.7	85.2	85.7
Soil	2	23.8	50.1	23.0	34.1	54.5	53.6	28.5	44.9	68.4	70.4	39.2	51.7
	4	16.1	33.5	28.2	27.8	57.3	46.0	30.0	43.0	51.7	54.5	74.6	65.8
	Av.	19.9	41.8	25.6	30.9	55.9	49.8	29.3	44.0	60.0	62.4	56.9	58.7
Soil and	1	47.8	58.5	42.6	50.1	77.3	73.8	50.2	66.4	57.0	23.4	58.0	49.9
litter	5	65.5	86.2	120.1	94.9	115.8	127.9	90.3	110.8	105.2	74.1	94.4	91.7
	Av.	56.6	72.4	81.3	72.5	96.6	100.9	70.3	88.6	81.0	48.7	76.2	70.8
						Pan Lysimeters							
Litter	9					48.0	65.5	44.4	52.6	48.0	47.3	38.6	42.3
	11					48.2	67.7	32.8	49.0	70.7	65.9	57.4	61.8
	16					38.4	69.5	33.5	47.2	61.5	66.5	40.8	50.4
	18					43.0	51.7	23.3	38.9	34.6	44.0	38.4	39.0
	Av.					44.4	63.4	33.5	46.9	53.7	55.9	43.7	48.4
Soil	7					9.76	20.3	19.9	17.0	3.4	5.5	15.6	11.1
	10					19.40	18.6	16.8	18.2	14.3	17.6	15.5	15.7
	13					7.20	24.9	22.9	18.8	8.7	42.7	13.3	19.2
	15					5.00	12.2	15.5	11.2	6.0	15.4	17.0	14.6
	Av.					10.34	19.0	18.8	16.3	8.1	20.3	15.4	15.2
Soil and	8					0.28	6.08	0.0	2.1	0.4	3.5	5.3	4.0
litter	12					2.22	6.35	3.5	4.1	1.7	2.2	7.2	5.1
	14					1.78	8.70	11.6	7.6	6.9	16.4	23.6	18.9
	17					0.68	2.37	0.0	1.0	0.7	2.1	1.1	1.2
	Av.					1.24	5.88	3.8	3.7	2.4	6.0	9.3	7.3

*Total rainfall for the year.

TABLE 2. WATER COLLECTED IN EMPTY LYSIMETERS IN PERCENTAGE OF RAINFALL IN THE OPEN

Dates	Rainfall inches	Tank No. 1	2	4	5
10/23–12/4	2.35	57.8	66.2	59.8	58.8
12/7	1.51	60.6	61.4	68.2	88.6
12/8–12/16	2.58	54.4	65.7	76.5	77.3
12/17–1/5	4.20	59.0	56.6	71.0	67.3
1/6–1/17	1.82	113.7	106.4	119.0	143.2
(1/18–2/1	4.03)		All overflowed		
2/2–2/15	1.21	63.0	75.2	78.4	81.1
Total (omitting 1/18–2/1)	13.67 Mean	65.8	68.8	76.7	81.5
Mean for the four tanks			73.2		

