

BLACK ROCK FOREST PAPERS

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THE LEACHING OF SOME PLANT NUTRIENTS FOLLOWING THE BURNING OF FOREST LITTER

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THE LEACHING OF SOME PLANT NUTRIENTS FOLLOWING THE BURNING OF FOREST LITTER

WHEN a forest area is burned the organic matter is more or less completely destroyed and the mineral nutrients are released at a much more accelerated rate than occurs through the process of normal decomposition. The intensity of the fire and consequently the depth to which the duff is destroyed governs the quantity of mineral nutrients thus released. In a sense, the fire concentrates the mineral nutrients by rapidly releasing them from the organic compounds so that these elements become more readily available to the trees and to the ground flora. But plants and trees on a burned area may be killed or weakened to the extent that only a small part of the readily available nutrients can be utilized. For the first year or two after the burn the same situation prevails if sprouts appear, or if the area is invaded by pioneer species. Until the burned area is again well stocked there may be some loss of water-soluble nutrients through leaching. Even on an unburned forested area leaching of water-soluble nutrients is continuous, though probably at a slower rate. Leaching from fallen leaves occurs to a greater or lesser extent depending on length of exposure, species, and amount of precipitation. Some leaching also occurs from soils, particularly those soils whose normal organic matter has been depleted either through fire or indirectly through improper silvicultural practices. In the past, most of the area within the Black Rock Forest has been subjected to repeated burning. Consequently nutrients, especially nitrogen, have been lost.

Experimental

This experiment was designed to determine what nutrients were leached from sand and from soil following the burning of forest litter. While this experiment does not duplicate actual field conditions it is believed that the results obtained will indicate to some degree what happens on such areas and will provide some leads for a future field study along similar lines.

Two boxes each 36 inches square and 32 inches deep, more or less water-tight along the sides, were placed on the ground in the open near the Black Rock Forest Laboratory located in Cornwall-on-Hudson, N. Y. Along the vertical center line of each side of the boxes 2½ inch holes were bored at 6 inches, 17 inches, and 28 inches from the top to permit removal of samples at the several depths. These holes were plugged with removable rubber stoppers. On January 6th, 1940, one box was filled with uniform, washed beach sand and the second box with an infertile loamy clay, uniform throughout, taken from a local road cut at a depth of about three feet. Soil or sand, to a depth of ⅛ to ¼ inch, was removed from the top of each box and 132 grams of leaf ashes were spread on the uppermost surface of each box. The removed sand or soil was used to cover and hold the added leaf ashes. The leaf ashes used were derived from leaves collected December 13, 1939, south of the Nitrogen Plots at Aleck Meadow, under control trees numbers 35

and 36. The leaves were gathered from an area of 2 square yards and to a depth of 1½—2 inches under each of the above trees. So far as could be determined only the 1939 leaf fall was included in the samples. The species represented were red oak, some chestnut oak, red maple and white oak. It will be noted that the leaves were gathered from a total area of 4 square yards. This procedure was followed to simulate the burning of the litter plus the upper layers of the duff, because the duff was frozen at this time (Dec., 1939) and could not be readily collected. The leaves were air-dried and then burned under a hood until they were apparently all consumed except for small particles of charcoal which could be identified in the ashes. These particles were probably the remains of small twigs and stout petioles. The two lots of ashes were thoroughly mixed together. The weights of the leaves and of the resulting ashes with the results of the chemical analyses of both leaves and ashes are shown in Table No. 1. The higher ash weight of Sample No. 1 is due to incomplete combustion as was evidenced by the presence of the charcoal particles. From Table No. 1 it is seen that the quantity of nitrogen lost is dependent, for one thing, on the completeness of combustion. Sample No. 1, for instance, had an ash nitrogen percent of 0.82 and Sample No. 2, 0.38 percent of nitrogen. The organic matter in Sample No. 2 was more completely destroyed than in Sample No. 1. Hence the nitrogen percent (.82) of Sample No. 1 is higher than the nitrogen percent (.38) of Sample No. 2, due to the loss of nitrogen through volatilization in Sample No. 1. Potassium and phosphorus on the other hand are not easily volatilized and hence are more concentrated in Sample No. 2 than in Sample No. 1.

