LYSIMETER STUDIES IN OKLAHOMA

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In order to gain some information on the amount of water which is lost from soils by drainage (percolation) under central Oklahoma conditions and to learn what qualities of plant nutrient materials are lost with this water, a lysimeter[1] study was begun on the Agronomy Farm in 1938 and continued through 1944. The lysimeters consisted of forty-eight cylindrical cores of natural undisturbed soils of four types. The cores were fitted closely into asphalted sheet-steel cylinders and nearly buried in the ground in symmetrical formation. The surfaces of the soil cores were made even with that of the surrounding field while the tops of the steel cylinders were left protruding about three inches above the ground level. This arrangement produced an unnatural condition in that it prevented run-off of rain water, except as explained later. However, it had the advantage that the amount of water lost by drainage could be compared more directly with the amount of rainfall.

Each soil core was thirty-six inches in diameter by fifty-four inches in depth. Thus each one had a surface area of one six-thousandth acre, contained thirty-two cubic feet of soil, and weighed two tons (approximate figures). Each core rested on a shallow layer of washed river sand on top of a concave concrete foundation. Drainage water passed from the bottom of the concrete receptacle through copper tubing into large bottles in nearby cisterns.

The leachate from each lysimeter was measured as often as necessary and an aliquot sample of water saved for chemical analysis. Analyses were made on a quarterly basis of the spring, summer, fall, and winter leachings. Only slight amounts of drainage occurred in 1938 and 1939 and these leachates were contaminated by excess lime, potash, and silica from the as yet unweathered concrete bases. Consequently, only nitrate-nitrogen data were kept for these years. By the spring of 1940 this contamination had apparently ceased and analyses were made of the leachates from then through 1944 for the various materials shown in Table I.

SOILS AND TREATMENTS USED

The soils used in the present study were obtained from areas in the State representative of the following types: (1) Derby loamy fine sand, (2) Vernon fine sandy loam, (3) Grant silt loam and, (4) Gerald clay loam. The cores were obtained by excavation to the depth of five feet around cylindrical pillars or columns of soil. These were shaped carefully until the steel cylinders could be fitted snugly down over them and the tops of the soil masses were within three inches of the tops of the casings. The cores were then broken off at the bottom and shaped to fit their concrete bases. They were then lifted by a derrick to a truck, transported to the experiment field, and carefully installed. These operations were done at the time when the moisture contents of the soils were such that the cores would not crack or collapse when handled.

The crops grown were cotton, oats, wheat, buckwheat, and soybeans. The soils were treated only once—at the beginning—with various combinations of nitrogen, phosphorus, potassium, and lime in moderate amounts. Manure was used in one instance.

[1]A metal cylinder arranged to contain soil on which crops can be grown and from which drainage water can be collected and measured.

RESULTS

Crop Yields. At no time during the entire experiment did the crop yields prove to be statistically significant. Instead, they varied quite irregularly and unpredictably. They were always low—lower than it is believed they would have been under normal field conditions with the same soil types. Both the lowness and variations in yield are here believed to be due to a moisture condition which will be discussed more fully below. In a lysimeter, the soil is narrowly and closely contained. There is no connection of the soil therein with the outside soil. Thus there is little sidewise movement, or seepage, of moisture; instead, there is only vertical movement. Whether seepage, or lack of it, was an important factor in the present study is not known. Unless rains came frequently the lysimeters which happened to drain most quickly, for the time being, gave the lower yields. The extra moisture in the cores which drained more slowly was readily detectable.

In the two heavier soils, however, excess moisture due to poor drainage proved to be a disadvantage in wet years. In 1942, both the Gerald and Grant soils became completely waterlogged and produced no crop. This condition held over during 1943, in the Gerald soil. During this time very little rainfall penetrated these soils and, as a result, only a small amount of water was lost in drainage from them. These soils were the only ones from which any run-off occurred. The clay they contained seems evidently to be of a montmorillonitic type which swells greatly when wet and prevents movement of gravitational water.