TABLE 3. PRECIPITATION AND LEACHATE COLLECTED IN LITERS AND IN PERCENT OF TOTAL FOR EACH PERIOD

	1st year 1933–34				2nd year 1934–35				3rd year 1935–36			
	Period				Period				Period			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Rainfall, in l. eq.*	50.4	93.7	88.5	232.6	79.4	88.6	93.3	261.4	41.7	52.3	134.5	228.5
Rainfall, in %	21.7	40.3	38.0	100	30.4	33.9	35.7	100	18.3	22.9	58.8	100
Litter, liters	27.7	60.4	138.8	226.9	63.9	85.9	81.8	231.5	36.5	44.8	114.6	195.9
Litter, %	12.2	26.6	61.2	100	27.6	37.1	35.3	100	18.6	22.9	58.5	100
Soil, liters	10.1	39.2	22.7	71.9	43.4	44.1	27.3	114.8	25.1	32.6	76.5	134.2
Soil, %	14.0	54.5	31.5	100	37.8	38.4	23.8	100	18.7	24.3	57.0	100
Soil & litter, liters	28.5	67.9	72.3	168.6	76.7	89.4	65.6	231.6	33.8	25.5	102.5	161.7
Soil & litter, %	16.9	40.2	42.9	100	33.1	38.6	28.3	100	20.9	15.8	63.3	100
Pan Lysimeters												
Rainfall, in l. eq.**					39.7	44.3	46.7	130.7	20.9	26.1	67.2	114.2
Rainfall, in %					30.4	33.9	35.7	100	18.3	22.9	58.8	100
Litter, liters					17.64	28.08	15.64	61.36	11.20	14.62	29.44	55.27
Litter, %					28.7	45.8	25.5	100	20.2	26.4	53.4	100
Soil, liters					4.11	8.42	8.76	21.29	1.69	5.31	10.33	17.33
Soil, %					19.3	39.6	41.1	100	9.8	30.6	59.6	100
Soil & litter, liters					0.49	2.60	1.77	4.87	0.50	1.58	6.25	8.33
Soil & litter, %					10.1	53.5	36.4	100	6.1	18.9	75.0	100

*Liter equivalent. 1 inch rain over the area of the tanks (314.2 sq. in.) = 5140 cc.
**Liter equivalent. 1 inch of rain over the area of the pans (157.1 sq. in.) = 2570 cc.

TABLE 4. NITROGEN IN LEACHATE FROM TANK LYSIMETERS DURING THE SECOND YEAR 1934–35

	PERIOD							
	1st Apr. 10–Jl. 15		2nd Jl. 15–Nov. 20		3rd Nov. 20–Apr. 10		Total av. lbs. per acre (Av. of duplicates)	% of total
Litter								
No.	3	6	3	6	3	6		
NH_3-N mgs.	15	18	17	28	15	12	2.31	9.3
NO_3-N mgs.	41	55	100	180	28	49	9.97	40.1
Org. N mgs.	65	50	127	226	49	54	12.56	50.6
Total lbs. per A.	5.35	5.38	10.79	19.11	4.1	5.1	24.84	100.0
Av. %	21.6		60.0		18.4			100.0
Soil								
No.	2	4	2	4	2	4		
NH_3-N mgs.	27	27	6	9	9	4	1.80	4.5
NO_3-N mgs.	251	209	498	490	47	55	34.10	84.6
Org. N mgs.	12	11	45	94	18	20	4.40	10.9
Total lbs. per A.	12.77	10.84	24.17	26.07	3.2	3.5	40.30	100.0
Av. %	29.3		62.3		8.4			100.0
Soil and Litter								
No.	1	5	1	5	1	5		
NH_3-N mgs.	31	20	5	13	6	5	1.76	3.7
NO_3-N mgs	282	285	242	612	34	194	36.28	76.1
Org. N. mgs.	37	34	66	249	24	28	9.64	20.2
Total lbs. per A.	15.4	14.94	13.78	38.46	2.8	10.0	47.68	100.0
Av. %	31.9		50.6		13.5			100.0

TABLE 5. NITROGEN IN LEACHATE FROM TANK LYSIMETERS DURING THE THIRD YEAR, 1935–36

	PERIOD							
	1st Apr. 10–Jl. 15		2nd Jl. 15–Nov. 20		3rd Nov. 20–Apr. 17		Total Av. lbs. per A.	% of total
Litter								
No.	3	6	3	6	3	5		
NH_3-N mgs.	3	9	29	39	34	58	3.78	22.1
NO_3-N mgs.	10	53	23	82	21	25	4.71	27.5
Org. N mgs.	62	51	62	89	53	76	8.65	50.4
Total lbs. per A.	3.3	5.0	5.0	9.2	4.8	7.0	17.14	100.0
Av. %	24.2		41.4		34.4			100.0
Soil								
No.	2	4	2	4	2	4		
NH_3-N mgs.	3	1	14	7	23	20	1.5	5.6
NO_3-N mgs.	210	192	173	171	116	170	22.7	84.4
Org. N mgs.	29	20	19	17	21	16	2.7	10.0
Total lbs. per A.	10.6	9.4	9.[illegible]	8.6	7.1	9.1	26.9	100.0
Av. %	37.1		32.7		30.2			100.0
Soil and Litter								
No.	1	5	1	5	1			
NH_3-N mgs.	12	0	5	20	26	23	1.9	9.3
NO_3-N mgs.	39	211	13	248	70	114	15.3	74.6
Org. N mgs.	24	38	8	23	20	38	3.3	16.1
Total lbs. per A.	3.3	11.0	1.1	12.8	5.1	7.7	20.5	100.0
Av. %	34.9		33.9		31.2			100.0