The boxes were frequently weeded to prevent the establishment of any plant growth or the addition of organic matter. All wind-borne debris of any kind was removed. Any plants showing above ground were immediately pulled. Nevertheless, some roots undoubtedly remained in the upper layer, especially in the soil box. Most plants could be easily removed "entire" from the sand box. Some moss, which formed on the surface of the soil was carefully removed. The boxes were given no other attention.

The boxes were sampled on the following dates: 1st. sampling, January 2, 1941; 2nd. sampling, January 2nd, 1942, and the 3rd. and last sampling on December 15, 1942, giving an elapsed period of very nearly three years from the start to the end of the experiment. Four samples from each level (one from each side) were removed from each box. The samples from each level taken from the respective boxes were mixed thoroughly and quantities of soil or sand from the "mixed sample" were used in the chemical analyses. Soil or sand less than 4 inches from the sides of the box was discarded. The first samples were taken with a long spoon. The second and last samples were removed with an auger.

TABLE No. 1
(Leaf and Leaf-Ash Data)

	Sample No. 1	Sample No. 2
Area of sampling	2 square yards	2 square yards
Depth of sampling	1½-2 inches	1½-2 inches
Weight of air-dried leaves	2066 grams	2046 grams
Weight of ashes	201 grams	77 grams
Charcoal present in ashes ¹	Much	Occasional particles
Color of ashes	Grayish black	Light gray
Total N (%) ² in leaves	1.77	1.70
Total N (%) ² in ashes	0.82	0.38
Total P (%) ² in ashes	0.34	0.93
Total K (%) ² in ashes	1.73	4.47

¹ By ocular inspection.

² Analyzed for N, P, and K by the micro-Kjeldahl, ammonium molybdate, and cobalt methods respectively.

All samples were air-dried and then passed through a 10-mesh screen.

Physical Condition of Soil Samples

The soil samples of December, 1942, from each level, after being mixed were placed on clean white sheets of paper and arranged in a row from left to right beginning with surface level and followed in order by the 6, 17, and 28-inch levels respectively. The sand samples of the above dates were arranged in like manner and photographed. Although the color and structure of the soil and sand were uniform throughout when first placed in their respective boxes, upon removal the soil appeared darkest at the top level and gradually lightened with increasing depth. The lightest color was observed at the lowest depth, 28 inches. The same color difference was noticed in the sand, but here it was less pronounced than in the soil. Both the soil and sand from the lower level tended to remain in lumps. This tendency was less as the surface was neared. The lower levels retained more moisture, were under more pressure, and as a result may have tended to be cemented together in lumps.

Organic Matter

The soil used in this experiment had a content of 4.4% organic matter, but following the addition of the ashes the organic matter tested 9.0% in the surface level. No organic matter could be detected in the sand used in this experiment, but immediately after the leaf ashes were added to the surface level the organic content rose to 5.0%. The surface level of the soil box gave somewhat higher organic matter tests for the three years of

this experiment than the tests did at the beginning (4.4%) of 1940 before leaf ashes were added. The reason for this will be explained a little later on. No increase or decrease (from 4.4%) in the organic matter content of the soil for the years 1940-1942 could be detected in the 6-inch level nor in the 17-inch level, except at the end of 1942 when the percent of the organic matter went down to 3.6%. The 28-inch level in the soil box showed a quite consistent decrease from the original content of 4.4% organic matter to about 3.4%. From the end of 1940 to the end of 1942 the organic matter in the sand box fluctuated from a maximum of 1.1% to a negative reaction. No definite trend in the sand was apparent in any of the various levels, nor for any year. Both the soil and the sand boxes lost practically all the organic matter or its equivalent which had been gained by the addition of the leaf ashes.

The organic matter in the leaf ashes might have caused this darkening by diffusing through the soil or sand. Subsequent analyses for organic matter support this supposition to some extent. But it does not explain why the percentage of organic matter in the two lowest levels of the soil box at the end of 1942 was smaller than at the beginning of the experiment, December, 1939. Evidently some factor or factors were at work which removed or changed the organic matter into non-reducing substances. Exactly what these factors were is difficult to say. Perhaps the soil in the upper levels contained more organic matter than the lower. The soil in the upper levels could be maintained at or above what it was in December, 1939, whereas the lower levels, having less organic matter than the upper, showed the loss of their organic matter by falling below the percentage found in December, 1939.