Loss of Water in Drainage. From a study of the amounts of water which were lost by drainage it is believed that the amount of leaching which took place in the soil depended strongly on the following factors, or conditions: (1) Amount and distribution of rainfall; (2) soil texture—including type of clay minerals present; (3) kind and density of ground cover (transpiration); (4) evaporation (temperature and air movement); (5) hydrostatic pressure, or tension.

Although the last factor mentioned is certainly active in field soils, it seems to be much more so in the lysimeters here used. The mechanism of this force in the present instance is not well understood. Its effects can be nearly completely stated when it is said that, after rains, some lysimeters started draining while others did not. When leaching recurred after subsequent rains, the rates for the various lysimeters were not the reverse of the previous time but were entirely of a hit-and-miss type. That is, if one core drained scantily one time, it would not necessarily drain heavily the next.

In general, however, there was a partial equalization of drainage during the total period of study so that the total drainage from a certain soil series was more nearly comparable to that of the others. Nevertheless, variation in drainage in some of the soils within a certain series was considerable. This caused variations in amounts of water available for crop growth in otherwise comparable lysimeters and produced variations in crop yield greater, evidently, than those caused by the fertilizer treatments. The water factor was evidently the most important one in the crop yields obtained.

Drainage took place through the soil cores only once in 1938 and once in 1939. Throughout the rest of the time, however, drainage was generally responsive to rainfall. The total amounts of water which leached through the soils expressed as per cent of the total rainfall for the duration of the experiment, were as follows:

Derby loamy fine sand, 25 to 40 per cent; Vernon fine sandy loam, 25 to 33 per cent; Vernon fine sandy loam (fallow), 30 to 45 per cent; Grant silt loam,[2] 10 to 15 per cent; Gerald clay loam,[2] 5 to 10 per cent.

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[2]The water which ran off these soils in 1942 and 1943 was not measured.

The above-stated variations in percentage represent the minima and maxima, respectively, for the individual lysimeters within the particular soil series. The average of all water losses is approximately the average of the two amounts given in each case. It is apparent that the heavier a soil is, other things being equal, the greater the resistance it offers to leaching. It follows naturally that there is accordingly more run-off water from clayey soils than from sandy ones. The fallowed soil lost significantly more water in drainage than the unfallowed soil of the same type.

Loss of Minerals in Drainage. The figures shown in Table I represent the average compostion of the drainage waters from the four different soils from 1940 to 1944, inclusive. They show the amounts of nutrients in pounds per acre that would be lost when a million pounds of water leached through an acre of land. This amount of water is approximately equivalent to 4.5 acre-inches. An idea of the actual annual loss of soil minerals may be gained as follows.

The average annual rainfall for the five years during which the drainage water was analyzed was approximately 37.5 inches. The drainage from the Derby soil amounted to an average of approximately one-third of the rainfall, or 12.5 inches. Dividing this figure by 4.5 (mentioned above) gives a factor of 2.8; multiplying the figures for the various elements given in the table by this factor gives the approximate average annual loss in pounds per acre from the Derby soil. The factors for the other soils would be somewhat smaller.

There was very little evidence of any pronounced or characteristic seasonal effect on the out-go of mineral elements in the drainage water, except for sod soil as will be mentioned below. Nitrates came out of the sandy soils at all times. The same was true to a slightly smaller degree in the Gerald and Grant soils. In 1942, and again in 1943, these soils were waterlogged and lost no nitrogen at all. Even when they resumed normal drainage in 1944, the nitrate content of their leachates was not so high as that of the other soils. No ammonia was detected in the water from any soil at any time and nitrates were never found except in traces.

An interesting thing was noticed in the Gerald soil after resumption of drainage in 1944. The potassium content of its leachate was almost twice that of its previous water. The same effect was present in the Grant soil, also, but to a lesser extent. The other elements from these soils continued coming out about as before.

Table I shows that nitrogen was lost more readily from the light soils than from the heavy ones; the total nitrogen contents of the latter are appreciably greater than those of the former. Calcium and nitrogen appeared to have some sort of reciprocal relationship. Lime evidently accelerated the loss of nitrogen and nitrogen increased the out-go of calcium. Further, lime tended to increase potassium losses. Phosphate apparently tended to retard the loss of nitrogen from all four soils and particularly from the sandy soils. There was some evidence that it also retarded calcium loss while organic matter appeared to increase it.