TABLE 6. TOTAL NITROGEN IN LEACHATE
Milligrams per Liter and Pounds per Acre

	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.	4.19	5.50	1.83	3.09	1.91	3.95	1.28	2.44	2.58	3.60	1.17	1.99
Litter, lb./A.	5.10	14.60	11.17	30.87	5.38	14.91	4.55	24.84	4.15	7.10	5.90	17.15
Soil, mg./l.	5.82	16.08	6.31	11.58	6.18	12.94	2.78	7.97	9.05	6.13	2.40	4.56
Soil, lb./A.	2.60	27.70	6.30	36.60	11.80	25.12	3.35	40.27	10.00	8.80	8.10	26.90
Soil & litter, mg./l.	1.61	6.31	6.61	8.49	4.49	6.13	2.22	4.67	4.80	6.19	1.41	2.88
Soil & litter, lb./A.	2.00	40.00	21.00	63.00	15.16	26.12	6.40	47.68	7.15	6.95	6.40	20.50
Pan Lysimeters												
Litter, mg./l.					4.02	7.41	1.13	4.82	2.29	2.07	0.88	1.48
Litter, lb./A.					6.24	18.30	1.57	26.11	2.26	2.66	2.30	7.22
Soil, mg./l.					2.21	4.57	1.55	2.87	2.15	0.81	0.79	0.93
Soil, lb./A.					0.80	3.39	1.20	5.39	0.32	0.38	0.72	1.42
Soil & litter, mg./l.					5.10	5.46	1.09	3.81	1.59	1.22	0.67	0.83
Soil & litter, lb./A.					0.22	1.25	0.17	1.64	0.07	0.17	0.37	0.61

TABLE 7. NITROGEN IN LEACHATE FROM PAN LYSIMETERS DURING THE FIRST YEAR, 1934–35

Average of Four Pans

	PERIOD				
	1st Apr. 10–Jl. 15	2nd Jl 15–Nov. 20	3rd Nov. 20–Apr. 10	Total av. lbs. per A.	% of total
Litter					
NH_3-N mgs.	14.08	20.36	4.32	3.41	13.1
NO_3-N mgs.	7.02	102.61	4.41	10.03	38.4
Org. N mgs.	49.76	85.09	9.12	12.67	48.5
Total lbs. per A.	6.24	18.31	1.57	26.11	100.0
% of total	23.9	70.1	6.00		100.0
Soil					
NH_3-N mgs.	1.55	5.35	1.71	0.76	14.1
NO_3-N mgs.	3.71	20.71	6.42	2.71	50.2
Org. N mgs.	3.85	12.48	5.50	1.92	35.7
Total lbs. per A.	0.80	3.39	1.20	5.39	100.0
% of total	14.8	62.9	22.3		100.0
Soil and Litter					
NH_3-N mgs.	0.50	1.10	0.20	0.16	9.7
NO_3-N mgs.	1.35	7.69	0.98	0.88	53.7
Org. N mgs.	0.70	5.41	0.72	0.60	36.6
Total lbs. per A.	0.22	1.25	0.17	1.64	100.0
% of total	13.4	76.2	10.4		100.0