Chemical Analysis

The soil and sand samples were analyzed for nitrate, nitrite and ammonia nitrogen, phosphorus, potassium, and calcium, using Spurway's methods.¹

These methods are sufficiently accurate to measure relative easily available nutrient concentrations in the soil. The organic matter in the samples was measured by the Colorimetric Cenco-Wilde-Patzer Method,² while the pH was obtained with a Youden outfit using the quinhydrone electrode. Hydrochloric acid (0.135 N.) was used to extract the potassium and phosphorus. The results of the chemical analyses of the contents of the soil and the sand boxes immediately before and after leaf-ashes were added are shown in Table No. 2. The results at the end of 1, 2, and 3 years are shown in Tables 3 and 4.

Nitrogen

The soil in the uppermost level showed an increase from 10 ppm. nitrate to 56 ppm. after the ashes were added. At the end of the first year this same level had lost all excess nitrate but the bottom level had increased from 10 to 40 ppm. After three years (January, 1940 through December, 1942) very little nitrate remained in the soil box. Before any ashes were added to the sand 3 ppm. nitrate was measured, but following the addition of the ashes 15 ppm. nitrate was present. By the end of the first year, January, 1941, the concentration had fallen to 10 ppm. in the surface and had increased to 7 ppm. in the bottom level. By the end of 1941 no nitrate could be detected at any level and this also proved to be true in 1942. Nitrite nitrogen was present to the extent of 16 ppm. in the surface of the soil box at the end of 1940, but thereafter none could be found in any but the 28-inch level (at the end of 1941). Nitrite nitrogen was found in the sand box only twice and then only a trace was present. Traces of nitrite were found in both boxes however, immediately after adding the leaf ashes to the soil and to the sand. The test for ammonia on both soil and sand before the addition of leaf ashes gave a negative reaction. Tests made immediately after

the ashes had been added revealed only a trace of ammonia in both boxes in the surface layer. Both boxes showed no ammonia present at the end of 1940, but the 1941 and 1942 tests showed that 2 ppm. of ammonia were present in both boxes and in all layers, except in the case of the soil (28-inch level) which at the end of 1941 had a concentration of 10 ppm. of ammonia present.

Phosphorus

The results of analyses of soil and sand for potassium and phosphorus immediately before (December, 1939) and after adding leaf ashes (December, 1942), are shown in Table No. 5. Analyses for phosphorus in the soil and in the sand before the ashes were added gave only a negative reaction, but following the addition of the ashes 1 ppm. of phosphorus was found in the soil and 2.5 ppm. in the sand. No consecutive significant amounts of phosphorus were found for the entire interval of 1940 through 1942 in the soil box except in the top level at the end of 1941 when 1 ppm. was found. The surface level of the sand box had 3.0 ppm. phosphorus present at the end of 1940, the 1941 analyses disclosed that there was 1.0 ppm. of phosphorus present in all levels of the sand box, but the 1942 analyses revealed only a trace of this element.

Potassium

The soil analyzed 5 ppm. of potassium before any leaf ashes were added but the sand gave only a negative reaction. The tests made on both the soil and the sand following the addition of the ashes showed the concentration of potassium to have risen to 40 ppm. The analyses made at the end of each of the three years of this experiment showed that the concentration of potassium in the soil box at all levels remained about the same as before the ashes were added. The sand box also lost all the potassium it had gained through the addition of leaf-ashes. No potassium could be detected in the sand box except in the two lower levels at the end of 1942 and here only a trace was found.

TABLE No. 2

Soil and Sand Controls

(Analyzed Immediately before and after Leaf Ashes were Added)

Material Tested	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Phosphorus	Potassium	Calcium	pH	% Organic Matter
Soil ¹	10 ³	tr	0	0	5	20	5.70	4.4
Soil and Ashes ²	56	tr	tr	1.0	40	200	8.24	9.0
Sand ¹	3	0	0	0	0	0	5.03	0.0
Sand and Ashes ²	15	tr	tr	2.5	40	150	8.36	5.0

¹ Representative samples from the soil and sand.

² These samples taken from the topmost inch in each box.

³ Numerals are in terms of parts per million of soil extract for nitrogen, phosphorus, potassium, and calcium. Tr = trace.