Fallowing decreased the out-go of potash and increased that of nitrogen. It also affected the loss of silica and alumina—decreasing the former and increasing the latter. The loss of magnesium was comparatively small and quite uniform regardless of treatment or type of soil. Phosphorus never appeared in the drainage water in amounts greater than traces. The out-go of chlorine and sulphur seemed to be very little related to either soil type or treatment. The same could be said for silica and alumina, with the possible exception of the fallowed soils. Mention has already been made of the potash loss from the heavier soils. Even though there was a temporary large out-go from them in 1944, the average potash loss from the heavier soils per unit of leachate was significantly greater than from the sandy soils.

In another set of lysimeters, which are being used in a different study, two uncropped soils received organic matter at the rate of two tons per acre per year. The organic matter was left on the surface of one soil, undisturbed, while on the other it was worked into the top six inches of soil. The out-go of minerals into the drainage water of the cultivated soil was considerably higher than that from the uncultivated soil; nitrogen and magnesium were one-third higher while calcium was two-thirds higher. On other soils, where a continuous sod was maintained, the loss of water in drainage was only approximately one-third as much as that from the cultivated soils. The loss of all minerals, including nitrogen, from the sod soils was approximately half as much as from the cultivated soils. Practically all of the nitrogen that was lost from the sod soils came out in late fall, winter, and early spring drainage. Summer drainage water seldom contained more than traces of nitrates.

TABLE I

Composition of soil drainage water—parts per million

Lysimeter No.	Soil	Treatment[a]	SiO_2	R_2O_3[b]	Ca	Mg	Cl	S	N	P	K
1-2	Vernon	None	5	5	20	11	10	18	10	Trace	14
3-4	fine	LN	7	4	44	13	10	18	28	Trace	17
5-6	sandy	P	7	3	25	12	10	18	7	Trace	17
7-8	loam	LPN	7	3	45	13	12	16	22	Trace	16
9-10		Fallow	4	7	21	11	10	10	33	Trace	7
11-12		Fallow	4	7	22	10	10	10	36	Trace	9
13-14		L	6	4	30	12	10	18	17	Trace	13
15-16		LLN	7	4	58	13	10	18	24	Trace	14
17-18		LP	7	3	35	11	12	17	11	Trace	17
19-20		LLPN	6	3	51	14	10	18	23	Trace	16
21	Grant	None	6	5	21	10	11	14	10	Trace	19
22	silt	L	7	4	24	11	12	14	11	Trace	22
23	loam	P	7	3	23	11	12	14	8	Trace	21
24		N	6	4	29	12	12	15	17	Trace	22
25		LP	7	3	25	11	11	14	8	Trace	22
26		LPN	7	3	32	12	11	14	13	Trace	23
27		LLN	7	4	39	12	12	14	16	Trace	23
28		LLPN	7	3	35	13	12	15	14	Trace	23
29	Gerald	None	8	2	45	11	15	15	9	Trace	24
30	clay	L	8	3	48	13	15	15	11	Trace	30
31	loam	P	8	2	45	13	17	14	6	Trace	33
32		LN	8	3	51	14	16	15	12	Trace	30
33		LP	8	2	45	13	18	15	8	Trace	33
34		LPN	8	2	52	14	15	14	11	Trace	32
35		LLN	8	3	63	14	16	16	15	Trace	33
36		LLPN	8	2	58	14	18	15	12	Trace	35
37-38	Derby	LPK	5	2	56	11	15	12	12	Trace	15
39-40	loamy	LLPKN	5	2	84	13	16	13	27	Trace	17
41-42	fine	LPKM	4	2	80	10	14	14	21	Trace	16
43-44	sand	LPK	4	2	55	13	15	14	15	Trace	16
45-56		PK	5	2	44	11	14	14	10	Trace	14
47-48		LLPKN	5	2	81	14	17	12	31	Trace	17

[a]L=lime; P=phosphate; M=manure; N=nitrogen; K=potash.
[b]Sesquioxides (mostly alumina).