TABLE 8. NITROGEN IN LEACHATE FROM PAN LYSIMETERS DURING THE SECOND YEAR, 1935–36

Average of Four Pans

	PERIOD				
	1st Apr. 11–Jl. 10	2nd Jl. 10–Nov. 14	3rd Nov. 14–Apr. 17	Total lbs. per acre	% of total
Litter					
NH_3-N mgs.	3.85	6.02	5.73	1.37	19.0
NO_3-N mgs.	9.93	11.69	9.11	2.70	37.4
Org. N mgs.	11.98	12.57	11.26	3.15	43.6
Total lbs. per A.	2.26	2.66	2.30	7.22	100.0
% of total	31.3	36.8	31.9		100.0
Soil					
NH_3-N mgs.	0.30	1.07	1.42	0.25	17.6
NO_3-N mgs.	1.60	0.93	2.30	0.43	30.3
Org. N mgs.	1.61	2.37	4.42	0.74	52.1
Total lbs. per A.	0.32	0.38	0.72	1.42	100.0
% of total	22.5	26.8	50.7		100.0
Soil and Litter					
NH_3-N mgs.	0.07	0.45	0.94	0.13	21.3
NO_3-N mgs.	0.15	0.31	1.01	0.13	21.3
Org. N mgs.	0.48	1.20	2.26	0.35	57.4
Total lbs. per A.	0.07	0.17	0.37	0.61	100.0
% of total	11.5	27.9	60.6		100.0

TABLE 9. TOTAL SOLIDS
Milligrams per Liter and Pounds per Acre

	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.	198.5	171.6	51.0	100.9	68.0	96.9	56.3	74.7	84.5	144.3	66.8	88.6
Litter, lb./A.	241.9	455.7	310.0	1007.6	191.8	366.8	202.6	761.2	136.2	288.0	340.3	764.5
Soil, mg./l.	109.1	152.5	76.1	121.4	83.2	88.0	59.9	79.7	101.2	94.8	54.1	71.4
Soil, lb./A.	48.8	259.9	75.4	384.1	158.8	172.1	71.7	402.6	110.9	134.2	176.8	421.9
Soil & litter, mg./l.	73.7	116.4	80.3	89.8	62.9	60.5	42.9	56.3	67.3	83.7	47.5	59.2
Soil & litter, lb./A.	93.7	347.1	225.2	666.0	207.9	241.8	124.4	574.1	99.5	104.9	216.8	421.2
Pan Lysimeters												
Litter, mg./l.					158.6	137.5	78.6	126.6	115.2	173.7	66.5	101.7
Litter, lb./A.					241.6	336.4	105.5	683.5	109.4	216.7	168.9	495.0
Soil, mg./l.					77.5	83.5	79.1	80.0	81.1	74.3	73.7	73.3
Soil, lb./A.					29.7	59.6	60.6	149.9	11.5	33.3	67.0	111.8
Soil & litter, mg./l.					121.2	90.1	73.7	83.3	89.0	84.9	66.5	71.5
Soil & litter, lb./A.					2.1	21.9	11.6	35.7	3.9	12.7	35.9	52.5

TABLE 10. ASH
Milligrams per Liter and Pounds per Acre

	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.	45.8	43.7	31.1	37.6	21.4	70.8	35.3	44.7	62.7	44.8	20.7	33.9
Litter, lb./A.	70.5	116.0	189.1	375.6	60.5	268.1	127.0	455.6	100.8	88.4	103.8	293.0
Soil, mg./l.	56.9	72.9	38.0	59.3	38.2	46.7	24.9	38.2	59.6	49.3	29.7	39.2
Soil, lb./A.	25.3	125.0	37.5	187.9	72.9	90.5	29.8	193.2	64.7	70.4	96.8	231.9
Soil & litter, mg./l.	57.8	61.2	45.4	48.1	30.4	29.4	15.7	26.0	39.2	44.4	26.0	31.6
Soil & litter, lb./A.	58.2	182.9	115.5	356.6	99.9	118.3	47.2	265.4	57.5	49.4	117.9	224.8
Pan Lysimeters												
Litter, mg./l.					35.9	103.5	46.1	68.7	87.9	47.2	22.0	40.9
Litter, lb./A.					55.5	253.1	62.5	371.0	83.8	59.5	56.1	199.4
Soil, mg./l.					37.5	41.2	43.8	41.3	44.3	40.7	39.6	39.1
Soil, lb./A.					14.4	29.5	33.5	77.4	6.4	17.2	36.1	59.7
Soil & litter, mg./l.					43.2	58.4	37.8	49.9	59.6	33.6	26.7	30.3
Soil & litter, lb./A.					0.8	14.5	6.1	21.4	2.6	4.7	15.0	22.3