TABLE No. 3
Soil Box
(Analyzed at the end of 1940, '41, and '42)

Depth from Which Samples Were Removed	Nitrate Nitrogen			Nitrite Nitrogen			Ammonia Nitrogen			Phosphorus			Potassium			Calcium			pH			% Organic Matter		
	1940	1941	1942	1940	1941	1942	1940	1941	1942	1940	1941	1942	1940	1941	1942	1940	1941	1942	1940	1941	1942	1940	1941	1942
	Surface ¹	10 ²	10	tr	16	0 ²	0	2	2	2	tr	1	tr	5	5	5	40	30	20	5.81	6.30	5.91	5.6	5.4
6-inch level	25	2	tr	0	0	0	2	2	2	0	tr	tr	5	tr	20	20	20	5.33	5.48	5.59	4.4	4.4	4.4	
17-inch level	32	25	tr	0	0	0	2	2	2	0	tr	0.5	5	tr	20	20	20	5.26	5.35	5.60	4.4	4.4	3.6	
28-inch level	40	25	2	0	2	0	10	2	2	0	tr	0	5	0	tr	20	0	4.94	5.33	5.84	3.4	3.4	3.2	

¹ Samples taken from the topmost inch.
² Numerals are in terms of parts per million of soil extract for nitrogen, phosphorus, potassium, and calcium.
³ Tr = trace.

TABLE No. 4
Sand Box
(Analyzed at the end of 1940, 1941, and 1942)

Depth from Which Samples Were Removed	Nitrate Nitrogen			Nitrite Nitrogen			Ammonia Nitrogen			Phosphorus			Potassium			Calcium			pH			% Organic Matter		
	1940	1941	1942	1940	1941	1942	1940	1941	1942	1940	1941	1942	1940	1941	1942	1940	1941	1942	1940	1941	1942	1940	1941	1942
	Surface ¹	10 ²	0 ³	tr	0	0	0	2	2	2	3.0	1	tr	0	0	0	20	0	6.11	5.37	5.72	0.0	1.0	0.7
6-inch level	tr	0	0	tr	0	0	2	2	2	0	1	tr	0	0	20	0	5.52	5.31	5.55	0.0	0.5	0.6		
17-inch level	0	0	tr	0	0	0	2	2	2	tr	1	tr	0	0	10	0	5.33	5.31	5.45	0.0	0.0	0.0		
28-inch level	7	0	0	tr	0	0	2	2	2	tr	1	0	0	0	tr	0	5.11	5.60	5.86	0.0	1.1	0.0		

¹ Samples taken from the topmost inch.
² Numerals are in terms of parts per million of soil extract for nitrogen, phosphorus, potassium, and calcium.
³ Tr = trace.

* The extraction of phosphorus and potassium with 0.135 N. HCl, (Table No. 5) from both the soil and the sand showed no significant change from the time just previous to the application of the leaf ashes (December, 1939) to December, 1942, three years after the ashes were applied to the soil and to the sand. The soil tested 5 ppm. of phosphorus and about 7 ppm. of potassium, while for sand it was 3.0 ppm. phosphorus and only a trace of potassium.

Calcium

The concentration of calcium increased from 20 ppm. before the ashes were added to 200 ppm. following the addition of the ashes in the surface level of the soil box. The surface level in the sand box gave a negative reaction for calcium before the ashes were added but following the addition of the ashes the calcium concentration rose to 150 ppm. The surface level in the soil box decreased in calcium from 40 ppm. by the end of 1940 to 30 ppm. by the end of 1941 and to 20 ppm. by the end of 1942. The balance of the levels was fairly stable at 20 ppm. by the end of 1941. At the end of 1940, the two upper levels in the sand box tested 20 ppm. of calcium and the 17-inch and 28-inch levels tested 10 ppm. and a trace respectively. Thereafter, at the most, only a trace of calcium could be detected in any of the levels of the sand box.

Hydrogen-ion Concentration

The addition of the leaf-ashes changed the pH in the soil box from 5.70 to 8.24 and in the sand box from 5.03 to 8.36. The pH of the surface level in the soil box fluctuated from year to year but remained at a higher pH

than at the beginning (5.70) of 1940. The other three levels in the soil box gave a lower pH than at the beginning of 1940, with the exception of the 28-inch level which gave a slightly higher pH (5.84). Further, there was a trend on the part of the three lower levels of the soil box gradually to become less acid from year to year. As in the case of the surface level of the soil box, the pH of the surface level in the sand box fluctuated from year to year but remained higher than at the beginning (5.03) of 1940. All the levels in the sand box showed a higher pH than at the beginning (5.03) of 1940. The 28-inch level of the sand box exhibited a trend to become less acid from year to year but this trend was not apparent in the other levels of the same box. All levels in the sand box at the end of 1941 were more acid than at the end of 1940 or at the end of 1942.

Discussion

The loss of nitrate nitrogen in both the boxes can be ascribed to leaching. The nitrate loss in both boxes by the end of 1942 included most of the nitrates originally present plus what was added in the leaf ashes. Nitrates are very soluble and hence are easily washed out of the soil. Particularly is this true where there are no roots to absorb the nitrates as they become available, nor sufficient organic matter to absorb them. In the soils found in the Black Rock Forest most of the organic matter is contained in the upper 4-6 inches. If this organic matter is rapidly destroyed by fire or improper silvicultural practices, one of the most powerful brakes against the loss of easily soluble nutrients is also destroyed. The nitrates were not fixed as is shown by the tendency to con-

TABLE No. 5
Tests for Reserve or "Fixed" Phosphorus and Potassium
(using 0.135 N. HCl extracting solution)

Material Tested	Date of Sampling	Phosphorus ¹	Potassium ¹
Soil	Dec., 1939 Beg. of Exp.	5.0	7.0
Soil and Ashes, Surface	Dec., 1942 Three years after adding the ashes	5.0	5.0
6-inch level	"	5.0	7.0
17-" "	"	5.0	10.0
28-" "	"	5.0	7.0
Sand	Dec., 1939 Beg. of Exp.	3.0	trace
Sand and Ashes, Surface	Dec., 1942 Three years after adding ashes	3.0	trace
6-inch level	"	3.0	trace
17-" "	"	3.0	trace
28-" "	"	3.0	trace

¹ Numerals are in terms of parts per million of the soil extract but these figures cannot be compared directly with the figures shown in Tables 2, 3, and 4 since 0.025 N. acetic acid solution was used as the extractive in the latter cases.

concentrate in the lowest levels in both boxes. Since no litter or duff was present in either box there was nothing except the soil colloids to prevent the leaching of this element. Moreover the leaching was more rapid in the sand box than in the soil box. This is to be expected since the organic content of the sand was lower with consequent lesser holding capacity than that of the soil. Furthermore, the downward movement of water was far more rapid in the sand, thus permitting the whole sand mass to be more thoroughly leached. Nitrite nitrogen in an appreciable quantity was found only once. This occurred in the soil box surface level at the end of 1940. It is not clear why this happened. It may have been due to the formation of a small pocket in the soil with poor aeration and consequent slow oxidation of nitrite to nitrate, or it may have been due to the reduction of some of the nitrates. Ammonia nitrogen was detected at the end of 1941 and 1942, but not at the end of 1940. This probably indicates that some organic matter was being reduced, especially since the ammonia was found at all levels in both boxes. The amount present, 2 ppm., is about the amount usually found in most soils with organic matter present. The ammonia is derived from the nitrogen in this matter. Unless this ammonia be rapidly converted to nitrates and absorbed by plants or other organisms or by soil colloids it is likely that it will be lost. Some plants can use ammonia directly but to what extent this is true in the case of forest trees and plants is not certain. One thing is clear, however, and that is that the ammonia should not be allowed to reach high concentrations. The decomposition of organic matter should be regulated so that the nitrogen thus produced will be utilized about as fast as it becomes available. If the duff or litter or both should be destroyed by fire it is obvious that this proper utilization cannot be accomplished.

Phosphorus was not fixed in the soil and it is likely that most of this was lost through leaching. The soil analyses did not disclose any significant trend either up or down in the phosphorus content for the last two years (1941 and 1942) and tests for reserve or fixed phosphorus were the same before as they were after the leaf ashes were added. The sand, on the other hand, gradually decreased from 3 ppm. of phosphorus at the end of 1940 in the surface level to 1 ppm. throughout all levels at the end of 1941. By the end of 1942 only a trace of phosphorus was found. This shows a gradual leaching from the surface layer and a diffusing through the sand mass followed by leaching from the sand generally. It is doubtful if the sand could fix but a very small amount of phosphorus added in the form of leaf ashes, and the tests for reserve or fixed phosphorus confirm this theory.

Both the sand and the soil boxes lost all the potassium which they had acquired through the addition of the leaf ashes. This loss occurred the first year in both boxes. The rapid disappearance of potassium from both boxes is a clear indication of the speed of leaching when fire destroys the organic layer at the surface of a soil. The soil box was able to maintain the potassium concentration originally present before the leaf ashes were added,

but the excess potassium derived from the leaf ashes was rapidly lost. The ability to retain the original potassium in the soil was due to the soil colloids as is shown by the fact that the sand, which had no detectable amount of organic matter also had no measurable quantity of potassium present before the leaf ashes were added, and the sand promptly lost the potassium it had gained through the addition of the leaf ashes. Tests for reserve or fixed potassium agree with the above statements.