TABLE 11. LOSS ON IGNITION
A. Milligrams per Liter and Pounds per Acre

	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.	140.6	128.0	19.9	63.5	46.6	26.1	21.0	30.0	21.8	99.5	46.1	54.6
Litter, lb./A.	171.4	339.7	120.9	632.0	131.3	98.7	75.6	305.6	35.4	199.6	236.5	471.5
Soil, mg./l.	58.3	79.6	38.1	62.7	45.0	42.1	35.0	41.5	41.6	45.6	24.4	32.1
Soil, lb./A.	23.5	134.9	37.9	196.2	75.9	81.6	41.9	209.4	46.2	63.8	80.0	190.0
Soil & litter, mg./l.	27.8	55.1	34.9	40.5	32.5	31.1	27.2	30.3	28.1	39.3	19.0	26.4
Soil & litter, lb./A.	35.5	164.2	109.7	309.4	108.0	123.5	77.2	309.7	42.0	55.5	98.9	196.4
Pan Lysimeters												
Litter, mg./l.					122.7	34.0	32.6	57.9	27.3	124.0	44.5	60.2
Litter, lb./A.					186.1	83.3	43.0	312.5	25.6	157.2	112.8	295.6
Soil, mg./l.					43.3	42.3	35.3	40.1	36.9	33.6	34.1	34.1
Soil, lb./A.					15.3	30.1	27.1	72.5	5.1	16.1	30.9	52.1
Soil & litter, mg./l.					78.0	31.7	35.9	33.3	29.6	51.4	39.8	41.1
Soil & litter, lb./A.					1.3	7.4	5.5	14.3	1.3	8.0	20.9	30.2
B. IN PERCENT OF TOTAL SOLIDS												
Tank Lysimeters												
Litter	70.9	74.5	39.0	62.7	68.5	26.9	37.3	40.1	26.0	69.3	69.5	61.7
Soil	48.2	51.9	50.3	51.1	47.8	47.4	58.4	52.0	41.7	47.5	45.2	45.0
Soil & litter	37.9	47.3	48.7	46.5	51.9	51.9	62.1	53.8	42.2	53.0	45.6	46.6
Pan Lysimeters												
Litter					76.7	24.8	40.8	45.7	23.4	72.5	66.8	59.7
Soil					51.5	50.5	44.7	48.4	44.3	48.3	46.1	46.6
Soil & litter					61.9	33.8	47.4	40.1	33.3	63.0	58.2	57.5

TABLE 12. CALCIUM
Milligrams per Liter and Pounds per Acre

	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.	10.0	8.0	2.95	5.14	3.62	4.60	4.65	4.34	4.96	9.73	5.12	6.19
Litter, lb./A.	12.2	21.3	17.8	51.3	10.2	17.3	16.7	44.2	8.35	19.32	25.71	53.38
Soil, mg./l.	12.3	20.4	6.5	14.7	9.32	8.15	5.39	7.95	7.60	9.38	5.17	6.47
Soil, lb./A.	5.5	34.8	6.4	46.7	17.8	15.9	6.4	40.1	8.35	13.44	16.45	38.24
Soil & litter, mg./l.	6.1	12.0	6.2	8.1	4.82	3.61	3.97	4.12	4.50	9.60	5.26	5.93
Soil & litter, lb./A.	7.6	34.9	17.3	59.9	15.9	14.9	11.3	42.1	6.96	11.61	23.67	42.24
Pan Lysimeters												
Litter, mg./l.					4.75	6.12	4.81	5.30	6.20	10.60	4.70	6.45
Litter, lb./A.					7.31	14.88	6.44	28.63	5.83	13.50	12.07	31.40
Soil, mg./l.					4.63	5.76	5.40	5.25	5.62	6.64	6.39	6.10
Soil, lb./A.					1.74	3.97	4.14	9.85	0.73	2.82	5.76	9.31
Soil & litter, mg./l.					8.61	4.05	5.68	4.41	5.0	6.50	5.86	5.59
Soil & litter, lb./A.					0.15	0.91	0.83	1.89	0.23	0.84	3.04	4.11