Calcium was not lost from the top level as rapidly as was potassium from either the sand or the soil box. Even the sand was able to hold on to some of the calcium at least until the end of the first year. The upper level in the soil box lost calcium gradually after the initial drop of from 200 ppm. January, 1940 to 40 ppm. by December, 1940. But calcium was present in the surface layers of both boxes at the beginning of 1940 (after the addition of leaf ashes) in greater concentration than was any of the other elements or radicals considered here. The great drop in calcium concentration is paralleled by a big drop in the pH of the surface layers of both boxes at the end of 1940.

Following the addition of the leaf ashes to the surface levels of both boxes the pH jumped from acid (5.70 for soil and 5.03 for sand) to alkaline (8.24 for soil and 8.36 for sand) but by the end of the first year (1940) both boxes were back on the acid side. The rapid change in the pH can be credited to the change in the concentration of the bases present in the leaf ashes, especially calcium. This sudden loss of calcium may explain why areas which are subjected to repeated burning tend in the long run to become more and more acid, especially when the total calcium in the soil is small to begin with.

Leaching is the chief cause of the loss of nutrients from the leaf ashes added to the soil and to the sand used in this experiment. It may be that diffusion of the nutrients from the ashes through a comparatively large soil or sand mass would add so little to the original nutrient concentration that any difference resulting would be masked. However, if the ions can migrate through soil or sand they can also be leached out, and since a large quantity of water (precipitation for 1940 through 1942 totalled 127.13 inches) did pass through the soil and sand some nutrients were lost by leaching. Some nutrients were undoubtedly also lost through the lateral movement of water moving to and down along the sides of the boxes. But this loss could not have been large because nitrates (which are very soluble) tended to collect in fairly high concentrations at the bottom of both boxes by the end of the first year (1940). The question arises as to whether or not phosphorus or potassium (using 0.135 N. HCl) in both soil and sand show by these methods that little or none of these elements were fixed permanently. The concentrations of phosphorus and potassium did not differ at the end of 1942 from the concentrations found at the beginning of the experiment before any leaf ashes were added to either the soil or the sand box. But the concentrations of the easily soluble nutrients fell perceptibly by the end of the first year (1940) and in most cases continued to de-

crease to some extent for the two years thereafter. No organic matter could be detected in the sand previous to the application of the ashes, but following this the organic matter reached 5.0% and in the soil box the percentage jumped from 4.4 to 9.0 after the ashes were added. By the end of 1942 only a trace of organic matter could be detected in the sand box. In the soil box the percent of organic matter in the lower levels was less at the close than at the start of the experiment; it was the same in the 6-inch level and greater in the surface level. This higher percent in the surface level can be traced to roots of small plants which invaded the soil box. The tops of these plants were removed but it was impossible to remove all of their roots. The organic matter contained in the leaf ashes added to both boxes consisted of small particles of what appeared to be charcoal. These particles could be easily washed free from the soil, and even more readily from the sand box. Hence the organic content of the soil and the sand reverted to what it was before the ashes were added. So it is seen that even after a fire has destroyed most of the organic matter in the upper layer of the soil, some of the organic matter that escapes the fire may be lost through leaching.

Conclusions

When the organic matter is destroyed by fire there is a loss of nitrogen through volatilization. The amount of loss is dependent on the intensity of the fire. The greater the amount of organic matter destroyed the greater is the loss of nitrogen by volatilization. Nitrates, calcium and potassium were lost by leaching from the soil and sand following the burning of the litter. Calcium was lost in the greatest quantities, followed next in order by nitrates. There is some evidence that phosphorus also was leached from both boxes. The addition of the leaf ashes changed the soil and sand reaction from the acid to the alkaline side but at the end of the first year the reaction had again become acid in both boxes.

REFERENCES

- ¹C. H. Spurway: Soil Testing, Tech. Bul. No. 132 (2nd Revision) March, 1938, Agric. Exp. Sta., Michigan State College.
- ²S. A. Wilde: Forest Soils, pp. 170-171, Madison, Wisconsin, 1942.