TABLE 13. MAGNESIUM
Milligrams per Liter and Pounds per Acre

	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.	2.57	1.92	1.09	1.49	1.18	1.64	.109	.93		No Data		
Litter, lb./A.	3.12	5.12	6.63	14.87	3.28	6.16	0.40	9.84				
Soil, mg./l.	4.90	3.71	2.11	3.34	1.90	[illegible].08	0	1.52				
Soil, lb./A.	2.16	6.32	2.09	10.57	3.62	4.07		7.69				
Soil & litter, mg./l.	1.88	3.08	2.42	2.49	1.56	0.94	0	0.87				
Soil & litter, lb./A.	2.37	9.45	6.68	18.50	4.92	4.04		8.96				
Pan Lysimeters												
Litter, mg./l.					1.06	2.24	.798	1.50				
Litter, lb./A.					1.66	5.46	1.00	8.12				
Soil, mg./l.					1.25	1.6[illegible]	0.82	1.18				
Soil, lb./A.					0.46	1.16	0.59	2.21				
Soil & litter, mg./l.					0.79	1.51	0.41	1.13				
Soil & litter, lb./A.					.014	.374	.097	.485				

Table 14. Potassium
Milligrams per Liter and Pounds per Acre

	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.	3.46	1.64	2.06	2.14	1.51	5.28	1.88	3.03	3.50	6.08	2.00	3.16
Litter, lb./A.	4.26	4.40	12.71	21.37	4.15	19.93	6.76	30.84	5.46	11.70	10.08	27.24
Soil, mg./l.	4.24	3.09	4.50	3.82	2.61	5.31	2.77	3.67	5.91	5.92	1.03	2.96
Soil, lb./A.	2.09	5.49	4.53	12.11	4.99	10.26	3.33	18.58	6.50	8.29	2.72	17.51
Soil & litter, mg./l.	3.31	3.55	3.02	3.09	2.37	4.31	1.63	2.90	6.43	5.31	1.16	2.58
Soil & litter, lb./A.	4.14	10.33	8.44	22.91	7.57	17.29	4.77	29.63	8.16	5.47	4.75	18.38
Pan Lysimeters												
Litter, mg./l.					2.75	3.56	1.81	2.91	3.20	3.51	2.29	2.80
Litter, lb./A.					4.55	8.70	2.47	15.72	3.16	4.48	5.99	13.63
Soil, mg./l.					1.47	1.88	1.34	1.65	3.17	2.11	2.28	2.24
Soil, lb./A.					0.61	1.48	1.01	3.10	0.47	0.94	2.01	3.42
Soil & litter, mg./l.					1.77	2.35	.128	1.52		2.53	1.73	
Soil & litter, lb./A.					0.03	0.59	0.03	0.65		0.34	1.01	

Table 15. Sulfur
Milligrams per Liter and Pounds per Acre

	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.	5.14	3.50	3.28	3.54	2.18	2.78	2.84	2.62	2.54	5.67	3.58	3.88
Litter, lb./A.	6.22	9.27	19.89	35.38	6.10	10.52	10.20	26.82	4.13	11.36	18.03	33.52
Soil, mg./l.	4.74	2.81	5.15	3.93	3.60	3.43	3.52	3.52	2.12	3.50	3.68	3.34
Soil, lb./A.	2.28	5.05	5.11	12.44	6.87	6.70	4.21	17.78	2.38	5.11	12.27	19.76
Soil & litter, mg./l.	6.28	3.62	3.61	4.15	3.10	3.85	3.36	3.35	2.66	5.88	5.06	4.77
Soil & litter, lb./A.	8.16	11.36	11.28	30.80	10.04	14.98	9.15	34.17	4.11	6.88	22.97	33.96
Pan Lysimeters												
Litter, mg./l.					2.67	3.61	3.93	3.34	3.55	5.71	3.02	3.73
Litter, lb./A.					4.16	8.80	5.07	18.03	3.34	7.30	7.54	18.18
Soil, mg./l.					3.66	5.57	3.98	4.59	4.87	5.89	5.97	5.58
Soil, lb./A.					1.52	4.00	3.09	8.61	0.70	2.37	5.45	8.52
Soil & litter, mg./l.					2.47	3.73	3.84	3.90		4.52	4.47	
Soil & litter, lb./A.					0.04	0.98	0.66	1.68		0.66	2.50	

Table 16. Phosphorus
Milligrams per Liter and Pounds per Acre

	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.									.149	.157	.077	.11
Litter, lb./A.						.655	.416		.244	.304	.392	.938
Soil, mg./l.		No							.037	.007	.016	.037
Soil, lb./A.		Data				.058	.054		.040	.105	.068	.213
Soil & litter, mg./l.									.034	.213	.016	.035
Soil & litter, lb./A.						.153	.159		.050	.114	.086	.250
Pan Lysimeters												
Litter, mg./l.									.194	.150	.066	0.11
Litter, lb./A.						.568	.198		0.20	0.17	0.17	0.54
Soil, mg./l.		No							.072	.033	.064	.06
Soil, lb./A.		Data				.088	.070		0.01	0.02	0.06	0.09
Soil & litter, mg./l.									.10	.106	.064	.15
Soil & litter, lb./A.						.033	.014		.004	.052	.054	.110

Table 17. Silica
Milligrams per Liter and Pounds per Acre

	SiO_2								Soluble Si			
	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.	4.00	2.0	1.8		2.7				0.30	0.81	0.50	0.55
Litter, lb./A.	4.88	5.35	11.06	21.29	7.52				1.30	1.07	2.46	4.83
Soil, mg./l.		6.9	4.67		4.4				2.00	2.01	2.12	2.38
Soil, lb./A.		12.34	4.56		8.40				2.26	3.04	8.77	14.07
Soil & litter, mg./l.	4.1	4.4	3.8		4.2				1.63	1.56	1.42	1.89
Soil & litter, lb./A.	5.16	13.02	10.57	28.75	14.03				2.16	1.71	9.62	13.52
Pan Lysimeters												
Litter, mg./l.					4.5				0.28	0.83	0.75	0.58
Litter, lb./A.					7.00				0.83	0.97	1.00	2.80
Soil, mg./l.		No			5.3				1.39	2.34	2.00	2.40
Soil, lb./A.		Data			2.06				0.33	0.82	2.52	3.67
Soil & litter, mg./l.					2.8					1.00	0.69	1.50
Soil & litter, lb./A.					0.05				0.05	0.10	0.96	1.11

Table 18. Iron
Milligrams per Liter and Pounds per Acre

	1933–34				1934–35				1935–36			
	1st	2nd	3rd	Total	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Tank Lysimeters												
Litter, mg./l.	0.85	0.93	0.33	0.55	0.50	0.55	0.36	0.47	0.72	0.78	0.10	0.38
Litter, lb./A.	1.04	2.46	1.98	5.48	1.42	2.09	1.28	4.79	1.17	1.58	0.50	3.25
Soil, mg./l.	0.35	0.25	0.31	0.27	0.35	0.27	0.54	0.37	0.65	0.59	0.087	0.30
Soil, lb./A.	0.12	0.41	0.31	0.84	0.67	0.53	0.65	1.85	0.74	0.76	0.30	1.80
Soil & litter, mg./l.	0.30	0.37	0.15	0.63	0.21	0.23	0.20	0.21	0.30	0.23	0.04	0.11
Soil & litter, lb./A.	0.39	1.09	3.22	4.70	0.72	0.93	0.54	2.19	0.31	0.27	0.18	0.76
Pan Lysimeters												
Litter, mg./l.					1.13	0.71	0.57	0.80	0.62	0.72	0.18	0.41
Litter, lb./A.					1.71	1.75	0.85	4.31	0.62	0.95	0.47	2.04
Soil, mg./l.					1.15	0.62	1.44	1.09	0.90	0.81	0.60	0.65
Soil, lb./A.					0.42	0.50	1.13	2.05	0.13	0.33	0.55	1.01
Soil & litter, mg./l.						0.79	0.87	0.71	1.0	0.62	0.37	0.44
Soil & litter, lb./A.						0.22	0.13		0.04	0.08	0.20	0.33

Table 19. Results of Tests on Mineral Soils from Lysimeters, Collected June 8, 1936

	Moisture %	M. E.* %	Rel. Wet.	pH	Rapid Soil Tests: NO_3-N	NH_3-N	P	K	Ca	Mg	Fe	Al	Mn
					Pounds per Acre								
Bare soil	**47.2**	**21.1**	**224**	**4.68**	7	9.5	12	100	400	10	60	500	32
Soil + litter	**43.9**	**20.0**	**219**	**4.80**	**2**	11.2	13	100	400	14	45	450	39
Field sample**	14.9	20.3	73	4.76	T	5.5	12	100	400	12	25	475	10

*Moisture Equivalent.
**Forest soil in the vicinity of the lysimeters.

TABLE 20. RESULTS OF TESTS ON MINERAL SOILS COLLECTED OCTOBER 23, 1936

	pH	Rapid Soil Tests							
		NO_3-N	NH_3-N	P	K	Ca	Mg	Al	Mn
		Pounds per Acre							
Bare soil									
Tank No. 2	4.47	2	7	23	110	425	10	325	15
Tank No. 4	4.42	3	7	15	100	400	10	290	23
Soil+litter									
Tank No. 1	4.51	2	7	25	100	400	15	350	10
Tank No. 5	4.40	4	8	30	125	475	14	275	20
Field soil A*	4.57	2	6	11	100	400	14	150	10
Field soil B	4.58	2	6	20	100	475	33	250	15

* Forest soil in the vicinity of the lysimeters.

TABLE 21. TOTAL AMOUNT OF MATERIAL OBTAINED DURING THE FULL PERIOD OF THE EXPERIMENT

	TANK LYSIMETERS (3 YRS.)			PAN LYSIMETERS (2 YRS.)		
	Litter	Soil	Soil + litter	Litter	Soil	Soil + litter
Leachate collected, liters	653.90	320.92	564.52	116.63	38.60	13.20
Leachate collected, inches	127.22	62.43	109.8	45.38	15.02	5.14
Total Nitrogen, lbs./A.	72.86	103.77	131.18	33.33	6.81	2.25
Total Nitrogen, lbs./inch of leachate	0.572	1.662	1.195	0.734	0.453	0.438
Total Nitrogen, lbs./inch of rainfall	0.518	0.738	0.933	0.350	0.071	0.024
Calcium, lbs./A.	148.90	125.00	144.20	60.03	19.16	6.00
Calcium, lbs./inch of leachate	1.170	2.002	1:313	1.323	1.276	1.167
Calcium, lbs./inch of rainfall	1.059	0.889	1.026	0.630	0.201	0.063
Potassium, lbs./A.	79.45	48.20	70.92	29.35	6.52	2.0
Potassium, lbs./inch of leachate	0.625	0.772	0.646	0.647	0.434	0.389
Potassium, lbs./inch of rainfall	0.565	0.343	0.505	0.308	0.068	0.020
Sulfur, lbs./A.	95.72	49.98	98.93	36.21	17.13	4.0
Sulfur, lbs./inch of leachate	0.752	0.801	0.901	0.798	1.140	0.778
Sulfur, lbs./inch of rainfall	0.681	0.355	0.704	0.379	0.180	0.040

TABLE 22. COMPARISON OF RESULTS OBTAINED BY INVESTIGATORS

	JOFFE		LUNT (Soil plus litter, pan lysimeters)	
	1929-30	1930-31	1934-35	1935-36
Rainfall, inches	37.26	34.14	50.85	44.45
Total leachate, liters	21.0	29.22	4.87	8.33
pH	4.8–6.4	4.8–6.4	6.0– 6.5	5.8–6.5
Conductivity x 10^{-5}	7.8–25.7	8.3–35.2	4.9–12.0	4–8
Nitrates lbs./A.	10.0	11.3	0.88	0.13
Total Nitrogen lbs./A.	13.4	19.4	1.64	0.61
Total Solids lbs./A.	362	563	36	53
Loss on ignition lbs./A.	140	258	14.3	30.2
Calcium	19.4	23.8	1.89	4.11
Sulfur	33.8	47.6	1.68	——

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